INFORMATION HANDOUT

For Contract No. 04-1637N4
At 04-SF-101-9.0

Identified by
Project ID 0400020923

PERMITS

Special Use Permit, National Park Service, Golden Gate National Recreation Area, signed February 5, 2015

US Army Corps of Engineers, Authorization to Replace and Extend Outfall, dated January 22, 2015

US Fish and Wildlife Service, Biological Opinion, dated October 21, 2014

San Francisco BCDC Permit, February 9, 2015

NOAA, National Fisheries Service, Endangered Species Act Section 7(a)(2) Concurrence, dated October 8, 2014

WATER QUALITY

SF Bay Regional Water Quality Control Board, Water Quality Certification, dated October 17, 2014

Water Quality Information

MATERIALS INFORMATION

Turbidity Curtain Information

Owner's Field Guide, Recommendations for SEAPILE AND SEATIMBER Composite Marine Products

Western Snowy Plover Monitoring Buffer Area

Aquatic Monitoring Outfall IJKL Area, Preliminary Site Investigation Report - Doyle Drive Outfall IJKL Crissy Field, San Francisco, California, dated August 2013

DTSC, Information Advisory for Clean Imported Fill Material, dated October 2001

Development of Presidio-Wide Cleanup Levels for Soil, Sediment, Groundwater, and Surface Water," dated October 30, 2002 and Table 7-6 revised May 2006

NOAA Tide Predictions, San Francisco, California 2015

US Army Corps of Engineers, Engineering and Design, NAVSTAR Global Positioning System Surveying, Engineer Manual

US Army Corps Engineers, Engineering and Design, Hydrographic Surveying, Engineer Manual

Preliminary Site Investigation Report, Doyle Drive Outfall IJKL, Crissy Field, San Francisco, California, dated August 2013

Foundation Recommendations, dated July 18, 2014

SPECIAL USE PERMIT SUMMARY SHEET

National Park Service
Golden Gate National Recreation Area
Business Management Division
Bldg. 201, Fort Mason
San Francisco, CA 94123
415.561. 4931

Permit Date(s): May 4, 2015 ï October 31, 2015 Permit #: **8142-15-0522**

PERMITTEE ADDRESS/ TELEPHONE/FAX CO-PERMITTEE ADDRESS/TELE-PHONE/FAX	**State of California, Department of Transportation** (ñStateò, ñCaltransò or ñPermitteeò) **Attn: Mark L. Weaver** **Deputy Director, District 4 Right of Way and Land Services** **111 Grand Avenue** **Oakland, CA 94612** **Phone: 510-286-5400** **Presidio Trust** **Attn: Craig Middleton** **PO Box 29052** **Presidio of San Francisco, CA 94129** **Phone: 415-561-5300**
EVENT	Right of Entry for access, mobilization, staging, construction and site restoration including dune restoration for the replacement and extension of a segment of storm water drain pipe in Crissy Field and the IJKL Outfall per NPS PEPC 46130.
LOCATION	NPS Golden Gate National Recreation Area; Presidio Area A, Route of IJKL Outfall in Crissy Field from Crissy Field Promenade extending into San Francisco Bay (See Permit Exhibit A: Location Map)
SIZE/HRS.	See Permit Exhibits A -- D, unless specified otherwise by subsequent NPS communication.
COST RECOVERY	Co-Permittees Cost: $60,000
CERTIFICATE OF INSURANCE	Presidio Trust: Self-insured State of California: Self-insured (w/ contractor(s) certificate) Bond: n/a
NPS STAFF	Prepared by Business Management Division, Stephen Kasierski, NPS Realty Specialist, and Andrea Lucas, NPS Landscape Architect and Project Liasion, GGNRA
ASSISTANCE	Park dispatch non-emergency (415) 561-5505 Park dispatch emergency 911
LOGISTICS	See attached full Permit with Attachments and Exhibits

Form 10-114

Rev. Jan. 00

UNITED STATES DEPARTMENT OF THE INTERIOR
National Park Service
Special Use Permit

Name of Use:	Right of Entry for access, mobilization, staging, construction and site restoration for the replacement and extension of a segment of storm water drain pipe in Crissy Field and the IJKL Outfall per NPS PEPC 46130.	Permit Effective:	May 4, 2015
		Permit Expires:	October 31, 2015

Long Term __

Short Term X

Permit #**8142-15-0522**
Printed February 4, 2015

Location: Crissy Field and San Francisco Bay, Presidio Area A
Golden Gate National Recreation Area, San Francisco, CA

Permittee:
State of California Department of Transportation
111 Grand Avenue
Oakland, CA 94612

And

Co-Permittee:
The Presidio Trust
PO Box 29052
Presidio of San Francisco, CA 94129

Permittee and Co-Permittee (collectively, ñPermitteesò) and their contractors, officers, agents and employees, are hereby authorized during the period from May 4, 2015 to October 31, 2015 to use, in the prescribed manner, the following described land or facilities in the below named area:

Non-exclusive right to enter Crissy Field, Presidio Area A, Golden Gate National Recreation Area IJKL Outfall (ñPermitted Project Areaò) per Permit ***Exhibit A: Permitted Project Area****.*

For the purpose(s) of: Mobilization, staging, construction and site restoration work including dune restoration and revegetation, as required for the replacement and extension of a segment of storm water drain pipe, a segment of the outfall facility referred to as the IJKL Outfall (ñProjectò) as described in Permit Exhibit D. Permittee and NPS will enter into a separate agreement to pay NPS to execute the dune restoration, plant salvage and dune revegetation.

This permit provides a Right-of-Entry to lands in the Permitted Project Area to support the construction phase and site restoration work of the project. Associated administrative cost recovery fee from the Co-Permittee of $60,000 will be invoiced by NPS to the Co-Permittee and paid by the Co-Permittee under the NPS/Co-Permittee Interagency Agreement # PT-013-IA-013 or its successor.

NPS grants the Permittee and the Co-Permittee the non-exclusive right to enter and use the Permitted Project Area for the purposes of conducting the work as described in NPS PEPC Project # 46130 as further described and conditioned in the following exhibits:

Exhibit A: Permitted Project Area
Exhibit B: Other Required Permits
Exhibit C: Permit Special Conditions and Permitted Project Area Restrictions

Exhibit D: Project Description
Exhibit E: Insurance and Letter of Self-Insurance

Term of the right of entry is May 4, 2015 through October 31, 2015, for the described work within Permitted Project Area only, as described in Exhibit A (Map of Permitted Project Area).
Authorizing legislation or other authority (see DO-53): Golden Gate National Recreation Area Enabling Legislation

NEPA & NHPA Compliance: __X_CATEGORICALLY EXCLUDED ___EA/FONSI ___EIS ___OTHER
APPROVED PLANS
PERFORMANCE BOND: Required____ Not Required _X_ Amount ï N/A
LIABILITY INSURANCE: Required _X__ Not Required ___ Amount ï See Section H

ISSUANCE of this permit is subject to the conditions on the reverse hereof and appended pages. Permittees recognize GGNRA as an ñAffected Agencyò by this work and Permitteeôs and Co-Permitteeôs broader work of the South Access to the Golden Gate Bridge-Doyle Drive Project as referenced in NPS Project PEPC #46130.

The undersigned hereby accepts this permit subject to the terms, covenants, obligations, and reservations, expressed or implied herein.

Permittee: _____
Mark L. Weaver Caltrans Date

Co-Permittee: _____
Craig Middleton, Executive Director Presidio Trust Date

Authorizing Official: _____
Frank Dean, General Superintendent GGNRA Date

CONDITIONS OF THIS PERMIT

A. General Conditions

1. In accordance with the signed, prior Permit # 8142-13-0536 for IJKL Storm Drain Replacement, this Special Use Permit #8142-15-0522 is solely for the projects described in NPS PEPC 46130 and as shown in Exhibit A and Exhibit D. The term of this Permit may be extended to cover a future phase if agreed in writing by all parties, subject to the terms and conditions of this permit continuing in full effect, and including cost recovery charges as applicable.ò

2. The Permittees shall exercise this privilege subject to the supervision of the General Superintendent, and shall comply with all applicable laws and regulations of the area.

3. Damages - The Permittees shall pay the United States for any damage resulting from this use, which would not reasonably be inherent in the use that the Permittees are authorized to make of the land described in this permit.

4. Benefit - Neither Members of, nor Delegates to Congress, or Resident Commissioners shall be admitted to any share or part of this permit or derive, either directly or indirectly, any pecuniary benefits to arise therefrom. Provided, however, that nothing herein contained shall be construed to extend to any incorporated company, if the permit be for the benefit of such corporation.

5. Assignment - This permit may not be transferred or assigned without the consent of the General Superintendent, in writing.

6. Revocation - This permit may be terminated upon breach of any of the conditions herein or at the discretion of the General Superintendent.

7. The Permittees are prohibited from giving false information; to do so will be considered a breach of conditions and be grounds for revocation [Re: 36 CFR 2.32(4)].

8. The following provisions constitute Condition 7 in accordance with Executive Order No. 11246 of September 24, 1965, as amended by Executive order no. 11375 of October 13, 1967.

NONDISCRIMINATION. If the use of the resource covered by this permit will involve the employment of a person or persons, the Permittees agree as follows.

(a) The Permittees will not discriminate against any employee or applicant for employment because of race, color, religion, sex, or national origin. The Permittees will take affirmative action to ensure that applicants are employed, and that employees are treated during employment, without regard to their race, color, religion, sex or national origin. Such action shall include, but not be limited to the following: employment, upgrading, demotion, or transfer; recruitment or recruitment advertising; layoff or termination; rates of pay or other forms of compensation; and selection for training, including apprenticeship. The Permittees agree to post in conspicuous places, available to employees and applicants for employment, notices to be provided by the Superintendent setting forth the provisions of this nondiscrimination clause.

(b) The Permittees will, in all solicitations or advancements for employees placed by or on behalf of the Permittees, state that all qualified applicants will receive consideration for employment without regard to race, color, religion, sex or national origin.

(c) The Permittees will send to each labor union or representative of workers with which he has a collective bargaining agreement or other contract or understanding, a notice, to be provided by the agency contracting officer, advising the labor union or workers' representative of the contractor's commitments under Section 202 of Executive Order No. 11246 of September 24, 1965, and shall post copies of the notice in conspicuous places available to employees and applicants for employment.

(d) The Permittees will comply with all provisions of Executive Order No. 11246 of Sept. 24, 1965, and of the rules, regulations, and relevant orders of the Secretary of Labor.

(e) The Permittees will furnish all information and reports required by Executive Order No. 11246 of September 24, 1965, and by the rules, regulations, and orders of the Secretary of Labor, or pursuant thereto, and will permit access to his books, records, and accounts by the Superintendent and the Secretary of Labor for purposes of investigation to ascertain compliance with such rules, regulations, and orders.

(f) In the event of the Permitteesô noncompliance with the nondiscrimination clauses of this contract or with any of such rules, regulations, or orders, this contract may be cancelled, terminated, or suspended in whole or in part and the Permittees may be declared ineligible for further United States contracts or permits in accordance with procedures authorized in Executive Order No. 11246 of Sept. 24, 1965, and such other sanctions may be imposed and remedies invoked as provided in Executive Order No. 11246 of September 24, 1965, or by rule, regulation, or order of the Secretary of Labor, or as otherwise provided by law.

(g) The Permittees will include the provisions of paragraphs (a) through (g) in every subcontract or purchase order unless exempted by rules, regulations, or orders of the Secretary of Labor issued pursuant to Section 204 of Executive Order No. 11246 of September 24, 1965, as amended, so that such provisions will be binding upon each subcontract or purchase order as the Superintendent may direct as a means of enforcing such provisions including sanctions for noncompliance. Provided, however, that in the event the Permittees become involved in, or is threatened with, litigation with a subcontractor or vendor as a result of such direction by the Superintendent, the

Permittees may request the United States to enter into such litigation to protect the interests of the United States.

9. This permit conveys no interest to the Permittees in any property or lands within Golden Gate National Recreation Area.

10. The Permittees shall not sublet any part of the permitted premises or grant any interest or privilege whatsoever in connection with this permit without permission in writing from the General Superintendent of Golden Gate National Recreation Area.

11. The Permittees shall not construct or install any permanent or temporary structure on the Permitted Project Area other than those specifically identified herein, without permission in writing from the General Superintendent of Golden Gate National Recreation Area.

12. Any unauthorized construction, alteration, or improvement done by the Permittees will be at the Permitteesô expense, will result in no claim or reimbursement for any part of said expense, and will not convey interest to the Permittees in the Permitted Project Area. Any such element may be retained, at the sole discretion of NPS, or removed per NPS with all removal and restoration costs borne by Permittees per the conditions of this permit.

13. The Permittees shall, at the Permitteesô expense, maintain the property under this permit in good order and conditions, protect said property against damage and destruction, and take all precautions necessary to minimize harm to park resources during construction and/or maintenance activities.

14. The Permittees shall promptly replace or repair any property of the United States damaged or destroyed by the Permitteesô use and occupancy of the permitted area, except for any losses, expenses, damage to property, or injuries to persons which is caused by the United Statesô negligence. The repair or replacement of United States property will be done to the satisfaction of the General Superintendent of Golden Gate National Recreation Area. If so required by the General Superintendent, the Permittees shall, in lieu of such repair or replacement, pay to the United States sufficient money to compensate for the loss sustained through such damage to or destruction of United States property.

B. <u>Acceptance of Permitted Project Area/ Hold Harmless</u>

1. The United States makes no warranty as to the condition, serviceability, or safety of the Permitted Project Area or any facilities thereof. The United States or its contractors, or any of their officers, agents, or employees, shall not be responsible for any loss, expense, damage to property, or injuries to persons which may arise from or be incident to the use and occupancy of the Permitted Project Area by the Presidio Trust and State of California, Department of Transportation or its contractors, officers, agents or employees (hereinafter collectively referred to as ñPermitteesò), and the Permittees shall hold the United States and its contractors, and any of their officers, agents or employees, harmless against liability for any such incident, except for such incidents caused by United States gross negligence.

C. <u>Compliance with Applicable Laws</u>

1. Permittees will comply with applicable public health and sanitation standards and codes.
2. In accordance with applicable Federal, State and local laws, the Permittees shall remove or dispose of all waste generated by the Permittees in construction, operation and maintenance of the project facilities during the term of the permit, including, but not limited to, human waste, trash, garbage, refuse, oil drums, petroleum products, ashes and equipment.
3. The Permittees shall comply with the laws and regulations enforced by the Golden Gate National Recreation Area and the National Park Service. The Permittees shall comply with the specified conditions within the scope of other statutes and lawful regulations, or guidelines thereunder, as may be found applicable to the Permitteesô occupancy and use of the Permitted Project Area, including, but not limited, to all conditions required by other regulatory agencies per the requirements of Permit Exhibit B.

C. Permit Term

TABLE 1. Permit Schedule Terms:

Area Name	Access/Construction Period- Start	Construction and Site restoration Completed	Construction Stage (per Caltrans project drawings)
Crissy Promenade Access Route	5/04/2015	10/31/2015	All Stages
Crissy Field Staging Area	5/4/2015	10/31/2015	Stages 1 ï 2
Beach -Wildlife Protection Area	5/15/2015	7/31/2015	Stage 1
Intertidal - Wildlife Protection Area	6/01/2015	7/31/2015	Stage 2
Marine -Wildlife Protection Area	6/01/2015	7/31/2015 Stage 2 10/31/2015 Stage 3	Stage 2 Stage 3

1. The term of this Permit shall be from May 4, 2015 through October 31, 2015, unless terminated pursuant to the conditions of this Permit.
2. Entry to the Permitted Project Area shall be for the period of May 4 through October 31, 2015 as described in Exhibit A, below, and Table 1, above.
3. Access onto the Wildlife Protection Area (WPA) portion of the Permitted Project Area, including, Beach, Intertidal and Marine WPA Areas shall not occur prior to May 15, 2015 unless explicitly approved by the NPS.
4. Access and construction in the Beach WPA shall be limited to May 15, 2015 through July 31, 2015, unless explicitly extended by NPS.
5. Access and construction in the Intertidal WPA shall be limited to June 1, 2015 through July 31, 2015, unless explicitly extended by NPS.
6. Access and construction in the Marine WPA shall be limited to June 1 through July 31, 2015, for Stage 2, and June 1 through October 31, 2015 for Stage 3 unless explicitly extended by NPS.
7. Access is subject to ñBlackout periodsò attached per Permit Exhibit C (Special Conditions ï Visitors and Programs).

E. Permit Management

This Permit must be kept on-site by the Permittee. During the Permit Term, prior to conducting activities on the Permitted Project Area, Permittee shall designate in writing to NPS the Permitteeôs Project Manager for administration of this Permit and all conditions, and a Permitteeôs designated Site Manager or his designee. Designee shall be identified prior to start of construction. The Project Manager or his designee shall be located on the Permitted Project Area during all workdays with activity authorized under this Permit. The Project Manager and Site Manager shall use their best efforts to ensure that all permitted activities comply with the permit conditions, directives, and instructions from NPS rangers/officers regarding NPS regulations and policies.

As of January 20, 2015 and as designated by Permittee, the Site Manager is Jonathan Ng, 510/393-5844, and the Project Manager is Joon Kang 510/622-0130.

F. Other Required Permits

See Permits, Exhibit B; List all permits or regulatory review, as required by federal, state, regional or local regulatory agencies for the proposed construction activities within Crissy Field. Other agenciesô jurisdictions include, but may not be limited, to the following: U.S. Fish and Wildlife Service, National Marine Fisheries Service, U.S. Army Corps

of Engineers, Regional Water Resources Agency, San Francisco Bay Conservation and Development Commission, and U.S. Coast Guard.

G. <u>Permit Special Conditions and Permittee staffing requirements for Protection of Visitors, Lands, Property and Buildings</u>

Permittees shall satisfy all requirements attached to this Permit as Exhibit C (ñPermit Special Conditionsò).

H. <u>Insurance</u>

Permittee is a self-insured government entity. Permittee is required to provide a letter of self-insurance to NPS as previously provided to the Presidio Trust per the agreement entered into July 16, 2009 between the Co-Permittee and Permittee for entry on to Presidio Trust property needed for the construction of the South Access to the Golden Gate Bridge, Doyle Drive Replacement Project in San Francisco (ñState-Presidio Trust Doyle Drive Agreementò).

The United States of America, Department of Interior, National Park Service, Golden Gate National Recreation Area, its agents and employees shall be named as Additional Insureds on the general liability and excess liability coverage of the Permitteeôs Contractorôs insurance as specified in Section 7-1.06 ñINSURANCEò of Caltrans Standard Specifications in place for the Project. Provide proof of Additional Insured and other insurance requirements to NPS. Permittee shall require its contractors and agents to indemnify, defend and hold harmless the NPS, the Co-Permittee, its employees and agents, to the same extent that they indemnify the Permittee. Permittee will provide certificates of insurance establishing the above. Said certificates shall specify the insurance or self-insurance coverage, provide that such insurance or self-insurance is primary over any insurance carried by the additional insureds, and provide that such policies shall not be cancelled or the coverage reduced without thirty (30) days written notice thereof to NPS.

Permittee shall require any and all Permitteeôs contractors and subcontractors accessing the Permitted Project Area for the purposes of this Permit to procure and maintain General Liability, Commercial Auto, Contractorôs Pollution Legal Liability, Workers Compensation insurance in accordance with Exhibit E of the State-Presidio Trust Doyle Drive Agreement. Such general liability and property insurance policy covering Permitteeôs contractorsô access to and activities on the Permitted Project Area shall be not less than $2,000,000 per occurrence, $5,000,000 aggregate covering both bodily injury and property damage. Prior to the start of construction, the Permittee shall provide the General Superintendent with a copy of the policy or Certificates of Insurance stating ñ**The United States of America, Department of the Interior, National Park Service, Golden Gate National Recreation Area and their agents and employees named as Additional Insured**.ò The Permittee is responsible for insuring other interests in the Permitted Project Area.

I. <u>Utilities</u>

During the term of this permit, the Permittees shall be responsible, at their expense, for furnishing and maintaining all utility services (water, sewer, telephone, electricity, gas, and garbage disposal) required for the Permitted Project Area. The installation and removal of any required utility meters will be at the expense of the Permittee.

Permittee and Co-Permittee shall coordinate for the connection, commencement and billing of all utilities noted above.

Exhibits

Exhibit A: Map of Permitted Project Area

Attachment A1: Location Map
Attachment A2: Map of Permitted Project Area

Exhibit B: Other Required Permits

The California Department of Transportation is required to work with the federal, state , regional, and local regulatory agencies in determining the requirements for all other permits, and to certify to NPS that it in fact has such clearance. Agencies to be contacted for this determination include:

U.S. Fish and Wildlife Service: Biological Opinion
National Marine Fisheries Service: Letter of Concurrence
U.S. Army Corps of Engineers: Section 404 permit
San Francisco Bay Regional Water Quality Resources Agency: Section 401 permit
San Francisco Bay Conservation and Development Commission: Coastal Zone Consistency Determination/Coastal Development Permit
U.S. Coast Guard: approval of storm water drain extension

Exhibit C: Permit Special Conditions and Permitted Project Area Restrictions

1. Permitteeôs Contractors
2. Standard of Care
3. Permitteeôs Staffing Requirements
4. Permitteeôs Conditions
5. Co-Permitteeôs Conditions

Exhibit D: Project Descripton

Attachment D1 - Hazardous Materials Testing Description
Attachment D2 ï Replacement of storm drain

Exhibit E: Insurance

Attachment E1 ï State of California Public Liability and Workersô Compensation Insurance
Attachment E2- The Contractorôs Certificate of Liability Insurance

General Project Location: Within Crissy Field and the San Francisco Bay, the Presidio of San Francisco, Golden Gate National Recreation Area, County of San Francisco

Exhibit A: Attachment A2: Map of Permitted Project Area

Exhibit B: Other Required Permits [ATTACH]

Exhibit C: Permit Special Conditions and Permitted Project Area Restrictions

1. Permitteeôs Contractors
2. Standard of Care
3. Permitteeôs Staffing Requirements
4. Permitteeôs Conditions
5. Co-Permitteeôs Conditions

Permittees and NPS are entering into this Permit solely for the purpose of allowing Permitteesô access, mobilization, staging, construction, and site restoration for the replacement and extension of a segment of storm water drain pipe in Crissy Field and the IJKL Outfall per NPS PEPC 46130 associated with the Doyle Drive Project. Any future construction or other activities on Presidio Area A not expressly authorized by this Permit will require additional authorization(s) from the National Park Service.

1. **Permitteeôs contractors and subcontractors** accessing the Permitted Project Area, under Permitteeôs supervision, shall only be those listed below:

   Upon approval of the contract, Permittee shall provide Contractor and Subcontractor names within three business days. NPS will be notified within three business days of additional subcontractorôs that may be added to the Project.

2. **Permitteesô Standard of Care:** On or about September 24, 2008, Permittee, Co-Permittee and other parties entered into a Programmatic Agreement pertaining to the avoidance, mitigation and/or treatment of historical, cultural and archaeological resources associated with the Doyle Drive Replacement Project within Presidio Area B, directly adjacent to Presidio Area A and the Permitted Project Area, and the Permittee and Co-Permittee are engaged in ongoing discussions, consultation and coordination with numerous parties, including NPS, regarding development and implementation of historical, cultural and natural resource mitigation measures, plans, and agreements pursuant to environmental documents related to the Doyle Drive Replacement Project.

   Permittee shall use its best efforts to ensure its activities under this Permit on Presidio Area A shall meet no lesser standard of appropriate measures than those recognized by the Co-Permittee and Permittee on Presidio Trust Area B for all such work related to the Doyle Drive Replacement Project.

3. **Permitteeôs Staffing Requirements**

   a. All Permitteeôs, contractor and subcontractor staff must attend an NPS-held environmental training prior to mobilization.

   b. Permitteeôs biologist will be present on the project site at all times during construction in Beach, Intertidal and Marine WPA areas.

   c. Permitteeôs qualified archeologist shall be on site during all excavation, grading, drilling, borings, bringing up spoils or handling cores.

   d. The Permittee shall not impact the historic buried Crissy Airfield when accessing the site or when removing existing sod, irrigation or other subgrade elements at or around the Staging Area.

   e. At least two Traffic Control Personnel shall be present on site with the contact information of Public Information Officers during any vehicle or other equipment crossing through any public traffic; visitor bike lane, multi-use path, Crissy Field Promenade Access Route, trail or path within Presidio Area A sites to ensure visitor safety and no conflicts with pedestrians, cyclists or roadway vehicles.

   f. The Site Manager or his designee shall be on-site during any Project activity (including mobilization and staging) and available to communicate with NPS representatives as needed. Permitteeôs contractors must

be under Permitteeôs supervision upon entering and working within the Permitted Project Area on Crissy Field and San Francisco Bay.

g. Project Supervisor: Provide a project supervisor (either Site Manager or his designee per Permit Section E) from Permittee as a single point of contact. That person is required to be on-call to NPS for 24 hours per day, seven days a week in case of emergencies in relationship to the project, and must be available within 20 minutes during work hours for project-related matters, if requested by NPS Project Liaison Andrea Lucas or NPS Facility Management representative. Provide emergency contact numbers.

4. **Permittees Conditions**

a. COMMUNICATIONS, SCHEDULING and REVIEW

i. Co-Permittee shall submit its peer review of the IJKL design and functionality. NPS is solely reliant on the engineering reviews of the Co-Permittee for the design and construction functionality of the IJKL Outfall.

b. PRIOR TO MOBILIZATION and CONSTRUCTION

1. SUBMITTALS: The following documents shall be submitted to NPS for review and approval a minimum of 15 working days prior to Permitteeôs entry into the Permitted Project Area under this Permit. No mobilization, staging, construction, or other activities in the Permitted Project Area shall begin until NPS has approved in writing all of the following submittals:

a. Plans, Specifications and Estimates (PS&E)
- IJKL Outfall Design: A complete bid set of construction documents and specifications, including all addenda and change orders as they occur. This shall include a description and plans describing any temporary structures, shoring, platforms, or access roads.
- Construction Staging
- Traffic Management
  - Construction Traffic Management, including identification of access routes and parking for vehicles and equipment
  - Public Access Management, including methods to minimize impacts for visitors, bicyclists, and pedestrians (public traffic). The plan shall maintain safe, continuous public pedestrian and bicycle access across the Crissy Airfield and Crissy Field Promenade.
    - Flagging
    - Signage
    - Fencing
    - Any other needed safety measures
- Hazardous Material Testing, Handling and Disposal
- Special Provisions
- Job Site Management

b. Detailed Construction and Staging Plan for the staging areas identified in the Permitted Project Area, including: A list of equipment that will be stored in the staging areas, grading plans, fencing plans, locations and sizes of stockpile areas, and public information signage locations. The staging areas shall be the minimum needed to accommodate contractorôs needs and shall be reduced in size as the construction footprint shrinks.

c. Health and Safety Plan, including worker safety

d. SWPPP, including Spill Prevention Plan

e. Debris and containment plan describing the methods that will be used to capture and dispose of any debris or containments, including sediment and turbidity, that are or threaten to be, released into San Francisco Bay waters
f. Temporary Trestle Design
g. Shoring Plan
h. Noise Monitoring and Abatement Plan, including a description of the duration and time of day for noise-generating equipment use and a description of how noise levels will be reduced to levels at or below those required.
i. Environmental Monitoring Plans
    - Turbidity Monitoring Plan
    - Hydroacoustic Sound Monitoring Plan
    - Biological Monitoring Plan
j. IJKL Outfall Environmental Permits
    - USFWS BO
    - NOAA LOC
    - RWQCB 401
    - ACOE 404
    - BCDC CZMA
    - Coast Guard - approval
k. Preconstruction photo survey and documentation of staging area, access routes, and construction footprint.

2. Stormwater Management:

    a. Permittee shall submit a Stormwater Pollution Prevention Plan (SWPPP) to NPS for at least 21 working days review prior to finalizing the document, concurrent or prior to the submittal to the Regional Water Quality Control Board for NPS review.
    b. Erosion and sediment control materials used on-site shall be free of plastic, including biodegradable or photodegradable plastics, and any materials shall be certified weed free.
    c. Permittee shall provide the waste discharge identification number (WDID) within three business days of the State Water Resource's Board approval of the NOI, and prior to any ground disturbing activities.

3. Visitor Outreach:
    a. Two weeks prior to mobilization and access to the staging areas under this Permit, Permittee shall submit a public information plan for NPS review and comment, including informational signage; detour and site closure signs; and an information brochure.
    b. Permittee shall post NPS-approved informational signage and the flier at the site at least two weeks prior to mobilization under this Permit. Information shall be posted adjacent to the site during the work during the duration of the project. Signs should include contact information.

4. At least two weeks prior to start of mobilization, Permittee shall notify the NPS biologist for the site to coordinate salvage of dune plants.

5. Gulf of the Farallones Beach Access: Permittee shall provide a Plan for beach access west of the pier to NPS and to Gulf of the Farallones National Marine Sanctuary for approval and provide the access structures as approved (for example, gate and stairs) prior to closing the Permitted Project Area to the public.

6. Approvals: No approvals required from NPS by the Special Use Permit or the Special Conditions herein shall be unreasonably withheld. NPS will act upon any required submittal by approving it or providing specific reasons for not doing so within 15 working days of the date it is submitted.

ii. SCHEDULING AND START-UP

1. WORK SCHEDULE: Provide the weekly Project work schedule to NPS prior to the start of Construction including Mobilization. Per the Plans, Specifications and Estimates (PS&E) the schedule shall include a specific daily work plan and milestones indicating initial entry into the Permitted Project Areas for mobilization, staging, and construction.
2. Provide updated work schedule upon Permitteeôs issuance of Notice to Proceed.
3. PRE-PROJECT MEETING: Conduct a field meeting prior to mobilization (including layout of construction fence and other activities related to designated access routes in the Permitted Project Areas) with NPS Project Liaison, Andrea Lucas; NPS Facility Management representative; and representative of Gulf of the Farallones Marine Sanctuary.
4. PRE-CONSTRUCTION MEETING: After the Pre-Project Meeting and prior to start of construction activities on May 15, conduct a field meeting with NPS Project Liaison, Andrea Lucas, and the NPS Facility Management representative.
5. PRE-CONSTRUCTION ENVIRONMENTAL TRAINING: After the Pre-Project Meeting and prior to start of construction activities on May 15, conduct a field meeting with NPS Project Liaison, Andrea Lucas, and the NPS Natural Resources representative.
6. NOTIFICATION: Prior to construction, notify the NPS Facility Management representative via Andrea Lucas at 415-561-4931 at least four working days prior to commencement of the construction.
7. UTILITY LOCATION: Conduct utility location surveys in coordination with NPS Project liaison, Presidio Trust, and utility location services (per industry standards), before finalizing construction excavation and impact locations. Mark locations of utilities including irrigation mains and lateral piping in coordination with NPS Facility Management representative.
8. Permittee shall provide a portable toilet(s) during the Permit Term, to be placed within the fenced portion(s) of Permitted Project Area.
9. Permittee shall provide covered trash receptacles and ensure adequate trash collection to keep the site clean. All Permitted Project Areas shall be kept free of trash. Absolutely no feeding of wildlife or allowing wildlife access to food waste or trash is allowed.

iii. DURING CONSTRUCTION:

1. Update progress with daily report to NPS Project liaison via email to *andrea_lucas@nps.gov*.
2. Conduct a field meeting with NPS Facility Management representative each morning to identify undertaking for that day, ensure that their work is done in an authorized area, and is in accordance with the workplan and safety plan.

iv. PROJECT DATA COLLECTION and REPORTING:

1. Permittee shall keep a daily biological monitoring log and daily turbidity monitoring log, and the copies of the logs will be made available to NPS weekly (per Section d, below, Sensitive Species).

2. Permitteeôs qualified archeologist shall review all excavation, drilling, borings, bringing up spoils or handling cores and shall immediately report to NPS representative any findings during borings or core-sampling.
3. Permittee shall provide NPS a copy of results of any other surveys, data collection, and hazardous materials investigations and recommended remediation actions within 30 days of the report.

b. SAFETY

i. Permittee shall install a temporary 6 foot high chain link fencing around staging area(s), and around the boundaries of the Permitted Project Area. Fencing shall not block access along the Crissy Field Promenade indicated in Permit Exhibit A.

ii. Upon completion of construction on the Beach WPA, the temporary fence (between the Crissy Field Promenade and the beach indicated in Permit Exhibit A), shall be relocated to the north, as safety permits, to provide lateral (east-west) pedestrian visitor beach access as indicated in Permit Exhibit A. It is understood that full visitor beach access may not be feasible until completion of the project.

iii. Spill proof containment is required with presence of any fuel-based vehicle or equipment in accord with approved Spill Plan.

iv. Permitteeôs Contractor and onsite officers, agents, and employees shall comply with the approved Health and Safety Plan, including visitor and worker safety measures.

v. Permittee shall provide flaggers when Permittee or contractor vehicles use or cross any public paths.

c. GENERAL

i. Prior to entering the Permitted Project Area under this Permit, State Site Manager shall ensure all equipment and vehicles used by Caltrans, contractors, and sub-contractors shall be washed and weed free before entering the Permitted Project Area. Permittee shall comply with Executive Order 13112 (Invasive Species).

ii. Refueling or maintenance of equipment is permitted only within the approved staging areas. Spill kits shall be accessible at all times.

iii. Pile material shall be HDPE or another inert, NPS approved material.

iv. Staging for the project shall be limited to non-environmentally sensitive areas as indicated in the Permitted Project Areas: a) 52,272 SF on Crissy Field, and b) off shore barges, located within 800 feet offshore of Crissy Beach in San Francisco Bay. Staging areas are shown on Attachment A. Exact locations to be approved by NPS.

v. No personal vehicles shall be allowed in the Permitted Project Area or within Presidio Area A.

vi. No personal, construction-related, or Permitteeôs vehicles will be allowed to drive within or park in the Gulf of the Farallones National Marine Sanctuary campus.

vii. Equipment within the staging area(s) is permitted to remain overnight. All mobile equipment shall be stored overnight in the fenced staging area. Tracked vehicles and other equipment not feasible to move daily from the construction area to the staging area may be permitted on the beach. No equipment is permitted overnight on public trails.

viii. Access to Permitted Project Areas will be limited to Mason Street and the designated segment of the Crissy Field Promenade per Exhibit A, and through the beach access gate across from the Crissy Field Staging Area per Exhibit A. No other entry to the beach is permitted.

ix. Soil and sediment excavated or dredged from the bay side of the Mean Lower Low Water (MLLW) line (at elevation -2.48 NGVD29) shall not be reused on site on the land side of the MLLW line.

x. Soil and sand salvaged during operations may be used for backfill if laboratory testing demonstrates that levels of hazardous substances and contaminants in the material are below levels suitable for unrestricted use. Contaminant levels shall be compared to residential and ecological special status levels for Beach Dune lithology presented in Table 7.2 of the Presidio Trust Document *Development of Presidio-Wide Cleanup Levels for Soil, Sediment, Groundwater and Surface Water*, dated October 30, 2002, revised May 2006. All sampling shall meet the requirements of the DTSC Informational Advisory, *Clean Imported Fill Material*, dated October 2001. For any proposed onsite reuse, Permittee shall provide NPS with a report describing the proposed reuse and the sampling and testing which was done. The report shall be stamped pursuant to California Professional Code Section and include copies of laboratory test reports for all analytical data. All soils and sediments not suitable for reuse on site shall be disposed at approved permitted offsite disposal facility, per state and Federal requirements. Alternate disposal or reuse methods may be proposed to NPS for approval.

xi. Any soil or sediments material removed from below the water, shall be tested to determine a suitable disposal method and location. If the dredged material is unsuitable for offshore disposal, it will be disposed at an approved landfill reuse site, and notification will be provided to NPS.

xii. No soil shall be imported to the site without prior approval of NPS.

d. SENSITIVE SPECIES

i. Prior to May 15, 2015, Permittee shall coordinate with NPS to complete focused surveys targeted for rare plants that may not have been in bloom and thus unidentifiable during previous vegetation surveys. If rare plants are found within the Permitted Project Areas, no construction shall be permitted until plant protection and/or mitigation measures are developed and implemented.

ii. Prior to any on-site construction a worker Environmental Awareness Training, required for all project personnel (including those on project-related watercraft), will be conducted by NPS or a NPS approved representative.

iii. Whenever possible, all existing vegetation will be preserved. In coordination with NPS, some existing vegetation located on the beach within the Permitted Project Area will be salvaged and transplanted or maintained by NPS. Any costs for maintenance prior to transplanting shall be borne by Permittee.

iv. ESA Fencing: Prior to construction on the Beach WPA, Permittee shall verify ESA fencing locations with NPS. Temporary orange safety fencing will be placed in the Beach WPA in a manner that protects, to the extent feasible, the existing foredune vegetation from the construction activity areas, and will be placed prior to start of construction in coordination with NPS. The Permittee will maintain the ESA fencing throughout construction. No access is permitted into an ESA without prior approval from NPS.

v. Surveys: Prior to construction, Permittee shall complete a biological survey of the Beach WPA and the Intertidal WPA to determine presence of western snowy plover and presence of any nesting birds. If plover are present in the Permitted Project Area, no work may commence until approval is given by NPS and USFWS. If nesting birds, nests, or evidence of breeding is present in the Permitted Project Area, no vegetation removal is permitted until approval is given by NPS and USFWS.

vi. Permitteeôs biologist shall monitor the beach and Intertidal WPA throughout the construction for snowy plover. Should a snowy plover be observed within the WPA, the State Project Manager shall suspend construction activities within a 50 ft-radius of the bird until the bird leaves the site voluntarily.[1] The State Project Manager shall immediately contact both the U.S. Fish and Wildlife Service and the NPS.

vii. The following measures will be implemented during construction in the Intertidal WPA and the Marine WPA (Stages 2 and 3 of project):

a. Monitoring for aquatic resources will be completed daily and include the following:

1. Underwater sound measurements at the distances of 10 meters and 20 meters, and at mid-depths of bay from pile driving locations;
2. Turbidity levels;
3. Evaluation of fish mortality and injury rates by the use of visual observations and collections during pile driving events; and
4. Observations of bird predation and behavior.

b. Data from the monitoring program will be made available to NPS weekly.

c. Permitteeôs biological monitor will survey the project area if construction activity occurs during California grunion *(Leuresthes tenuis*) spawning season (nights of the full and new moons, spawning occurs after high tides in spring and summer months). Spawning areas will be marked to reroute access routes to avoid impacts. Monitoring shall continue throughout construction activity during California grunion spawning season.

d. Turbidity curtain: During excavation work (Stage 2), temporary sediment control measures will be implemented. The temporary turbidity curtain will be secured to the Bay floor using 52 helical or fluke-type anchors, which will help keep the turbidity in a controlled area.

e. During construction, turbidity shall not increase by more than 10 percent if the ambient turbidity of the receiving water is greater than 50 Nephelometric Turbidity Units (NTU), or by more than 5 NTU if the ambient turbidity of the receiving water is less than or equal to 50 NTU. If monitoring shows an increase in turbidity that exceeds the water quality thresholds described above, the Permittee shall stop work until measures are taken to contain turbidity to acceptable levels.

f. An aquatic ñSafety Zoneò of 1,300 feet radius will be established in accordance with National Marine Fisheries Service (NMFS) and the Marine Mammal Protection Act (MMPA). During all construction activities within this area, Permitteeôs Biological monitor(s) will observe and record their observations of marine mammals and special-status fish within this zone. Any marine mammal or special-status fish observation within this zone will be reported immediately to the NPS Representative. If a marine mammal or special status species is observed within or approaching 100 feet of pile driving locations, the Permitteeôs Site Manager is required to delay pile driving of the segment until the animal(s) has moved outside of the 100 feet radius of pile driving locations or the animal has not been re-sighted within 15 minutes.

g. Permitteeôs Biological monitor(s) will be on-site during all construction-related activities at least 30 minutes before, during, and at least 30 minutes after pile driving activities, to monitor the work area for marine mammals and special-status fish.

h. Permittee shall use a ñsoft startò technique at the beginning of each pile installation, to allow any special-status species and/or marine mammal that may be in the immediate area to leave before impact piling reaches full energy. The soft start will require an initial set of 3 strikes from the impact hammer at 40 percent energy, followed by a 1-minute waiting period, then two subsequent 3-strike sets.

i. Permittee shall ensure hydroacoustic sound levels do not exceed the following thresholds established by NMFS: 206 dB Peak SPL at 0 m; 187 dB cSEL at 2 m; 150 dB RMS at 16 m.[2]

j. Night Construction: Night construction will be minimized to the extent practicable and used only as necessary for coordination with low tide access in the Intertidal WPA, or construction, diver, or pedestrian safety. Low lighting will be used and will be directed to the construction activity area and will be shielded from upward/lateral dispersal. After August 1, when watercraft may approach the beach in the early morning, lighting will be directed away from the beach.

e. VISITORS AND PROGRAMS

i. All proposed work within the Permitted Project Areas will be completed in the Permit Term.

ii. In coordination with NPS Project Liaison, Permittee will work with Noemi Margaret Robinson, NPS Office of Special Park Uses, to ensure that there are no conflicts with scheduled public activities.

iii. Activities of Permittee under this Permit cannot unreasonably interfere with any park programs, uses, NPS services, or the natural soundscape of surrounding park areas. To help insure that, Permittee will ensure that its contractors use only the least impacting equipment, vehicles and systems in implementing the authorized work under this Permit.

iv. Noise Monitoring:

1. During any noise-generating activity during the Permit Term, and per NPS Liaison, such as installing sheet piling, sound sample measurements in decibels and duration will be conducted on the first day of such activity and last day of that week at two time intervals daily (9AM-9:15AM) and (1:30PM-1:45PM) at the following locations: Crissy Center educational Center, Crissy Marsh (western end), and the Gulf of the Farallones Marine Sanctuary visitor and educational center.

2. Weekly reports of such will be reviewed with the NPS Project Liaison at the end of the first week of such activities in the Crissy WPA and within the Crissy field.

3. <u>During regular Work Hours</u> as described below under ñTime of Work Restrictionsò, noise levels shall not exceed five (5) decibels above ambient, measured at the closest point of nearest a) occupied residential tenanted building or b) occupied commercial tenanted building in which business activities are occurring. Project work that may exceed these criteria includes, but is not limited to; pile driving, excavation, dredging, and sheet pile installation. To the extent that such work will exceed five (5) decibels

[2] NOAA Endangered Species Act Section 7(a)(2) Concurrence Letter and Magnuson-Stevens Fishery Conservation and Management Act Response for the Couth Access to the Golden Gate Bridge-Doyle Drive: IJKL Outfall Replacement Project. October 8, 2014.

above ambient, measured at those points, the Permittee shall notify NPS Project Manager at least 3 days in advance of commencing such periods of work.

4. The parties acknowledge and understand that project work outside the regular Work Hours may be required. Outside of regular Work Hours as described in ñTime of Work Restrictionsò, below, noise levels shall not exceed five (5) decibels above ambient, measured at the closest point of nearest a) occupied residential tenanted building or b) occupied commercial tenanted building in which business activities are occurring. Project work that may exceed these criteria includes, but is not limited to; pile driving, excavation, dredging, and sheet pile installation. To the extent that such work will exceed five (5) decibels above ambient, measured at those points, the Permittee shall notify NPS Project Manager at least 3 days in advance of commencing such periods of work.

v. Time of Work Restrictions: Work Hours: Equipment operations on land are restricted to Mondays through Fridays from 7AM to 7 PM. No work will take place on Saturdays or Sundays without prior approval from NPS. NPS will provide a minimum of 6 weekend days as work days, exact date to be determined by NPS. The project requires off shore work during low tides; low tides may occur outside of the Time of Work Restrictions. The Project or Site Manager shall provide NPS Project Liaison with a schedule of dates where work is anticipated before 7 AM or after 7 PM a minimum of 3 days prior to proposed construction for review and approval.

vi. Blackout dates: No work shall occur on the following dates: Monday, May 25, 2015 (Memorial Day), Friday, July 3, 2015 (Independence Day observed), Monday, September 7, 2015 (Labor Day), Thursday, October 8, 2015, Friday October 9, 2015 (Fleet Week), and Monday, October 12, 2015 (Columbus Day).

vii. Additional work hour or day restrictions may be placed on Permitteeôs activity after consultation with Permittees, if Project activities unreasonably interfere with public activities. If NPS believes that is the case, NPS Project Liaison will meet and confer with Permitteeôs Project Manager and Site Manager, and shall identify and implement appropriate mitigations for Permittee to undertake while getting work completed on a timely basis.

b. SITE RESTORATION

i. Permittee shall restore the Permitted Project Area, Access Routes and any other area affected by the Project. At the Permitteeôs expense, elements such as grades, fences, soil, irrigation, turf, dunes, plantings and any damage to roads, trails, and/or the Crissy Field Promenade caused by the project, per coordination and approval of NPS, shall be restored to at least pre-project condition and quality. All restoration plans shall be submitted and approved by NPS prior to implementation. All restoration shall be completed by the end of the Permit Term.

ii. By July 31, 2015, Permittee shall recontour the beach in the project area above the (Mean Higher High Water) MHHW line to conditions consistent with the pre-construction photo surveys and consistent with the surrounding beach contours.

iii. Submit a Site Restoration Plan to NPS for approval 2 weeks prior to executing the work.

iv. DUNE RESTORATION AND REVEGETATION BY NPS

1. Planting in Beach WPA: Work will be done by NPS per separate agreement with the Permittee.

2. Plant materials shall be those salvaged from the site and stored for the purpose of restoration, and/or new plants approved by NPS and that are propagated and grown at the Golden Gate National Parks Conservancy Native Plant Nursery. All expenses will be borne by the Permittees.

3. By June 1, 2015, Permittee will provide NPS with the necessary funds to propagate plants for, and replant, weed and monitor, disturbed on-site vegetation within the Beach WPA.

3. **Co-Permittee Conditions:**

a. Co-Permittee shall ensure that any activity that it undertakes in Presidio Area A related to this Permit is consistent with the authorized activities and complies with the conditions listed above.

b. The Co-Permittee has historically maintained the IJKL Outfall and will continue to maintain the outfall consistent with current practice through the Term of this Permit. NPS is solely relying on the Co-Permittee for engineering review of the functional design of the IJKL outfall including hydraulic analysis and maintenance considerations. Co-Permittee shall submit its peer review of the outfall design to NPS no later than April 1, 2015. After the term of this Permit, the Co-Permittee and NPS intend to enter into an agreement for management of utility infrastructure in Area A, including the IJKL outfall constructed during the term of this Permit.

Located on Crissy Beach, at the northern shore of San Francisco, California, the outfall is an existing terminus of a storm drain system that conveys rainfall run-off from a 125-ac watershed within the Presidio to San Francisco Bay.

To address the deficiency of the existing pipeline, Caltrans, the Federal Highway Administration (FHWA), and the PT propose to replace approximately 170 ft of the existing 42-in outside diameter HDPE pipe from the existing manhole located on the beach, leading to the outfall in the Bay, and extend the pipe another approximately 296 feet, to just beyond the expected 50-year beach accretion point. The replacement and extension will consist of a 54-in outside diameter Solid Wall High Density Polyethylene (SW-HDPE) pipe for a total pipeline length of 460 ft. The pile and cross-tie configuration that supports and stabilizes the pipe will be similar to the one used for the previous extension of the outfall that was completed in year 2000, which consisted of 13-in-diameter, fiber-reinforced HDPE piles and HDPE cross ties. Aesthetically, the new outfall is designed to be mostly hidden during low tide.

Approximately the first 270 ft of the pipe will be fully buried. Of this length, approximately the last 105 ft will be supported by 8 new 13-in HDPE piles while the first 165 ft is supported by 14 existing 13-in HDPE piles. These new piles will be impact-driven using a hydraulic impact hammer to approximately 30 to 35 ft below the beach surface. The last 190 ft will be supported above the Bay bottom on 16 new 13-in HDPE piles. These 35-ft-long piles will be impact-driven to approximately 24 ft below the bottom of the Bay; the top of the piles are designed to remain below the mean lower-low water (MLLW) mark, except for the last set of pilings. For safety reasons, the last set of pilings will be above the mean higher high water (MHHW) and delineated with signage as recommended by the U.S. Coast Guard.

Construction of the outfall replacement will occur in three distinct stages: Stages 1 will occur in the onshore zone, Stage 2 will occur in the intertidal and offshore subtidal zones, and Stage 3 will occur in the offshore zone.

In addition, the cover and frame of an existing 24-in manhole vault in Crissy Field, just south of the Crissy Field promenade, will be replaced with a 36-in manhole cover and frame to facilitate future maintenance. This will substantially reduce the future need for PT maintenance staff to access the manhole on the beach to maintain the pipe.

Construction stages are characterized by differing site conditions, which will be subjected to different methods of construction. The onshore and offshore construction means and methods will be determined by the project contractor. Construction will occur between May and October during the dry season to primarily avoid over-wintering western snowy plover and migrating fish. Normal construction activities will occur Monday through Friday from 7:00 am to 6:00 pm with early morning, and weekend work subject to tidal levels and as permitted by the National Park Service (NPS). The new outfall will be constructed in three stages as follows:

Stage 1 (May 15 to July 31): Onshore Construction at Crissy Beach

The onshore (beach) project footprint is 0.75-ac (32,670 ft^2). Since the onshore footprint is sandy, temporary timber construction mats will be laid on the sand to provide construction access. Staging and storage will occur on Crissy Field, described below under ñStagingò. Barges will be used as work and storage platforms and to stockpile dredged material. Outfall construction vehicles and equipment may include support trucks (e.g., pickup trucks, dump trucks, flatbed trucks), trailers, excavators, loader/backhoes, a crane, and a pile driver.

Stage 2 (June 1 to July 31): Intertidal and Offshore Construction in San Francisco Bay

After the outfall on the beach is constructed and backfilled during Stage 1, Stage 2 construction will continue

into the intertidal zone and the Bay. Excavation and disposal of dredged material will occur during Stage 2 construction.
The construction vehicles and equipment to be used and stored on off-shore barges may include an excavator, a pile driver, a loader/backhoe, and dump trucks as well as other tools necessary to excavate within the intertidal zone. Divers also will assist in the underwater pipe installation.

Stage 3 (June 1 to October 31): Offshore Construction in San Francisco Bay
During Stage 2 construction in the Bay, the turbidity curtain will be removed and Stage 3 construction will be completed using equipment similar to that used in Stage 2. The removal of the turbidity curtain in Stage 2 may occur simultaneously with Stage 3.

Attachment D1 - Hazardous Materials Testing Description
Attachment D2 - Storm Drain Replacement Work

Exhibit E: Insurance and Letter of Self-Insurance.
Attachment E1 - Insurance Information
Attachment E2 - Insurance Information

Exhibit D: Project Description
Exhibit E: Insurance and Letter of Self-Insurance

Term of the right of entry is May 4, 2015 through October 31, 2015, for the described work within Permitted Project Area only, as described in Exhibit A (Map of Permitted Project Area).
Authorizing legislation or other authority (see DO-53): Golden Gate National Recreation Area Enabling Legislation

NEPA & NHPA Compliance: _X_ CATEGORICALLY EXCLUDED ___EA/FONSI ___EIS ___OTHER
APPROVED PLANS
PERFORMANCE BOND: Required___ Not Required _X_ Amount – N/A
LIABILITY INSURANCE: Required _X_ Not Required ___ Amount – See Section H

ISSUANCE of this permit is subject to the conditions on the reverse hereof and appended pages. Permittees recognize GGNRA as an "Affected Agency" by this work and Permittee's and Co-Permittee's broader work of the South Access to the Golden Gate Bridge-Doyle Drive Project as referenced in NPS Project PEPC #46130.

The undersigned hereby accepts this permit subject to the terms, covenants, obligations, and reservations, expressed or implied herein.

Permittee: Mark Shindler for District Office Chief — 2/4/15
Mark L. Weaver — Caltrans — Date

Co-Permittee: 2/5/15
Craig Middleton, Executive Director — Presidio Trust — Date

Authorizing Official: A. Roth for Deputy Superintendent — 2/4/2015
Frank Dean, General Superintendent — GGNRA — Date

CONDITIONS OF THIS PERMIT

A. General Conditions

1. In accordance with the signed, prior Permit # 8142-13-0536 for IJKL Storm Drain Replacement, this Special Use Permit #8142-15-0522 is solely for the projects described in NPS PEPC 46130 and as shown in Exhibit A and Exhibit D. The term of this Permit may be extended to cover a future phase if agreed in writing by all parties, subject to the terms and conditions of this permit continuing in full effect, and including cost recovery charges as applicable."

2. The Permittees shall exercise this privilege subject to the supervision of the General Superintendent, and shall comply with all applicable laws and regulations of the area.

3. Damages - The Permittees shall pay the United States for any damage resulting from this use, which would not reasonably be inherent in the use that the Permittees are authorized to make of the land described in this permit.

4. Benefit - Neither Members of, nor Delegates to Congress, or Resident Commissioners shall be admitted to any share or part of this permit or derive, either directly or indirectly, any pecuniary benefits to arise therefrom. Provided, however, that nothing herein contained shall be construed to extend to any incorporated company, if the permit be for the benefit of such corporation.

5. Assignment - This permit may not be transferred or assigned without the consent of the General Superintendent, in writing.

DEPARTMENT OF THE ARMY
SAN FRANCISCO DISTRICT, U.S. ARMY CORPS OF ENGINEERS
1455 MARKET STREET, 16TH FLOOR
SAN FRANCISCO, CALIFORNIA 94103-1398

JAN 22 2015

Regulatory Division

Subject: File Number 2014-00272S

Mr. Joon Kang, Project Manager
California Department of Transportation
P.O. Box 23660, 111 Grand Avenue
Oakland, California 94623-0660

Dear Mr. Kang:

This correspondence is in reference to your submittal of August 15, 2014, concerning Department of the Army (DA) authorization to replace and extend an existing drainage outfall located approximately 1,000 feet north of Highway 101 post mile 9.8, on the south side of the Golden Gate Bridge, at Crissy Beach in the City and County of San Francisco, California (37°48' 19.72" N, -122°27'56.95"W).

Work within U.S. Army Corps of Engineers' (Corps) jurisdiction will include replacement and extension of a portion of the existing 42-inch diameter high density polyethylene (HDPE) pipe with a 54-inch diameter HDPE pipe that will extend approximately 296 feet beyond the mouth of the existing outfall. The pipe will be a total of 466 feet long with the first 235 feet from the manhole buried under the beach and bay floor, and the last 231 feet supported above the bay floor by 13-inch HDPE piles.

Project elements will include:

- Modification of an existing manhole in Crissy Field from a 24-inch structure to a 36-inch structure to more effectively facilitate future maintenance;
- Removal of existing the 170 foot long, 42-inch diameter HDPE from existing manhole structure to the outfall at Crissy Beach;
- Modification of 14 existing HDPE piles that support the existing outfall pipe so that the piles are at an elevation to support the new outfall pipeline;
- Installation of twenty-four 13-inch HDPE piles by hydraulic impact driving to support the new outfall pipe;
- Installation of 466 linear feet of 54-inch HDPE outfall pipe which will be secured to the piles by crossties; and,
- Installation of a temporary access trestle using fifty 13-inch steel pipe piles to support a timber platform 16 feet wide spanning from the shore out 240 feet into the bay. A vibratory hammer will be used to drive all of the piles on and off shore. One test pile on shore will be "proofed" 80 feet from mean higher high water, where a vibratory driver will be used to drive the pile within six inches of its designed depth; an impact hammer

will then be used to drive the pile the remaining depth to confirm its load bearing capacity (10-20 blows). The trestle will be removed by July 31, 2014.

The project will permanently impact approximately 0.013 acre of San the Francisco Bay due to installation of 231 feet of 54-inch HDPE pipe above the bay floor and eighteen 13-inch HDPE piles which will support the 54-inch HDPE outfall pipe above the bay floor. The project will temporarily impact 12.68 acres of the San Francisco Bay due to installation of temporary shoring, excavation and removal of the existing 42-inch pipe, installation of the new 54-inch pipe, and installation air bubble curtains at the locations where 13-inch HDPE piles to support the outfall will be driven. All work shall be completed in accordance with the plans and drawings titled "Stage Construction Plan" dated January 17, 2015, and provided in one figure as enclosure 1.

Section 404 of the Clean Water Act (CWA) generally regulates the discharge of dredged or fill material below the plane of ordinary high water in non-tidal waters of the United States, below the high tide line in tidal waters of the United States, and within the lateral extent of wetlands adjacent to these waters. Section 10 of the Rivers and Harbors Act generally regulates construction of structures and work, including excavation, dredging, and discharges of dredged or fill material, occurring below the plane of mean high water in tidal waters of the United States; in former diked baylands currently below mean high water; outside the limits of mean high water but affecting the navigable capacity of tidal waters; or below the plane of ordinary high water in non-tidal waters designated as navigable waters of the United States. Navigable waters of the United States generally include all waters subject to the ebb and flow of the tide; and/or all waters presently used, or have been used in the past, or may be susceptible for future use to transport interstate or foreign commerce. An approved jurisdictional determination was completed and date certified January 20, 2015 (enclosure 2).

Based on a review of the information in your submittal, the project qualifies for authorization under Department of the Army Nationwide Permit (NWP) 7 for *Outfall Structures and Associated Intake Structures*, 77 Fed. Reg. 10,184 (Feb. 21, 2012) (enclosure 3), pursuant to Section 404 of the CWA of 1972, as amended (33 U.S.C. § 1344 *et seq.*) and Section 10 of the Rivers and Harbors Act (RHA) of 1899, as amended (33 U.S.C. § 403 *et seq.*). The project must be in compliance with the terms of the NWP, the general conditions of the Nationwide Permit Program, and the San Francisco District regional conditions cited in enclosure 4. You must also be in compliance with any special conditions specified in this letter for the NWP authorization to remain valid. Non-compliance with any term or condition could result in the revocation of the NWP authorization for your project, thereby requiring you to obtain an Individual Permit from the Corps. This NWP authorization does not obviate the need to obtain other State or local approvals required by law.

This verification will remain valid until March 18, 2017, unless the NWP authorization is modified, suspended, or revoked. Activities which have commenced (i.e., are under construction) or are under contract to commence in reliance upon a NWP will remain authorized provided the activity is completed within 12 months of the date of a NWP's expiration, modification, or revocation, unless discretionary authority has been exercised on a case-by-case basis to modify, suspend, or revoke the authorization in accordance with 33 C.F.R. § 330.4(e) and 33 C.F.R. § 330.5 (c) or (d). This verification will remain valid if, during the time period between now and March 18, 2017, the activity complies with any subsequent modification of the NWP authorization. The Chief of Engineers will periodically review NWPs and their conditions and will decide to modify, reissue, or revoke the permits. If a NWP is not modified or reissued within five years of its effective date, it automatically expires and becomes null and void. It is incumbent upon you to remain informed of any changes to the NWPs. Changes to the NWPs would be announced by Public Notice posted on our website (http://www.spn.usace.army.mil/Missions/RegulatoryPublicNotices.aspx). Upon completion of the project and all associated mitigation requirements, you shall sign and return the Certification of Compliance, enclosure 5, verifying that you have complied with the terms and conditions of the permit.

You shall comply with all terms and conditions set forth by the "Water Quality Certification for the U.S. Highway 101 Crissy Beach Storm Drain IJKL Outfall Extension Project, San Francisco" issued by the San Francisco Bay, Regional Water Quality Control Board on October 17, 2014 (enclosure 6). You shall consider such conditions to be an integral part of the NWP authorization for your project.

This authorization will not be effective until you have obtained a concurrence from the San Francisco Bay Conservation and Development Commission that your project will comply with California's Coastal Zone Management Act. If the Commission fails to act on a valid request for concurrence with your certification within six months after receipt, the Corps will presume a concurrence has been obtained. You shall submit a copy of the concurrence to the Corps prior to the commencement of work.

General Condition 18 stipulates that project authorization under a NWP does not allow for the incidental take of any federally-listed species in the absence of a biological opinion (BO) with incidental take provisions. As the principal federal lead agency for this project, the California Department of Transportation (Caltrans) initiated consultation with the United States Fish and Wildlife Service (USFWS) to address project related impacts to listed species, pursuant to Section 7(a) of the Endangered Species Act of 1973, as amended (16 U.S.C. § 1531 *et seq.*). By letter of October 21, 2014 USFWS issued a BO (Caltrans EA 1637N1) cited in enclosure 7, with an incidental take statement for western snowy plover (*Charadrius alexandrinus nivosus*).

As the principal federal lead agency for this project, the Caltrans also initiated consultation with the National Marine Fisheries Service (NMFS) to address project related impacts to listed species under NMFS purview, pursuant to Section 7(a) of the Endangered Species Act of 1973, as amended (16 U.S.C. § 1531 *et seq*). By letter of October 8, 2014, NMFS concurred with the determination that the project was not likely to adversely affect Sacramento River winter-run Chinook salmon Evolutionarily Significant Unit (ESU) (*Oncorhynchus tshawytscha*) or its critical habitat, Central Valley spring-run Chinook salmon ESU (*Oncorhynchus tshawytscha*), Central California Coast steelhead Distinct Population Segment (DPS) (*Oncorhynchus mykiss*) or its critical habitat, Central Valley steelhead DPS (*Oncorhynchus mykiss*), or North American green sturgeon southern DPS (*Acipenser mediostris*) or its critical habitat (enclosure 8).

The Caltrans also initiated consultation with the NMFS to address project related impacts to Essential Fish Habitat (EFH) for various life stages of fish species managed with the Pacific Groundfish Fishery Management Plan, Coastal Pelagics Fishery Management Plan, and Pacific Coast Salmon Fishery Management Plan, pursuant to Magnuson-Stevens Fishery Conservation and Management Act of 1996, as amended (16 U.S.C. § 1801 *et seq.*). In their letter of October 8, 2014, NMFS stated that they determined the proposed project would adversely affect EFH but that the proposed action contains adequate measures to avoid, mitigate or otherwise offset the adverse effects to EFH. NMFS therefore had no practical EFH recommendations to provide to avoid or reduce the magnitude of the adverse effects.

General Condition 20 stipulates that any project affecting a historic property may not commence construction until the provisions of 33 C.F.R. pt. 325, Appendix C, have been satisfied. As the Federal lead agency for this project, the Caltans initiated consultation with the State Historic Preservation Officer (SHPO). A Programmatic Agreement (PA), cited in enclosure 9, titled "Programmatic Agreement Among the Federal Highway Administration, the California Department of Transportation, the San Francisco County Transportation Authority, the Presidio Trust, the National Park Service, the Department of Veterans Affairs, the California State Historic Preservation Officer, the Advisory Council on Historic Recreation and Parks Department for the South Access to the Golden Gate Bridge, Doyle Drive Replacement Project, San Francisco, California," was finalized in October 2008. Failure to comply with the PA's stipulation requirements would constitute non-compliance with the NWP authorization for your project.

In order to ensure compliance with this NWP authorization, the following special conditions shall be implemented:

1. To remain exempt from the prohibitions of Section 9 of the Endangered Species Act, the non-discretionary Terms and Conditions for incidental take of federally-listed western snowy plover shall be fully implemented as stipulated in the Biological Opinion entitled, "Biological Opinion on the Effects of the Proposed South Access to

the Golden Gate Bridge – Doyle Drive: IJKL Outfall Replacement Project, San Francisco County, California (Caltrans EA 1637N1)" (pages 22-24) dated October 21, 2014 (enclosure 7). Project authorization under the NWP is conditional upon compliance with the mandatory terms and conditions associated with incidental take. Failure to comply with the terms and conditions for incidental take, where a take of a federally-listed species occurs, would constitute an unauthorized take and non-compliance with the NWP authorization for your project. The USFWS is, however, the authoritative federal agency for determining compliance with the incidental take statement and for initiating appropriate enforcement actions or penalties under the Endangered Species Act.

2. The NMFS concurred with the determination that the project was not likely to adversely affect Sacramento River winter-run Chinook salmon ESU or its critical habitat, Central Valley spring-run Chinook salmon ESU, Central California Coast steelhead Distinct Population Segment (DPS) or its critical habitat, Central Valley steelhead DPS, or North American green sturgeon southern DPS or its critical habitat. This concurrence was premised, in part, on project work restrictions outlined in enclosure 8. These work restrictions are incorporated as special conditions to the NWP authorization for your project to ensure unauthorized incidental take of species and loss of critical habitat does not occur.

3. The NMFS determined the proposed project would adversely affect EFH but that the proposed action contains adequate measures to avoid, mitigate or otherwise offset the adverse effects to EFH. The work restrictions outlined in enclosure 8 are incorporated as special conditions to the NWP authorization for your project to offset adverse effects to EFH.

4. A Programmatic Agreement cited in enclosure 9, titled "Programmatic Agreement Among the Federal Highway Administration, the California Department of Transportation, the San Francisco County Transportation Authority, the Presidio Trust, the National Park Service, the Department of Veterans Affairs, the California State Historic Preservation Officer, the Advisory Council on Historic Recreation and Parks Department for the South Access to the Golden Gate Bridge, Doyle Drive Replacement Project, San Francisco, California," was finalized in October 2008. Project authorization under the NWP is conditional upon your compliance with the mandatory stipulations of the PA cited in enclosure 9.

You may refer any questions on this matter to Lisa Mangione of my Regulatory staff by telephone at (415) 503-6763 or by e-mail at lisa.mangione@usace.army.mil. All correspondence should be addressed to the Regulatory Division, South Branch, referencing the file number at the head of this letter.

The San Francisco District is committed to improving service to our customers. My Regulatory staff seeks to achieve the goals of the Regulatory Program in an efficient and cooperative manner, while preserving and protecting our nation's aquatic resources. If you would like to provide comments on our Regulatory Program, please complete the Customer Service Survey Form available on our website: http://www.spn.usace.army.mil/Missions/Regulatory.aspx

Sincerely,

Jane M. Hicks
Chief, Regulatory Division

Enclosures

Copy Furnished (w/ encl 1 only):

CA RWQCB, Oakland, CA

Copies Furnished (w/o encls):

U.S. EPA, San Francisco, CA
CA SWRCB, Sacramento, CA

United States Department of the Interior

FISH AND WILDLIFE SERVICE
Sacramento Fish and Wildlife Office
2800 Cottage Way, Suite W-2605
Sacramento, California 95825-1846

In Reply Refer to:
08ESMF00-
2014-F-0369-2

OCT 21 2014

Mr. Vincent P. Mammano, Division Administrator
Federal Highways Administration
California Division
650 Capital Mall, Suite 4-100
Sacramento, California 95814

Subject: Biological Opinion on the Effects of the Proposed South Access to the Golden Gate Bridge-Doyle Drive: IJKL Outfall Replacement Project, San Francisco County, California (Caltrans EA 1637N1)

Dear Mr. Mammano:

This letter responds to a letter from the California Department of Transportation (Caltrans), dated February 28, 2014, which requested formal consultation for the proposed South Access to the Golden Gate Bridge-Doyle Drive: IJKL Outfall Replacement Project in San Francisco County, California. Your letter was received by the U.S. Fish and Wildlife Service (Service) on March 4, 2014 (Caltrans EA 1637N1). This document represents the Service's response to your request for consultation on the effects of the project on the threatened Pacific Coast population of the western snowy plover (*Charadrius alexandrinus nivosus*). This letter is issued under the authority of the Endangered Species Act of 1973, as amended (16 U.S.C. 1531 et seq.) (Act).

The Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users legislation (23 U.S.C. 327) allows the Secretary of the U.S. Department of Transportation acting through the Federal Highway Administration (FHWA) to establish a Surface Transportation Project Delivery Pilot Program, whereby a State may assume the FHWA responsibilities under the National Environmental Policy Act for environmental review, agency consultation and other action pertaining to the review or approval of a specific project. Caltrans assumed these responsibilities for the FHWA on July 1, 2007 through a Memorandum of Understanding within the State of California (http://www.dot.ca.gov/ser/downloads/MOUs/nepa_delegation/sec6005mou.pdf).

One listed plant species, the endangered San Francisco lessingia (*Lessingia germanorum*), occurs within Crissy Marsh, but was determined not to present within the action area based on botanical surveys. Therefore, the proposed action will have no effect on this species. The remainder of this biological opinion is on the effects of the project on the Pacific Coast population of the western snowy plover. Caltrans determined that the proposed project would have no effect on the designated critical

habitat for the western snowy plover, as the project is not located within designated critical habitat. This biological opinion is based on: (1) the South Access to the Golden Gate Bridge-Doyle Drive: IJKL Outfall Replacement Project, Biological Assessment dated February 2014; (2) Addendum to the Biological Assessment dated July 2014; (3) the February 5, 2014, site visit; (4) miscellaneous correspondence and electronic mail concerning the proposed action between Caltrans and the Service; and (5) other information available to the Service.

Consultation History

May 10, 2013	Caltrans requested technical assistance with conservation measures for the Pacific Coast population of the western snowy plover.
June 14, 2013	Caltrans requested technical assistance with geotechnical test borings associated with the proposed action.
February 5, 2014	The Service attended a site visit with Caltrans to discuss the project and potential effects to the Pacific Coast population of the western snowy plover.
March 4, 2014	The Service received a letter requesting the initiation of formal consultation dated February 28, 2014, and a Biological Assessment dated February 2014 for the South Access to the Golden Gate Bridge-Doyle Drive: IJKL Outfall Replacement Project.
July 23, 2014	The Service received an Addendum to the Biological Assessment dated July 2014 addressing changes to the proposed project description.
October 3, 2014	The Service issued a draft biological opinion to Caltrans.
October 17, 2014	The Service received comment letter dated October 16, 2014, from Caltrans regarding the draft biological opinion.
October 20, 2014	The Service had a conference call with Caltrans to discuss concerns they had with the draft biological opinion with regards to wildlife exclusion fencing and nesting snowy plover surveys.
May 10, 2013 - October 20, 2014	Electronic and phone correspondence between Caltrans and the Service.

BIOLOGICAL OPINION

Description of the Proposed Action

The following project description, inclusive of the proposed compensation and proposed conservation measures, was provided by Caltrans and is an excerpt from the February 2013 Biological Assessment and July 2014 Addendum to the Biological Assessment with minor modifications for reasons of clarity and accuracy provided by the Service.

Project History

The existing Outfall IJKL (outfall) at Crissy Beach currently drains an urbanized 125-acre basin that is the largest of the three primary watersheds in the Presidio. This outfall does not provide adequate capacity for current stormwater discharges from the watershed. To address this deficiency and the additional run-off from the project, Caltrans, the FHWA, and the Presidio Trust propose to increase the capacity of the existing outfall pipeline and extend the outfall farther into the Bay to compensate for future beach accretion. The shoreline at Crissy Beach has accreted almost 180 feet since 1997, burying the outfall in 6 feet of sand. The outfall was upgraded last in 2000 by the Presidio Trust, when a 42-inch outside diameter, 175-foot high-density polyethylene (HDPE) pipe extension was installed because sand accretion had blocked the end of the outfall. Additional sand accretion has blocked the end of the outfall again, and stormwater often backs up into the existing pipe, causing flooding on Mason Street and Crissy Field during major rain events. Maintaining the ability to discharge from the pipeline requires that the Presidio Trust Utility Department regularly use a backhoe to remove the sand from the end of the outfall, so water from the pipe can discharge into San Francisco Bay. Clearing accumulated sand from the outfall has to be done regularly, and especially before, during, and after major storm events. After it is re-opened, the outfall can become blocked again within hours due to tidal action. Outfall maintenance requirements are time-consuming, costly, and can be dangerous in severe storm conditions. They typically result in an unstable and unsafe sand channel at the mouth of the excavated outfall opening.

Project Description

The project will replace approximately 170 feet of the existing 42-inch outside diameter HDPE pipe from the existing manhole, located on the beach, leading to the outfall in the San Francisco Bay (Bay). The replacement and extension will use a 54-inch outside diameter HDPE pipe that will extend the outfall into the Bay by approximately 296 feet beyond the expected 50-year beach accretion point, for a total pipeline length of 466 feet. The pile and cross-tie configuration that are intended to support and stabilize the pipe will be similar to the ones used for the previous extension of the outfall that was completed in year 2000, which consisted of 13-inch diameter fiber-reinforced HDPE piles and cross ties. Aesthetically, the new outfall is designed to be hidden during low tide. A nautical chart correction referencing the outfall will be submitted to the U.S. Coast Guard and other coordination will take place during construction.

Approximately the first 235 feet of the pipe will be fully buried. Of this length, approximately the last 105 feet will be supported by 14 existing 13-inch HDPE piles and 6 new 13-inch HDPE piles. These new piles will be impact-driven to approximately 30 to 35 feet below the beach surface. The last 231 feet will be supported above the Bay's bottom on 18 new 13-inch HDPE piles. These 35-foot-long piles also will be impact-driven to approximately 24 feet below the Bay's bottom; the tops of the piles are designed to be below the mean lower-low water elevation.

Construction of the replacement pipeline and outfall extension will include three distinct areas: onshore (beach), intertidal zone, and offshore (bay/subtidal). These three areas are characterized by differing site conditions, and therefore will be subject to different methods of construction. The onshore and offshore construction means and methods will be determined by the project contractor.

In addition, the top section of an existing 24-inch manhole vault in Crissy Field, just south of the Crissy Field promenade, will be replaced with a 36-inch manhole opening to facilitate future

maintenance. This will greatly minimize the future need for Presidio Trust maintenance staff to access the manhole on the beach to maintain the pipe. The new culvert will be constructed in three stages.

Stage 1: Onshore Construction at Crissy Beach

Stage 1 will occur from May 15 to July 1. The onshore project footprint is 0.75 acre (32,670 square feet). Construction access will be provided using plywood sheets for traction on beach sand. Staging and storage will occur on Crissy Field and at the Stillwell parking area. Outfall construction vehicles and equipment likely will include support trucks (i.e., pickup trucks, dump trucks, flatbed trucks), trailers, excavators, loader/backhoes, a crane, and a pile driver. The onshore construction work is expected to include the following:

1. Installation of temporary chain link fencing and posting signs (i.e., no access, detour, informational, and construction signs).

2. Installation of temporary, environmentally sensitive area fencing.

3. Installation of temporary shoring (vibratory) on the beach, from the existing manhole to the mean higher high-water (MHHW) mark, for a total length of approximately 177 feet and buried to a maximum depth of 30 feet. The trench will be approximately 16 feet wide by 15 feet deep.

4. Installation of a water-filled cofferdam, approximately 4 feet high by 8 feet wide, placed at the end of the temporary sheet piles.

5. Excavation of approximately 1,300 cubic yards (cy) between the temporary shoring to expose and remove the existing pipe.

6. Removal of the existing 42-inch outside diameter by 170-foot pipe, leaving a 3-foot pipe stub.

7. Driving the 14 existing 13-inch-diameter plastic piles 6 feet deeper into the sand.

8. Installation of 54-inch outside diameter by 177-foot HDPE pipe.

9. Backfilling with sand.

10. Removal of the temporary shoring and water-filled cofferdam. Beach construction access is prohibited after July 1, except for the water-filled cofferdam removal.

11. Restoration of the beach area.

Stage 2: Intertidal and Offshore Construction at Crissy Beach

Stage 2 will occur from June 1 to July 31. Intertidal and Offshore Barges will be used as work and storage platforms and to stockpile dredged material. The construction vehicles and equipment to be used and stored on these barges may include an excavator, a loader/backhoe, and dump trucks as

well as other tools necessary to excavate within the tidal zone. Divers also will assist in the underwater pipe installation. After the culvert on the beach is constructed and backfilled during Stage 1, Stage 2 construction will be conducted within the tidal zone and in San Francisco Bay. The intertidal and offshore construction work is expected to include the following:

1. Installation of a temporary turbidity control curtain to enclose the construction site, using two barges and a tugboat. Approximately 330 helical or fluke-type anchors, approximately 2 feet x 2 feet, are expected to be used to secure the turbidity curtain to the Bay floor. After the completion of Stage 2, and prior to Stage 3, the turbidity curtain will be removed.

2. Driving the 14 new 13-inch diameter by 35-foot long HDPE plastic piles into the sand.

3. Excavating, stockpiling, and testing approximately 800 cy of material, to determine whether it will be acceptable for disposal at an approved disposal site or will have re-use potential, per the specifications For safety and stability purposes, excavation and placing of cross-ties and pipe will be done during low tides.

4. Placing a 171-foot long by 54-inch outside diameter HDPE pipe into the water by pulling it, after it is fused on the barge.

5. Connecting the pipe to the 177-foot long HDPE pipe that was installed during Stage 1; this will be completed by divers.

6. Backfilling with approved backfill material, per the specifications.

7. Removal of the turbidity control curtain. Beach construction access is prohibited after July 1, except for turbidity control curtain removal.

Stage 3: Offshore/Subtidal Construction in San Francisco Bay

Stage 3 will occur from July 1 to October 31. After completion of Stage 2 construction within the tidal zone, the turbidity control curtain will be removed and Stage 3 construction will be completed using vehicles and equipment similar to that used in Stage 2. The offshore construction work is expected to include the following:

1. Placement of ten 48-inch diameter steel containment casings at the specified locations where permanent piles will be installed. These casings are for the sole purpose of turbidity control and containment.

2. Driving ten 13-inch diameter HDPE piles inside the steel casings.

3. Removal of the ten 48-inch diameter steel containment casings after an acceptable turbidity level has been reached.

4. Placement of a 54-inch outside diameter by 118-foot long HDPE pipe into the water by pulling it, after it is fused on the barge.

5. Connecting the pipe to the 171-foot long HDPE pipe that was installed during Stage 2; this will be completed by divers.

Project Construction Best Management Practices

The following best management practices will be implemented during construction activity:

Excavation Disposal Plan

Approximately 2,100 cy of excavated material will be generated during Stage 1 and Stage 2 construction. All excavated material will be tested and either stockpiled at the proposed staging/stockpile location or hauled to an approved offsite disposal facility. If the excavated material falls below toxicity requirements, it will be reused as backfill and/or beach restoration material. Alternatively, dredged material will be tested to determine whether it is suitable for disposal at San Francisco Deep Ocean Disposal Site. If the dredged material is unsuitable for offshore disposal, it will be disposed at an approved landfill reuse site.

Noise Monitoring

Noise monitoring devices will be in-place during all construction activities, per the specifications. Ambient noise readings will be taken and analyzed so that they meet noise parameters designated to reduce effects on marine mammals, fish, and the public.

Water Pollution Control Plan

To avoid and/or minimize effects on environmental resources during construction, the project contractor will control/prevent spills, store materials, and manage stockpiles and waste in accordance with Caltrans' standard Best Management Practices (BMP)s.

Temporary Sediment and Turbidity Control Measures

The following temporary sediment control measures will be implemented as needed: SC- 1 (Silt Fence); SC-4 (Check Dams); SC-5 (Fiber Rolls); SC-7 (Street Sweeping); and SC-10 (Drainage Inlet Protection). A water-filled cofferdam will be placed along the shoreline, adjacent to the construction site during Stage 1 onshore beach excavation. During Stage 2, the perimeter of the entire offshore construction site will be enclosed with a temporary turbidity control curtain then removed before Stage 3. Lastly, 48-inch-diameter steel casings will be temporarily placed at pile locations for turbidity control during Stage 3.

Dewatering Operations (Jobsite Management)

Dewatering is not anticipated to be necessary except during the Stage 1 trench work.

Turbidity Levels

During in-water excavation work (Stages 2 and 3), temporary sediment control measures (such as the installation of turbidity curtains and steel containment casings) will be implemented. The temporary turbidity curtain would be secured to the Bay floor using 330 helical or fluke-type

anchors, which would help keep the turbidity in a controlled area. In addition, testing and monitoring will be implemented so that the waters will be free of changes in turbidity that can cause nuisance or adversely affect marine wildlife and habitat. Increases from normal background light penetration or turbidity relatable to waste discharge will not be greater than 10 percent in areas where natural turbidity is greater than 50 Nephelometric Turbidity Units.

Staging

To minimize effects on the project footprint, staging will occur in the following locations:

1. Offshore, onboard barges;

2. In Crissy Field, near the construction site access gate across the promenade, which is the most environmentally friendly location because of its proximity to the construction site; and

3. At Stillwell Hall parking lot, located across from Crissy Field and Mason Street.

Water Pollution Control Plan

WM-3 (Stockpile Management) will be implemented in all staging areas. All construction-related staging and equipment storage will be limited to upland areas, away from waters of the U.S. and sensitive habitat areas. Access to construction sites will be limited to Mason Street and the Crissy Field promenade, and then through the beach access gate.

Construction Work Scheduling

Project construction incorporates environmental work windows to minimize effects to listed species that may occur within the Action Area. All environmental work windows have been incorporated into the project schedule to avoid effects on onshore and offshore habitats. Onshore construction activities within 100 feet of the MHHW mark will be limited to May 15 through July 1, when the western snowy plover is not typically present.

Offshore construction activities more than 100 feet seaward of the MHHW mark will be limited to June 1 through October 31, during the typical dry season, to avoid migrating fish. Construction hours typically will be from 7:00 a.m. to 6:00 p.m.

Temporary Structures Required for Construction

Stage 1: Onshore Construction (Temporary Shoring)

Temporary shoring (sheet piles) will be installed onshore in a manner that provides support for the excavation of Stage 1 work on the beach. The temporary shoring structure will be 16 feet wide by 180 feet long, 0.064 acre (2,788 square feet), extending from the existing manhole on the beach to the MHHW mark. In addition, a water-filled cofferdam will be placed in a u-shaped layout at the open end of the sheet piles in order to contain sediment and as a turbidity control measure. After the completion of Stage 1 and before the end of July, the temporary shoring structures will be

removed, and the area restored to its original state. A temporary turbidity control curtain will be assembled in the intertidal area as shown in sheet 2 of 4 in the Water Pollution Control Program (WPCP).

Stage 2: Intertidal and Offshore Construction (Turbidity Control)

Within the tidal zone, construction will occur from June 1 to July 31 and will extend approximately 170 feet into the Bay, from MHHW to a point where excavation ends. Prior to the beginning of pipe excavation, the temporary turbidity curtain will be moved from the intertidal area where it was assembled, and placed as shown in sheet 3 of 4 in the WPCP. After the completion of Stage 2, and prior to Stage 3, the turbidity curtain will be removed.

Stage 3: Offshore Construction (Turbidity Control)

Offshore construction will occur from July 1 to October 31, and will include placement of 48-inch diameter steel casings around the pile locations and driving the ten 13-inchdiameter HDPE piles inside the steel casings. This will take place for the last 118 feet of pipe, as shown in sheet 4 of 4 of the WPCP.

Project Effects to Land Cover Types

The 117.94 ac action area including a 900-foot buffer on land and 1,300-foot buffer in the water from the onshore and in-water shoring. The 900-foot buffer is the distance sound travels from the loudest piece of equipment, a vibratory pile driver at 96 dBA, to a point where the sound level has diminished back to ambient levels of about 70 dBA. The 1,300-foot buffer is the Level B Harassment Threshold (120 dBA RMS) that establishes the range for projected sound impacts of sheet pile vibration. Table 1 quantifies the anticipated temporary and permanent project effects to various land cover types.

Table 1: Expected Temporary and Permanent Effects on Land Cover Type

Land Cover Type	Habitat within Action Area (acres)	Habitat within Project Footprint (acres)	Temporary Effects (acres)	Permanent Effects (acres)	Total Effects (acres)
Developed	25.56	0.00	0.00	0.000	0.00
Northern Foredune	6.27	0.02	0.00	0.023	0.02
Beach	5.40	0.75	0.75	0.000	0.75
Intertidal	3.95	1.14	1.14	0.000	1.14
Bay/Subtidal	76.76	11.45	11.45	0.013	11.46
Total	117.94	13.36	13.34	0.036	13.38

General Conservation Measures

To reduce potential effects to sensitive biological resources, Caltrans proposes to incorporate construction BMPs and avoidance and minimization measures into the proposed roadway construction project. These measures will be communicated to the contractor through the use of special provisions included in the contract bid solicitation package. These measures include the following:

1. **Seasonal Restrictions**. Construction actions will be scheduled to minimize effects on listed species and habitats. The two phases of construction will be subject to the following seasonal restrictions:

    a. The onshore phase from the foredunes out to 100 feet from the MHHW mark will be restricted to May through July to avoid effects to the Pacific Coast population of the western snowy plover.

    b. The in-water work will be restricted to June through October, which includes the area from 100 feet from the MHHW mark out to the limits of the project footprint.

2. **Environmental Awareness Training**. Prior to the start of construction, a qualified biologist will conduct an educational training program for all construction personnel including contractors and subcontractors. The training will include, at a minimum, a description of the Pacific Coast population of the western snowy plover, and its habitat within the action area; an explanation of the status of the species and protection under state and Federal laws; the avoidance and minimization measures to be implemented to reduce take of this species; communication and work stoppage procedures in case a listed species is observed within the action area; and an explanation of the Environmentally Sensitive Areas (ESAs) and wildlife exclusion fencing and the importance of maintaining these structures. A fact sheet conveying this information will be prepared and distributed to all construction personnel. Upon completion of the program, personnel will sign a form stating that they attended the program and understand all the avoidance and minimization measures and implications of the Act. Documentation of the training, including sign-in sheets, would be kept on file and would be available on request.

3. **Environmentally Sensitive Areas (ESA)**. Prior to the start of construction, ESAs – defined as areas containing sensitive habitats adjacent to or within construction work areas for which physical disturbance is not allowed – will be clearly delineated using high visibility orange fencing. Construction work areas include the active construction site and all areas providing support for the proposed action including areas used for vehicle parking, equipment and material storage and staging, access roads, etc. The ESA fencing will remain in place throughout the duration of the proposed action, while construction activities are ongoing, and will be regularly inspected and fully maintained at all times. The final project plans will depict all locations where ESA fencing will be installed and will provide installation specifications. The bid solicitation package special provisions will clearly describe acceptable fencing material and prohibited construction-related activities including vehicle operation, material and equipment storage, access roads and other surface-disturbing activities within ESAs.

4. **High Tide Restrictions**. During periods of forecasted extreme high (e.g., king) tides all on-shore construction activities would temporarily cease and all equipment and materials will be relocated above the king tide high water mark.

5. **Nesting Bird Surveys**. Clearing and grubbing of vegetation should occur outside of the nesting bird season (February 1 to August 31) if possible. Vegetation clearing conducted during the nesting season will be preceded by preconstruction nesting bird surveys. If preconstruction surveys indicate the presence of nests of any special-status species or species

protected under the Migratory Bird Treaty Act, as amended, the Service will be contacted to determine if non-disturbance buffers are appropriate and if any additional avoidance and minimization measures necessary.

6. **Species Observation in Action Area**. Should a western snowy plover be observed within the action area, the resident engineer will suspend construction activities within a 50-ft radius of the bird until the bird leaves the site voluntarily. The resident engineer will immediately contact the agency-approved project biologist(s) and the Service. The Service-approved biologist will monitor the plover(s) to determine if the project is resulting in harassment. Any signs of harassment will be documented and reported to the Service.

7. **Preconstruction Surveys for Rare Plants**. Focus surveys targeted for rare plants that may not have been in bloom and thus unidentifiable during the previous vegetation surveys would be completed prior to construction. If rare plants are founds to be within the project footprint, Caltrans will notify Service and to determine if reinitiation is necessary.

8. **Reduce Spread of Invasive Species**. To reduce the spread of invasive non-native plant species and minimize the potential decrease of palatable vegetation for wildlife species, Caltrans will comply with Executive Order 13112. This order is provided to prevent the introduction of invasive species and provide for their control in order to minimize the economic, ecological, and human health impacts. In the event that high- or medium-priority noxious weeds, as defined by the California Department of Food and Agriculture or the California Invasive Plant Council, are disturbed or removed during construction-related activities, the contractor will contain the plant material associated with these noxious weeds and dispose of it in a manner that will not promote the spread of the species. The contractor will be responsible for obtaining all permits, licenses, and environmental clearances for properly disposing of materials. Areas subject to noxious weed removal or disturbance will be replanted with fast-growing native grasses or a native erosion control seed mixture. If seeding is not possible, the area should be covered to the extent practicable with heavy black plastic solarization material until the end of the project.

9. **Replant, Reseed, and Restore Disturbed Areas**. The National Park Service (NPS) or their designee will revegetate all slopes or unpaved areas that are temporarily affected by the proposed action will be revegetated with an assemblage of native grasses and shrubs characteristic of the floristic region and native local habitats to stabilize soils and prevent erosion. NPS will replant with an assemblage of native plants sourced from the Presidio nursery to restore habitat values. A revegetation plan with success criteria will be submitted to the Service for review and approval. Temporary effects comprise areas denuded, manipulated, or otherwise modified from their existing, pre-project conditions, thereby removing one or more essential components of a listed species' habitat as a result of project activities that include, but are not limited to, construction, staging, storage, lay down, vehicle access, parking, etc. Temporary effects must be restored to baseline habitat values or better within one year following initial disturbance. Areas subject to ongoing operations and maintenance are not considered temporary even if they are restored within one year following initial disturbance. Affected areas not fulfilling these criteria are considered permanent.

10. **Nighttime Construction**. To the extent practicable, nighttime construction would be minimized.

11. **Artificial Lighting**. Except when necessary for construction, driver, or pedestrian safety, lighting of the project footprint by artificial lighting during nighttime hours would be minimized to the maximum extent practicable. Any pre-dawn barge lighting will be directed away from onshore.

12. **Avoidance of Entrapment**. To prevent inadvertent entrapment of animals during construction, all excavated, steep-walled holes or trenches more than 1-foot deep will be covered with plywood or similar materials at the close of each working day or provided with one or more escape ramps constructed of earth fill or wooden planks. The Service-approved biologist shall inspect all holes and trenches at the beginning of each workday and before such holes or trenches are filled. All replacement pipes, culverts, or similar structures stored in the action area overnight will be inspected before they are subsequently moved, capped, and/or buried. If at any time a listed species is discovered, the Resident Engineer and Service-approved biologist will be notified immediately and the Service-approved biologist shall implement the species observation and handling protocol outlined below.

13. **Vehicle Use**. Vehicle use will occur in the project footprint which consists entirely of sand. Disturbance to the sand (tire ruts) will be removed by the tides except the area of the project footprint that is above the high tide line, which will be re-contoured back to the original elevations to the best extent practicable after the onshore construction is complete.

14. **Best Management Practices (BMPs)**. Storm Water Pollution Prevention Plans (SWPPP) and erosion control BMPs will be developed and implemented to minimize any wind or water-related erosion and will be in compliance with the requirements of the Regional Water Quality Control Board. The SWPPP will reference the Caltrans Construction Site BMPs Manual. This manual is comprehensive and includes many other protective measures and guidance to prevent and minimize pollutant discharges and can be found online at: http://www.dot.ca.gov/hq/construc/stormwater/manuals.htm. Protective measures will include, at a minimum:

    a. No discharge of pollutants from vehicle and equipment cleaning is allowed into any storm drains or watercourses.

    b. Vehicle and equipment fueling and maintenance operations must be at least 50 feet away from watercourses, except at established commercial gas stations or established vehicle maintenance facility.

    c. Spill containment kits will be maintained onsite at all times during construction operations and/or staging or fueling of equipment.

    d. Dust control measures will consist of regular truck watering of construction access areas and disturbed soil areas with the use of organic soil stabilizers to minimize airborne dust and soil particles generated from graded areas. Regular truck watering

will be a requirement of the construction contract. Any material stockpiles will be watered, sprayed with tackifier, or covered, to minimize dust production and wind erosion

e. Coir rolls or straw wattles that do not contain plastic or synthetic monofilament netting will be installed along or at the base of slopes during construction to capture sediment.

f. Protection of graded areas from erosion using a combination of silt fences, fiber rolls, etc. along toes of slopes or along edges of designated staging areas, and erosion control netting (such as jute or coir) as appropriate on sloped areas. Erosion control materials that use plastic or synthetic monofilament netting will not be used within the action area. This includes products that use photodegradable or biodegradable synthetic netting, which can take several months to decompose. Acceptable materials include natural fibers such as jute, coconut, twine or other similar fibers.

15. **Construction Site Management Practices**. The following site restrictions will be implemented to avoid or minimize effects on listed species and their habitats:

a. A speed limit of 15 miles per hour in the project footprint in unpaved areas will be enforced to reduce dust and excessive soil disturbance.

b. Construction access, staging, storage, and parking areas, will be located within the project Caltrans Right of Way outside of any designated ESA or outside of the Caltrans ROW in areas environmentally cleared by the contractor. Access routes and the number and size of staging and work areas will be limited to the minimum necessary to construct the proposed project. Routes and boundaries of roadwork will be clearly marked prior to initiating construction or grading.

c. To the maximum extent practicable, any borrow material will be certified to be non-toxic and weed free.

d. All food and food-related trash items will be enclosed in sealed trash containers and properly disposed of off-site.

e. No pets from project personnel will be allowed anywhere in the action area during construction.

f. No firearms will be allowed on the project site except for those carried by authorized security personnel, or local, State or Federal law enforcement officials.

g. A Spill Response Plan will be prepared. Hazardous materials such as fuels, oils, solvents, etc. will be stored in sealable containers in a designated location that is at least 50 feet from hydrologic features.

h. All equipment will be properly maintained and free of leaks. Servicing of vehicles and construction equipment including fueling, cleaning, and maintenance will occur at least 50 feet from any hydrologic features unless it is an existing gas station.

Action Area

The action area is defined in 50 CFR § 402.02, as "all areas to be affected directly or indirectly by the Federal action and not merely the immediate area involved in the action." For the purposes of the effects assessment, the action area encompasses 117.94 acres extending 900 feet from the project footprint on land and 1,300 feet on the water. The action area accounts for the effects of project construction or operations due to construction noise, dust, light, and other construction effects that extend beyond the project footprint. Habitat within the action area comprises 25.56 acres of developed land, 6.27 acres of foredune, 5.40 acres of beach, 3.95 acres of intertidal waters, and 76.76 acres of San Francisco Bay/subtidal waters.

Analytical Framework for the Jeopardy Determinations

Jeopardy Determination

In accordance with policy and regulation, the jeopardy analyses in this biological opinion relies on four components: (1) the *Status of the Species*, which evaluates the Pacific Coast population of the western snowy plover range-wide condition, the factors responsible for that condition, and its survival and recovery needs; (2) the *Environmental Baseline*, which evaluates the condition of the Pacific Coast population of the western snowy plover in the action area, the factors responsible for that condition, and the relationship of the action area to the survival and recovery of the Pacific Coast population of the western snowy plover; (3) the *Effects of the Action*, which determines the direct and indirect impacts of the proposed Federal action and the effects of any interrelated or interdependent activities on the Pacific Coast population of the western snowy plover; and (4) *Cumulative Effects*, which evaluates the effects of future, non-Federal activities in the action area on the Pacific Coast population of the western snowy plover.

In accordance with policy and regulation, the jeopardy determination is made by evaluating the effects of the proposed Federal action in the context of the Pacific Coast population of the western snowy plover current status, taking into account any cumulative effects, to determine if implementation of the proposed action is likely to cause an appreciable reduction in the likelihood of both the survival and recovery of this species in the wild.

The jeopardy analyses in this biological opinion places an emphasis on consideration of the range-wide survival and recovery needs of the Pacific Coast population of the western snowy plover and the role of the action area in the survival and recovery of the Pacific Coast population of the western snowy plover as the context for evaluating the significance of the effects of the proposed Federal action, taken together with cumulative effects, for purposes of making the jeopardy determination.

Status of the Species and Environmental Baseline

<u>Pacific Coast Population of the Western Snowy Plover</u>

Listing Status: The Pacific coast population of the western snowy plover was listed as threatened on March 5, 1993 (Service 1993). The 1993 listing defined the Pacific coast population as "those individuals that nest adjacent to or near tidal waters, and includes all nesting colonies on the

mainland coast, peninsulas, offshore islands, adjacent bays, and estuaries" (Service 1993). In this finding, the Service generally refers to plovers nesting at locations other than on the Pacific coast as "interior" populations, which encompasses populations nesting east or west of the Rocky Mountains, on the Gulf Coast, or in central Mexico. A five-year review was completed during the status review conducted for the 12-month petition finding to delist the Pacific coast population of the western snowy plover. The 12-month finding published on April 21, 2006, determined that delisting was not warranted due to continued existence of threats to the distinct population segment and its habitat, and recommended the species remain listed as threatened (Service 2006). Critical Habitat was designated for this species on September 25, 2005 (Service 2005). A final recovery plan was published for the Pacific coast Population of the Western Snowy Plover on September 13, 2007 (Service 2007).

Taxonomy and Distribution: Two subspecies of snowy plover recognized by the American Ornithological Union (AOU 1957), nest in North America: the western snowy plover and the Cuban snowy plover (*Charadrius alexandrinus tenuirostis*). The Cuban snowy plover, nests along the Gulf coast from Louisiana to western Florida and south through the Caribbean (American Ornithological Union (AOU) 1957; Service 1993; Page *et al.* 1995). The subspecific status of populations breeding east of the Rocky Mountains, now considered to belong to the subspecies *C. a. nivosus*, has been questioned. Some consider these populations to belong more appropriately to the subspecies *C. a. tenuirostris* (Warriner *et al.* 1986). Others consider the subspecies *C. a. tenuirostris* to be a paler version of the western snowy plover rather than a separate subspecies (Page *et al.* 1995).

The breeding range of the western snowy plover includes sites in California, Oregon, Washington, Nevada, Utah, Arizona, Colorado, New Mexico, Kansas, Oklahoma, Texas, and Baja California, central and northeastern Mexico, as well as irregularly visited sites in Saskatchewan, Canada, and Wyoming and Montana (Page *et al.* 1995). Some plovers nesting on the Pacific coast migrate north or south to other Pacific coastal wintering sites, while others stay at their breeding sites year round. Birds nesting in the interior, west of the Rocky Mountains (the western interior population) winter in coastal California and Baja California, Mexico, and often commingle with the Pacific coast western snowy plovers. However, some individuals from the southern California interior do not migrate (Page *et al.* 1995). Plovers from the interior east of the Rockies are migratory, probably wintering on the Gulf Coast, except for small numbers of year-round residents in Texas, Arizona, and New Mexico. Plovers nesting on the Gulf coast may sometimes winter at other Gulf coast locations, while those nesting in central Mexico are likely year-round residents (Page *et al.* 1995).

Description and Natural History: Snowy plovers are small shorebirds, about 6 inches long, with pale brown upperparts, buff colored bellies, and darker patches on their shoulders and heads. Their dark gray-to-black legs are a useful distinguishing feature when comparing to other plover species (Page *et al.* 1995). Snowy plovers consume flies, beetles, crabs, polychaete worms, amphipods, sand hoppers, moths, grasshoppers, small crustaceans, mollusks, and plant seeds (Page *et al.* 1995). They forage by pursuing their prey on foot, picking from the surface or probing in sand and loose soils, and will charge dense aggregations of flies, snapping their bill at those flushed (Purdue 1976, Page *et al.* 1995). Within the San Francisco Bay Area, snowy plovers forage on brine flies and brine shrimp (Feeney and Maffei 1991, Page *et al.* 2000). Exposed mudflats, the open water on salt ponds, historic channels, and excavated "borrow ditches" provide foraging areas in the South Bay. Brine flies are usually found in greatest densities at the shallow margins of salt ponds or puddles.

The timing of the nesting season varies with location, but in coastal California it tends to run from March 1 through September 30 (Page *et al.* 1995). Breeding locations tend to be sandy areas close to water, including beaches, salt pans, alkaline playas, and gravel bars on the tidally influenced portion of coastal rivers where prey (usually brine flies and other insects) are abundant. In the South San Francisco Bay, snowy plovers nest on low, barren to sparsely vegetated dry salt ponds as well as on levees and islands, and at pond edges (Page *et al.* 2000). In some areas, snowy plovers nest within dry salt ponds; in other areas where ponds typically hold water through the summer (e.g., the Newark salt ponds), nests are located primarily on levees and pond edges. Plovers preferentially use light-colored substrates such as salt flats and are often located near disruptive objects such as rocks or surface irregularities, and may be constructed in depressions created by footprints and vehicles (Feeney and Maffei 1991, Page *et al.* 1995, Marriott 2003). Clutches, which most commonly consist of three eggs, are laid in shallow scrapes or depressions in the substrate sometimes lined with shell fragments, salt crystals, plant debris, fish bones, exoskeletons, and pebbles or similar local materials (Page *et al.* 2000; Page *et al.* 1995). Snowy plovers generally form monogamous pair bonds and share incubation duties, but western snowy plover females typically desert the brood shortly after hatching, and may re-nest with a new male if time remains in the breeding season. Males typically care for the young until they fledge, which takes about a month, and may re-nest with a new partner if sufficient time remains in the season (Stenzel *et al.* 1994). This results in a serially polygamous breeding system in which males may double clutch and females may triple clutch during a single season (Page *et al.* 1995).

The breeding season of the western snowy plover in California, from nest initiation to fledging of chicks, is considered to be March 1 to September 30. Unlike sandy beach habitat, saltpan habitat used for nesting in the South Bay takes some time to dry after rains. For this reason, nesting habitat within salt ponds may not be available in the early part of the breeding season – March or early April. During years of late rains, nesting habitat may not become available until well into the breeding season, e.g., late April or May (Hannon and Clayton 1995). The snowy plover is opportunistic, capable of moving around among potential breeding areas and breeding where conditions are suitable. The abundance and distribution of snowy plovers in the South Bay shifts annually, and is also dynamic within a given nesting season. Early in each breeding season, many ponds may not be suitable for nesting due to late rains creating muddy substrates, and nesting may be concentrated at a few ponds with suitable conditions. Later in the season, as more ponds dry out and become available for nesting, snowy plovers may be more dispersed among many nesting locations, and nest in lower densities. In 1990 nest density at four Oliver/Eden Landing ponds averaged 1 nest per 6.3 acres, with a range of 1 nest per 3.1 to 14.2 acres (Feeney and Maffei 1991). In 2006, nest density on four ponds in the South Bay averaged 1 nest per 74 acres with a range of 1 nest per 13 to 417 acres (San Francisco Bay Bird Observatory [SFBBO], unpub. data). In 2006, these numbers reflect large areas of ponds not used by snowy plovers probably due to water on the surface of the pond, and to a low number of plovers scattered over a large area.

Some snowy plovers remain in their coastal breeding areas year-round, while other individuals are migratory. In San Francisco Bay, higher numbers in winter indicate that snowy plovers from the Great Basin population probably move into the area for the winter. At the same time, some individuals that nest in the San Francisco Bay Area probably migrate south as far as Mexico (Service 2007). There is overlap between the San Francisco Bay population and the adjacent coastal nesting population. Birds banded at Monterey Bay and in Oregon have been seen in the San Francisco Bay (Feeney and Maffei 1991). It is not known whether this species nested inside San Francisco Bay before conversion of salt marsh to salt evaporation ponds. However, these ponds have provided

suitable nesting and foraging habitat since the beginning of the 20th century (Grinnell *et al.* 1918). Within San Francisco Bay, snowy plovers were noted to be a common nester in this area by 1918 (Page and Stenzel 1981).

Population Status and Trends: Surveys along the Pacific coast indicate that the numbers of breeding snowy plovers have ranged from a low of 976 in 2000 to a high of 1,904 in 2004; in 2006 1,723 plovers were counted along the Pacific coast (Service 2007). In 1977, nesting snowy plovers in the San Francisco Bay accounted for 22 percent of all snowy plovers counted along the coast; in 2006 only 6 percent of the snowy plovers along the entire Pacific coast were counted in the San Francisco Bay. Nearly all of the San Francisco Bay nesting occurs south of State Route 92 (San Mateo Bridge) in the South Bay (Page and Stenzel 1981, Page *et al.* 1991, Service 2007).

Although snowy plovers in the San Francisco Bay occasionally nest on levees and islands, the majority of nests are currently found on flats within dry or partially dry ponds (Feeney and Maffei 1991, Fischer 1998). A few ponds, particularly in Eden Landing, as well as Ponds A22 in Alviso and SF2 near the Ravenswood Pier, have long been used regularly for nesting by snowy plovers. In the past, such regular use resulted from the type and consistency of management of these ponds for salt production (e.g., the same ponds representing the same stage in the salt-making process provided conditions that were consistently suitable for use by nesting snowy plovers). Other ponds are used more sporadically, and in any given year there may be extensive habitat in the South Bay that is ostensibly suitable for nesting but is unoccupied by the species. The highest numbers of nesting snowy plovers occur at Eden Landing where snowy plovers have recently been focused in Ponds E6A and E6B in 2003 and 2004 (Strong and Dakin 2004; Strong *et al.* 2004a) and in E8A, E12 and E14 in 2007 (SFBBO unpub. data). Numbers of nests in the Eden Landing ponds have ranged from 10 nests in 1999 (Casady 1999) to 84 nests in 2007 (SFBBO unpub. data), although nest finding effort has not been consistent throughout this time period. Low numbers of breeding snowy plovers also occur in the Ravenswood Complex, Warm Springs Complex, and Alviso Complex. At Warm Springs, Pond A22 was used, with more than 10 adults found during the 2003 nesting season, and a high count of 32 snowy plovers at A22 in 2004 (Strong *et al.* 2004a). Low densities of snowy plovers have been recorded during the breeding season, sometimes with nests or chicks, at some other Alviso salt ponds, primarily at A6 and A8 (Ryan and Parkin 1998; Strong *et al.* 2004a). Pond A6 has since been occupied by a colony of approximately 20,000 California Gulls (*Larus californicus*). Snowy plovers also nested in the late 1990s in Alviso Pond A3N and in a small impoundment immediately east of Pond A12 in 2006 (B. Bousman, pers. comm.).

The Oliver Salt Ponds, relatively small ponds adjacent to Eden Landing on either side of the east end of the San Mateo Bridge, have been used regularly for nesting, although not in recent years. In 1989, Feeney and Maffei (1991) found 29 nests here, and 152 individual snowy plovers during the nesting season. To the south, in 1995, Hannon and Clayton (1995) found 90 nests in the Newark Ponds near the Dumbarton Bridge. The Patterson ponds, between Ponds N4A and N1A, have also been used regularly by nesting snowy plovers, at least up until 2001, when eight nests were found here (Marriott and Schelin 2001); no nests have been found here since then probably due to vegetation encroachment on the ponds. Page *et al.* (1979) and Rigney and Rigney (1981) also provide census information for Cargill ponds between Eden Landing and Warm Springs, but current data on the number of snowy plovers breeding in these ponds are not available. Due to limited habitat in these areas it is doubtful that large numbers of plovers use these areas. Marriott and

Schelin (2001) surveyed the Newark ponds and found no nests, and they noted that levee over-topping by Cargill in 2000 had diminished the suitability of levees in these ponds for snowy plover nesting.

Threats: Degradation and use of habitat for human activities has been largely responsible for the decline in the snowy plover breeding population (Page *et al.* 1995). Other important threats to the snowy plover are mammalian and avian predators, and human disturbance (Page et al. 1995). Human disturbance, including disturbance from domestic dogs (*Canis lupus familiaris*), can lead to nest abandonment or direct trampling of eggs or chicks. In addition, because young chicks are dependent on adults for protection, human disturbance resulting in the separation of chicks from adults can lead to the death of the chicks. Precocial chicks feed themselves but require the protection of an adult for brooding and evasion of predators (Page *et al.* 1995). Additional pressures include oiling, entanglement in fishing line, striking objects, and shooting; in the South Bay, the use and maintenance of levee roads for access to salt ponds also causes disturbances to nesting snowy plovers.

Non-native predators, such as red fox (*Vulpes vulpes*), have had major negative effects on snowy plover populations in California; for example, in the South Bay, two snowy plover nests were known to have been depredated by red foxes in 1993 and 1994 in the Coyote Hills and Dumbarton areas (Harding *et al.* 1998), and such events have probably occurred much more frequently than is known. Efforts to curtail nest depredation by mammalian predators through a predator management program have greatly enhanced nesting success by snowy plovers on the Central Coast of California (Neuman *et al.* 2004). In the South Bay, no strong increase in nest success was noted between 1991 and 1996, after a predator management plan was implemented, except at a few nests where enclosures were used (Harding *et al.* 1998). Overall nest success in the South Bay has been fairly high in some recent years, with 80 percent nest success in 2001 (n = 78 nests) and 58 percent in 2006 (n = 81 nests, Robinson *et al.* 2006). However, predation levels have dramatically increased over the past four years, from 5 percent in 2004 (n = 59 nests) to 41 percent in 2007 (n = 84 nests) largely due to avian predation (Strong *et al.* 2004b, SFBBO, unpub. data). Fledging success is unknown, and may be far less due to avian predators.

Avian predators, particularly corvids (crows and ravens) and California gulls, are increasingly becoming an issue for snowy plover reproductive success (Strong et al 2004b, SFBBO unpub. data). The American crow (*Corvus brachyrhynchos*) and common raven (*Corvus corax*) are adept at finding snowy plover nests and preying on eggs. Corvid numbers are increasing throughout California, at least partially in response to increased availability of food from anthropogenic sources, such as garbage dumps (Boarman and Heinrich 1999, Verbeek and Caffrey 2002). Numbers of California gulls have increased exponentially in the South Bay over the past few decades (Strong *et al.* 2004b). Other avian predators, including loggerhead shrikes (*Lanius ludovicianus*), American kestrels (*Falco sparverius*), and northern harriers (*Circus cyaneus*) have been documented taking snowy plover chicks, and in some areas, have dramatically reduced fledging success (K. Neuman, pers. comm.). Nest camera studies begun in 2009 in the Bay area also indicate red-tailed hawks (*Buteo jamaicensis*) as a predator of concern (SFBBO, unpub. data).

Studies in San Diego County (Hothem and Powell 2000), at Point Reyes (Schwarzbach *et al.* 2005), and in the South Bay (Schwarzbach and Adelsbach 2003) have found elevated mercury levels in snowy plover eggs. At Point Reyes, high levels of mercury in unhatched eggs were thought to be a possible reason for the inviability of these eggs. In the San Diego County and South Bay studies;

however, concentrations of mercury in snowy plover eggs were below known embryotoxic thresholds established for other species.

Environmental Baseline

The population at Crissy Field was discovered in 2005 and was not included in the recovery plan. Based on its location, it would be included in the Sonoma to Monterey Counties, California Recovery Unit, which extends along the California coast from the Mendocino/Sonoma county border south to the Monterey/San Luis Obispo county border. The recovery goal for the Pacific coast population of the western snowy plover is to ensure the long-term viability of the species such that it can be delisted. The three objectives to achieve this goal are as follows: 1) increase population numbers distributed across the range of the Pacific coast population of the western snowy plover; 2) conduct intensive ongoing management for the species and its habitat and develop mechanisms to ensure management in perpetuity; and 3) monitor western snowy plover populations and threats to determine success of recovery actions and refine management actions (Service 2007).

A portion of the beach and northern foredunes habitat at Crissy Field has been designated as a Wildlife Protection Area (WPA) to protect sensitive plants and western snowy plovers that utilize the nearshore waters of the San Francisco Bay. Within the WPA, habitat extends the length of the action area in the form of northern foredune (6.27 acres) and beach (5.40 acres). The Golden Gate National Recreation Area has restored northern foredune habitat within the action area and greater extent of Crissy Field. The northern foredunes are fenced to keep dogs and humans out of these sensitive areas and to promote recruitment of native plants and overwintering western snowy plovers. Caltrans identified six native plant species within the foredune habitat including coastal sand verbena (*Abronia latifolia*), pink san verbena (*Abronia ubellata*), silver bur ragweed (*Ambrosia chamissonis*), sandhill sagebrush (*Artemisia pycnocephala*), beach primrose (*Camissonia cheiranthifolia*), American dunegrass (*Leymus mollis*), and chamisso bush lupine (*Lupinus chamissonis*).

Caltrans reported that a comprehensive monitoring program for snowy plover in the WPA is jointly run by the Golden Gate National Recreation Area (GGNRA) and Golden Gate Audubon Society. Annual monitoring of overwintering western snowy plover in the WPA began in 2000, and has continued through the current year. Data is available through April of 2013 (Merkle 2013, and Zlatunich and Lynes 2010 in Caltrans 2014a). Prior to 2006 monitoring did not follow a standardized protocol. In 2006, a formal monitoring protocol was implemented based on the protocol used to track western snowy plover nesting and overwintering activity at Ocean Beach. Therefore, the data reviewed for the purposes of evaluating plover presence in the action area is based on the data set from 2006 to 2013 provided by the GGNRA (Merkel 2013 in Caltrans 2014a).

Pacific coast population of western snowy plovers has overwintered in the action area from August through May since February 2005; however, they have not been documented to nest within the action area (Merckle 2013 in Caltrans 2014a). Western snowy plovers typically arrive at the Crissy Field WPA in August or September and remain through the following March (Caltrans 2014a). Western snowy plovers were documented staying through May in 2012, and the earliest arrival was reported on July 26, 2008 (Caltrans 2014a). The seasonal average occurrence of snowy plovers ranges from 1.9 to 5.1 individuals with peak numbers reported in December. Available monitoring data indicates that although sufficient breeding habitat is present in the WPA, western snowy plovers typically leave the WPA in April or May to migrate to other breeding sites and have not been

documented to nest at Crissy Field. Post-breeding plovers typically begin to return in late July or early August (Merckle 2013 in Caltrans 2014a).

Effects of the Action

The proposed action will be divided into three stages: 1) onshore construction, 2) intertidal and offshore construction, and 3) offshore/subtidal construction. The phasing of each stage has been timed to minimize the effects to the western snowy plover. Onshore construction will occur from May 15 to July 1 after western snowy plovers have left the action area, so no direct or indirect effects to plovers will occur. However, a small portion of northern foredunes (0.02 acres) will be removed to facilitate the installation of the new outfall pipe. Caltrans designed the project to minimize disturbance to northern foredune habitat as it provides refugia for overwintering western snowy plovers. Approximately 0.75 acres of beach habitat will be disturbed during this phase, disrupting western snowy plover foraging habitat. Vehicles and heavy construction equipment will be used to excavate and remove the existing outfall pipe and install the new pipe. Based on the sandy substrate, this will require the use of sheet piles for shoring. Caltrans will return the beach habitat to original grade and is expected to recover quickly based on natural environmental processes including tidal action and winds. The intertidal and offshore construction will occur from June 1 to July 31 when western snowy plovers are not present within the action area. Caltrans will temporarily affect 1.14 acres of intertidal habitat due to excavation, sheet pile installation, and removal, and construction of the new outfall pipe. This area is expected to recover due quickly due to regular tidal action. Foraging habitat within the beach and intertidal areas is expected to recover prior to the return of wintering snowy plovers. The third stage will occur from July 1 to October 31 and will extend from 100 feet from the MHHW mark outward into the San Francisco Bay. This stage overlaps with the earliest arrival of western snowy plovers within the action area and has the potential to affect normal behavioral patterns of western snowy plovers within the action area due to the proximity of work within 100 feet of MHHW mark, increased human activity, and noise associated with construction activities resulting in startle or alarm behavior, flushing or avoidance of foraging and refugia sites within the action area, and increased stress within individual plovers. Caltrans proposes to minimize these effects by working from barges and avoiding accessing the site from the beach and using vibratory hammers within 800 feet of the shoreline to install sheet piles in lieu of pile driving.

Caltrans has minimized the need for vegetation removal by largely avoiding the foredune habitat; however, the minimal amount of vegetation clearing required due to its proximity to the existing pipe alignment will occur at the beginning of the project when western snowy plovers are not present within the action area. Caltrans proposes to further minimize these effects by locating construction staging, storage and parking areas outside of sensitive habitat; clearly marking construction work boundaries to prevent crews from affecting more habitat than is absolutely necessary, and avoiding effects to restored northern foredune habitat to the extent practicable. Following construction, Caltrans will reconstruct northern foredune habitat and the GGNRA will revegetate all disturbed northern foredune habitat. In addition, preconstruction surveys will be conducted prior to and regularly throughout the active construction phase and Service-approved monitors will be present at all times during all construction activities including pile driving, vegetation clearing, and cleanup activities.

Caltrans proposes to minimize risks associated with using construction equipment within sensitive habitat by implementing a SWPPP, erosion control BMPs and a Spill Response Plan, which will

consist of refueling, oiling or cleaning of vehicles and equipment a minimum of 100 feet from aquatic resources; installing coir rolls, straw wattles and/or silt fencing to capture sediment and prevent runoff or other harmful chemicals from entering the wetland; and locating staging, storage and parking areas away from aquatic habitats.

Temporary effects comprise areas denuded, manipulated, or otherwise modified from their existing, pre-project conditions, thereby removing one or more essential components of a listed species' habitat as a result of project activities that include, but are not limited to, construction, staging, storage, lay down, vehicle access, parking, etc. Temporary effects may result in altered behavioral responses such as increased stress, avoidance, and abandonment of nesting, foraging or wintering sites, or increasing severity leading to sub-lethal or lethal effects to individual western snowy plovers. Temporary effects must be restored to baseline habitat values or better within one year following initial disturbance. Areas subject to ongoing operations and maintenance are not considered temporary even if they are restored within one year following initial disturbance. Affected areas not fulfilling these criteria are considered permanent. Construction within northern foredune, beach, intertidal and San Francisco Bay/subtital habitat would result in the permanent loss and/or degradation of 0.04 acres and the temporary loss and/or degradation of 13.34 acres of Pacific coast population of western snowy plover habitat.

These effects will be further minimized by installing environmentally sensitive area fencing to keep workers from straying into otherwise undisturbed northern foredune, beach and intertidal habitat; erecting wildlife exclusion fencing to western snowy plovers from wandering onto the construction site; implementing storm water and erosion BMP's; educating workers about the presence of western snowy plovers, their habitat, identification, regulatory laws, and avoidance and minimization measures; and requiring a Service-approved biologist(s) to be present to monitor project activities within or adjacent to suitable habitat.

Cumulative Effects

Cumulative effects include the effects of future State, Tribal, local or private actions that are reasonably certain to occur in the action area considered in this biological opinion. Future Federal actions that are unrelated to the proposed action are not considered in this section because they require separate consultation pursuant to section 7 of the Act. No other State, Tribal, local or private actions are anticipated in the action area within the foreseeable future.

Conclusion

After reviewing the current status of the Pacific coast population of the western snowy plover; the environmental baseline for the action area; the effects of the proposed South Access to the Golden Gate Bridge-Doyle Drive: IJKL Outfall Replacement Project and the cumulative effects; it is the Service's biological opinion that the project, as proposed, is likely to adversely affect this species, but is not likely to jeopardize its continued existence. This determination is based on our opinion that the magnitude of the effects of this action does not appreciably reduce the likelihood of both the survival and recovery of this species in the wild.

INCIDENTAL TAKE STATEMENT

Section 9(a)(1) of the Act and Federal regulation pursuant to section 4(d) of the Act prohibit the take of endangered and threatened fish and wildlife species without special exemption. Take is defined as harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or to attempt to engage in any such conduct. Harass is defined by the Service as an intentional or negligent act or omission which creates the likelihood of injury to a listed species by annoying it to such an extent as to significantly disrupt normal behavioral patterns which include, but are not limited to, breeding, feeding, or sheltering. Harm is defined by the Service to include significant habitat modification or degradation that results in death or injury to listed species by impairing behavioral patterns including breeding, feeding, or sheltering. Incidental take is defined as take that is incidental to, and not the purpose of, the carrying out of an otherwise lawful activity. Under the terms of section 7(b)(4) and section 7(o)(2), taking that is incidental to and not intended as part of the agency action is not considered to be prohibited taking under the Act provided that such taking is in compliance with this Incidental Take Statement.

The measures described below are non-discretionary, and must be implemented by Caltrans so that they become binding conditions of any grant or permit issued to Caltrans, as appropriate, in order for the exemption in section 7(o)(2) to apply. Caltrans has a continuing duty to regulate the activity covered by this incidental take statement. If Caltrans (1) fails to require Caltrans to adhere to the terms and conditions of the incidental take statement through enforceable terms that are added to the permit or grant document, and/or (2) fails to retain oversight to ensure compliance with these terms and conditions, the protective coverage of section 7(o)(2) may lapse.

Amount or Extent of Take

Conservation measures proposed by the project proponent and described above in the *Description of the Proposed Action* section of this biological opinion will reduce, but do not eliminate, the potential for incidental taking of the Pacific coast population of the western snowy plover. The Service anticipates that incidental take of western snowy plovers may be difficult to detect based on the cryptic nature and vagility of the species, and tendency to flush from an area when disturbed inhibiting prolonged observation of individuals. Losses of this species may also be masked by seasonal and annual fluctuations in abundance, density, and overwintering site selection. The Service considers the number of western snowy plovers subject to harassment from noise, habitat disturbance, increased human presence, and construction activities to be approximately eight (8) individuals based on the maximum number of individuals observed in the action area during annual species monitoring by GGNRA and the Golden Gate Audubon Society. The Service, therefore, anticipates the following levels of take as a result of implementation of the proposed action: the harassment of all Pacific coast population of western snowy plovers within the action area during the construction phase of the proposed action due to habitat disturbance, increased human activity, use of heavy equipment, vibratory hammer and pile driving operations, and the removal and installation of the outfall pipeline within the single calendar year of the proposed construction timeline. No injury or mortality is expected as the majority of construction activities and all construction activities within the northern foredune, beach, and intertidal areas will be conducted outside the overwintering period when western snowy plovers are known to use the action area. The proposed action is not expected to result in harm based on the limited effects to northern foredune habitat and restoration efforts of the NPS, and the temporary nature of effects to beach

and intertidal foraging areas that will return to nominal conditions prior to the arrival of wintering western snowy plovers.

Effect of the Take

In the accompanying biological opinion, the Service determined that the level of anticipated take is not likely to jeopardize the Pacific coast population of the western snowy plover.

Reasonable and Prudent Measures

The Service has determined that the following reasonable and prudent measure is necessary and appropriate to minimize impacts of incidental take of Pacific coast population of the western snowy plover:

1. Minimize the effects to the Pacific coast population of the western snowy plover by implementing the proposed action as described and the following terms and conditions.

Terms and Conditions

In order to be exempt from the prohibitions of section 9 of the Act, Caltrans must comply with the following terms and conditions, which implement the reasonable and prudent measure, described above and outline required reporting/monitoring requirements. These Terms and Conditions are nondiscretionary.

The following Terms and Conditions implement the Reasonable and Prudent Measure number 1:

1. **Compliance with Biological Opinion**. Caltrans shall include Special Provisions that include the Conservation Measures and the Terms and Conditions of this biological opinion in the solicitation for bid information for all contracts for the project that are issued by them to all contractors. Caltrans shall require all contractors and subcontractors to comply with the Act in the performance of the proposed action and shall perform the action as outlined in the Project Description of this biological opinion as provided by Caltrans in the Biological Assessment dated September 2013, and all other supporting documentation submitted to the Service in support of the action. Changes to the Project Description or performance of work outside the scope of this biological opinion are subject to the requirements of reinitiation of formal consultation.

2. **Implementation of Biological Opinion**. Caltrans shall ensure the Resident Engineer or their designee shall have full authority to implement and enforce all Conservation Measures and Terms and Conditions of this biological opinion. The Resident Engineer or their designee shall maintain a copy of this biological opinion onsite whenever construction is in progress. Their name(s) and telephone number(s) shall be provided to the Service at least 30 calendar days prior to groundbreaking at the project.

3. **Biological Monitor Approval and Stop Work Authority**. The qualifications of all proposed Service-approved biological monitors shall be presented to the Service for review and written approval at least 30 calendar days prior to project initiation. The Service-approved biological monitors shall keep a copy of this biological opinion in his/her

possession when onsite. The Service-approved biological monitors shall communicate through the Resident Engineer or their designee, verbally, by telephone, email, or hardcopy with Caltrans personnel, construction personnel or any other person(s) at the project site or otherwise associated with the project to ensure that the terms and conditions of this biological opinion are met. The Service-approved biologist(s) through communication with the Resident Engineer shall have oversight over implementation of the Terms and Conditions in this Biological Opinion, and shall have the authority to stop project activities if they determine any of the requirements associated with these Terms and Conditions are not being fulfilled. If the Service-approved biologist(s) exercises this authority, the Service shall be notified by telephone and email within 24 hours. The Service contact is Coast-Bay Division Chief of the Endangered Species Program, Sacramento Fish and Wildlife Office at telephone (916) 414-6600.

4. **Biological Monitoring Records**. The Service-approved biologist(s) shall maintain monitoring records that include: (1) the beginning and ending time of each day's monitoring effort; (2) a statement identifying the listed species encountered, including the time and location of the observation; (3) the time the specimen was identified and by whom and its condition; and (4) a description of any actions taken. The Service-approved biologist(s) shall maintain complete records in their possession while conducting monitoring activities and shall immediately surrender records to the Service or their designated agents upon request. If requested, all monitoring records shall be provided to the Service within 30 of the completion of monitoring work.

5. **Agency Access**. If verbally requested through the Resident Engineer or Construction Inspector, before, during, or upon completion of ground breaking and construction activities, Caltrans shall ensure the Service or their designated agents can immediately and without delay, access and inspect the project site for compliance with the proposed project description, conservation measures, and terms and conditions of this Biological Opinion, and to evaluate project effects to the Pacific coast population of the western snowy plover and its habitat.

6. **Proper Use of Erosion Control Devices**. To prevent Pacific coast population of the western snowy plovers from becoming entangled, trapped, or injured, erosion control materials that use plastic or synthetic monofilament netting will not be used within the action area. This includes products that use photodegradable or biodegradable synthetic netting, which can take several months to decompose. Acceptable materials include natural fibers such as jute, coconut, twine or other similar fibers.

7. **Biological Monitoring**. A Service-approved biologist(s) shall be onsite during all activities that may result in take of Pacific coast population of the western snowy plover as determined by the Service. A minimum of one Service-approved biologist shall be on-site throughout the project duration. However, an adequate number of Service-approved biologists to monitor the effects of the project on the Pacific coast population of the western snowy plover. The Service will consider the implementation of specific project activities without the oversight of an on-site Service-approved biologist on a case-by-case basis.

8. **Western Snowy Plover Nesting Surveys**. Within 600 feet of the project footprint, focused preconstruction surveys for active western snowy plover nests will be conducted

within two weeks prior to the start of construction and monthly thereafter throughout the duration of the nesting season from February 1 to September 30. If active nests – nests with egg(s) or young present, all construction activities within the survey buffer shall cease immediately and the Service shall be notified within 24 hours of the observation and a 600-foot no-disturbance buffer will be established until the young have fledged. The Service-approved biologist(s) shall conduct clearance surveys for western snowy plovers at the beginning of each day and regularly throughout the workday when construction activities are occurring during the overwintering season from August 1 through May 1. If a western snowy plover is observed, the Service-approved biologist shall implement the species observation protocol outlined below.

9. **Recontouring Beach and Foredunes.** Following the completion of work within the northern foredune and beach areas, Caltrans shall recontour the beach and foredune area above the MHW mark to facilitate the restoration of foredune habitat in coordination with revegetation activities by the NPS.

Reporting Requirements

In order to monitor whether the amount or extent of incidental take anticipated from implementation of the project is approached or exceeded, Caltrans shall adhere to the following reporting requirements. Should this anticipated amount or extent of incidental take be exceeded, Caltrans must reinitiate formal consultation as per 50 CFR 402.16.

1. The Service must be notified within one (1) working day of the finding of any injured or dead listed species or any unanticipated damage to its habitat associated with the proposed project. Notification will be made to the Coast-Bay/Forest Foothills Division Chief of the Endangered Species Program at the Sacramento Fish and Wildlife Office at (916) 414-6600, and must include the date, time, and precise location of the individual/incident clearly indicated on a U.S. Geological Survey 7.5 minute quadrangle or other maps at a finer scale, as requested by the Service, and any other pertinent information. When an injured or dead individual of the listed species is found, Caltrans shall follow the steps outlined in the Disposition of Individuals Taken section below.

2. Other pertinent reporting information such as monitoring reports (if not included as a term and condition), notification of project completion/implementation, etc. including when this information is due to the Service.

Disposition of Individuals Taken
Injured listed species must be cared for by a licensed veterinarian or other qualified person(s), such as the Service-approved biologist. Dead individuals must be sealed in a resealable plastic bag containing a paper with the date and time when the animal was found, the location where it was found, and the name of the person who found it, and the bag containing the specimen frozen in a freezer located in a secure site, until instruction s are received from the Service regarding the disposition of the dead specimen. The Service contact person is the Coast-Bay Division Chief of the Endangered Species Program at the Sacramento Fish and Wildlife Office at (916) 414-6600.

CONSERVATION RECOMMENDATIONS

Section 7(a)(1) of the Act directs Federal agencies to utilize their authorities to further the purposes of the Act by carrying out conservation programs for the benefit of endangered and threatened species. Conservation recommendations are discretionary agency activities to minimize or avoid adverse effects of a proposed action on listed species or critical habitat, to help implement recovery plans, or to develop information. The Service recommends the following actions:

1. Caltrans District 4 should work with the Service to develop a conservation strategy that would identify the current safe passage potential along Bay Area highways and the areas where safe passage for wildlife could be enhanced or established.

2. Caltrans should assist the Service in implementing recovery actions identified in the *Western Snowy Plover* (*Charadrius alexandrinus nivosus*) *Pacific Coast Population Recovery Plan* (Service 2007).

3. Caltrans should consider participating in the planning for a regional habitat conservation plan for the Pacific coast population of the western snowy plover and other listed and sensitive species.

4. Encourage participation of prospective permittees in a program being developed by Federal and State resource agencies to limit and reverse the spread of non-native Spartina within the Estuary.

5. Encourage or require the use of appropriate California native species in re-vegetation and habitat enhancement efforts associated with any projects authorized by the Service.

6. Facilitate additional educational programs geared toward the importance and conservation of tidal marsh and seasonal wetlands.

In order for the Service to be kept informed of actions minimizing or avoiding adverse effects or benefiting listed species or their habitats, the Service requests notification of the implementation of any conservation recommendations.

REINITIATION--CLOSING STATEMENT

This concludes formal consultation on the South Access to the Golden Gate Bridge-Doyle Drive: IJKL Outfall Replacement Project. As provided in 50 CFR §402.16, reinitiation of formal consultation is required where discretionary Federal agency involvement or control over the action has been retained (or is authorized by law) and if: (1) the amount or extent of incidental take is exceeded; (2) new information reveals effects of the agency action that may affect listed species or critical habitat in a manner or to an extent not considered in this opinion; (3) the agency action is subsequently modified in a manner that causes an effect to the listed species or critical habitat not considered in this opinion; or (4) a new species is listed or critical habitat designated that may be affected by the action. In instances where the amount or extent of incidental take is exceeded, any additional take will not be exempt from the prohibitions of section 9 of the Act, pending reinitiation.

If you have any questions regarding this biological opinion on the proposed South Access to the Golden Gate Bridge-Doyle Drive: IJKL Outfall Replacement Project, San Francisco County, California, contact Jerry Roe or Ryan Olah at the letterhead address or at (916) 414-6600.

Sincerely,

Jennifer M. Norris
Field Supervisor

Enclosure

cc:
Joyce Ambrosius, NOAA Fisheries, Santa Rosa, California
Tania Pollak, NPS, San Francisco, California
Melanie Brent, Caltrans, Oakland, California
John Yeakel, Caltrans, Oakland, California
Arn Aarreberg, California Department of Fish and Wildlife, Napa, California

LITERATURE CITED

American Ornithologists' Union (AOU). 1957. Checklist of North American Birds. Fifth edition. American Ornithologists' Union, Washington, D.C. 168 pp.

Boarman, W.I. and B. Heinrich. 1999. Common Raven (*Corvus corax*), The Birds of North America Online (A. Poole, Ed.). Ithaca: Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/476.

California Department of Transportation (Caltrans). 2014a. Biological Assessment, South Access to the Golden Gate Bridge-Doyle Drive: IJKL Outfall Replacement Project, Caltrans District 04, San Francisco County, EA 04-1637N1. Oakland, California. February.

Casady, D.S. 1999. Snowy Plover (*Charadrius alexandrines* [sic]) Nesting at the Baumberg Tract Salt Ponds, Hayward, California, 1999. CDFG. Yountville, California.

Feeney, L.R. and W.A. Maffei. 1991. Snowy Plovers and Their Habitat at the Baumberg Area and Oliver Salt Ponds, Hayward, California March 1989 through May 1990. Report prepared for the City of Hayward. Hayward, California. 162 p.

Fischer, B. 1998. Western Snowy Plover Breeding Survey and Nest Characterization; Don Edwards San Francisco Bay National Wildlife Refuge 1998. Unpublished Report. San Francisco Bay National Wildlife Refuge Complex. Newark, California.

Grinnell, J., H.C. Bryant, and T.I. Storer. 1918. The Game Birds of California. University of California Press. Berkeley, California. 642 pp.

Hannon, M. and B. Clayton. 1995. Western Snowy Plover Breeding Survey, San Francisco Bay National Wildlife Refuge, 1995. Unpub. report. U.S. Fish and Wildlife Service. Newark, California. 19 p.

Harding, E.K, J. Albertson, D.F. Doak, and J. Takekawa. 1998. Predator Management in San Francisco Bay Wetlands: Past Trends and Future Strategies. Final Report. Prepared for Service Division of Ecological Services. Sacramento, California.

Hothem, R.L. and A.N. Powell. 2000. Contaminants in Eggs of Western Snowy Plovers and California Least Terns: Is There a Link to Population Decline? Environmental Contamination and Toxicology 65:42-50.

Marriott, M.A. 2003. Microhabitat characteristics predictive of Snowy Plover (*Charadrius alexandrinus nivosus*) nest site selection in South San Francisco Bay. Unpublished Masters Thesis. Humboldt State University. Humboldt, California.

Marriott, M.A. and C. Schelin. 2001. Pacific Coast Western Snowy Plover Monitoring Program at the Don Edwards San Francisco Bay National Wildlife Refuge, the Eden Landing Ecological Reserve, and Selected Cargill Salt Division Properties, Year 2001. Unpub. Report, U.S. Fish and Wildlife Service. Newark, California.

Neuman, K.K, G.W. Page, L.E. Stenzel, J.C. Warriner, and S. Warriner. 2004. Effect of Mammalian Predator Management on Snowy Plover Breeding Success. Waterbirds 27(3):257-263.

Page, G.W, C.M. Hickey, and L.E. Stenzel. 2000. Western Snowy Plover. In: Olofson PR, editor. Goals Project. Baylands Ecosystem Species and Community Profiles: Life Histories and Environmental Requirements of Key Plants, Fish and Wildlife. San Francisco Bay Area Wetlands Ecosystem Goals Project. San Francisco Bay Regional Water Quality Control Board. Oakland, California. p 281-283.

Page, G.W. and L.E. Stenzel. 1981. The breeding status of the Snowy Plover in California. Western Birds 12:1–40.

Page, G.W, L.E. Stenzel, and C.M. Wolfe. 1979. Aspects of the Occurrence of Shorebirds on a Central California Estuary. Studies in Avian Biology 2:15-32.

Page, G.W, L.E. Stenzel, and W.D. Shuford. 1991. Distribution and Abundance of the Snowy Plover on its Western North American Breeding Grounds. Journal of Field Ornithology 62(2):245-255.

Page, G.W, L.E. Stenzel, J.C. Warriner, and P.W.C. Paton. 1995. Snowy Plover (Charadrius alexandrinus). In: A. Pool, F. Gill, editors. The Birds of North America: No. 154. Academy of Natural Sciences, Philadelphia, and American Ornithologists' Union, Washington, DC.

Purdue, J. R. 1976. Adaptations of the Snowy Plover on the Great Salt Plains, Oklahoma. Southwestern Naturalist. 21:347-357.

Rigney, M. and T. Rigney. 1981. A Breeding Bird Survey of the South San Francisco Bay Salt Pond Levee System, 1981. South Bay Institute for Avian Studies. Alviso, California.

Robinson, C., C. Strong, L. Tucci, and J. Albertson. 2006. Western Snowy Plover Numbers, Nesting Success, and Avian Predator Surveys in the San Francisco Bay, 2006. San Francisco Bay Bird Observatory and U.S. Fish and Wildlife Service. Alviso and Newark, California.

Ryan, T.P. and J.L. Parkin. 1998. The Western Snowy Plover in Southern San Francisco Bay: Summary of Detections Made During Colonial Waterbird Monitoring Surveys from 1981 to 1997. San Francisco Bay Bird Observatory. Alviso, California. 19 p.

Schwarzbach, S. and T. Adelsbach. 2003. Field Assessment of Avian Mercury Exposure in the Bay-Delta Ecosystem. Final Report to the California Bay Delta Authority. Sacramento, California. pp. 30.

Schwarzbach, S., M. Stephenson, T. Ruhlen, S. Abbott, G.W. Page, and D. Adams. 2005. Elevated Mercury Concentrations in Failed Eggs of the Snowy Plovers at Point Reyes National Seashore. Baseline 50:1444-1447.

Stenzel, L.E., J.C. Warriner, J.S. Warriner, K.S. Wilson, F.C. Bidstrup, and G.W. Page. 1994. Long Distance Breeding Dispersal of Snowy Plovers in Western North America. Journal of Animal Ecology 63:887-902.

Strong C.M. and R. Dakin R. 2004. Western Snowy Plover Breeding Season Surveys for 2003. Unpub. report. San Francisco Bay Bird Observatory. Alviso, California.

Strong, C.M., N. Wilson, and J. Albertson. 2004a. Western Snowy Plover Numbers, Nesting Success, and Avian Predator Surveys in the San Francisco Bay, 2004. Unpub. report. San Francisco Bay Bird Observatory. Alviso, California.

Strong, C.M., Spear, L.B., T.P. Ryan. R.E. Dakin. 2004b. Forster's Tern, Caspian Tern, and California Gull Colonies in San Francisco Bay: Habitat Use, Numbers and Trends, 1982-2003. Waterbirds, 27:411-423.

U.S. Fish and Wildlife Service (Service). 1993. Endangered and Threatened Wildlife and Plants; Determination of Threatened Status for the Pacific Coast Population of the Western Snowy Plover; Final Rule. **Federal Register** 58(42):12864-12874.

_____. 2005. Endangered and Threatened Wildlife and Plants; Final Designation of Critical Habitat for the Pacific Coast Population of the Western Snowy Plover; Final Rule. **Federal Register** 70(188):56970-57119.

_____. 2006. Endangered and Threatened Wildlife and Plants: 12-Month Finding on a Petition to Delist the Pacific Coast Population of the Western Snowy Plover; Notice of 12-Month Petition Finding. **Federal Register** 71(77):20607-20264.

_____. 2007. Recovery Plan for the Pacific Coast Population of the Western Snowy Plover (*Charadrius alexandrinus nivosus*). In 2 volumes. Sacramento, California. xiv + 751 pages.

Verbeek, N.A. and C. Caffrey. 2002. American Crow (*Corvus brachyrhynchos*), The Birds of North America Online (A. Poole, Ed.). Ithaca: Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/647.

Warriner, J. S., J. C. Warriner, G. W. Page, and L. E. Stenzel. 1986. Mating System and Reproductive Success of a Small Population of Polygamous Snowy Plovers. Wilson Bulletin 98(1):15-37.

San Francisco Bay Conservation and Development Commission
455 Golden Gate Avenue, Suite 10600, San Francisco, California 94102 tel 415 352 3600 fax 415 352 3606

February 9, 2015

California Department of Transportation
111 Grand Avenue
P.O. Box 23660
Oakland, California 94623-5636

ATTENTION: Melanie Brent, Deputy District Director

SUBJECT: BCDC Permit No. M2014.036.00

Dear Ms. Brent:

Enclosed please find an original of BCDC Permit No. M2014.036.00, stamped "BCDC Original," and one copy, stamped "Permittee's Copy," both executed by the Executive Director.

You must: (1) **complete** the acknowledgment section of the permit stamped "BCDC Original," which indicates that you have read and that you understand all of the terms and conditions of the permit; and (2) **return** the entire "BCDC Original" to the Commission's office within the ten-day time period. The copy stamped "Permittee's Copy" should be retained by you for your records along with the Notice of Completion, which must be returned to us upon project completion.

Furthermore, your permit contains special conditions, which require you to take certain specific actions, including submitting the approval from Golden Gate National Recreation Area once it is received and notifying the Presidio Trust, or other federal entity, of the need for a consistency determination prior to taking control of the outfall. Understand that **no** work may commence on the project until the permit stamped "BCDC Original" is executed and returned to the Commission. Until the Commission receives the executed permit, the California Department of Transportation does not have the necessary authorization for the work authorized under the permit. The commencement of any work within the Commission's jurisdiction without the necessary authorization from the Commission is a violation of the McAteer-Petris Act and could subject the California Department of Transportation to substantial fines.

If you should have any questions regarding the permit or the procedure outlined above, please contact Erik Buehmann of our staff at 415-352-3645 or erik.buehmann@bcdc.ca.gov.

Very truly yours,

Erik Buehmann
Coastal Program Analyst

EB/ra

BCDC PERMIT NO. M2014.036.00

CALIFORNIA DEPARTMENT OF TRANSPORTATION

NOTICE OF COMPLETION AND DECLARATION OF COMPLIANCE

San Francisco Bay Conservation
and Development Commission
455 Golden Gate Avenue, Suite 10600
San Francisco, CA 94102

Ladies and Gentlemen:

You are hereby informed that the work authorized by the above-referenced permit was completed on _____.

I have personally reviewed the terms and conditions of the permit, the final plans approved by or on behalf of the Commission, and the completed project and hereby certify that the project is in compliance with all terms and conditions of the permit and conforms to the plans previously reviewed and approved by or on behalf of the Commission. I further certify that all conditions of the permit, particularly with regard to plan review, public access areas and improvements, recordation, open space restrictions and other special conditions have been met.

I, _____, hereby declare under penalty of perjury that the foregoing is true and correct and that if called upon to testify to the contents of this notice, I would so testify.

Executed on this _____ day of _____, 20_____,

at _____, California.

_____

(Permittee)

_____

Title

San Francisco Bay Conservation and Development Commission
455 Golden Gate Avenue, Suite 10600, San Francisco, California 94102 tel 415 352 3600 fax 415 352 3606

PERMIT NO. M2014.036.00

February 9, 2015

California Department of Transportation
111 Grand Avenue
P.O. Box 23660
Oakland, California 94623-5636

ATTENTION: Melanie Brent, Deputy District Director

Ladies and Gentlemen:

I. Authorization

A. **Authorized Project**. Subject to the conditions stated below, the permittee, the California Department of Transportation, is hereby authorized to do the following:

Location: In the Bay and within the 100-foot shoreline band, at Crissy Field (Park), north of Doyle Drive, in the Golden Gate Recreation Area, a park priority use area on Bay Plan Map No. 4, in the City and County of San Francisco.

Description: **In the Bay and Within the 100-foot Shoreline Band**

Remove an approximately 170-foot-long outfall and replace, use, and maintain it in-kind with a new approximately 460-foot-long, 54-inch-diameter HDPE (High Density Polyethylene) outfall, approximately 270 feet of which would be buried beneath the beach and bay floor (the landward portion), and approximately 190 feet would be supported above the bay floor by approximately 16 13-inch diameter HDPE piles, (the bayward portion). The buried pipe would be supported by eight 13-inch diameter HDPE piles, and 14 existing HDPE piles. The project would occur over an approximately 45,440-square-foot (1.04 acre) area.

B. **Based on Application Dated**. This authority is generally pursuant to and limited by your application dated November 18, 2013, including its accompanying and subsequently submitted exhibits and correspondence and all conditions of this permit.

C. **Deadlines for Commencing and Completing Authorized Work**. Work authorized herein must commence prior to October 31, 2018, or this permit will lapse and become null and void. Such work must also be diligently pursued to completion and must be completed within three years of commencement, or by October 31, 2021, whichever is earlier, unless an extension of time is granted by amendment of the permit.

II. Special Conditions

The authorization made herein shall be subject to the following special conditions, in addition to the standard conditions in Part IV:

A. **Construction Plans.** The improvements authorized herein shall be built generally in conformance with the figure entitled "Storm Drain Outfall IJKL," prepared by the California Department of Transportation, and dated July 10, 2010, and all subsequent amendments and changes submitted with the application. No substantial changes shall be made to these plans without prior review and written approval by the Commission staff.

B. **Construction Timing**. All construction and removal activities shall be confined to May 15 to October 31 to minimize disturbance to migratory waterfowl, nesting resident birds, and migrating fish.

C. **Golden Gate National Recreation Area Approval**. Prior to any construction activity on removing the existing outfall and installing its replacement, the permittee shall obtain approval from the Golden Gate National Recreation Area and submit the relevant documentation to the Commission staff.

D. **Transfer to Federal Entity.** Prior to the transfer of control and maintenance responsibility to the Presidio Trust, the Golden Gate National Recreation Area, or any other federal entity, the permittee shall notice the receiving entity of the need for a consistency determination from the Commission. Furthermore, the permittee shall provide notice to the Commission prior to the transfer of control and maintenance responsibility to a federal entity.

E. **Habitat Protection**. The work authorized by this permit shall be performed so as to prevent any significant adverse impact on any tidal marsh, tidal flat, eelgrass habitat or other sensitive Bay resources. If any unforeseen adverse impacts occur to any such area as a result of the activities authorized herein, the permittee shall restore the area to or improve the area above its previous condition, which may include returning the disturbed area to its original elevation and soil composition and, if the area does not revegetate to its former condition within one year, seeding all disturbed areas with appropriate vegetation.

F. **Creosote Treated Wood**. No pilings or other wood structures that have been pressure treated with creosote shall be used in any area subject to tidal action in the Bay or any certain waterway, in any salt pond, or in any managed wetland within the Commission's jurisdiction as part of the project authorized herein.

G. **Removal of existing Outfall**. Within two months of use of the replacement outfall, the 170-foot-long existing outfall must be fully removed, disposed at an authorized upland location outside the Commission's jurisdiction and disturbed shoreline, intertidal, and subtidal areas returned to this pre-construction condition.

H. **Maintenance and Replacement of Authorized Facilities.** Any in-kind repairs and maintenance of an authorized structure or improvement shall only use construction material that is approved by the Commission in consultation with the Regional Water Quality Control Board and the California Department of Fish and Game for use in San Francisco Bay. Construction shall only occur during those months of the year, as approved by the Commission in consultation with resource agencies such as U.S. Fish and Wildlife Service, Department of Fish and Game and National Marine Fisheries Service, that avoid or minimize potential impacts to fish and wildlife. BCDC staff should be contacted to confirm current restrictions.

I. **Water Quality**. Prior to undertaking any work authorized herein on any outfall pipe or similar facility, the permittee shall receive all necessary approvals from the California Regional Water Quality Control Board, San Francisco Bay Region, for any discharge or emission from such structure.

J. **Notice to Contractor**. The permittee(s) shall provide a copy of this Permit to any contractor or person working in concert with the permittee(s) to carry out the activities authorized herein and shall point out the special conditions contained herein.

III. Findings and Declarations

On behalf of the Commission, I find and declare that:

A. **Project**. The project authorized by this permit involves the replacement of an outfall pipeline with a new outfall which will extend significantly further into the Bay. Work will occur within the Commission's Bay and Shoreline Band jurisdiction. Therefore the project involves the placement of outfall pipes approved by the California Regional Water Quality Control Board, San Francisco Bay Region, as defined in the Commission's Regulation Section 10601(a)(4) for the work in the Bay, and the placement of small amounts of inert, inorganic material and the extraction of small amounts of material from the shoreline band, as defined in Commission Regulation Section 10601(b)(1), and thus is defined as a "minor repair or improvement" for which the Executive Director may issue a permit, pursuant to Government Code Section 66632(f) and Regulation Section 10622(a).

B. **Consistency with Commission Law and Policies**. As conditioned, the project authorized herein is consistent with the McAteer-Petris Act and with the San Francisco Bay Plan in that it will not adversely affect the Bay nor public access to and enjoyment of the Bay. The project is designed to accommodate increased stormwater runoff resulting from the new Doyle Drive approach to the Golden Gate Bridge (subject to BCDC Letter of Agreement for Consistency Determination No. C2008.002). The existing outfall regularly silts with sand, backing up and resulting in flooding on Mason Street and Crissy Field during large rain events. The existing outfall end requires frequent clearing with a backhoe. The new extended outfall authorized by this permit will increase the capacity and will not suffer from blockages.

The permittee originally requested to authorize the project through an amendment to BCDC Letter of Agreement for Consistency Determination No. C2008.002, which held the Doyle Drive project consistent with the Commission's Coastal Zone Management Plan. Commission Staff reviewed the proposal and determined that because the permittee was a state agency, there was no federal entity co-applicant, and the project itself took place within the Commission's McAteer-Petris Act jurisdiction, that the project was properly approved through an administrative permit pursuant to Government Code Section 66632(f) and Regulation Section 10622(a).

Special Condition II.B limiting work to specific times of the year is included to ensure that the project is consistent with the San Francisco Bay Plan policies on Fish, Other Aquatic Organisms, and Wildlife. The work windows, which correspond to the time limitations imposed by the Regional Water Quality Control Board in its water quality certification and the United States Fish & Wildlife Service in its consultations with the permittee, are designed to minimize impacts to fish and birds, including the western snowy plover. In addition, Special Conditions II.E-I are included to ensure the project complies with the Bay Plan policies on Fish, Other Aquatic Organisms, and Wildlife and Water Quality by requiring habitat restoration of all areas disturbed during construction, the prohibition of creosote treated wood, and approved by the Regional Water Quality Control Board of all work on the outfall.

Pursuant to Regulation Section 10311, the Executive Director waived the filing requirement that the permittee demonstrate legal interest in the property where fill would be placed (contained in Appendix F of Regulation Section 11721.) However, the approval is necessary for the permittee to satisfy the property interest requirements of Government Code Section 66605(g). Special Condition II.C is included to ensure that the permittee obtains approval from the Golden Gate National Recreation Area, property owner for the site, to conduct the work, and forwards that approval to the Commission.

The permittee has stated that ongoing ownership and maintenance of the new outfall will be transferred to the Presidio Trust after construction is completed. In the event that a federal entity takes control of the structure, a consistency determination under the Coastal Zone Management Act will be required for the transfer and ongoing maintenance. Special Condition II.D is included to require the permittee to provide notice of the need for a consistency determination to the federal entity and to provide notice to the Commission of the upcoming transfer.

Although the project will result in the closure of portions of Crissy Field during construction, the closure will be temporary and the project is phased to allow continued horizontal movement along the shoreline. Therefore, no new public access is required for this project.

C. **Public Trust**. The Commission finds that the fill authorized herein is consistent with public trust needs for the area.

D. **Coastal Zone Management Act.** The Commission further finds, declares, and certifies that the activity or activities authorized herein are consistent with the Commission's Amended Management Program for San Francisco Bay, as approved by the Department of Commerce under the Federal Coastal Zone Management Act of 1972, as amended.

E. **California Environmental Quality Act.** The project authorized by this permit is subject to a re-validation of the Environmental Impact Report that was prepared and approved for the Doyle Drive Golden Gate Bridge South Access Project pursuant to CEQA by the San Francisco Transportation Authority. The original notice of determination for the EIR was filed on December 17, 2008 and the re-validation was filed on October 15, 2014. The Federal Highway Administration concurred with a re-validation for the Environmental Impact Statement under the National Environmental Policy Act on November 4, 2014.

F. **Administrative Listing.** Pursuant to Regulation Section 10620, this project was listed with the Commission on February 5, 2015.

G. **Enforcement Program and Civil Penalties.** The Commission has an enforcement program that reviews its permits for compliance. The Commission may issue cease and desist and civil penalty orders if violations are discovered. The McAteer-Petris Act provides for the imposition of administrative civil penalties ranging from $10 to $2,000 per day up to a maximum of $30,000 per violation. The Act also provides for the imposition of court-imposed civil penalties of up to $30,000 in addition to any other penalties, penalties for negligent violations of between $50 and $5,000 per day, knowing and intentional penalties of between $100 and $10,000 per day, and exemplary penalties, which are supplemental penalties, in an amount necessary to deter future violations. In addition, anyone who places fill, extracts materials, or makes any substantial change in use of any water, land or structure within the area of the Commission's jurisdiction without securing a permit from the Commission is guilty of a misdemeanor.

IV. Standard Conditions

A. **Permit Execution**. This permit shall not take effect unless the permittee(s) execute the original of this permit and return it to the Commission within ten days after the date of the issuance of the permit. No work shall be done until the acknowledgment is duly executed and returned to the Commission.

B. **Notice of Completion**. The attached Notice of Completion and Declaration of Compliance form shall be returned to the Commission within 30 days following completion of the work.

C. **Permit Assignment**. The rights, duties, and obligations contained in this permit are assignable. When the permittee(s) transfer any interest in any property either on which the activity is authorized to occur or which is necessary to achieve full compliance of one or more conditions to this permit, the permittee(s)/transferors and the transferees shall execute and

submit to the Commission a permit assignment form acceptable to the Executive Director. An assignment shall not be effective until the assignees execute and the Executive Director receives an acknowledgment that the assignees have read and understand the permit and agree to be bound by the terms and conditions of the permit, and the assignees are accepted by the Executive Director as being reasonably capable of complying with the terms and conditions of the permit.

D. **Permit Runs With the Land**. Unless otherwise provided in this permit, the terms and conditions of this permit shall bind all future owners and future possessors of any legal interest in the land and shall run with the land.

E. **Other Government Approvals**. All required permissions from governmental bodies must be obtained before the commencement of work; these bodies include, but are not limited to, the U. S. Army Corps of Engineers, the State Lands Commission, the Regional Water Quality Control Board, and the city or county in which the work is to be performed, whenever any of these may be required. This permit does not relieve the permittee(s) of any obligations imposed by State or Federal law, either statutory or otherwise.

F. **Built Project must be Consistent with Application**. Work must be performed in the precise manner and at the precise locations indicated in your application, as such may have been modified by the terms of the permit and any plans approved in writing by or on behalf of the Commission.

G. **Life of Authorization**. Unless otherwise provided in this permit, all the terms and conditions of this permit shall remain effective for so long as the permit remains in effect or for so long as any use or construction authorized by this permit exists, whichever is longer.

H. **Commission Jurisdiction**. Any area subject to the jurisdiction of the San Francisco Bay Conservation and Development Commission under either the McAteer-Petris Act or the Suisun Marsh Preservation Act at the time the permit is granted or thereafter shall remain subject to that jurisdiction notwithstanding the placement of any fill or the implementation of any substantial change in use authorized by this permit. Any area not subject to the jurisdiction of the San Francisco Bay Conservation and Development Commission that becomes, as a result of any work or project authorized in this permit, subject to tidal action shall become subject to the Commission's "bay" jurisdiction.

I. **Changes to the Commission's Jurisdiction as a Result of Natural Processes**. This permit reflects the location of the shoreline of San Francisco Bay when the permit was issued. Over time, erosion, avulsion, accretion, subsidence, relative sea level change, and other factors may change the location of the shoreline, which may, in turn, change the extent of the Commission's regulatory jurisdiction. Therefore, the issuance of this permit does not guarantee that the Commission's jurisdiction will not change in the future.

J. **Violation of Permit May Lead to Permit Revocation**. Except as otherwise noted, violation of any of the terms of this permit shall be grounds for revocation. The Commission may revoke any permit for such violation after a public hearing held on reasonable notice to the permittee(s) or their assignees if the permit has been effectively assigned. If the permit is revoked, the Commission may determine, if it deems appropriate, that all or part of any fill or structure placed pursuant to this permit shall be removed by the permittee(s) or their assignees if the permit has been assigned.

K. **Should Permit Conditions Be Found to be Illegal or Unenforceable**. Unless the Commission directs otherwise, this permit shall become null and void if any term, standard condition, or special condition of this permit shall be found illegal or unenforceable through the application of statute, administrative ruling, or court determination. If this permit becomes null and void, any fill or structures placed in reliance on this permit shall be subject to removal by the permittee(s) or their assignees if the permit has been assigned to the extent that the Commission determines that such removal is appropriate. Any uses authorized shall be terminated to the extent that the Commission determines that such uses should be terminated.

L. **Permission to Conduct Site Visit**. The permittee(s) shall grant permission to any member of the Commission's staff to conduct a site visit at the subject property during and after construction to verify that the project is being and has been constructed in compliance with the authorization and conditions contained herein. Site visits may occur during business hours without prior notice and after business hours with 24-hour notice.

M. **Abandonment**. If, at any time, the Commission determines that the improvements in the Bay authorized herein have been abandoned for a period of two years or more, or have deteriorated to the point that public health, safety or welfare is adversely affected, the Commission may require that the improvements be removed by the permittee(s), its assignees or successors in interest, or by the owner of the improvements, within 60 days or such other reasonable time as the Commission may direct.

N. **Best Management Practices**

1. **Debris Removal.** All construction debris shall be removed to an authorized location outside the jurisdiction of the Commission. In the event that any such material is placed in any area within the Commission's jurisdiction, the permittee, its assigns, or successors in interest, or the owner of the improvements, shall remove such material, at their expense, within ten days after they have been notified by the Executive Director of such placement.
2. **Construction Operations.** All construction operations shall be performed to prevent construction materials from falling, washing or blowing into the Bay. In the event that such material escapes or is placed in an area subject to tidal action of the Bay, the permittee shall immediately retrieve and remove such material at its expense.

O. **In-Kind Repairs and Maintenance.** Any in-kind repair and maintenance work authorized herein shall not result in an enlargement of the authorized structural footprint and shall only involve construction materials approved for use in San Francisco Bay. Work shall occur during periods designated to avoid impacts to fish and wildlife. The permittee(s) shall contact Commission staff to confirm current restricted periods for construction.

Executed at San Francisco, California, on behalf of the San Francisco Bay Conservation and Development Commission on the date first above written.

LAWRENCE J. GOLDZBAND
Executive Director
San Francisco Bay Conservation
and Development Commission

By: _____
BRAD McCREA
Regulatory Program Director

BM/EB/ra

* *

Receipt acknowledged, contents understood and agreed to:

Executed at_____ _____
Applicant

On _____ By: _____

_____
Print Name and Title

cc: U. S. Army Corps of Engineers, Regulatory Section
San Francisco Bay Regional Water Quality Control Board, Certification Section
U.S. Environmental Protection Agency, Compliance and Enforcement Section
City and County of San Francisco, Planning Department
Golden Gate National Recreation Area
Presidio Trust

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
West Coast Region
777 Sonoma Avenue, Room 325
Santa Rosa, California 95404-4731

October 8, 2014 **Refer to NMFS No**: WCR-2014-1444

Hardeep Takhar
District Chief, Office of Biological Sciences and Permits
California Department of Transportation
111 Grand Avenue
Oakland, California 94610

Re: Endangered Species Act Section 7(a)(2) Concurrence Letter and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Response for the South Access to the Golden Gate Bridge-Doyle Drive: IJKL Outfall Replacement Project (Caltrans Expenditure Authorization [EA] number 1637N1)

Dear Mr. Takhar:

On September 18, 2014, NOAA's National Marine Fisheries Service (NMFS) received your request for a written concurrence that California Department of Transportations' (Caltrans) South Access to the Golden Gate Bridge-Doyle Drive: IJKL Outfall Replacement Project is not likely to adversely affect species listed as threatened or endangered or critical habitats designated under the Endangered Species Act (ESA). Effective October 1, 2012, Caltrans will be acting as the lead agency as per the Memorandum of Understanding (MOU) between the Federal Highway Administration (FHWA) and Caltrans pursuant to the Moving Ahead for Progress in the 21st Century Act (MAP-21). This law allows the Secretary of Transportation to assign, and Caltrans to assume, responsibility for the environmental review, consultation, or other actions required under any environmental law with respect to one or more highway projects within the state of California. The MOU is an extension of previous agreements between FHWA and Caltrans in 2007 and 2010, under a similar law. Therefore, Caltrans is considered the federal action agency for ESA consultations with NMFS for federally funded projects. This response to your request was prepared by NMFS pursuant to section 7(a)(2) of the ESA, implementing regulations at 50 CFR 402, and agency guidance for preparation of letters of concurrence.

NMFS also reviewed the proposed action for potential effects on essential fish habitat (EFH) designated under the Magnuson-Stevens Fishery Conservation and Management Act (MSA), including conservation measures and any determination you made regarding the potential effects of the action. This review was pursuant to section 305(b) of the MSA, implementing regulations at 50 CFR 600.920, and agency guidance for use of the ESA consultation process to complete EFH consultation.

This letter underwent pre-dissemination review using standards for utility, integrity, and objectivity in compliance with applicable guidelines issued under the Data Quality Act (section 515 of the Treasury and General Government Appropriations Act for Fiscal Year 2001, Public Law 106-554). The concurrence letter will be available through NMFS' Public Consultation Tracking System [https://pcts.nmfs.noaa.gov/pcts-web/homepage.pcts[1]]. A complete record of this consultation is on file at NMFS North-Central Coast Office in Santa Rosa, California.

Proposed Action and Action Area

Caltrans and the Presidio Trust propose to replace and upgrade the IJKL outfall at Crissy Beach, located approximately 0.70 miles east of the Golden Gate Bridge on the northern tip of the City of San Francisco in San Francisco County, California. The Presidio of San Francisco is separated into the following five storm water drainage basins: D, E, F, GH, and IJKL. The IJKL basin is the largest of the 5 basins and drains an urbanized area that is approximately 125 acres. The IJKL outfall is a 175 foot long and 42-inch diameter high density polyethylene (HDPE) pipe that is buried beneath Crissy Beach and terminates at approximately mean higher high water (MHHW) on the Central San Francisco Bay. Substrate along the proposed outfall site is sand and water depths range from 0 to approximately 15 feet at MHHW. The outfall was upgraded in 2000 but has since been buried due to natural beach accretion (widening) and requires regular excavation to release impounded water in the Presidio. Following completion of the Presidio Parkway (currently underway), additional runoff from approximately 12 acres of impermeable surfaces is expected to flow into the outfall. For these reasons, the IJKL outfall is considered undersized and insufficient.

The proposed project will involve construction in the following stages from May 15 to October 31:

Stage 1: Onshore (beach) construction above MHHW will occur in one season from May 15th to July 1st and involve excavation and replacement of the existing outfall pipe with a 177 foot long and 54-inch diameter HDPE pipe. Fourteen existing 13-inch diameter HDPE piles positioned on either side of the outfall pipe will be driven an additional 6 feet into the sand with a hydraulic impact hammer to accommodate the replacement pipe. The replacement outfall pipe will be installed along the same alignment and approximately 10 feet below grade (approximately 6 feet lower in elevation than the existing pipe). Following installation of the replacement pipe, excavated areas will be backfilled with approved backfill material and the beach area will be restored to the pre-project condition.

Stage 2: Construction in the intertidal zone (between MHHW and mean lower low water [MLLW]) will occur in one season from June 1st to July 31th and involve extending the outfall pipe 171 feet into the bay. All work will be conducted from barges and within a fabric turbidity curtain installed on either side of the proposed extension alignment. Fourteen 35 foot long and 13-inch diameter HDPE piles will be driven with a hydraulic impact hammer into the sand on either side of the proposed extension alignment (a maximum of 285 strikes will occur in a given day). The position of the pipe extension will range from approximately 6 feet below grade at the near shore end to above grade at the offshore end. Within the intertidal zone, excavation will occur along

[1] Once on the PCTS homepage, use the following PCTS tracking number within the Quick Search column: WCR-2014-1444, or search for the project by name: South Access to the Golden Gate Bridge-Doyle Drive: IJKL Outfall Replacement Project.

approximately 85 linear feet of the proposed pipe alignment to accommodate the near shore portion of the pipe extension. The pipe will then be pulled into place with a barge. Excavation, pipe placement, and cross tie (pipe and pile connector) installation, and backfilling will occur during low tides. Following installation of the extension pipe, excavated areas will be backfilled with approved backfill material and turbidity curtains will be removed.

Stage 3: Offshore construction below MLLW will occur in one season from July 1st to October 31st and involve extending the outfall pipe an additional 118 feet. The pipe will be elevated off the sand bottom by ten HDPE piles and all work will be conducted from a barge or by divers. Prior to pile installation, ten 48-inch diameter steel casings will be set on the sand at proposed pile locations on either side of the extension alignment to contain turbidity. Ten 35 foot long and 13-inch diameter HDPE piles will then be driven within the casings using a hydraulic impact hammer (a maximum of 285 strikes will occur in a given day). The pipe will be pulled into place with a barge.

During impact hammer pile driving, underwater sound will be monitored utilizing the Underwater Noise Monitoring Plan template established by the Fisheries Hydroacoustic Working Group (FHWG[2]). NMFS uses the following thresholds to correlate physical injury to fish: 206 decibels (dB) (re: 1 μPa) peak sound pressure level (SPL) for any single strike and any size fish; and a daily cumulative sound exposure level (cSEL) of 187 dB (re: 1 μPa2-sec) for fish 2 grams or larger. NMFS also uses a 150 dB root-mean-square pressure (RMS) threshold for sub-injury (*i.e.*, behavioral responses) for fish. Hydroacoustic monitoring data collected during installation of piles similar to those proposed in this project were used to estimate the distances from the pile to reach the current thresholds for injury and sub-injury. As a result, NMFS does not anticipate sound pressure threshold values to be exceeded beyond the following distances surrounding each pile: 206 dB Peak SPL at 0 m; 187 dB cSEL at 2 meters; and 150 dB RMS at 16 meters. Monitoring will verify the thresholds are not exceeded beyond these expected distances during construction.

There are no interrelated or interdependent activities associated with the proposed action.

The action area encompasses the proposed project footprint, including portions of water column, bed, and shore of the Central San Francisco Bay, and an approximately 30 meter distance beyond the edges of the outfall extension to account for temporary effects from underwater noise and turbidity. Therefore, the action area will extend below MHHW and into the San Francisco Bay in a rectangular area approximately 120 meters in length and approximately 62 meters in width.

Action Agency's Effects Determination

Caltrans has determined the potential impacts related to the IJKL Outfall Replacement Project are not likely to adversely affect (NLAA) listed steelhead, Chinook salmon, and green sturgeon and their critical habitat. Caltrans has asked NMFS for concurrence with these determinations. Caltrans' finding of NLAA is based on the following: (1) the low likelihood of listed salmonids and green sturgeon in the action area during in-water construction; and, (2) implementation of conservation measures (*e.g.*, turbidity control best management practices, spill prevention and

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[2] The FHWG is an interagency group consisting of representatives from NMFS West Coast Region, U.S. Fish and Wildlife Service Regions 1 & 8, California/Oregon/Washington Departments of Transportation, California Department of Fish and Wildlife, and FHWA.

response procedures, *etc.*) will limit construction-related impacts to temporary, localized increases in suspended sediment, turbidity and noise during in-water construction activities.

Available information indicates the following listed species (Evolutionarily Significant Units (ESU) or Distinct Population Segments [DPS]) under the jurisdiction of NMFS may be affected by the proposed project:

Sacramento River winter-run Chinook salmon ESU (*Oncorhynchus tshawytscha*)
endangered (70 FR 37160; June 28, 2005)
critical habitat (58 FR 33212; June 16, 1993);
Central Valley spring-run Chinook salmon ESU (*Oncorhynchus tshawytscha*)
threatened (70 FR 37160; June 28, 2005);
Central California Coast steelhead DPS (*Oncorhynchus mykiss*)
threatened (71 FR 834; January 5, 2006)
critical habitat (70 FR 52488; September 2, 2005);
Central Valley steelhead DPS (*Oncorhynchus mykiss*)
threatened (71 FR 834; January 5, 2006); and
North American green sturgeon southern DPS (*Acipenser medirostris*)
threatened (71 FR 17757; April 7, 2006)
critical habitat (74 FR 52300; October 9, 2009).

The life history of steelhead is summarized in Busby *et al.* (1996) and Chinook salmon life history is summarized in Myers *et al.* (1998). Central California Coast (CCC) steelhead, Central Valley steelhead, Sacramento River winter-run Chinook salmon, and Central Valley spring-run Chinook salmon use Central San Francisco Bay primarily as a migration corridor. These anadromous salmonids pass through the estuary to rear as juveniles or to upstream areas to spawn as adults. Their migrations generally take place in the winter and spring months.

The life history of threatened green sturgeon in California is summarized in Adams *et al.* (2002) and NMFS (2005). The southern DPS of North American green sturgeon are anadromous, making migrations to the Sacramento River in the spring, with peaks in April-June (Moyle *et al.* 1995). Spawning occurs within the upper reaches of the Sacramento River. Juveniles spend one to four years in freshwater, before migrating downstream to spend three to four years in the lower delta and bays prior to entering the ocean. Green sturgeon may be present in San Francisco Bay and near the project site year-round.

Regarding EFH, the Caltrans has determined that the proposed action would have only minimal adverse effects on EFH or federally managed fisheries in California waters. Caltrans' finding is based on the minimal temporary impacts during project construction. The project site is located within an area identified as EFH for various life stages of fish species managed with the Pacific Coast Salmon Fishery Management Plans (FMP), the Pacific Groundfish FMP, and the Coastal Pelagic FMP. The project area is also within an area designated as Habitat Areas of Particular Concern (HAPC) for various federally-managed fish species within the Pacific Groundfish FMP. HAPC are described in the regulations as subsets of EFH that are rare, particularly susceptible to human-induced degradation, especially ecologically important, or located in an environmentally stressed area. Designated HAPC are not afforded any additional regulatory protection under MSA;

however, federal projects with potential adverse impacts to HAPC are more carefully scrutinized during the consultation process. As defined in the Pacific Groundfish FMP, San Francisco Bay, including the project area, is identified as estuary HAPC.

ENDANGERED SPECIES ACT

Effects of the Action

Under the ESA, "effects of the action" means the direct and indirect effects of an action on the listed species or critical habitat, together with the effects of other activities that are interrelated or interdependent with that action (50 CFR 402.02). The applicable standard to find that a proposed action is not likely to adversely affect listed species or critical habitat is that all of the effects of the action are expected to be discountable, insignificant, or completely beneficial. Beneficial effects are contemporaneous positive effects without any adverse effects to the species or critical habitat. Insignificant effects relate to the size of the impact and should never reach the scale where take occurs. Discountable effects are those extremely unlikely to occur.

The effects of the proposed action are reasonably likely to include degradation of water quality during pile driving and outfall pipe installation, elevated levels of underwater sound during pile driving, and disturbance of benthic habitat. However, the project's proposed work schedule avoids the co-occurrence of these anticipated effects with the above listed anadromous salmonids. By completing in-water work activities between June 1 and October 30, the proposed construction schedule avoids primary migration periods of CCC steelhead, Central Valley steelhead, Central Valley spring-run Chinook salmon, and Sacramento River winter-run Chinook salmon in the San Francisco Bay. Thus, NMFS anticipates threatened and endangered anadromous salmonids will not be present in the action area during construction, and impacts associated with construction are expected to be temporary and fully dissipate when construction activities cease. Based on the above, any construction effects to listed anadromous salmonids are anticipated to be discountable.

For threatened green sturgeon, construction activities associated with installation of the outfall pipe extension and new piles may have effects on water quality. As sand is excavated and new pilings are installed, disturbance of the substrate will likely result in temporary increases in turbidity in the adjacent water column. Turbidity and suspended sediment can affect fish by disrupting normal feeding behavior, reducing growth rates, increasing stress levels, and reducing respiratory functions (Benfield and Minello 1996, Nightingale and Simenstad 2001). However, turbidity control measures are proposed (*i.e.*, turbidity curtain and containment casings) and this project site is subject to strong tidal currents and elevated levels of turbidity are expected to quickly disperse from the project area with tidal circulation. Increased turbidity levels created by this project are expected to be short term, localized, and considerably lower than the thresholds commonly cited as the cause of these possible behavioral and physical impacts. With regard to water quality, the effects of project construction on green sturgeon are expected to be insignificant.

The proposed project includes the use of an impact hammer to install twenty-four 13-inch diameter HDPE piles. Available information indicates that fish may be injured or killed when exposed to very high levels of underwater sound pressure generated from use of impact hammers to drive piles.

As distance from the pile increases, sound pressure levels are attenuated and the potential harmful effects to fish also decrease. Based on hydroacoustic data collected previously from similar projects with impact hammers on HDPE piles (ICF Jones & Stokes 2012), sound pressure levels generated during the installation of twenty-four 13-inch diameter HDPE piles by this project over the course of several days should not present a risk of physical injury or mortality to threatened green sturgeon. However, pile driving activities could result in noise that may startle green sturgeon and result in agitation or temporary dispersion from the action area. If green sturgeon were to react to the sound produced by the pile driving activities and disperse from the affected area, adequate water depths and habitat located within the adjacent open waters of Central San Francisco Bay would be expected to provide fish sufficient area to occupy outside the affected zones. Thus, the effects of underwater sound levels associated with impact hammer pile driving are expected to be insignificant to green sturgeon.

The action area is located within designated critical habitat for winter-run Chinook salmon, CCC steelhead, and the southern DPS of green sturgeon. Physical and biological features essential for the conservation of Sacramento River winter-run Chinook salmon include access from the Pacific Ocean to appropriate areas in the upper Sacramento River to spawn; habitat areas for juveniles that are not contaminated and have adequate prey; and access downstream so that juveniles can migrate from spawning grounds to San Francisco Bay and the Pacific Ocean. Primary constituent elements (PCEs) of designated critical habitat for CCC steelhead include estuarine areas free of obstruction with water quality, water quantity, and salinity conditions supporting juvenile and adult physiological transitions between fresh- and saltwater; and juvenile and adult forage, including aquatic invertebrates and fishes, supporting growth and maturation. The PCEs of designated critical habitat for the southern DPS of green sturgeon in estuarine areas include food resources, water flow, water quality, migratory corridor, water depth, and sediment quality. PCEs include sites essential to support one or more life stages of the species. These in turn contain physical and biological features that are essential to the conservation of the species.

Construction activities are expected to have minor and temporary impacts on designated critical habitat. Implementation of conservation measures (*i.e.*, turbidity control best management practices and spill prevention and response procedures) are expected to limit temporary and localized increases in suspended sediment and turbidity during in-water construction activities. Underwater sound levels associated with pile driving are not expected to rise to levels associated with physical injury and mortality to fish, and ample habitat is available around the action area for fish to disperse if they are disturbed by underwater noise. Therefore, impacts associated with construction activities are expected to be temporary and to fully dissipate when construction activities cease.

Post-construction, the project will result in the permanent impacts to habitat along approximately 295 linear feet of the outfall and the loss of approximately 0.01 acres of open water and benthic habitat. Portions of the outfall pipe will be completely buried, partially buried, or suspended off the bottom and benthic habitat below the pipe footprint could be covered or shaded. However, the existing outfall pipe is buried and requires daily excavation with heavy equipment during winter months to allow drainage of the basin. These activities result in repeated discharge of sediment into the San Francisco Bay, and the potential for fuel or fluid spills on Crissy Beach and/or in the San Francisco Bay. Excavation of the outfall pipe will no longer be necessary following completion of the project as the outfall will be constructed to accommodate 50 years of estimated beach accretion.

Dissolved oxygen levels within the discharge are also expected to improve as the water in the basin will no longer be able to stagnate for extended periods before draining.

The upgraded outfall will receive runoff from an additional 12 acres of impermeable surfaces associated with the Presidio Parkway. Runoff from the majority of this area will be routed through permanent best management practices (BMPs) (*i.e.,* bio-filtration swales) that are expected to capture the bulk of contaminant loads, especially during the first flush of runoff generated from early season storms and longer storm periods. If feasible, contaminants from runoff associated with the remaining impermeable area of the Presidio Parkway will be addressed with similar permanent BMPs. Some impermeable surfaces within the Presidio and IJKL basin were constructed before treatment of runoff was common practice. If it is not feasible to treat all new impermeable surfaces associated with the Presidio Parkway, a compensatory impermeable area within the Presidio will be treated with permanent BMPs. Permanent BMPs will be continuously maintained by Caltrans and some existing (untreated) impermeable surfaces within the IJKL basin are also expected to flow through these permanent BMPs. Although runoff from the Presidio Parkway will increase freshwater discharge through the outfall, contaminant loads are likely to remain unchanged or improve due to the incorporation of permanent BMPs. Furthermore, IJKL outfall discharge will continue to occur in an area that experiences strong currents and winds which will rapidly mix and dilute the buoyant freshwater discharge from the basin to insignificant levels.

During construction, the installation of pipe extensions and pilings in the action area are expected to disturb bottom sediments and the associated benthic invertebrate community. In response to these impacts to benthic invertebrates, foraging by fish may be temporarily affected until the benthic community and habitat functions recover. However, the forage area that will be temporarily altered by the project is a very small proportion of the total forage area available to winter-run Chinook salmon, CCC steelhead, and green sturgeon in the San Francisco Bay. Considering the small area affected and that the benthic community in the project area is expected to fully recover within several months to a few years (Oliver *et al.* 1977; Watling *et al.* 2001), the potential effects of project construction on listed fish foraging are insignificant. For the above reasons, these effects are not expected to impair or degrade PCEs of critical habitat for Chinook salmon, CCC steelhead, or the southern DPS of green sturgeon.

Conclusion

Based on this analysis, NMFS concurs with Caltrans that the proposed action is not likely to adversely affect the subject listed species and designated critical habitats.

Reinitiation of Consultation

Reinitiation of consultation is required and shall be requested by Caltrans or by NMFS, where discretionary Federal involvement or control over the action has been retained or is authorized by law and (1) new information reveals effects of the action that may affect listed species or critical habitat in a manner or to an extent not previously considered; (2) the identified action is subsequently modified in a manner that causes an effect to the listed species or critical habitat that was not considered in this concurrence letter; or if (3) a new species is listed or critical habitat

designated that may be affected by the identified action (50 CFR 402.16). This concludes the ESA portion of this consultation.

MAGNUSON-STEVENS FISHERY CONSERVATION AND MANAGEMENT ACT

Under the MSA, this consultation is intended to promote the protection, conservation and enhancement of EFH as necessary to support sustainable fisheries and managed species' contribution to a healthy ecosystem. For the purpose of the MSA, EFH means "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity", and includes the associated physical, chemical, and biological properties that are used by fish (50 CFR 600.10) and "adverse effect" means any impact which reduces either the quality or quantity of EFH (50 CFR 600.910(a)). Adverse effects may include direct, indirect, site-specific or habitat-wide impacts, including individual, cumulative, or synergistic consequences of actions.

NMFS determined the proposed action would adversely affect EFH as follows: (1) increased turbidity; (2) increased underwater noise; and (3) permanent impacts to the bed and open water of the San Francisco Bay. During outfall pipe and pile installation, disturbance of the substrate will likely result in temporary and localized increases in turbidity. As described above, elevated turbidity from suspended sediment can affect fish by disrupting normal feeding behavior, reducing growth rates, increasing stress levels and predation risk, and reducing respiratory functions. Due to the turbidity control measures and the localized nature of water quality effects associated with this project, adverse effects to EFH are expected to be temporary and localized and turbidity levels will return to background soon after construction is complete.

The proposed action will permanently impact approximately 0.01acres of EFH due to the installation of an approximately 295 foot long outfall pipe extension and fourteen 13-inch diameter support piles below MHHW in the San Francisco Bay. Most of these impacts will result from the installation of piles or outfall pipe below grade in the sand bottom, on top of the sand bottom, or suspended above the sand bottom (this only pertains to the pipe). Submerged aquatic vegetation does not occur in the action area and therefore the project will have no effect on submerged aquatic vegetation. There will be a minor loss of shallow, sand-bottom foraging habitat for fish (approximately 0.01 acres). Over time, it is likely that Crissy Beach will continue to accrete and widen, and exposed portions of the outfall pipe and piles will be buried under sand, which will help return some of the lost foraging habitat.

Based on information provided by Caltrans, the proposed action may result in localized temporary degradation of water quality, increased underwater noise, and disturbance of the benthic community. NMFS has determined the proposed action would adversely affect EFH; however, the proposed action contains adequate measures to avoid, minimize, mitigate, or otherwise offset the adverse effects to EFH. Therefore, NMFS has no practical EFH Conservation Recommendations to provide to avoid or reduce the magnitude of these effects.

Caltrans must reinitiate EFH consultation with NMFS if the proposed action is substantially revised in a way that may adversely affect EFH (50 CFR 600. 920(l)). This concludes the MSA portion of this consultation.

Please direct questions regarding this letter to Mr. Joseph Heublein, North Central Coast Office, at (707) 575-1251, or via e-mail at joe.heublein@noaa.gov.

Sincerely,

Joyce Anderson

for William W. Stelle, Jr.
Regional Administrator

cc: John Yeakel, Caltrans, District 4
Copy to ARN File #151422WCR2014SR00231
Copy to Chron File

Literature Cited

Adams, P.B., C.B. Grimes, J.E. Hightower, S.T. Lindley, and M.L. Moser. 2002. Status Review for North American Green Sturgeon, *Acipenser medirostris.* National Marine Fisheries Service, Southwest Fisheries Science Center. 49 pages. [Document available at: http://www.nwr.noaa.gov/Other-Marine-Species/upload/grn-sturgeon-status.pdf].

Benfield, M. C. & T. J. Minello. 1996. Relative effects of turbidity and light intensity on reactive distance and feeding of an estuarine fish. Environmental Biology of Fish, 46: 211-216.

Busby, P.J., T.C. Wainwright, G.J. Bryant, L. Lierheimer, R.S. Waples, F.W. Waknitz, and I.V. Lagomarsino. 1996. Status review of West Coast steelhead from Washington, Idaho, Oregon and California. United States Department of Commerce, National Oceanic and Atmospheric Administration Technical Memorandum NMFS-NWFSC-27. 261 pages. [Document available at: http://www.nwfsc.noaa.gov/assets/25/4245_06172004_122523_steelhead.pdf]

ICF Jones & Stokes2012. Compendium of Pile Driving Sound Data: Appendix I. Prepared for: California Department of Transportation, Sacramento, CA, October, 2012.

Moyle, P.B., R.M. Yoshiyama, J.E. Williams, and E.D. Wikramanayake. 1995. Fish species of Special Concern in California. Second edition. Final report to CA Department of Fish and Game, contract 2128IF.

Nightingale, B. and C.A. Simenstad, Jr. 2001. Dredging activities: Marine issues. Seattle, WA 98105: Washington State Transportation Center, University of Seattle. (http://depts.washington.edu/trac/reports/reports.html)

NMFS (National Marine Fisheries Service). 2005. Green Sturgeon (*Acipenser medirostris*) Status Review Update. National Marine Fisheries Service, Southwest Fisheries Science Center. 31 pages. [Document available at: http://swr.nmfs.noaa.gov/psd/Final%20Green%20 Sturgeon%20Status%20Review%20Update.pdf]

Oliver, J. S., P. N. Slattery, L. W. Hulberg and J. W. Nybakken 1977. Patterns of succession in benthic infaunal communities following dredging and dredged material disposal in Monterey Bay. U.S. Army Corps of Engineers. Technical Report D-77-27.

Watling, L., R. H. Findlay, L. M. Lawrence and D. F. Schick. 2001. Impact of a scallop drag on the sediment chemistry, microbiota, and faunal assemblages of a shallow subtidal marine benthic community. Journal of Sea Research, 46: 309-324.

October 17, 2014
CIWQS Place No. 808370
Regulatory Measure No. 397636

Sent via electronic mail--no hard copy to follow

California Department of Transportation
Attn: Nidal Tuqan
Nidal_Tuqan.dot.ca.gov
111 Grand Ave.
Oakland, CA 94612

Subject: Water Quality Certification for the U.S. Highway 101 Crissy Beach Storm Drain IJKL Outfall Extension Project, San Francisco

Department Project No.: EA 04-1637N4

Dear Mr Tuqan:

We have reviewed and hereby issue water quality certification (Certification) to the California Department of Transportation (Department) for the U.S. Highway 101 Crissy Beach IJKL storm drain outfall extension (Project). The Department has applied for Nationwide Permit 7 for Outfall Structures and Associated Intake Structures from the U.S. Army Corps of Engineers pursuant to Section 404 of the Clean Water Act (33 U.S.C. § 1344). As such, the Department has applied to the San Francisco Bay Regional Water Quality Control Board (Water Board) for a Clean Water Act Section 401 water quality certification that the Project will not violate State water quality standards.

The Water Board received the application for Certification for the Project (Application) on August 11, 2014. Supplemental information was sent via email on August 21, 2014, September 24, 2014, September 25, 2014 and October 15, 2014. The Application was deemed complete on October 15, 2014. The full fee payment was received by the Water Board on August 11, 2014.

Project: The following Project description was derived from the Application and supplemental information received by Water Board staff.

The Department proposes to replace an existing drainage outfall located at Crissy Beach approximately 1000 feet north of Highway 101 post mile 9.8. The Project will extend the existing outfall further offshore to compensate for future beach accretion. The mouth of the existing outfall is approximately six feet below the beach ground elevation and requires regular maintenance to keep the outlet clear.

The Project will replace approximately 170 feet of the existing 42-inch outside diameter high density polyethylene (HDPE) pipe from an existing manhole to the current outfall on the beach. The replacement and extension pipe will be a 54-inch outside diameter HDPE that will extend

approximately 296 feet beyond the mouth of the existing outfall. The pipe will be a total of 466 feet long with the first 235 feet from the manhole buried under the beach and bay floor, and the last 231 feet supported above the bay floor by 13-inch HDPE piles.

Proposed project elements will include:

- Modification of an existing manhole in Crissy Field from a 24-inch structure to a 36-inch structure to more effectively facilitate future maintenance,
- Removal of existing the 170 foot long, 42-inch diameter HDPE from existing manhole structure to the outfall at Crissy beach,
- Modification of 14 existing HDPE piles that support the existing outfall pipe so that the piles are at an elevation to support the new outfall pipeline,
- Installation of 24 – 13-inch HDPE piles by hydraulic impact driving to support the new outfall pipe, and
- Installation of 466 linear feet of 54-inch HDPE outfall pipe which will be secured to the piles by crossties.

Impacts: Project implementation would permanently impact approximately 0.025 acre of San Francisco Bay due to installation of 231 feet of 54-inch HDPE pipe above the bay floor and 18 - 13-inch HDPE piles which will support the 54-inch HDPE outfall pipe above the bay floor.

Project implementation would temporarily impact 0.50 acre of San Francisco Bay and jurisdictional beach habitat due to installation of temporary shoring, excavation and removal of the existing 42-inch pipe, installation of the new 54-inch pipe, and installation air bubble curtains at the locations where 13-inch HDPE piles to support the outfall will be driven.

See Attachment for impact locations.

Roadway Pollutant Impacts: Project implementation will result in no new or reworked impervious area. Stormwater runoff from impervious areas may contain hydrocarbons, metals, volatile organic compounds, trash, and sediment at levels that may significantly impact waters of the state if left untreated.

Hydromodification Impacts: Added impervious areas may result in alterations to existing hydrologic regimes, resulting in erosion and/or changes of sediment transport in receiving waters (hydromodification). Because the Project will not result in any added impervious area, hydromodification mitigation is not required.

Avoidance and Minimization: The Department has avoided and minimized impacts to San Francisco Bay by enclosing the work area with heavy duty floating silt curtain, removing and preserving existing vegetation in a National Park Service nursery to be restored once construction is complete, and proposing work during appropriate environmental work windows for onshore and offshore habitats.

Mitigation: Because the Project will eliminate the need for mechanical clearing and maintenance of the outlet which currently occurs routinely due to the location of the existing outfall location, additional mitigation for permanent impacts shall not be required for the Project.

To mitigate for temporary impacts to the beach and San Francisco Bay, the Department shall restore all temporarily impacted areas to pre-project or improved conditions. The Department shall also provide funding to the National Park Service for pre-construction removal, storage, and post-construction planting of existing beach vegetation.

CEQA Compliance: The Project is described under the re-validation of the Environmental Impact Report (EIR) that was prepared and approved for the Doyle Drive Golden Gate Bridge South Access Project pursuant to the provisions of the California Environmental Quality Act by the San Francisco Transportation Authority (SFTA). The SFTA filed a Notice of Determination for the EIR on December 17, 2008 (SCH No. 2000032006). The EIR was re-validated on October 15, 2014.

Certification: I hereby issue an order certifying that any discharge from the referenced project will comply with the applicable provisions of sections 301 (Effluent Limitations), 302 (Water Quality Related Effluent Limitations), 303 (Water Quality Standards and Implementation Plans), 306 (National Standards of Performance), and 307 (Toxic and Pretreatment Effluent Standards) of the Clean Water Act, and with other applicable requirements of State law. This discharge is also regulated under State Water Resources Control Board Order No. 2003 - 0017 – DWQ, "General Waste Discharge Requirements for Dredge and Fill Discharges That Have Received State Water Quality Certification" which requires compliance with all conditions of this Water Quality Certification. The following conditions are associated with this certification:

1. The Department shall adhere to the terms of Nationwide Permit No. 7, issued to the Department by the U.S. Army Corps of Engineers, and the Biological Opinions issued to the Department by the U.S. Fish and Wildlife Service and the National Marine Fisheries Service for the Project.

2. This certification does not allow for the take, or incidental take, of any special status species. The Department shall utilize the appropriate protocols, as approved by the California Department of Fish and Wildlife (CDFW), National Marine Fisheries Service, and/or U.S. Fish and Wildlife Service, to ensure that project activities do not adversely impact water quality or the Beneficial Use of the Preservation of Rare and Endangered Species.

3. The Project shall be constructed in conformance with the Project Description described in this Certification and Certification application materials. Any change in the Project that could impact State waters may require compensatory mitigation and shall first be reported to and found acceptable by the Water Board Executive Officer;

4. All work performed within waters of the State shall be completed in a manner that minimizes impacts to beneficial uses and habitat. Measures shall be employed to minimize disturbances along the shoreline that will adversely impact the water quality of waters of the State. Disturbance or removal of vegetation shall not exceed the minimum necessary to complete Project implementation;

5. Except for vehicles and equipment required for work in San Francisco Bay, no fueling, cleaning or maintenance of vehicles or equipment shall take place within jurisdictional waters or within any areas where an accidental discharge to jurisdictional waters may occur;

6. Dredging/excavation in San Francisco Bay shall not cause turbidity in the receiving waters (i.e., San Francisco Bay) to increase by more than 10 percent if the ambient turbidity of the receiving water is greater than 50 NTU, or by more than 5 NTU if the ambient turbidity of the receiving water is less than or equal to 50 NTU.

7. The Department shall submit a turbidity monitoring plan at least 60 days prior to the anticipated start of project construction activities for acceptance by Water Board staff. The turbidity monitoring plan shall include monitoring methods, a reporting plan if turbidity levels are not in compliance with Condition 6, and shall specify the exact locations for monitoring turbidity at the project site.

8. The Department shall submit the Dredging Operation Plan and Solid Debris Management Plan as described in the Application to the Water Board for acceptance at least 60 days prior to the anticipated start of dredging activities.

9. Except for disposal of material dredged or excavated from the Bay, no debris, soil, silt, sand, cement, concrete, or washings thereof, or other construction related materials or wastes, oil or petroleum products or other organic or earthen material shall be allowed to enter into or be placed where it may be washed by rainfall or runoff into waters of the State. When operations are completed, any excess material shall be removed from the work area and any areas adjacent to the work area where such material may be washed into waters of the State.

10. The Department shall not use or allow the use of erosion control products that contain synthetic materials within waters of the State at any time. The Department shall request approval from Water Board staff if an exception from this requirement is needed at a specific location. In upland and riparian areas, the Department shall prioritize the use of wildlife-friendly biodegradable (not photo-degradable) erosion control products. The Department shall not use or allow the use of erosion control products that contain synthetic netting for permanent erosion control (i.e. erosion control materials to be left in place for two years or after the completion date of the Project).

    If the Department finds that erosion control netting or products have entrapped or harmed wildlife, personnel shall remove the netting or product and replace it with wildlife-friendly biodegradable products;

11. The discharge of sediment to San Francisco Bay, or to areas where sediment may discharge to San Francisco Bay, is prohibited. The Department shall implement all appropriate sediment and erosion control construction best management practices, including management of excavated materials during the excavation, transport, and stockpiling process;

12. All work shall be completed between May 15 and October 31;

13. The Department shall maintain a copy of this water quality certification at the Project site so as to be available at all times to site operating personnel. It is the responsibility of the Department to assure that all personnel (employees, contractors, and subcontractors) are adequately informed and trained regarding the conditions of this certification;

14. This certification action is subject to modification or revocation upon administrative or judicial review, including review and amendment pursuant to Section 13330 of the California Water Code (CWC) and Section 3867 of Title 23 of the California Code of Regulations(23 CCR);

15. This certification action does not apply to any discharge from any activity involving a hydroelectric facility requiring a Federal Energy Regulatory Commission (FERC) license or an amendment to a FERC license, unless the pertinent certification application was filed pursuant to California Code of Regulations (CCR) Title 23, Subsection 3855(b) and that application specifically identified that a FERC license or amendment to a FERC license for a hydroelectric facility was being sought; and,

16. Certification is conditioned upon total payment of the full fee required in State regulations (23 CCR Section 3833). Water Board staff received full payment of $5,333.00 on August 11, 2014.

We anticipate your cooperation in implementing these conditions. However, please be advised that any violation of water quality certification conditions is a violation of State law and subject to administrative civil liability pursuant to California Water Code (CWC) section 13350. Failure to respond, inadequate response, late response, or failure to meet any condition of this certification may subject you to civil liability imposed by the Water Board to a maximum of $5,000 per day per violation or $10 for each gallon of waste discharged in violation of this certification. Also, any requirement for a report made as a condition to this action (e.g. Condition Nos. 6 and 7) is a formal requirement pursuant to CWC Section 13267, and failure to submit, late or inadequate submittal, or falsification of such technical report(s) is also subject to civil liability pursuant to CWC Section 13268.

We anticipate no further action on this request. Should new information come to our attention that indicates a water quality problem with this project, the Water Board may issue Waste Discharge Requirements pursuant to 23 CCR Section 3857.

If you have any question, please contact Derek Beauduy at (510) 622-2348, or via e-mail to derek.beauduy@waterboards.ca.gov.

Sincerely,

Dyan C. Whyte
for

Bruce H. Wolfe
Executive Officer

cc (via e-mail): Mr. Bill Orme SWRCB-DWQ
Ms. Melissa Escaron, CDFW
Ms. Lisa Mangione, USACE
Ms. Katerina Galacatos, USACE
Mr. Jason Brush, USEPA
Mr. Ryan Olah, USFWS
Mr. Hardeep Takhar, Caltrans
Mr. Cyrus Vafai, Caltrans
Mr. Dale Bowyer, Water Board

WATER QUALITY INFORMATION HANDOUT
CONTRACT NO. 1637N4

IJKL OUTFALL
State Route 101, San Francisco
04-SCL-101 at Crissy Field

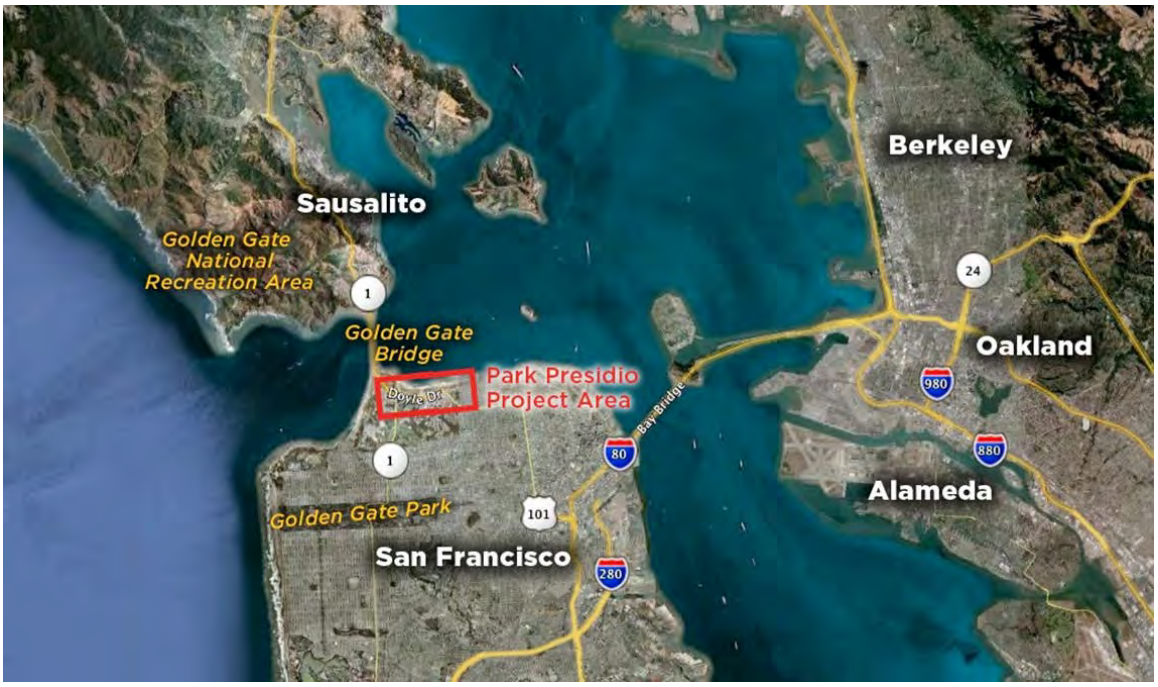
California Department of Transportation
District 4, 111 Grand Avenue
Oakland, CA 94612

Storm Water Information

Disclaimer

A “Disclaimer” is required specifying that the information provided in the Storm Water Information Handout is just a guideline and is to be used for information purposes only and should not be considered a sole source document to adhere to the requirements of the new National Pollutant Discharge Elimination System (NPDES) Construction General Permit (CGP), Number CAS000002, adopted on September 2, 2009. The contractor is required to provide water quality monitoring, sampling and implement best management practices (BMPs) based on standard industry operations, field conditions and conditions encountered based on the contractor’s means and methods. The information in this handout is not to be construed in any way as a waiver of the provisions in the CGP. Bidders and contractors are cautioned to make independent investigations and examinations as they deem necessary to satisfy the conditions encountered in performance of work, with respect to the following: sampling and monitoring locations, distribution of watershed areas for sizing of BMPs, and selection of BMPs in order to conform to the requirement of the contract documents and the CGP.

Project Vicinity


Berkeley
Sausalito
Golden Gate
National
Recreation Area
1
24
Golden Gate
Bridge
Oakland
Park Presidio
Project Area
Doyle Dr
980
Bay Bridge
80
880
1
Alameda
Golden Gate Park
101
San Francisco
280

Risk Assessment

	A	B	C
1	**Sediment Risk Factor Worksheet**		**Entry**
2	**A) R Factor**		
3	Analyses of data indicated that when factors other than rainfall are held constant, soil loss is directly proportional to a rainfall factor composed of total storm kinetic energy (E) times the maximum 30-min intensity (I30) (Wischmeier and Smith, 1958). The numerical value of R is the average annual sum of EI30 for storm events during a rainfall record of at least 22 years. "Isoerodent" maps were developed based on R values calculated for more than 1000 locations in the Western U.S. Refer to the link below to determine the R factor for the project site.		
4	http://cfpub.epa.gov/npdes/stormwater/LEW/lewCalculator.cfm		
5	**R Factor Value**		7.76
6	**B) K Factor (weighted average, by area, for all site soils)**		
7	The soil-erodibility factor K represents: (1) susceptibility of soil or surface material to erosion, (2) transportability of the sediment, and (3) the amount and rate of runoff given a particular rainfall input, as measured under a standard condition. Fine-textured soils that are high in clay have low K values (about 0.05 to 0.15) because the particles are resistant to detachment. Coarse-textured soils, such as sandy soils, also have low K values (about 0.05 to 0.2) because of high infiltration resulting in low runoff even though these particles are easily detached. Medium-textured soils, such as a silt loam, have moderate K values (about 0.25 to 0.45) because they are moderately susceptible to particle detachment and they produce runoff at moderate rates. Soils having a high silt content are especially susceptible to erosion and have high K values, which can exceed 0.45 and can be as large as 0.65. Silt-size particles are easily detached and tend to crust, producing high rates and large volumes of runoff. Use Site-specific data must be submitted.		
8	Site-specific K factor guidance		
9	**K Factor Value**		0.32
10	**C) LS Factor (weighted average, by area, for all slopes)**		
11	The effect of topography on erosion is accounted for by the LS factor, which combines the effects of a hillslope-length factor, L, and a hillslope-gradient factor, S. Generally speaking, as hillslope length and/or hillslope gradient increase, soil loss increases. As hillslope length increases, total soil loss and soil loss per unit area increase due to the progressive accumulation of runoff in the downslope direction. As the hillslope gradient increases, the velocity and erosivity of runoff increases. Use the LS table located in separate tab of this spreadsheet to determine LS factors. Estimate the weighted LS for the site prior to construction.		
12	LS Table		
13	**LS Factor Value**		2.303
14			
15	**Watershed Erosion Estimate (=RxKxLS) in tons/acre**	5.7188096	
16	**Site Sediment Risk Factor**	**Low**	
17	Low Sediment Risk: < 15 tons/acre		
18	Medium Sediment Risk: >=15 and <75 tons/acre		
19	High Sediment Risk: >= 75 tons/acre		
20			

Receiving Water (RW) Risk Factor Worksheet	Entry
A. Watershed Characteristics	**yes/no**
A.1. Does the disturbed area discharge (either directly or indirectly) to a **303(d)-listed waterbody impaired by sediment** (For help with impaired waterbodies please visit the link below) or has a **USEPA approved TMDL implementation plan for sediment**?:	**no**
http://www.waterboards.ca.gov/water_issues/programs/tmdl/integrated2010.shtml	
OR	
A.2. Does the disturbed area discharge to a waterbody with designated beneficial uses of SPAWN & COLD & MIGRATORY? (For help please review the appropriate Regional Board Basin Plan)	
http://www.waterboards.ca.gov/waterboards_map.shtml	
Region 1 Basin Plan	
Region 2 Basin Plan	
Region 3 Basin Plan	
Region 4 Basin Plan	
Region 5 Basin Plan	
Region 6 Basin Plan	
Region 7 Basin Plan	
Region 8 Basin Plan	
Region 9 Basin Plan	

Combined Risk Level Matrix

Receiving Water Risk	Sediment Risk: Low	Sediment Risk: Medium	Sediment Risk: High
Low	Level 1	Level 2	
High	Level 2		Level 3

Project Sediment Risk: Low

Project RW Risk: Low

Project Combined Risk: Level 1

Risk Assessment:

The calculation of "R" factor

Figure 1-Erosivity Index Zone Map

The EI distribution zone is 24

Table 1-Erosivity Index Table

EI percentage (May 13, 2015 to October 31, 2015)

66.5 - 47.1 = 19.4

Figure 4_ Isoerodent map of California =40

R factor is 19.4 X 40% = 7.76

Use the populate K and LS provided by the SMARTs based on Lat 37.805211, Long -122.466319

K = 0.32

LS = 2.303

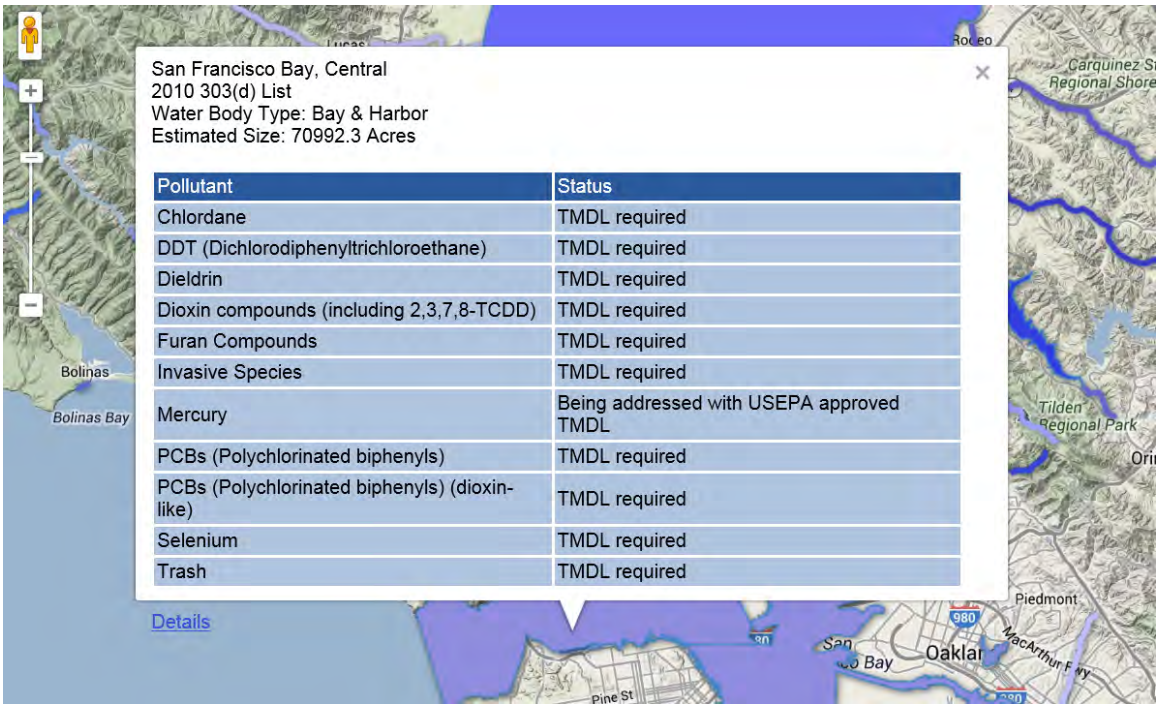
R x K x LS = 7.76 x 0.32 x 2.303 = 5.718 (Low)

Receiving water is Low

The project is Risk Level 1

Receiving Water Risks: LOW

Project drains to San Francisco Bay (Central) which is not a sediment/siltation impaired water body, or has COLD/MIGR/SPWN beneficial uses, so receiving water risk is low.



Pollutant	Status
Chlordane	TMDL required
DDT (Dichlorodiphenyltrichloroethane)	TMDL required
Dieldrin	TMDL required
Dioxin compounds (including 2,3,7,8-TCDD)	TMDL required
Furan Compounds	TMDL required
Invasive Species	TMDL required
Mercury	Being addressed with USEPA approved TMDL
PCBs (Polychlorinated biphenyls)	TMDL required
PCBs (Polychlorinated biphenyls) (dioxin-like)	TMDL required
Selenium	TMDL required
Trash	TMDL required

CENTRAL BASIN

	Human Consumptive Uses								Aquatic Life Uses						Wildlife Use	Recreational Uses		
COUNTY Waterbody	AGR	MUN	FRSH	GWR	IND	PROC	COMM	SHELL	COLD	EST	MAR	MIGR	RARE	SPWN	WARM	WILD	REC-1	REC-2	NAV
SAN FRANCISCO COUNTY																			
Golden Gate Channel							E				E	E	E	E		E	E	E	E
San Francisco Bay Central					E	E	E	E		E		E	E	E		E	E	E	E
Crissy Field Lagoon										E						E	E	E	
Golden Gate Park Lakes															E	E		E	
Lobos Creek		E												E	E	E	E	E	
Mountain Lake															E	E	E	E	
MARIN COUNTY																			
San Rafael Creek									E						E	E	E	E	E
Corte Madera Creek							E		E			E	E	E	E	E	E	E	E
Larkspur Creek									E				E	E	E	E	E	E	
Tamalpais Creek									E			E	E	E	E	E	E	E	
Ross Creek (Marin)									E			E	E	E	E	E	E	E	
Phoenix Lake		E					E		E				E	E	E	E	E*	E	
Phoenix Creek			E						E						E	E	E	E	
Bill Williams Creek			E						E					E	E	E	E	E	
Sleepy Hollow Creek									E			E	E	E	E	E	E	E	
San Anselmo Creek									E			E	E	E	E	E	E	E	
Fairfax Creek									E					E	E	E	E	E	
Cascade Creek									E			E	E	E		E	E	E	
Richardson Bay					E		E	E		E		E	E	E		E	E	E	E
Arroyo Corte Madera del Presidio								E	E			E	E	E	E	E	E	E	
Warner Creek (Mill Valley, Marin)									E			E	E	E	E	E	E	E	
Old Mill Creek									E			E	E	E	E	E	E	E	
Willow Reed Creek									E				E	E	E	E	E	E	

Rainfall Data

Rainfall Intensity can be obtained by the following link:

http://www.wrcc.dri.edu/pcpnfreq/nca5y24.gif

Refer to chapters 800, Highway Drainage Design of Highway Design Manual for information on runoff coefficient and shed map. The weighted runoff coefficient of 0.55 is recommended for the project area.

Turbidity Curtain Information

Contact Information
for
Elastec AmericanMarine

Duane Bennish
Division Manager

Elastec/American Marine

Tel: +1 (618) 384-2787
Fax: +1 (321) 636-5787
Skype: duanebennish.elastecami
Email: dbennish@elastec.com
Web: www.elastec.com

Warning:

The lead-time between the placement of an order and delivery of the curtain from the manufacturer is at least 4 weeks.

Design
of
The Turbidity Curtain

Dist	COUNTY	ROUTE	POST MILES TOTAL PROJECT	SHEET No.	TOTAL SHEETS
04	SF	101	9.0	3	37

REGISTERED CIVIL ENGINEER DATE

PLANS APPROVAL DATE

REGISTERED PROFESSIONAL ENGINEER No. Exp. CIVIL STATE OF CALIFORNIA

THE STATE OF CALIFORNIA OR ITS OFFICERS OR AGENTS SHALL NOT BE RESPONSIBLE FOR THE ACCURACY OR COMPLETENESS OF SCANNED COPIES OF THIS PLAN SHEET.

NOTE:

FOR ACCURATE RIGHT OF WAY DATA, CONTACT RIGHT OF WAY ENGINEERING AT THE DISTRICT OFFICE.

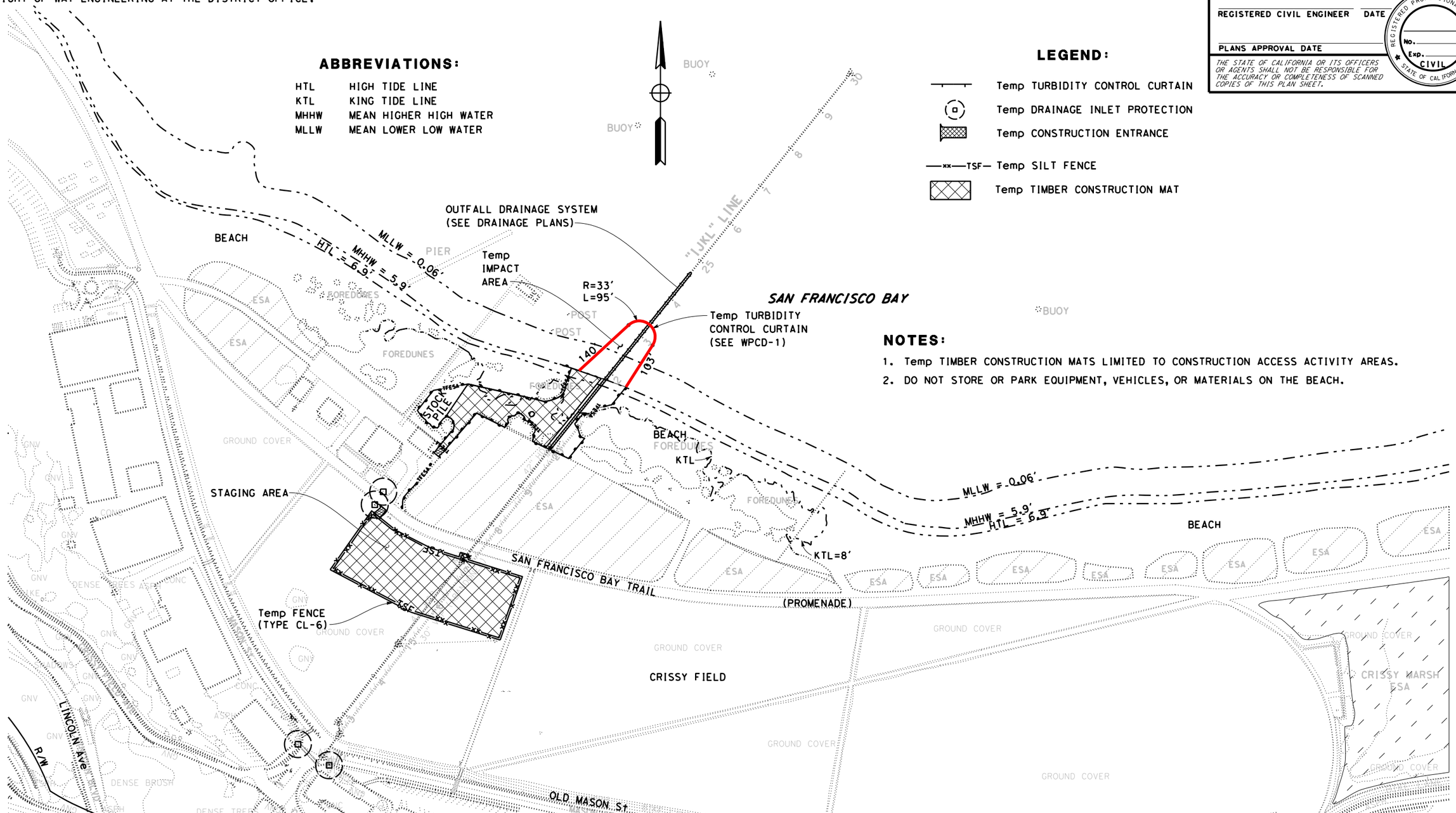
ANCHORING TURBIDITY CURTAIN EVERY 15' WITH DUAL ANCHORING SYSTEM (52 ANCHORS TOTAL)

ABBREVIATIONS:

HTL	HIGH TIDE LINE
KTL	KING TIDE LINE
MHHW	MEAN HIGHER HIGH WATER
MLLW	MEAN LOWER LOW WATER

LEGEND:

- Temp TURBIDITY CONTROL CURTAIN
- Temp DRAINAGE INLET PROTECTION
- Temp CONSTRUCTION ENTRANCE
- —xx—TSF— Temp SILT FENCE
- Temp TIMBER CONSTRUCTION MAT



NOTES:

1. Temp TIMBER CONSTRUCTION MATS LIMITED TO CONSTRUCTION ACCESS ACTIVITY AREAS.
2. DO NOT STORE OR PARK EQUIPMENT, VEHICLES, OR MATERIALS ON THE BEACH.

TEMPORARY WATER POLLUTION CONTROL PLAN

SCALE: 1" = 100'

APPROVED FOR TEMPORARY WATER POLLUTION CONTROL WORK ONLY

WPC-1

REVISED BY	DATE REVISED
JC	10/23/14

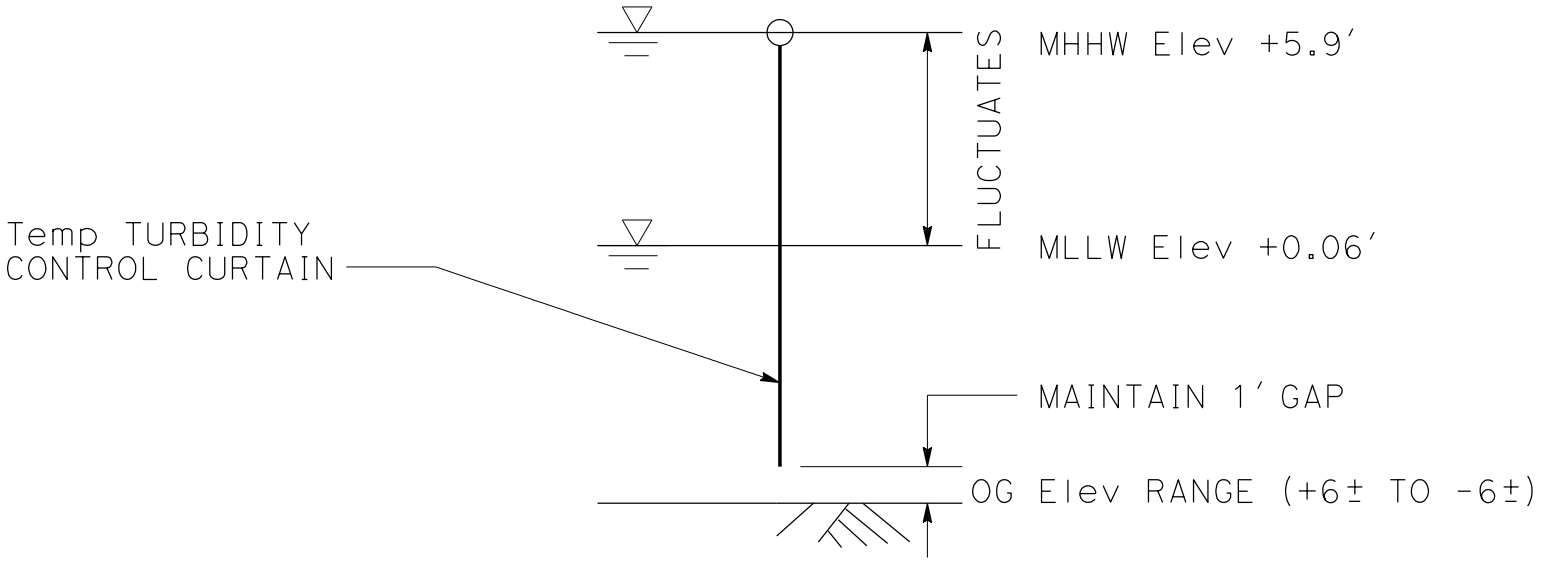
CALCULATED-DESIGNED BY	CHECKED BY
JENNIFER CHEN	KAMRAN NAKHJIRI

FUNCTIONAL SUPERVISOR: KAMRAN NAKHJIRI

STATE OF CALIFORNIA - DEPARTMENT OF TRANSPORTATION

Caltrans® WATER QUALITY

LAST REVISION 10-29-14 | DATE PLOTTED => 10/29/2014 | TIME PLOTTED => 11:30:28 AM



TEMPORARY TURBIDITY CONTROL CURTAIN DEPTH DETAIL

Specifications

for

Type III Ruffwaterscreen Turbidity Control Curtain

401 Shearer Blvd. Cocoa, FL. 32922 USA
Tel. 321-636-5783 Fax.321-636-5787
E-mail: dbennish@elastec.com
Web Page: www.siltcurtains.com

TYPE III
RUFFWATERSCREEN
TURBIDITY CONTROL CURTAIN
SPECIFICATIONS

Description: Ruffwaterscreen consists of a heavy vinyl coated fabric skirt supported by a flotation encased in vinyl coated fabric. It features a pair of load carrying cables below the floatation, and a galvanized chain ballast at the bottom of the skirt.

Section Length: Normally 100 feet but adjustable by special order.

Draft (Skirt Depth): Depth at 3 feet to 30 feet or more by custom design.

Freeboard: 12 inches.

Flotation Element: 12" octagonal expanded polystyrene "logs" placed end to end in the top fabric pocket with separations between "logs" to allow folding for shipment and storage.

Fabric: Normally, 22 ounce per square yard vinyl coated nylon or polyester or a combination with geotextile filter depending on application.

BASE FABRIC: 22 oz PVC fabric Yellow
500 Lbs/square inch tensile strength
(specification sheet available on request)

PERMEABLE FABRIC:
(Optional Skirt design) Mirafi 404
(specification sheet available on request)

Color: Safety Yellow (other colors available- additional cost may apply)

Tension Cable:	**2 each 5/16" galvanized steel cable, with a break strength of 10,540 lbs, is sheathed in vinyl and seamed into the fabric one on each side of the skirt 20" below the flotation. These cables are shackled to the section connectors for uniform tension load transfer.**
Ballast:	**The ballast/tension member is a 3/8", or heavier, galvanized steel chain enclosed in a double layer fabric pocket at the bottom of the skirt. The ballast chain enables the skirt to hang vertically in the water column. The ballast chain is shackled to a stainless steel stress plate at the end of each section. A hook and ring arrangement is provided to transfer the load from one section to the next through the stress plates.**
Section Connector:	**Sections of Ruffwaterscreen are joined together by sliding together the aluminum Universeal connectors that extend from the top of the flotation down the edge of the skirt. Below the connectors, skirts are joined by rope ties between evenly spaced grommets on the skirts. The ballast chain/stress plates are attached via a safety hook and ring. No tools are required**
Anchor Points:	**Provided every 50'** **Standard anchoring is 1 anchor every 100' in one directional flow (on upstream side), or, 2 every 100' (one on each side) if bi-directional is anticipated. Should flows increase or additional anchors be needed, the points will already be in place 50'OC.**
Reefing System:	**To raise and lower the curtain skirt. This allows for the system to match the depth requirements of the project exactly. (This furling/unfurling feature is optional)**
Optional Items:	**Marker Buoys, Anchor Systems, Navigational Warning Lights, Repair Kits, Oil Spill Kit, Incinerators, Debris Boom**

*****Additional information can be found at www.elastec.com *****

Technical assistance? Please call 800-871-4156 or email dbennish@elastec.com

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ECOOLAMI TXN226 22oz Fabric Specification

1.0 STYLE#			TXN226				
2.0 BASE FABRIC	ENGLISH			METRIC			
2.1 Weight	6.00		ozlyd² -	203.4		g\m²	
2.2 Fiber			Polyester				
2.3 Fabric Style			Woven				
3.0 COATED FABRIC							
3.1 Total Weight	22	± 1.5	ozlyd²	745.8	± 50.85	g\m²	
3.2 Type of Coating			PVC				
3.3 Coating Distribution			60 / 40				
3.4 Width	61	± 0.25	in.	154.9	± 0.64	cm.	
3.5 Sealing Properties	Dielectric	X		Thermal	X		
						TEST METHODS	
4.0 MECHANICAL PROPERTIES						Fed.Std/191A	ASTM
4.1 Tensile Strength							
Grab Warp	500		lbs.	222		daN	5100	D751-A
Fill	450		lbs.	200		daN	
1" Strip Warp	400		lbs.\ in.	356		daN\5cm	5102	D751-B
Fill	300		lbs.\ in.	267		daN\5cm	
4.2 Adhesion R.F.	12.5		lbs.\ in.	11.1		daN\5cm		D751
4.3 Adhesion Thermal	12.5		lbs.\ in.	11.1		daN\5cm	
4.4 Tear Strength, Tongue Warp	110		lbs.	48.9		daN	5134	D751-B
Fill	110		lbs.	48.9		daN	
4.5 Low Temperature	-65		° F	-54		° C		D2136
4.6 High Temperature,Cont/Interm.	180 / 200		° F	82 / 93.33		° C		D1204
4.7 Abrasion Resistance(Taber)	Wheel	H18	Load	1000		g.	
To Exposed Fabric (Face)	Cycles	300	wgt.loss			g\cy	5306	D3884
4.8 Puncture							
Screwdriver	100		lbs.	44.4		daN	5120	D751Mod.
Ball	400		lbs.	177.8		daN	5120	D751
4.9 Hydro Resistance	600		psi.	4.1 X 10		Pa	5512	D751-A
4.10 Flame Resistance							
Time of Afterflame			sec. Max.			sec. Max.	
Length of Char			in. Max.			cm. Max.	

COMMENTS:

TENCATE GEOSYNTHETICS
Americas

Mirafi® FW404

Mirafi® FW404 is composed of high-tenacity monofilament polypropylene yarns, which are woven into a stable network such that the yarns retain their relative position. Mirafi® FW404 geotextile is inert to biological degradation and resists naturally encountered chemicals, alkalis, and acids

TenCate Geosynthetics Americas Laboratories are accredited by a2La (The American Association for Laboratory Accreditation) and Geosynthetic Accreditation Institute – Laboratory Accreditation Program (GAI-LAP). NTPEP Number: GTX-2012-01-008

Mechanical Properties	Test Method	Unit	Minimum Average Roll Value	
			MD	CD
Wide Width Tensile Strength	ASTM D4595	lbs/in (kN/m)	250 (43.8)	230 (40.3)
Grab Tensile Strength	ASTM D4632	lbs (N)	400 (1780)	315 (1402)
Grab Tensile Elongation	ASTM D4632	%	15	15
Trapezoid Tear Strength	ASTM D4533	lbs (N)	150 (668)	165 (734)
CBR Puncture Strength	ASTM D6241	lbs (N)	1150 (5118)	
Apparent Opening Size (AOS)[1]	ASTM D4751	U.S. Sieve (mm)	40 (0.43)	
Percent Open Area	COE-02215	%	1.0	
Permittivity	ASTM D4491	sec^{-1}	0.90	
Permeability	ASTM D4491	cm/sec	0.07	
Flow Rate	ASTM D4491	$gal/min/ft^2$ ($l/min/m^2$)	70 (2852)	
Abrasion Resistance	ASTM D4886	% retained	60 (typical)	
UV Resistance (at 500 hours)	ASTM D4355	% strength retained	90	

[1] ASTM D4751: AOS is a Maximum Opening Diameter Value.

Physical Properties	Unit	Typical Value
Mass/Unit Area (ASTM D5261)	oz/yd^2 (g/m^2)	8.8 (298)
Thickness (ASTM D5199)	mils (mm)	34 (0.9)
Roll Dimensions (width x length)	ft (m)	15 x 300 (4.57 x 91.4)
Roll Area	yd^2 (m^2)	500 (418)
Estimated Roll Weight	lb (kg)	292 (132)

Percent Open Area (COE-02215) is not covered by our current A2LA accreditation.

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TENCATE
materials that make a difference

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Pendergrass, GA 30567

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Tel 888 795 0808

Fax 706 693 4400
www.tencate.com

FGS000015
ETQR21

GAI-LAP-25-97

Testing Lab 1291.01 & 1291.02

Curtain Installation Guide and Maintenance

1309 West Main, Carmi, IL 62821, USA
Tel: (618) 382 2525 Fax: (618) 382 3610
E-mail: elastec@elastec.com
Web Page: www.elastec.com

Silt Curtain/Boom Maintenance

A scheduled visual inspection is required to determine if all components are working as intended, is recommended. Special attention needs to be given to all load carrying components (i.e. cables, shackles anchors and connectors.) These should be attached correctly and free of build-up to function as intended. Periodic re-tensioning of the cables and anchors may be required and GPS readings should be taken if it is not able to visually determine correct location.

Scheduled cleaning is desirable to ensure that the barriers maintain their integrity. All marine growth (algae, etc) should be brushed off with stiff PVC bristled broom or pressure washers by divers (if in water.)

Sections can be removed and swapped out with spare section (should they be purchased) to enable cleaning on shore if so desired. When water elevation change occurs, adjustments may need to be made to anchor and mooring lines, to ensure they do not get submerged which may lead to failure.

Maintenance of these systems is paramount as excessive marine growth, if not removed, will cause system damage over extended periods. Each site has unique conditions and a schedule of maintenance can only be determined by either installing a test section on site to monitor prior to purchase and then determine exact growth under the conditions present or by inspections on installed barriers once they are fully deployed.

The manufacturer recommends following all installation recommendations, maintenance and emergency handling instruction to achieve best use and results from this system.

Cleaning and Preparation of Surfaces

1. Three methods are recommended for cleaning and preparation of Silt Curtain/Boom surfaces prior to repair. The three methods are:

    A. High pressure water cleaning – 1300 psi max
    B. Scrubbing with commercially available detergent
    C. Steam cleaning

NOTE: Dependent of the condition and severity of the soiled area, the three methods can be used singly or in combination.

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A. High Pressure Water Cleaning

1) Apply high pressure water to the soiled area of the boom without concentrating full pressure (1300 psi) for long periods of time (maximum of 5 minutes) to any one sport on the Silt Curtain/Boom fabric. Caution: Concentrating high pressure water in one spot for long periods of time may result in damage to the fabric and flotation.

2) Use a long handle brush to assist the water pressure in cleaning the Silt Curtain/Boom fabric.

3) Allow the Silt Curtain/Boom fabric to dry after cleaning.

B. Scrubbing With Commercially Available Detergent

NOTE: The Silt Curtain/Boom fabric manufacturer recommends Proctor and Gamble “Dawn” detergent as the commercially available cleaning agent.

1) Prior to detergent scrubbing, wash Silt Curtain/Boom with clean water to remove surface dirt and debris.

2) Using a bucket or container, mix detergent solution in accordance with the manufacturer’s label instructions.

3) Apply detergent solution to Silt Curtain/Boom fabric soiled area and scrub with long handle brush.

4) Rinse scrubbed area with clean water.

5) Allow PermaFence fabric to dry after cleaning.

C. Steam Cleaning

1) Use a commercial steam cleaner to remove dirt and debris from Silt Curtain/Boom fabric and hardware.

CAUTION: Wand of steam cleaner should be kept in constant motion to avoid damage to Silt Curtain/Boom fabric with high heat concentration (180°F at 80psi.)

2) Allow PVC fabric to dry after cleaning.

The following is an example of typical equipment, services and materials that may be needed for installation. This is by now means comprehensive and only a guide.

Prior to equipment arrival anchor points are to be identified and set as sturdy termination points for the Silt Curtain/Boom ends. These should be capable of holding horizontal load of equal to

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the TENSION CABLE load, plus a minimum safety factor of 1.2. This is something that owner engineers can design and have put in place by contractors.

Anchors to be made or available prior to our arrival if not purchased from us. This will save on time and owner money due to delays.

Minimum of 6 Personnel (3 each with experience in using heavy construction equipment (crane, forklift, workboat, welding, etc) and preferably with marine construction experience. The remaining 3 should be proficient in using hand tools like wrenches, ratchets, etc for general laboring.

Once the goods arrive on site, one will need a small crane or forklift to move the bundles of 15-meter lengths around and the anchors to the workboat/s. Each section weighs about 1000 lbs (dry weight) to a prepared staging area that is flat and suitable to work on- a parking lot area, boat ramp or similar is fine right next to the water.

Equipment typically required by contractor/owner

Two-way radios (1 for each boat) and 1 on shore for communication.

Hand tools such as adjustable wrenches, work knife, cable cutters, etc.

Two each work boats (preferably one with a flat bottom and the other with a V-hull), minimum 21' long, 8' wide, stable with minimum 90 HP motor on the back. Equipped with a strong centrally located towing point. The flat bottom boat should be capable of handling at least 1 anchor (more is preferred as it speeds installation) at a time and be equipped with a small derrick crane to raise/lower the anchor blocks into place- this depends on anchor size.

Safety equipment for all personnel- gloves, work vests, hard hats

First Aid box

Access to drinking water and ablution facilities.

Details of the Curtain System

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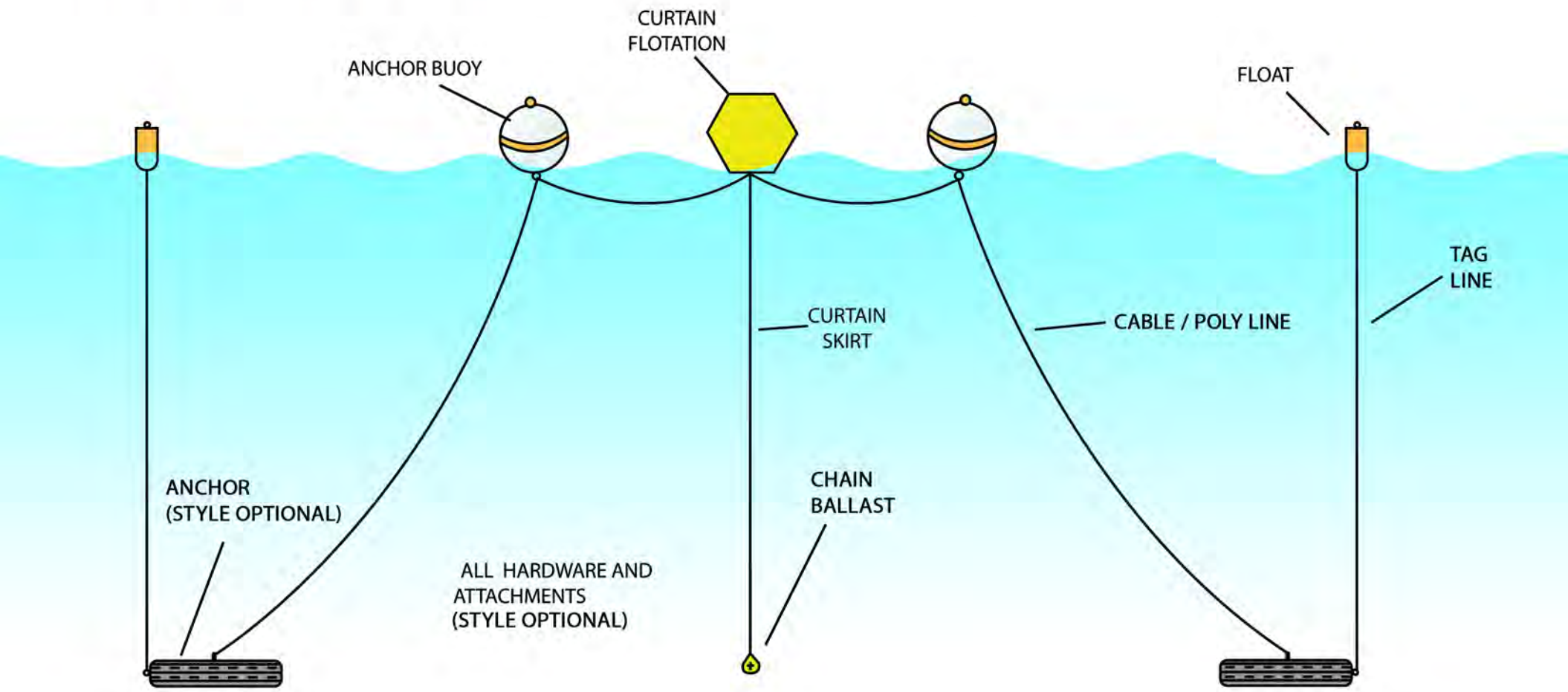
Innovative Environmental Products

Dual Anchor System



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DBC-013
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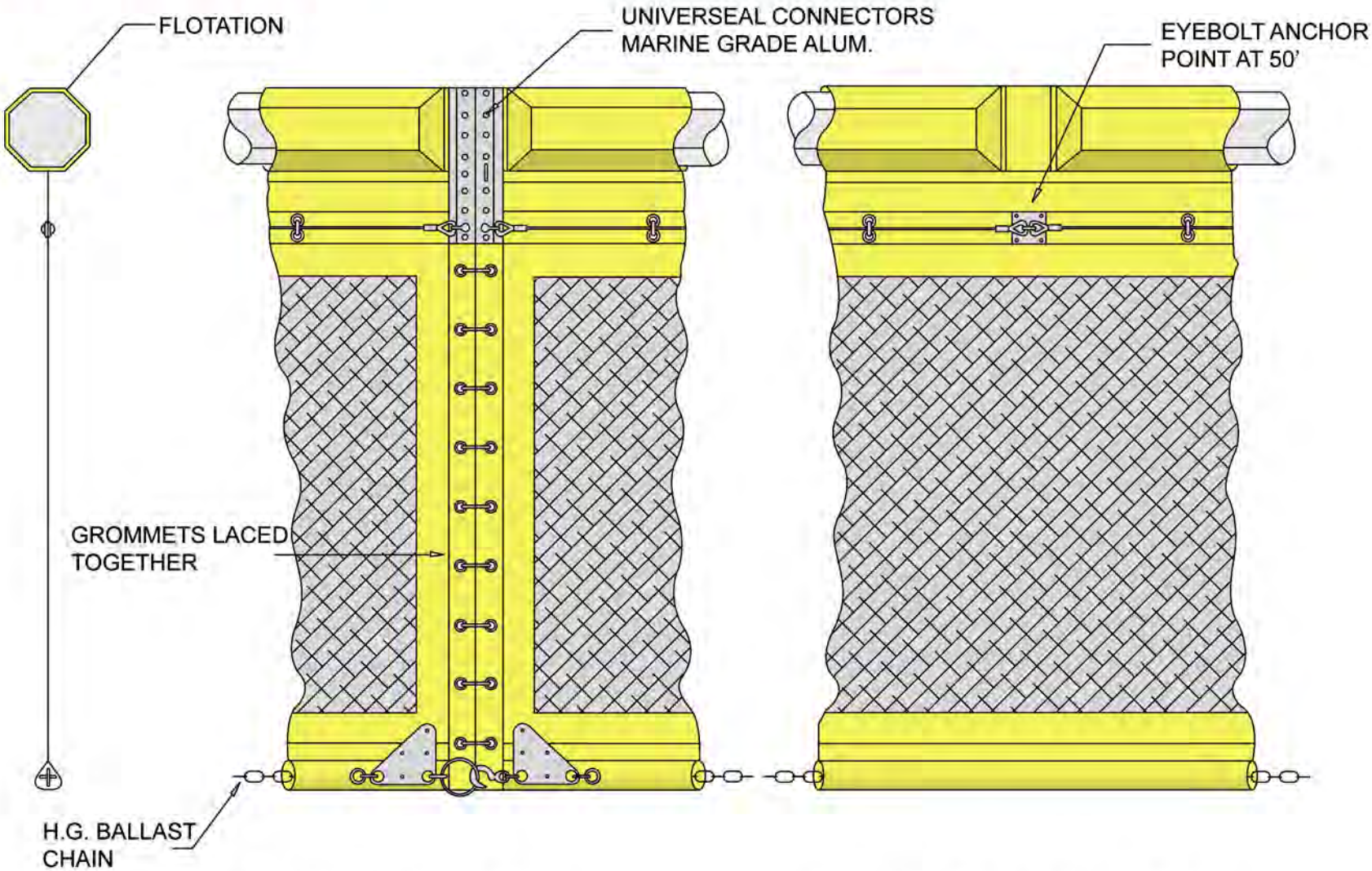
RuffWater with Filter Cloth



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ELASTEC INC.

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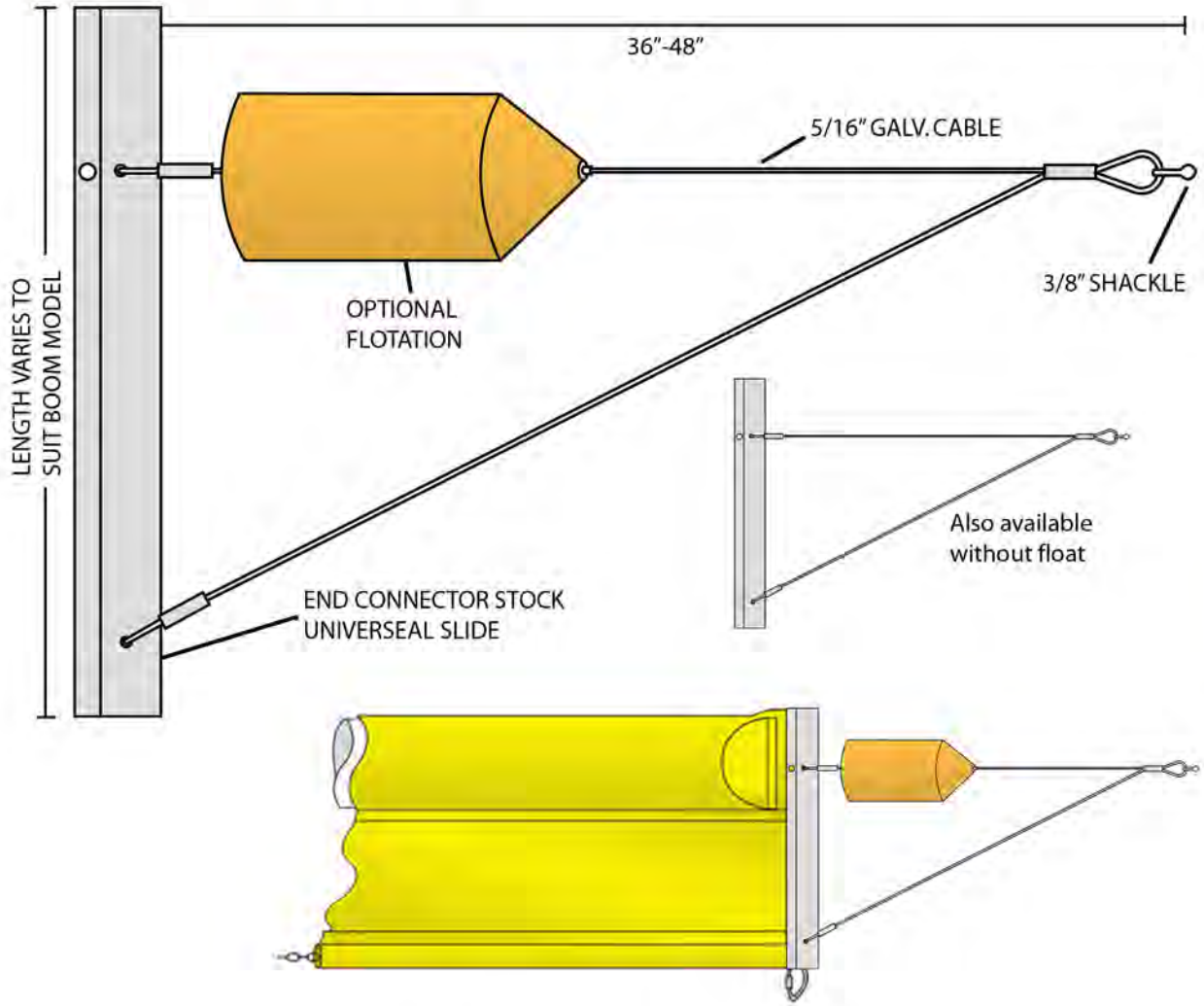
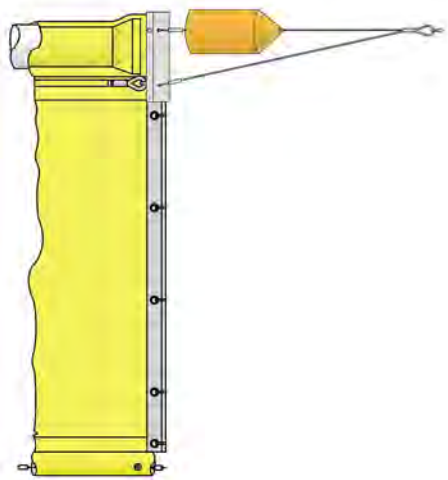
Tow Bridles



Tow Bridles can be provided with or without auxiliary floats. They may be used for handling the containment boom or silt curtain in water. Prior to deployment, the connector on the tow bridle should be mated to the boom or silt curtain and secured with a toggle pin. The shackle on the tow bridle will accept a line up to 3/4" in diameter. A choice of connectors are available.



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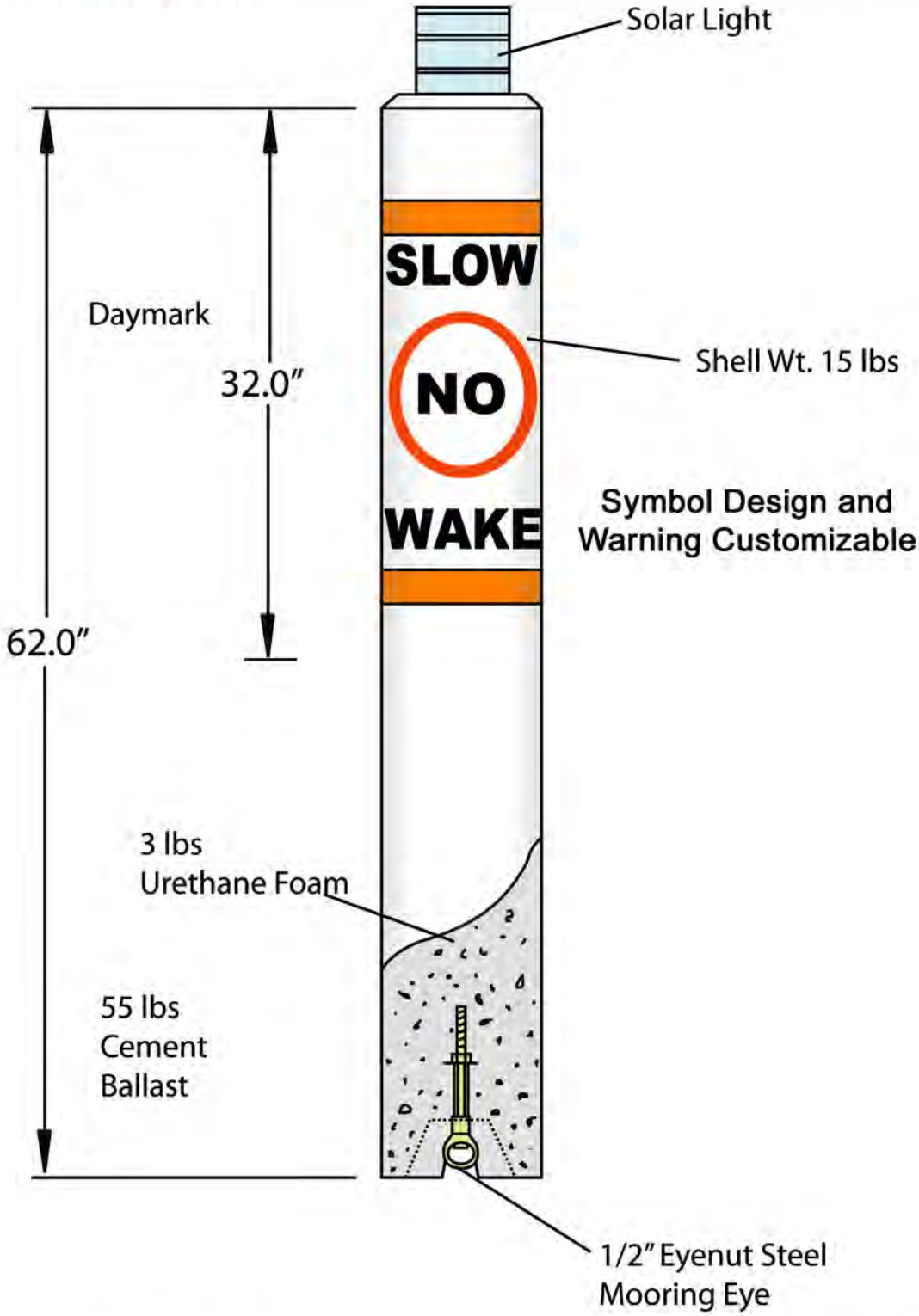
Solar Marker Regulatory Buoy



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11/06/08

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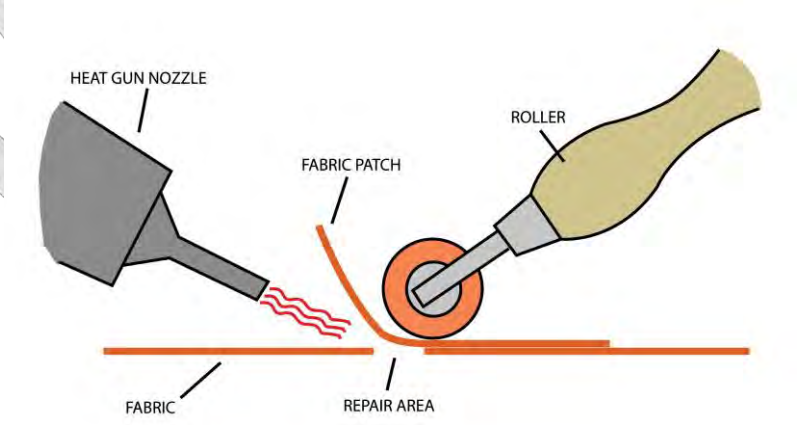
Boom Repair Kit Description

Elastec / American Marine offers kits for repairing boom and tank fabric using hot air gun technology.

The kit includes:

- One hot air gun (110 volt or 220 volt) with nozzle
- One silicone roller
- Repair fabric
- One set of instructions describing the repair of boom material

The kit is provided with detailed step by step instructions to allow the operator to make effective and cost efficient repairs of oil containment boom manufactured in PVC or Urethane . Supplied in waterproof toolbox.



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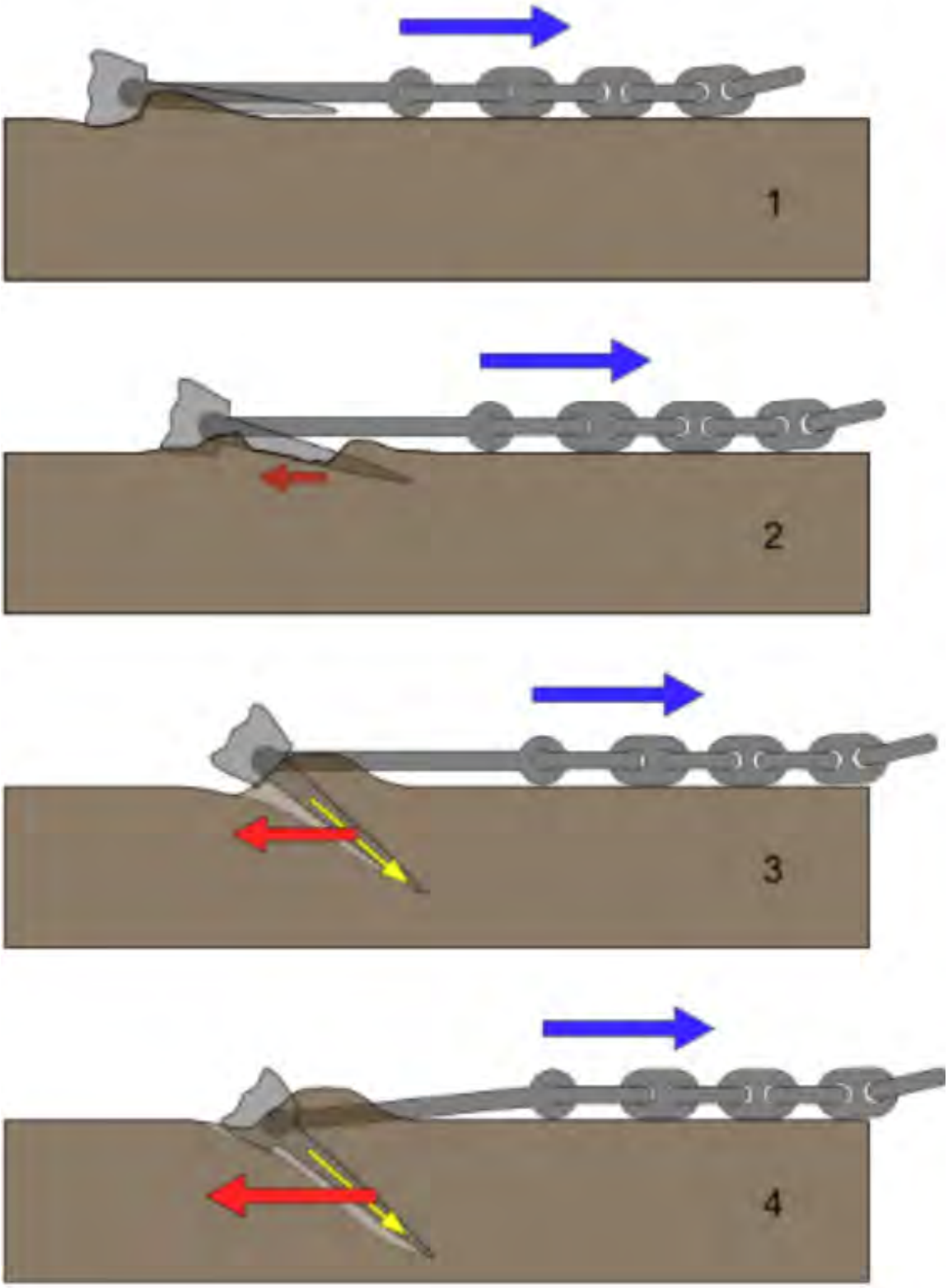
1
2
3
4

Monitoring Location

Dist	COUNTY	ROUTE	POST MILES TOTAL PROJECT	SHEET No.	TOTAL SHEETS
04	SF	101	9.0		

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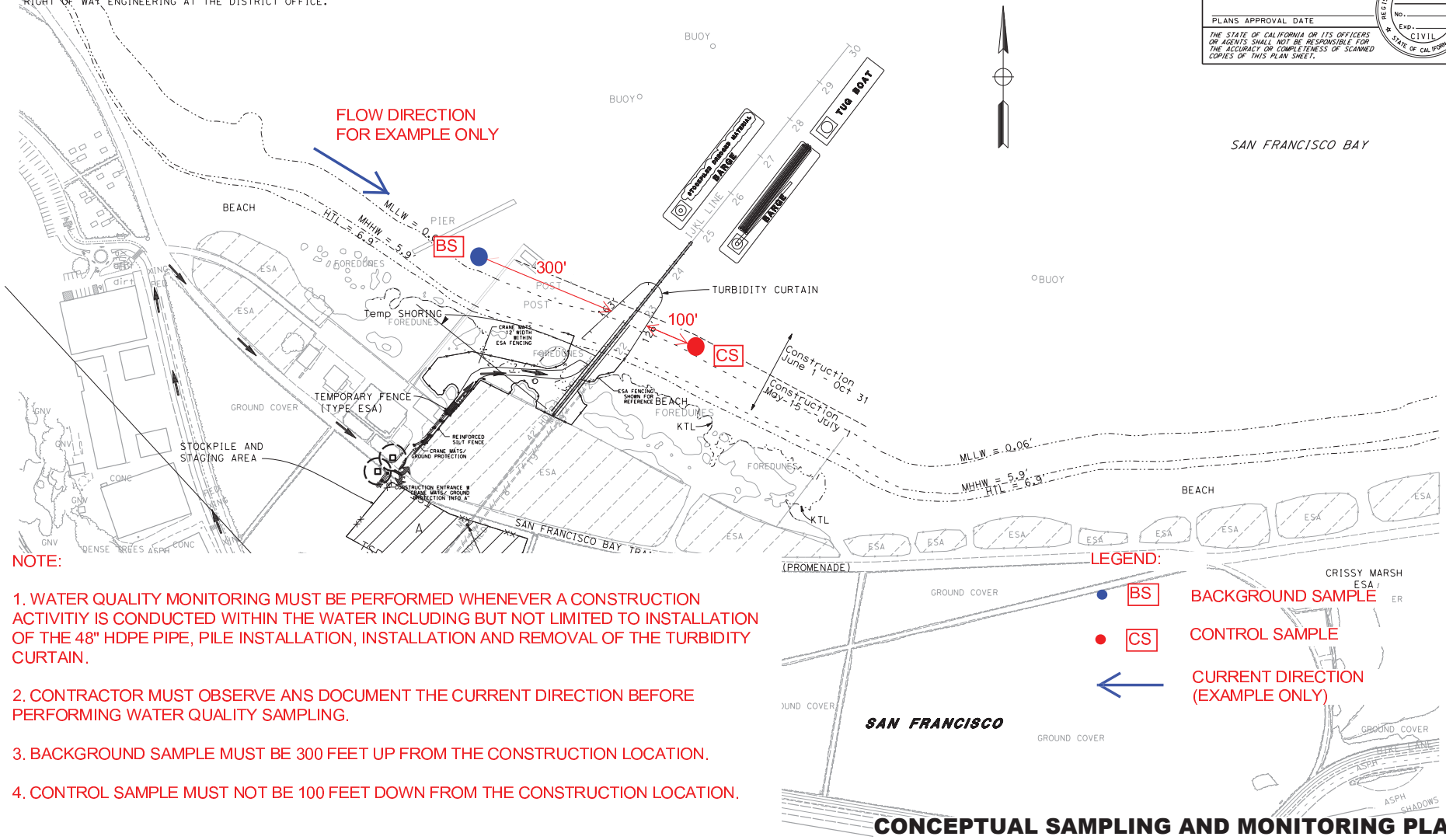

NOTE:

1. WATER QUALITY MONITORING MUST BE PERFORMED WHENEVER A CONSTRUCTION ACTIVITIY IS CONDUCTED WITHIN THE WATER INCLUDING BUT NOT LIMITED TO INSTALLATION OF THE 48" HDPE PIPE, PILE INSTALLATION, INSTALLATION AND REMOVAL OF THE TURBIDITY CURTAIN.

2. CONTRACTOR MUST OBSERVE ANS DOCUMENT THE CURRENT DIRECTION BEFORE PERFORMING WATER QUALITY SAMPLING.

3. BACKGROUND SAMPLE MUST BE 300 FEET UP FROM THE CONSTRUCTION LOCATION.

4. CONTROL SAMPLE MUST NOT BE 100 FEET DOWN FROM THE CONSTRUCTION LOCATION.

CONCEPTUAL SAMPLING AND MONITORING PLAN

APPROVED FOR WATER POLLUTION CONTROL WORK ONLY

SCALE 1"= 100'

STATE OF CALIFORNIA - DEPARTMENT OF TRANSPORTATION
Caltrans
WATER QUALITY

FUNCTIONAL SUPERVISOR: KAMRAN NAKHJIRI
CALCULATED-DESIGNED BY
CHECKED BY
REVISED BY
DATE REVISED

LAST REVISION 08-12-14
DATE PLOTTED => 10/27/2014
TIME PLOTTED => 4:34:02 PM

BORDER LAST REVISED 7/2/2010
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RELATIVE BORDER SCALE IS IN INCHES 0 1 2 3
UNIT 0702
PROJECT NUMBER & PHASE 04000209231

Dist	COUNTY	ROUTE	POST MILES TOTAL PROJECT	SHEET No.	TOTAL SHEETS
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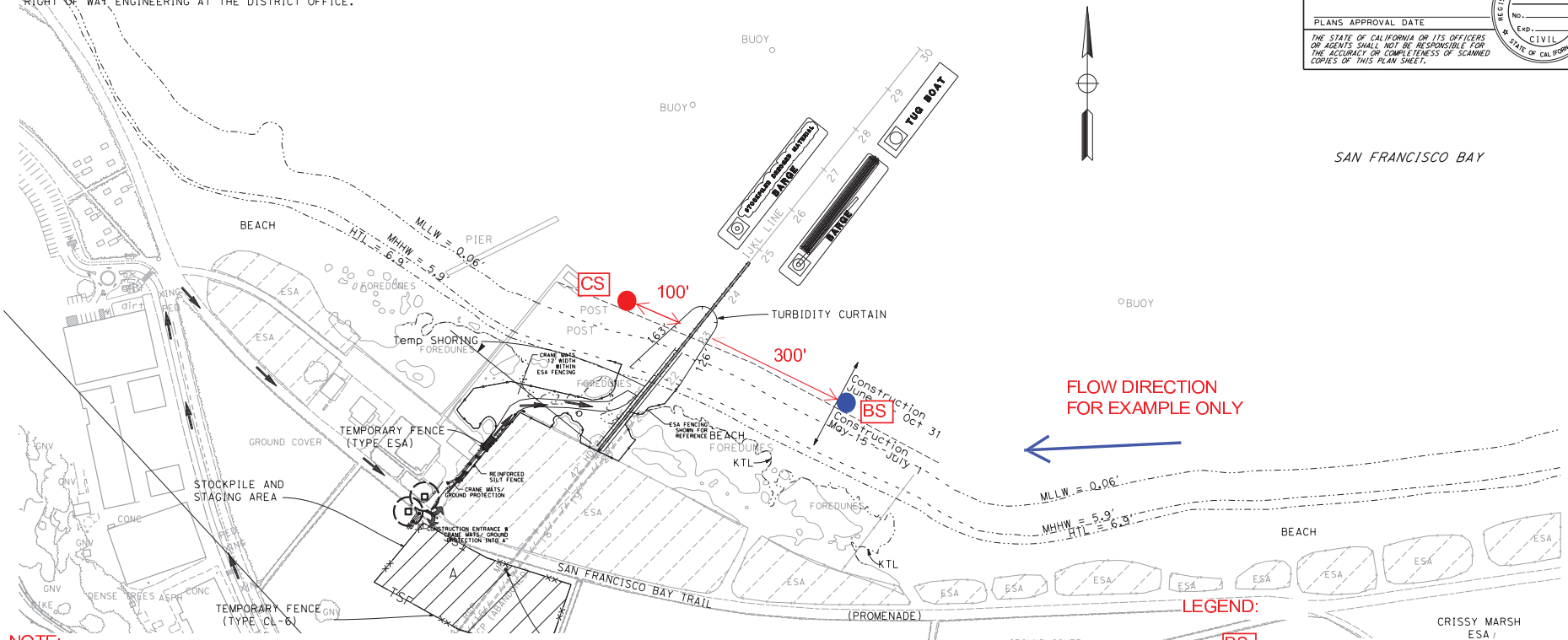

LEGEND:

- BS — BACKGROUND SAMPLE
- CS — CONTROL SAMPLE
- CURRENT DIRECTION (EXAMPLE ONLY)

NOTE:

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4. CONTROL SAMPLE MUST NOT BE 100 FEET DOWN FROM THE CONSTRUCTION LOCATION.

CONCEPTUAL SAMPLING AND MONITORING PLAN

SCALE 1"= 100'

STATE OF CALIFORNIA - DEPARTMENT OF TRANSPORTATION
Caltrans
WATER QUALITY

FUNCTIONAL SUPERVISOR: KAMRAN NAKHJIRI
CALCULATED-DESIGNED BY
CHECKED BY
REVISED BY
DATE REVISED

LAST REVISION 08-12-14
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Dist	COUNTY	ROUTE	POST MILES TOTAL PROJECT	SHEET No.	TOTAL SHEETS
04	SF	101	9.0		

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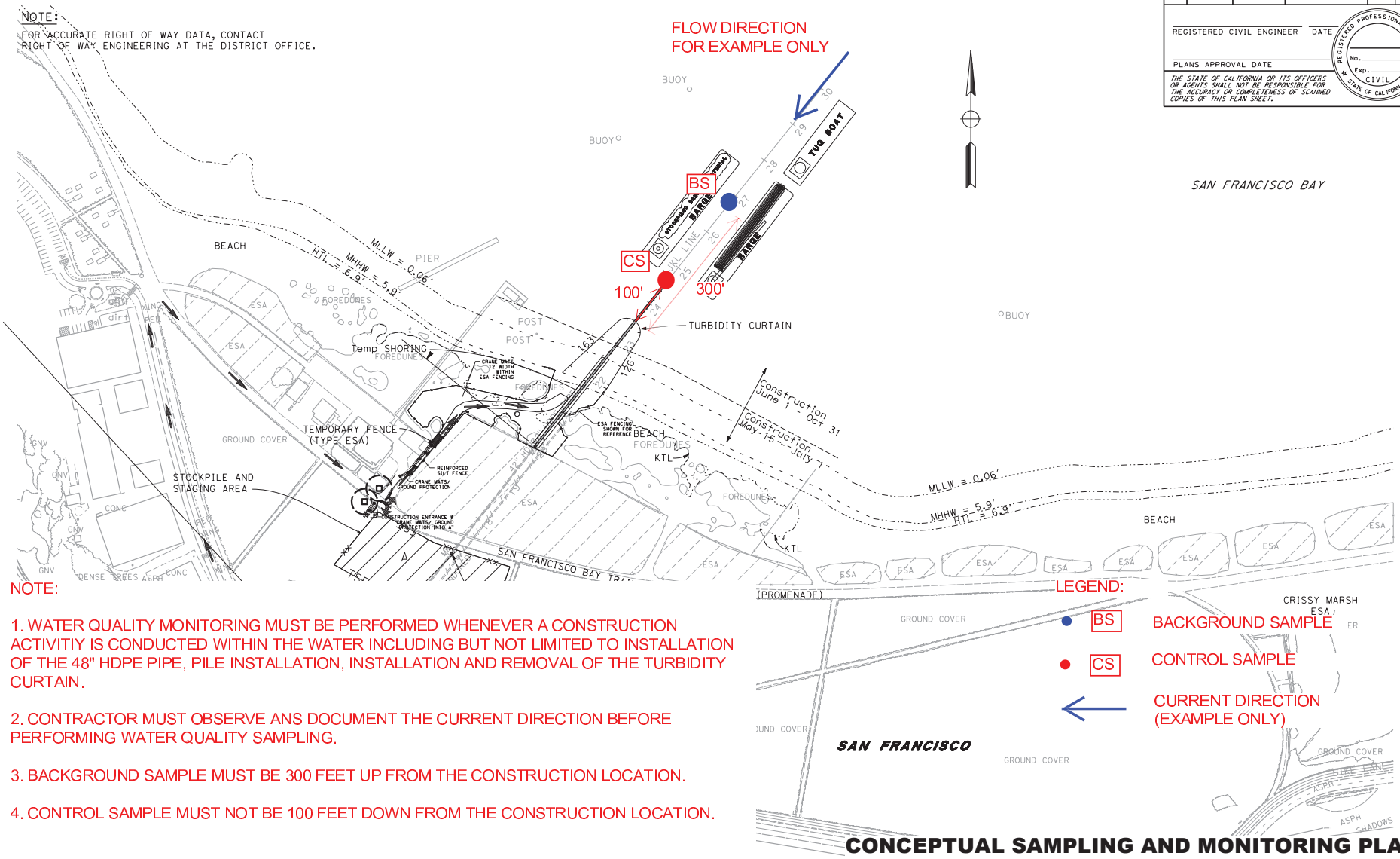

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- CURRENT DIRECTION (EXAMPLE ONLY)

CONCEPTUAL SAMPLING AND MONITORING PLAN

APPROVED FOR WATER POLLUTION CONTROL WORK ONLY

SCALE 1"= 100'

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Caltrans
WATER QUALITY

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PLANS APPROVAL DATE

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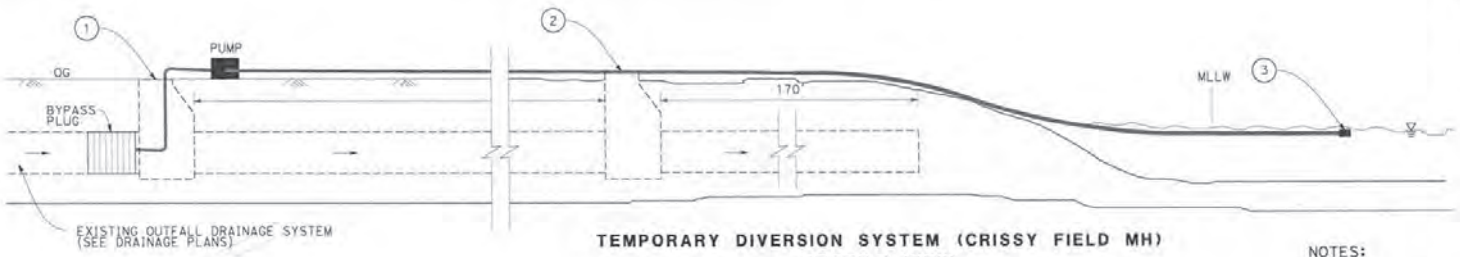
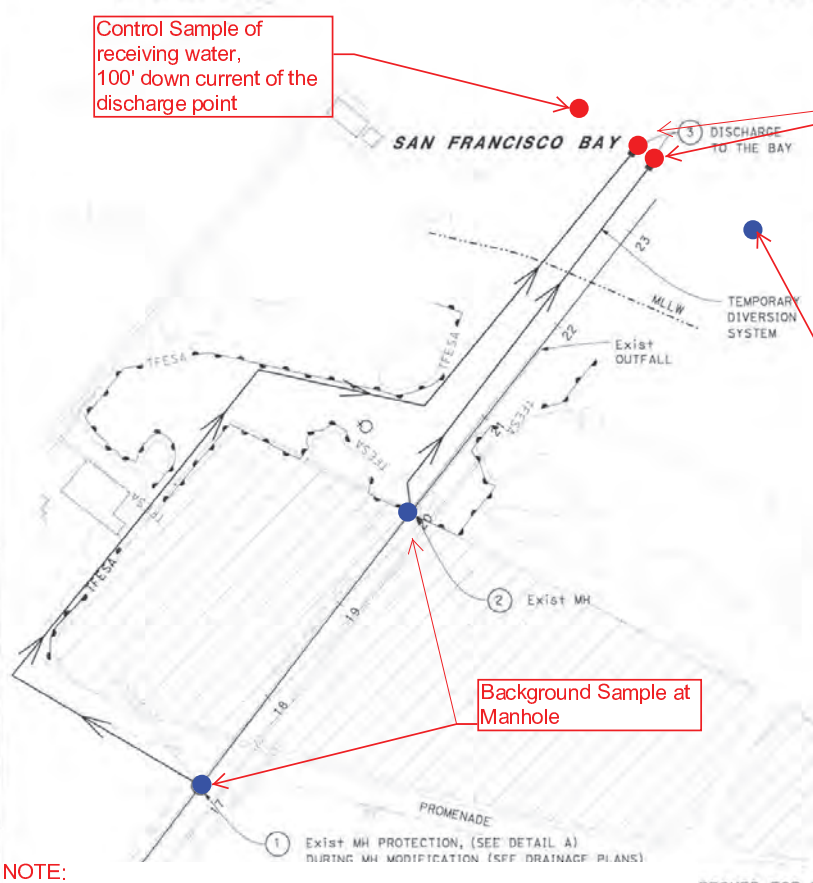
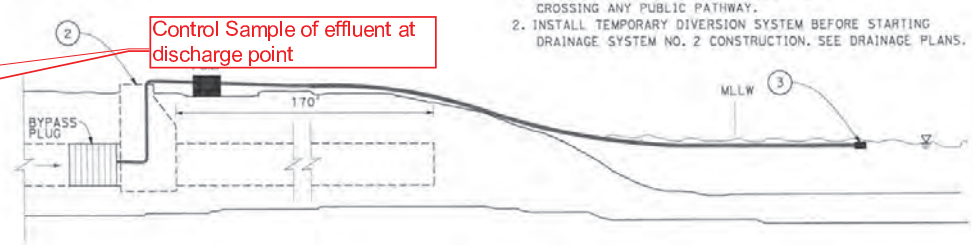


TEMPORARY DIVERSION SYSTEM (CRISSY FIELD MH)
PROFILE VIEW

NOTES:

1. BURY TEMPORARY DIVERSION SYSTEM WHEN CROSSING ANY PUBLIC PATHWAY.
2. INSTALL TEMPORARY DIVERSION SYSTEM BEFORE STARTING DRAINAGE SYSTEM NO. 2 CONSTRUCTION. SEE DRAINAGE PLANS.

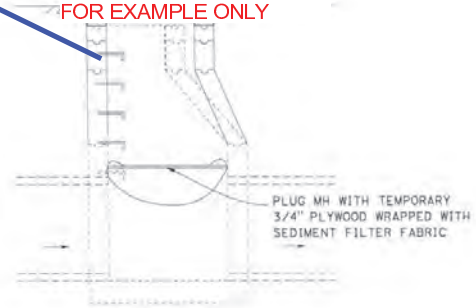




TEMPORARY DIVERSION SYSTEM
PROFILE VIEW

Background Sample of receiving water, 300' up current of the discharge point

CURRENT DIRECTION FOR EXAMPLE ONLY



DETAIL A

NOTE:
1. CONTRACTOR MUST OBSERVE ANS DOCUMENT THE CURRENT DIRECTION BEFORE PERFORMING WATER QUALITY SAMPLING.

CONCEPTUAL SAMPLING AND MONITORING PLAN FOR TEMPORARY DIVERSION SYSTEM

NOT TO SCALE

PROVED FOR WATER POLLUTION CONTROL WORK ONLY

STATE OF CALIFORNIA - DEPARTMENT OF TRANSPORTATION
Caltrans WATER QUALITY

FUNCTIONAL SUPERVISOR: KAMRAN NAKHJIRI

CALCULATED/DESIGNED BY | CHECKED BY | REVISED BY | DATE REVISED

JOB NUMBER | DATE PLOTTED => 20-SEP-2014 | TIME PLOTTED => 01:39 | 09-20-14

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OWNER'S FIELD GUIDE

Recommendations for SEAPILE® and SEATIMBER® Composite Marine Products

BEDFORD TECHNOLOGY
PO Box 609
2424 Armour Road
Worthington, MN 56187
Toll Free 800-721*-9037
(507) 372-5558 / Fax (507) 372-4570

DRIVING

10" (250 mm) SEAPILE COMPOSITE MARINE PILING

DRIVING SHOE:

Driving shoes are not supplied with 10″ SEAPILE Composite Marine Piling as a standard item. However, a steel point driving shoe may be provided as an attachment to the SEAPILE when required for difficult driving conditions.

HAMMER:

The minimum recommended hammer size for driving 10" SEAPILE Composite Marine Piling is 8,000 ft. lb. However, if readily available or the job calls for a sufficiently large number of piles to drive, a 10,000 ft. lb. hammer may be used for greater efficiency.

13" (330 mm) SEAPILE COMPOSITE MARINE PILING

DRIVING SHOE:

Driving shoes are not supplied with 13″ SEAPILE Composite Marine Piling as a standard item. However, a steel point driving shoe may be provided as an attachment to the SEAPILE when required for difficult driving conditions.

HAMMER:

The minimum recommended hammer size for driving 13" SEAPILE Composite Marine Piling is 10,000 ft. lb. However, if readily available or the job calls for a sufficiently large number of piles to drive, a 15,000 ft. lb. hammer may be used for greater efficiency.

16" (400 mm) SEAPILE COMPOSITE MARINE PILING

DRIVING SHOE:

Driving shoes are not supplied with 16″ SEAPILE Composite Marine Piling as a standard item. However, a steel point driving shoe may be provided as an attachment to the SEAPILE when required for difficult driving conditions.

HAMMER:

The minimum recommended hammer size for driving 16" SEAPILE Composite Marine Piling is 15,000 ft. lb. However, if readily available or the job calls for a sufficiently large number of piles to drive, a 25,000 ft. lb. hammer may be used for greater efficiency.

CUTTING

CHAIN SAWS AND CARBIDE TIP BLADES

The following chain saw specification is recommended to achieve efficient cutting:

Make:	Stihl
Model:	MS 660 Magnum
Size:	91.6 cc (5.6 cu. in.)
Power:	5.2 kW (7.0 bhp)
Bar length:	24”
Chain:	RAPCO’s carbide tip, with 77 ea drive links, part #521 400S RE
Mix ratio:	50:1 (2 6 fl. oz. of 2 cycle engine oil per gallon of 93 octane gasoline)

The following company supplies both new chains and reconditions old chain saw blades:

RAPCO
6000 N.E. 88 Street,
Suite D-104
Vancouver, WA
98665-0958

Contact: John Blehm on 800-959-6130

The Stihl MS 660 chainsaw will have a standard 3/8 pitch chainbar and a 3/8-8 chain sprocket. The RAPCO chains are 404 pitch, which will require the purchase of a 404 pitch chainbar and a 404-7 chain sprocket.

CUTTING CONSIDERATIONS

The following considerations are recommended for more efficient cutting and extending the blade life:

- Avoid contact with the ground or other objects that can break or dull the brittle carbide blade tips. The tips are extremely sharp and must be maintained with a diamond tool. Excessive sharpening will reduce the blade life.

- The saw and blade must be kept clean between cuts. Shavings should be blown out in between cuts using a compressed air hose. Check under the top chain cover and remove any plastic build up as required.

LIFE EXPECTANCY OF CARBIDE TIP CHAINS

The following approximate number of cuts can be expected for carbide tipped chains. “SP” refers to BEDFORD TECHNOLOGY SEAPILE Composite

Marine Piling and “ST” refers to BEDFORD TECHNOLOGY SEATIMBER Composite Marine Timber.

10" SP	with 1.00" fiberglass rebar	10 ea. cuts
13" SP	with 1.00" fiberglass rebar	10 ea. cuts
16" SP	with 1.25" fiberglass rebar	8 ea. cuts
10" x 10" ST	with 1.00" fiberglass rebar	12 ea. cuts
8" x 12" ST	with 1.00" fiberglass rebar	12 ea. cuts
12" x 12" ST	with 1.00" fiberglass rebar	12 ea. cuts

DRILLING AND COUNTER-BORING

POWER DRILL

The following drill specification is recommended for all drilling and countersinking:

Electric: 3/4" chuck, Milwaukee “Super Holeshooter,” 250-350 rpm or equivalent

Pneumatic: 3/4" chuck, 1.5 to 2 HP, 200-350 rpm,

DRILLING AND COUNTER-BORING PLASTIC WITH NO REBAR

Standard high speed steel twist drills are suitable for drilling holes up to 1-1/2" diameter. These are commonly available, but can be sourced from “MSC Industrial Supply Company” (Tel: 1-800-645-7270). If necessary, the tapered shank can easily be machined on a lathe with carbide tooling to allow for use in a standard chuck.

For larger holes, drilling a 1" or 1-1/8" diameter pilot hole is recommended. This is followed by a counter-bore type bit to enlarge the hole to the finished diameter. Counter-bore bits can be fabricated and supplied by BEDFORD TECHNOLOGY as required. Alternatively, fabrication drawings can be provided by BEDFORD TECHNOLOGY for customer fabrication. Extended shanks can be added to accommodate specific job needs.

DRILLING AND COUNTER-BORING PLASTIC WITH REBAR

Drilling a 1" or 1-1/8" pilot hole with a standard high speed steel twist drill is recommended. This is followed by a carbide insert, counter-bore type bit to enlarge the hole to the finished diameter.

Fabrication drawings can be provided by BEDFORD TECHNOLOGY for customer fabrication. Extended shanks can be added to accommodate specific job needs.

When rebar is encountered, increased caution is required by the operator. Application of light pressure to the drill will help reduce the risk of the bit snagging.

Carbide inserts for counter-bores can be procured from Valenite Inc. Call 1-800-544-3336 to locate the nearest distributor. VC29 grade insert part number #SPMW432 and lock screw part number PT-546T are used.

GENERAL CUTTING AND DRILLING

Customers may contact Bedford Technology to answer any questions about working with SEAPILE and SEATIMBER Composite Marine Products.

Phone: 1-800-721-9037 or 507-372-5558.

REPAIR TO THE PLASTIC MATRIX OF COMPOSITE MARINE PILING AND TIMBER

Required tools

1. Silicone caulk sealant.
2. Propane torch.
3. Shavings of plastic matrix, left over from cutting to length with a chain saw.
4. Putty knife
5. Sandpaper (80-100 grit) and wooden block.
6. Power sander, ideally battery powered orbital or palm type.

Method for deep abrasions, cuts, and grooves

1. Clean the pertinent area of dust and debris.
2. Apply commercially available, suitably colored silicone caulk sealant.
3. Smooth to achieve an even finish.

Method for small patches

1. Pre-heat the hole until the surrounding plastic is soft, not runny.
2. Press shavings into the hole and heat until liquefied.

3. Repeat in layers, until the void is flush, or standing slightly proud of the surface.
4. Allow each layer to cool before applying the next.
5. Sand the patch area, blending in until flush with the outer surface.

Method for larger patches

1. Cut a plug from a left over pile cut off piece to a slightly smaller shape than the depression.
2. Pre-heat the hole until the surrounding plastic is soft, not runny.
3. Press shavings into the hole and heat until liquefied.
4. Pre-heat the plug and press into the depression.
5. Press shavings into the gap around the plug and heat until liquefied.
6. Repeat in layers, until the gap is flush, or standing slightly proud of the surface.
7. Allow each layer to cool before applying the next.
8. Sand the patch area, blending in until flush with the outer surface.

LIFTING AND HANDLING OF COMPOSITE MARINE PILING AND TIMBER

PROPER LIFTING CONSIDERATIONS

The following considerations are recommended to resist damage to piling and timber:

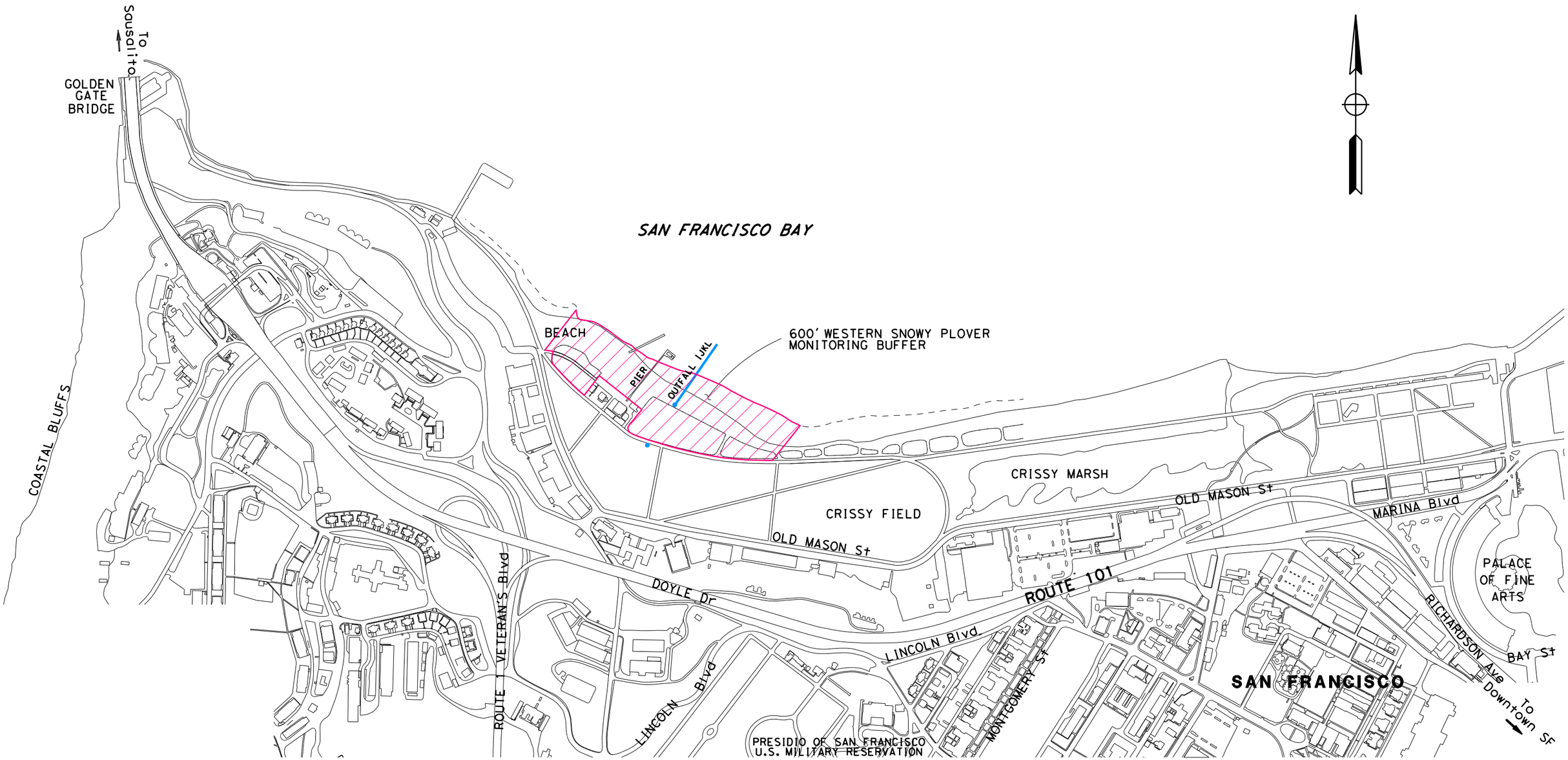
- Verify the weights and lengths of the material before each lift.
- Use a lifting beam to properly distribute the lifting load and ensure a straight, vertical lift on the pile or timber.
- Use a sling or choker attachment and secure tightly to the pile or timber. Do not use lifting devices that cut or gouge the material. Alternatively, holes may be field drilled to provide lifting points if allowed for in the contract specifications.
- Piles and timbers may be lifted at two pick points, provided the points are located at 1/5 of the overall length from each end. Otherwise, support the pile or timber at close intervals along the entire length.
- Stand up piles for driving by attaching to a single point on the piling that is 1/3 from one end.
- All lifting plans and procedures are the responsibility of the customer. Contact BEDFORD TECHNOLOGY to review lifting plans as required.

STORAGE OF COMPOSITE MARINE PILING AND TIMBER

PROPER STORAGE CONSIDERATIONS

The following considerations are recommended to resist damage to piling and timber:

- Use minimum 4”x4” plastic or wood lumber Dunnage for support.
- Space Dunnage at 6’ to 10’ maximum increments with support at each end of the pile or timber.
- Stack piles or timbers no more than 6’ in height. Chock, band, or tie outer rows to resist rolling.

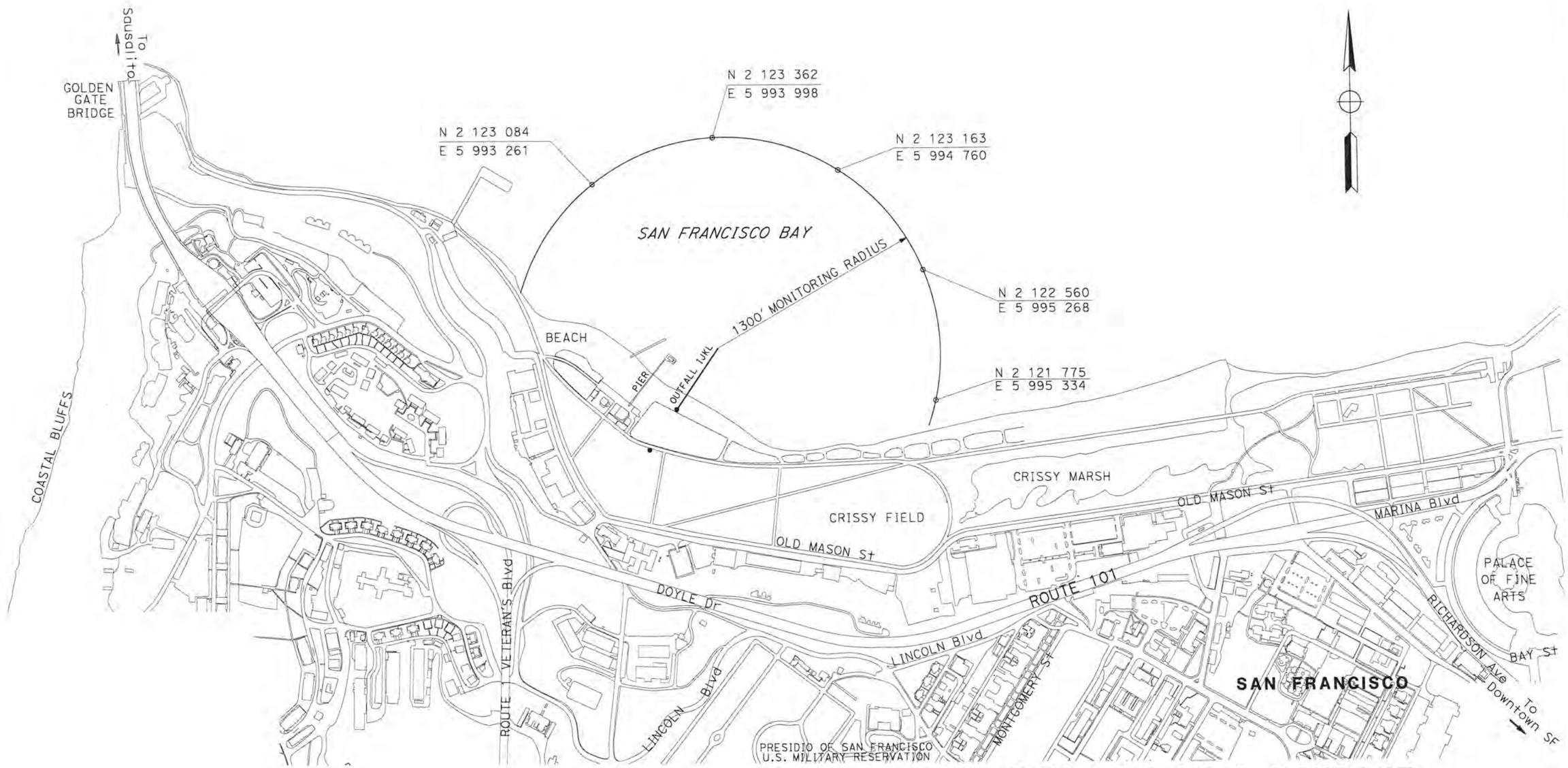


INFORMATIONAL HANDOUT

WESTERN SNOWY PLOVER MONITORING BUFFER

04-1637N1 SF-101-9.0

NO SCALE



INFORMATIONAL HANDOUT
AQUATIC MONITORING OUTFALL IJKL
04-1637N1 SF-101-9.0

NO SCALE

Information Advisory
Clean Imported Fill Material

October 2001

DEPARTMENT OF TOXIC SUBSTANCES CONTROL

It is DTSC's mission to restore, protect and enhance the environment, to ensure public health, environmental quality and economic vitality, by regulating hazardous waste, conducting and overseeing cleanups, and developing and promoting pollution prevention.

State of California

California Environmental Protection Agency

Executive Summary

This fact sheet has been prepared to ensure that inappropriate fill material is not introduced onto sensitive land use properties under the oversight of the DTSC or applicable regulatory authorities. Sensitive land use properties include those that contain facilities such as hospitals, homes, day care centers, and schools. This document only focuses on human health concerns and ecological issues are not addressed. It identifies those types of land use activities that may be appropriate when determining whether a site may be used as a fill material source area. It also provides guidelines for the appropriate types of analyses that should be performed relative to the former land use, and for the number of samples that should be collected and analyzed based on the estimated volume of fill material that will need to be used. The information provided in this fact sheet is not regulatory in nature, rather is to be used as a guide, and in most situations the final decision as to the acceptability of fill material for a sensitive land use property is made on a case-by-case basis by the appropriate regulatory agency.

Introduction

The use of imported fill material has recently come under scrutiny because of the instances where contaminated soil has been brought onto an otherwise clean site. However, there are currently no established standards in the statutes or regulations that address environmental requirements for imported fill material. Therefore, the California Environmental Protection Agency, Department of Toxic Substances Control (DTSC) has prepared this fact sheet to identify procedures that can be used to minimize the possibility of introducing contaminated soil onto a site that requires imported fill material. Such sites include those that are undergoing site remediation, corrective action, and closure activities overseen by DTSC or the appropriate regulatory agency. These procedures may also apply to construction projects that will result in sensitive land uses. The intent of this fact sheet is to protect people who live on or otherwise use a sensitive land use property. By using this fact sheet as a guide, the reader will minimize the chance of introducing fill material that may result in potential risk to human health or the environment at some future time.

The energy challenge facing California is real. Every Californian needs to take immediate action to reduce energy consumption. For a list of simple ways you can reduce demand and cut your energy costs, see our website at www.dtsc.ca.gov.

Overview

Both natural and manmade fill materials are used for a variety of purposes. Fill material properties are commonly controlled to meet the necessary site specific engineering specifications. Because most sites requiring fill material are located in or near urban areas, the fill materials are often obtained from construction projects that generate an excess of soil, and from demolition debris (asphalt, broken concrete, etc.). However, materials from those types of sites may or may not be appropriate, depending on the proposed use of the fill, and the quality of the assessment and/or mitigation measures, if necessary. Therefore, unless material from construction projects can be demonstrated to be free of contamination and/or appropriate for the proposed use, the use of that material as fill should be avoided.

Selecting Fill Material

In general, the fill source area should be located in nonindustrial areas, and not from sites undergoing an environmental cleanup. Nonindustrial sites include those that were previously undeveloped, or used solely for residential or agricultural purposes. If the source is from an agricultural area, care should be taken to insure that the fill does not include former agricultural waste process byproducts such as manure or other decomposed organic material. Undesirable sources of fill material include industrial and/or commercial sites where hazardous ma-

Potential Contaminants Based on the Fill Source Area

Fill Source:	Target Compounds
Land near to an existing freeway	Lead (EPA methods 6010B or 7471A), PAHs (EPA method 8310)
Land near a mining area or rock quarry	Heavy Metals (EPA methods 6010B and 7471A), asbestos (polarized light microscopy), pH
Agricultural land	Pesticides (Organochlorine Pesticides: EPA method 8081A or 8080A; Organophosphorus Pesticides: EPA method 8141A; Chlorinated Herbicides: EPA method 8151A), heavy metals (EPA methods 6010B and 7471A)
Residential/acceptable commercial land	VOCs (EPA method 8021 or 8260B, as appropriate and combined with collection by EPA Method 5035), semi-VOCs (EPA method 8270C), TPH (modified EPA method 8015), PCBs (EPA method 8082 or 8080A), heavy metals including lead (EPA methods 6010B and 7471A), asbestos (OSHA Method ID-191)

**The recommended analyses should be performed in accordance with USEPA SW-846 methods (1996). Other possible analyses include Hexavalent Chromium: EPA method 7199*

Recommended Fill Material Sampling Schedule

Area of Individual Borrow Area	Sampling Requirements
2 acres or less	Minimum of 4 samples
2 to 4 acres	Minimum of 1 sample every 1/2 acre
4 to 10 acres	Minimum of 8 samples
Greater than 10 acres	Minimum of 8 locations with 4 subsamples per location

Volume of Borrow Area Stockpile	Samples per Volume
Up to 1,000 cubic yards	1 sample per 250 cubic yards
1,000 to 5,000 cubic yards	4 samples for first 1000 cubic yards +1 sample per each additional 500 cubic yards
Greater than 5,000 cubic yards	12 samples for first 5,000 cubic yards + 1 sample per each additional 1,000 cubic yards

terials were used, handled or stored as part of the business operations, or unpaved parking areas where petroleum hydrocarbons could have been spilled or leaked into the soil. Undesirable commercial sites include former gasoline service stations, retail strip malls that contained dry cleaners or photographic processing facilities, paint stores, auto repair and/or painting facilities. Undesirable industrial facilities include metal processing shops, manufacturing facilities, aerospace facilities, oil refineries, waste treatment plants, etc. Alternatives to using fill from construction sites include the use of fill material obtained from a commercial supplier of fill material or from soil pits in rural or suburban areas. However, care should be taken to ensure that those materials are also uncontaminated.

Documentation and Analysis

In order to minimize the potential of introducing contaminated fill material onto a site, it is necessary to verify through documentation that the fill source is appropriate and/or to have the fill material analyzed for potential contaminants based on the location and history of the source area. Fill documentation should include detailed information on the previous use of the land from where the fill is taken, whether an environmental site assessment was performed and its findings, and the results of any testing performed. It is recommended that any such documentation should be signed by an appropriately licensed (CA-registered) individual. If such documentation is not available or is inadequate, samples of the fill material should be chemically analyzed. Analysis of the fill material should be based on the source of the fill and knowledge of the prior land use.

Detectable amounts of compounds of concern within the fill material should be evaluated for risk in accordance with the DTSC Preliminary Endangerment Assessment (PEA) Guidance Manual. If

metal analyses are performed, only those metals (CAM 17 / Title 22) to which risk levels have been assigned need to be evaluated. At present, the DTSC is working to establish California Screening Levels (CSL) to determine whether some compounds of concern pose a risk. Until such time as these CSL values are established, DTSC recommends that the DTSC PEA Guidance Manual or an equivalent process be referenced. This guidance may include the Regional Water Quality Control Board's (RWQCB) guidelines for reuse of non-hazardous petroleum hydrocarbon contaminated soil as applied to Total Petroleum Hydrocarbons (TPH) only. The RWQCB guidelines should not be used for volatile organic compounds (VOCs) or semi-volatile organic compounds (SVOCS). In addition, a standard laboratory data package, including a summary of the QA/QC (Quality Assurance/Quality Control) sample results should also accompany all analytical reports.

When possible, representative samples should be collected at the borrow area while the potential fill material is still in place, and analyzed prior to removal from the borrow area. In addition to performing the appropriate analyses of the fill material, an appropriate number of samples should also be determined based on the approximate volume or area of soil to be used as fill material. The table above can be used as a guide to determine the number of samples needed to adequately characterize the fill material when sampled at the borrow site.

Alternative Sampling

A Phase I or PEA may be conducted prior to sampling to determine whether the borrow area may have been impacted by previous activities on the property. After the property has been evaluated, any sampling that may be required can be determined during a meeting with DTSC or appropriate regulatory agency. However, if it is not possible to analyze the fill material at the borrow area or determine that it is appropriate for use via a Phase I or PEA, it is recommended that one (1) sample per truckload be collected and analyzed for all compounds of concern to ensure that the imported soil is uncontaminated and acceptable. (See chart on Potential Contaminants Based on the Fill Source Area for appropriate analyses). This sampling frequency may be modified upon consultation with the DTSC or appropriate regulatory agency if all of the fill material is derived from a common borrow area. However, fill material that is not characterized at the borrow area will need to be stockpiled either on or off-site until the analyses have been completed. In addition, should contaminants exceeding acceptance criteria be identified in the stockpiled fill material, that material will be deemed unacceptable and new fill material will need to be obtained, sampled and analyzed. Therefore, the DTSC recommends that all sampling and analyses should be completed prior to delivery to the site to ensure the soil is free of contamination, and to eliminate unnecessary transportation charges for unacceptable fill material.

Composite sampling for fill material characterization may or may not be appropriate, depending on quality and homogeneity of source/borrow area, and compounds of concern. Compositing samples for volatile and semivolatile constituents is not acceptable. Composite sampling for heavy metals, pesticides, herbicides or PAH's from unanalyzed stockpiled soil is also unacceptable, unless it is stockpiled at the borrow area and originates from the same source area. In addition, if samples are composited, they should be from the same soil layer, and not from different soil layers.

When very large volumes of fill material are anticipated, or when larger areas are being considered as borrow areas, the DTSC recommends that a Phase I or PEA be conducted on the area to ensure that the borrow area has not been impacted by previous activities on the property. After the property has been evaluated, any sampling that may be required can be determined during a meeting with the DTSC.

For further information, call Richard Coffman, Ph.D., R.G., at (818) 551-2175.

DEVELOPMENT OF PRESIDIO-WIDE CLEANUP LEVELS FOR SOIL, SEDIMENT, GROUNDWATER, AND SURFACE WATER

PRESIDIO OF SAN FRANCISCO, CALIFORNIA

Prepared for:

The Presidio Trust
34 Graham Street, P.O. Box 29052
San Francisco, California 94129-0052

Prepared by:

Erler & Kalinowski, Inc.
1870 Ogden Drive
Burlingame, California 94010

30 October 2002
Table 7-6 Revised May 2006

TABLES OF CONTENTS

DEVELOPMENT OF PRESIDIO-WIDE CLEANUP LEVELS FOR SOIL, SEDIMENT, GROUNDWATER, AND SURFACE WATER

Presidio of San Francisco, California

CONTENTS

Page

1. EXECUTIVE SUMMARY 1-1

2. INTRODUCTION 2-1

3. CHEMICAL-SPECIFIC ARARS 3-1

   3.1 Potential Chemical-Specific ARARs for Water 3-1
   3.2 Potential Chemical-Specific ARARs for Soil 3-2
   3.3 Potential Chemical-Specific ARARs For Petroleum Hydrocarbons 3-3

4. HUMAN HEALTH RISK-BASED PRGS FOR SOIL 4-1

   4.1 Purpose of Risk-based PRGs 4-1
   4.2 Human Health PRGs for Soil 4-1
      4.2.1 Potentially Exposed Populations 4-1
      4.2.2 Potential Human Health Exposure Pathways 4-2
      4.2.3 Non-carcinogen Target Risk Level 4-3
      4.2.4 Carcinogen Target Risk Level 4-4
      4.2.5 Lead Target Risk Level 4-4
      4.2.6 Human Health Toxicity Values 4-5
      4.2.7 Calculation of Human Health PRGs for PCOCs Other than Lead in Soil 4-6
      4.2.8 Human Health Exposure Parameters 4-7
      4.2.9 Human Health PRGs for PCOCs Other than Lead in Soil 4-8
      4.2.10 Human Health PRGs for Lead in Soil 4-9

5. ECOLOGICAL PRGS FOR SOIL AND SEDIMENT 5-1

   5.1 Derivation of Ecological PRGs for Soil and Sediment 5-1
   5.2 Potentially Exposed Species 5-3
      5.2.1 Plants 5-3
      5.2.2 Wildlife 5-4
      5.2.3 Indicator Plant and Wildlife Species 5-4
   5.3 Potential Ecological Exposure Pathways 5-5
      5.3.1 Terrestrial Habitats 5-6
      5.3.2 Aquatic Habitats 5-6
   5.4 Ecological Target Risk Level 5-7
   5.5 Ecological Toxicity Values 5-7
      5.5.1 Plants and Soil Fauna 5-8
      5.5.2 Wildlife 5-9
      5.5.3 Aquatic Life 5-11
   5.6 Calculation of Ecological PRGs for PCOCs Other than Lead in Soil and Sediment 5-12

DEVELOPMENT OF PRESIDIO-WIDE CLEANUP LEVELS FOR SOIL, SEDIMENT, GROUNDWATER, AND SURFACE WATER

Presidio of San Francisco, California

CONTENTS

Page

5.7 Ecological Exposure Parameters 5-13
5.7.1 Dietary Composition 5-14
5.7.2 Bioaccumulation Factors 5-15
5.8 Ecological PRGs for PCOCs Other than Lead in Soil and Sediment 5-15
5.8.1 Non-special Status Species PRGs 5-15
5.8.2 Special Status Species PRGs 5-16
5.9 Ecological PRGs for Lead in Soil and Sediment 5-17
5.9.1 Non-special Status Species PRGs 5-19
5.9.2 Special Status Species PRGs 5-19
5.10 DTSC Review of Ecological PRGs for soil 5-19

6. BACKGROUND CONCENTRATIONS OF METALS IN SOIL AND WATER AT THE PRESIDIO 6-1

6.1 Presidio Geology 6-1
6.1.1 Serpentinite 6-2
6.1.2 Colma Formation 6-3
6.1.3 Beach/Dune Sand 6-3
6.1.4 Chert/Shale 6-3
6.1.5 Greenstone 6-4
6.2 Approach to Developing Background Metals Concentrations in Soil 6-4
6.2.1 Regulatory Guidelines 6-4
6.2.2 Background Metals Data Set 6-5
6.2.3 Determining Metals Screening (PCOC) Levels 6-6
6.2.4 Determining Metals Threshold (COC) Levels 6-7
6.2.5 Summary of Background Threshold Data 6-8
6.3 Presidio Hydrogeology 6-8
6.4 Background Concentrations of Metals in Surface Water, Seeps, and Groundwater 6-9
6.4.1 Hypothesis that Serpentinite is a Natural Source of Chromium in Water 6-9
6.4.2 Evidence that Serpentinite is a Natural Source of Chromium in Water 6-10
6.4.3 Further Assessment Required to Confirm Other Metals in Water are Naturally Occurring 6-11

7. DERIVATION OF CLEANUP LEVELS 7-1

7.1 Planned Land Uses 7-1
7.1.1 Human Land Use 7-1
7.1.2 Ecological Land Use 7-3
7.2 Planned Water Resource Use 7-4

DEVELOPMENT OF PRESIDIO-WIDE CLEANUP LEVELS FOR SOIL, SEDIMENT, GROUNDWATER, AND SURFACE WATER

Presidio of San Francisco, California

CONTENTS

Page

7.3 Presidio Cleanup Levels Applicable to Specific Sites 7-5
- 7.3.1 Human Health Cleanup Levels for Non-Petroleum Compounds in Soil 7-6
- 7.3.2 Ecological Cleanup Levels for Non-Petroleum Compounds in Soil and Sediment 7-7
- 7.3.3 Human Health and Ecological Cleanup Levels for Petroleum Hydrocarbons and Constituents in Soil and Sediment 7-7
- 7.3.4 Cleanup Levels for Surface Water, Seeps, and Groundwater 7-8
- 7.3.5 Site-Specific Cleanup Level Selection Process 7-9
- 7.3.6 Summary 7-10

8. REFERENCES 8-1

LIST OF TABLES

3-1 Numeric Values of Potential Chemical-Specific ARARs for Water at Presidio Sites

3-2 Risk-Based Screening Levels for VOCs at Presidio Sites

3-3 Site Cleanup Requirements for Petroleum Hydrocarbons and Related Constituents at Presidio Sites

4-1 Summary of Potentially Exposed Populations and Complete Exposure Pathways

4-2 Exposure Factors Used to Calculate Human Health Preliminary Remediation Goals for Soil

4-3 Human Health Preliminary Remediation Goals for Soil Based on Residential Use

4-4 Human Health Preliminary Remediation Goals for Soil Based on Recreational Use

4-5 Human Health Preliminary Remediation Goals for Soil Based on Commercial/Industrial Use

4-6 Development of Human Health Preliminary Remediation Goals for Volatile Organic Compounds in Soil at the Presidio of San Francisco (Includes Vapor Intrusion Pathway)

4-7 Human Health Preliminary Remediation Goals for Volatile Organic Compounds in Soil and Sediment at the Presidio of San Francisco

4-8 Lead Intake Summary for Residential, Recreational, and Commercial/Industrial Users

5–1 Special Status Plant Species at the Presidio of San Francisco

5–2 Potential Occurring Special Status Wildlife at the Presidio of San Francisco

5–3 Development of Toxicity Benchmark Values for Chemicals Not Included in Army Remedial Investigation

5–4 Uncertainty Factors Used for Chemicals Not Included in Army Remedial Investigation

5–5 Low Toxicity Benchmark Values for Non-special Status Plants and Wildlife

5–6 High Toxicity Benchmark Values for Non-special Status Plants and Wildlife

LIST OF TABLES

5–7 Sediment Quality Criteria for Aquatic Life (Freshwater)

5–8 Sediment Quality Criteria for Aquatic Life (Marine)

5–9 Formulas for Calculation of Soil and Sediment Preliminary Remediation Goals for Wildlife at the Presidio of San Francisco

5–10 Wildlife Exposure Factors

5–11 Plant and Wildlife Bioaccumulation Factors

5-12 Soil Preliminary Remediation Goals for Non-special Status Plant and Wildlife Based on Low Toxicity Benchmark Values

5-13 Soil Preliminary Remediation Goals for Non-special Status Plant and Wildlife Based on High Toxicity Benchmark Values

5-14 Soil Preliminary Remediation Goals for Non-special Status Plant and Wildlife Species

5-15 Sediment Preliminary Remediation Goals for Non-special Status Wildlife Species

5-16 Sediment Preliminary Remediation Goals for Non-special Status Aquatic Life and Wildlife Species (Freshwater)

5-17 Sediment Preliminary Remediation Goals for Non-special Status Aquatic Life and Wildlife Species (Marine)

5-18 Soil Preliminary Remediation Goals for Special Status Plant Species Based on No-Observed-Effects-Concentrations

5-19 Soil Preliminary Remediation Goals for Special Status Wildlife Species Based on Toxicity Benchmark Values

5-20 Sediment Preliminary Remediation Goals for Special Status Wildlife Species Based on Toxicity Benchmark Values

5-21 Comparison of Soil Preliminary Remediation Goals of Non-special Status and Special Status Species

5-22 Comparison of Sediment Preliminary Remediation Goals of Non-special Status and Special Status Species (Freshwater)

5-23 Comparison of Sediment Preliminary Remediation Goals of Non-special Status and Special Status Species (Marine)

LIST OF TABLES

5-24 Summary of Ecological Preliminary Remediation Goals for Non-Petroleum Compounds in Soil

6-1 Summary of Background Data, Screening Levels, and Threshold Levels – Serpentinite Soil

6-2 Summary of Background Data, Screening Levels, and Threshold Levels – Colma Formation Soil

6-3 Summary of Background Data, Screening Levels, and Threshold Levels – Beach/Dune Soil

6-4 Summary of Background Data, Screening Levels, and Threshold Levels – Chert/Shale Soil

6-5 Summary of Background Screening and Threshold Data, Presidio Soils

6–6 Concentrations of Metals in Regional Background Soil Studies

6-7 Dissolved and Hexavalent Chromium Concentrations in Surface water, Seeps, and Groundwater

7-1 Steps to Identify Site-Specific Cleanup Levels Applicable at the Presidio

7-2 Summary of Selection of Preliminary Remediation Goals and Proposed Cleanup Levels for Non-Petroleum Compounds in Soil

7-3 Ecological Cleanup Levels for Non-Petroleum Compounds in Sediment at the Presidio of San Francisco (Freshwater)

7-4 Ecological Cleanup Levels for Non-Petroleum Compounds in Sediment at the Presidio of San Francisco (Marine)

7-5 Human Health and Ecological Cleanup Levels for Petroleum Hydrocarbons and Constituents in Soil and Sediment at the Presidio of San Francisco

7-6 Cleanup Levels for Surface Water, Seeps, and Groundwater at the Presidio of San Francisco

LIST OF FIGURES

2-1 Vicinity Map

2-2 Operable Units Being Addressed by The Presidio Trust

4-1 Potential Human Health Chemical Exposure Pathways

5-1 Potential Ecological Chemical Exposure Pathways for Terrestrial Habitats

5-2 Potential Ecological Chemical Exposure Pathways for Aquatic Habitats

6-1 Surface Deposits at the Presidio

6-2 Screening of Individual Outlier from Proposed Colma Background Data Set

6-3 Screening of Outlier Trend from Proposed Colma Background Data Set

6-4 Schematic Data Plot Showing Terminology Used to Define Screening and Threshold Metals Levels

6-5 Derivation of Screening Level Concentration for Chromium in Background Beach/Dune Soil

6-6 Derivation of Threshold Level Concentration for Chromium in Background Beach/Dune Soil

6-7 Groundwater Basins and Areas at the Presidio

6-8 Chromium Concentrations in Surface Water, Seeps, and Groundwater

7-1 Planned Human Land Use at the Presidio

7-2 Planned Ecological Land Use at the Presidio

7-3 Planned Vegetation Types at the Presidio

LIST OF APPENDICES

A Lead Spread Version 7.0 Computer Spreadsheets

B Crystal Ball™ Input Parameters and Monte Carlo Method Output

C Background Metals Data Sets for Serpentinite, Colma Formation, Beach/Dune, and Chert/Shale Samples

D Results of Army's Hexavalent Chromium Studies: Montgomery Watson, *Hexavalent Chromium in Serpentinite Bedrock and Groundwater in Upland Areas, July 1999*

E Copies of Johnson and Ettinger Model Runs for Volatile Organic Chemicals

F Responses to Comment Letters from the DTSC and RWQCB

LIST OF ACRONYMS/ABBREVIATIONS

§	Section
1,2-DCA	1,2-dichloroethane
2,4-D	2,4-dichlorophenoxyacetic acid
AA	graphite furnace atomic absorption
ABS	absorption factor
ACM	asbestos-containing material
AF	soil adherence factor
ARAR	Applicable or Relevant and Appropriate Requirement
Army	United States Department of Defense, Department of the Army
Army FS	*Final Feasibility Study Report, Presidio Main Installation, Presidio of San Francisco*, prepared by Dames & Moore, 1997
AT	averaging time
ATSDR	United States Department of Health and Human Services, Agency for Toxic Substances and Disease Registry
AUF	area use factor
BAAQMD	Bay Area Air Quality Management District
BAF	bioaccumulation factor
BAT	Best Available Technology
bgs	below ground surface
BRAC	Base Realignment and Closure Act
BTAG	U.S. EPA Region IX Biological Technical Advisory Group
BTEX	benzene, toluene, ethylbenzene, and xylenes
BW	body weight
CCR	California Code of Regulations
CCME	Canadian Council of Ministers of the Environment
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CF	conversion factor
CFR	Code of Federal Regulations
COC	chemical of concern
Contd	continued
Cr(III)	trivalent chromium
Cr(VI)	hexavalent chromium

LIST OF ACRONYMS/ABBREVIATIONS

CTR	California Toxics Rule
DEH	Directorate of Engineering and Housing
dicamba	3,6-dichloro-2-methoxybenzoic acid
DIR	total dietary ingestion rate
DOD	United States Department of Defense
DOE	United States Department of Energy
DTSC	California Environmental Protection Agency, Department of Toxic Substances Control
EBEP	SWRCB *California Enclosed Bays and Estuaries Plan, Water Quality Control Plan for Enclosed Bays and Estuaries of California*, dated 11 April 1991
Eh	oxidation-reduction potential
EKI	Erler & Kalinowski, Inc.
EqP	equilibrium partitioning
EPC	exposure point concentration
FD	field duplicate
FPALDR	Montgomery Watson *Fuel Product Action Level Development Report*, dated October 1995
FS	Feasibility Study
gm	gram
GMPA	NPS *General Management Plan Amendment*, dated July 1994
HEAST	Health Effects Assessment Summary Tables
HI	hazard index
HQ	hazard quotient
ICP	inductively coupled plasma
$Intake_i$	Intake (or dose) from pathway *i*
IRIS	Integrated Risk Information System
ISQG	interim sediment quality guideline
ISWP	SWRCB *California Inland Surface Waters Plan, Water Quality Control Plan for Inland Surface Waters of California*, dated 11 April 1991
IT Corporation	International Technology Corporation
kg	kilogram

LIST OF ACRONYMS/ABBREVIATIONS

L	liter
LOAEL	lowest-observed-adverse-effect level
LOEC	lowest-observed-effects-concentration
MCL	Maximum Contaminant Level
MCLG	Maximum Contaminant Level Goal
MCPP	2-(4-chloro-*o*-to(yl)oxy)propionic acid
µg	microgram
µg/dl	micrograms per deciliter
µg/kg	microgram/kilogram
µg/L	microgram per liter
mg	milligram
mg/kg	milligram per kilogram
mg/L	milligram per liter
mV	millivolt
NCEA	National Center for Environmental Assessment
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NEIC	U.S. EPA National Enforcement Investigations Center
NOAA	National Oceanic and Atmospheric Administration
NOAEL	no-observed-adverse-effect-level
NOEC	no-observed-effects-concentration
NPS	United States Department of the Interior, National Park Service
OEHHA	California Environmental Protection Agency, Office of Environmental Health Hazard Assessment
ORNL	Oak Ridge National Laboratory, U.S. Department of Energy
OSWER	Office of Solid Waste and Emergency Response
OU	Operable Unit
PA	Preliminary Assessment
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PCOC	potential chemical of concern
PEA	Preliminary Endangerment Assessment

LIST OF ACRONYMS/ABBREVIATIONS

PEC	probable effects concentration
PEL	probable effect level
PHGs	Drinking Water Public Health Goals
PHSH	Public Health Service Hospital
Presidio	Presidio of San Francisco
Presidio soil	serpentinite, Colma Formation, and beach/dune sand
PRG	Preliminary Remediation Goal
PRG_c	PRG based on carcinogenic effects
PRG_{nc}	PRG based on non-carcinogenic effects
Proposition 65	Safe Drinking Water and Toxic Enforcement Act
PTMP	*Presidio Trust Management Plan, Land Use Policies for Area B of the Presidio of San Francisco*, dated May 2002 (presents Trust's vision for use of Area B of the Presidio)
RAB	Restoration Advisory Board
RAO	Remedial Action Objective
RAP	Remedial Action Plan
RBSL	Risk-based Screening Level
RCRA	Resource Conservation and Recovery Act
Revised Final FS Report	*Revised Final Feasibility Study Report for Main Installation Sites*
RfD	Reference Dose
RI	Remedial Investigation
RME	reasonable maximum exposure
ROD	Record of Decision
RTECS	Registry of Toxic Effects of Chemical Substances, National Institute for Occupational Safety and Health
RWQCB	California Environmental Protection Agency, Regional Water Quality Control Board, San Francisco Bay Region
SA	surface area
SDWA	Safe Drinking Water Act
SF	slope factor
Soil Lead Guidance	*Revised Interim Soil Lead Guidance for CERCLA Sites and RCRA Corrective Action Facilities*, U.S. EPA, 14 July 1994

LIST OF ACRONYMS/ABBREVIATIONS

soil/sed	soil and sediment
SQB	sediment quality benchmark
SQC	sediment quality criterion
Superfund	collectively refers to CERCLA and SARA
SVOC	semivolatile organic compound
SWRCB	California Environmental Protection Agency, State Water Resources Control Board
TBV	Toxicity benchmark value
TCE	trichloroethene
TEC	threshold effects concentration
TIC	tentatively identified compound
TPH	total petroleum hydrocarbons
TOXNET	National Library of Medicine Toxicity Data Network
Trust	The Presidio Trust
TSCA	Toxic Substances Control Act
U.S. EPA	United States Environmental Protection Agency
VOC	volatile organic compound
VMP	NPS and Trust *Vegetation Management Plan and Environmental and Assessment for the Presidio of San Francisco*, dated May 2001

1. EXECUTIVE SUMMARY

1. EXECUTIVE SUMMARY

The Presidio Trust ("Trust") is in the process of transforming the Presidio ~~of~~ San Francisco ("Presidio") from an Army base to a financially self-sufficient National Park. To successfully complete the conversion, some remedial activities must be performed to address environmental issues from previous land uses and activities. This document presents the approach to develop cleanup levels and the framework to apply these cleanup levels to chemical release sites at the Presidio. These cleanup levels are anticipated to be applied to new decision documents at the Presidio.

The Trust has been working to develop cleanup levels with representatives of the Department of the Interior, National Park Service ("NPS"), California Environmental Protection Agency, Department of Toxic Substances Control ("DTSC"), United States Environmental Protection Agency ("U.S. EPA"), California Environmental Protection Agency, Regional Water Quality Control Board, San Francisco Bay Region ("RWQCB"), and community members of the Restoration Advisory Board ("RAB"). This document summarizes the derivation of human health and ecological cleanup levels for soil, sediment, groundwater, and surface water at the Presidio, and the development of background metal concentrations at the Presidio. This document presents for approval by regulatory agencies the proposed methodology for determining Presidio-specific cleanup levels based on the protection of human health and ecological receptors for a wide range of chemicals that may potentially be encountered in soil, sediment, and water at the Presidio.

The Presidio-specific cleanup levels presented in this document are based on site-specific preliminary remediation goals ("PRGs") calculated for the Presidio, and chemical-specific Applicable or Relevant and Appropriate Requirements ("ARARs") for potential chemicals of concern ("PCOCs") detected in various media at the Presidio. Chemical-specific ARARs and site-specific PRGs are compared to naturally occurring or background concentrations of metals in soil to establish cleanup levels for use at all areas of the Presidio. Also presented in this document are the procedures to determine which specific cleanup levels are applicable to a given chemical release site.

The cleanup levels developed in this document are anticipated to be applied to new decision documents at the following Presidio Operable Units ("OUs"): the Main Installation, Firing Ranges, Miscellaneous Sites, Basewide Cumulative Effects, as well as any unknown sites encountered in the future, and lead-based paint in soil. Petroleum program sites are technically covered by RWQCB Site Cleanup Requirements specified in Order No. 96–070, as described in Section 3. However, the cleanup levels presented in this document comply with Order No. 96–070, so this cleanup level document also applies to petroleum program sites and petroleum sites with CERCLA components.

2. INTRODUCTION

2. INTRODUCTION

This document presents the development and application of cleanup levels at chemical release sites at the Presidio. To develop cleanup levels, the Trust has been working with representatives of the NPS, DTSC, U.S. EPA, and RWQCB, and RAB community members. This document summarizes the derivation of human health and ecological cleanup levels for soil, sediment, groundwater, and surface water at the Presidio, and the development of background metal concentrations at the Presidio. The Presidio-specific cleanup levels are based on site-specific PRGs calculated for the Presidio, and chemical-specific ARARs for PCOCs detected in various media at the Presidio. Chemical-specific ARARs and site-specific PRGs are compared to naturally occurring or background concentrations of metals in soil to establish cleanup levels for use at all areas of the Presidio.

ARARs are laws, requirements, or other cleanup standards that pertain to the chemical release at a site. Chemical-specific ARARs for PCOCs identified at the Presidio are discussed in Section 3 and have been adopted as cleanup levels, when available and greater than naturally occurring or background concentrations of metals in soil and water. In the absence of such ARARs, Presidio-specific risk-based PRGs derived in Sections 4 and 5 are used as cleanup levels if the PRGs are greater than background concentrations of metals. Background concentrations of metals need to be considered in establishing cleanup levels because it is impracticable to remediate releases of metals to less than naturally occurring concentrations. Background concentrations of metals in soil and water are addressed in Section 6.

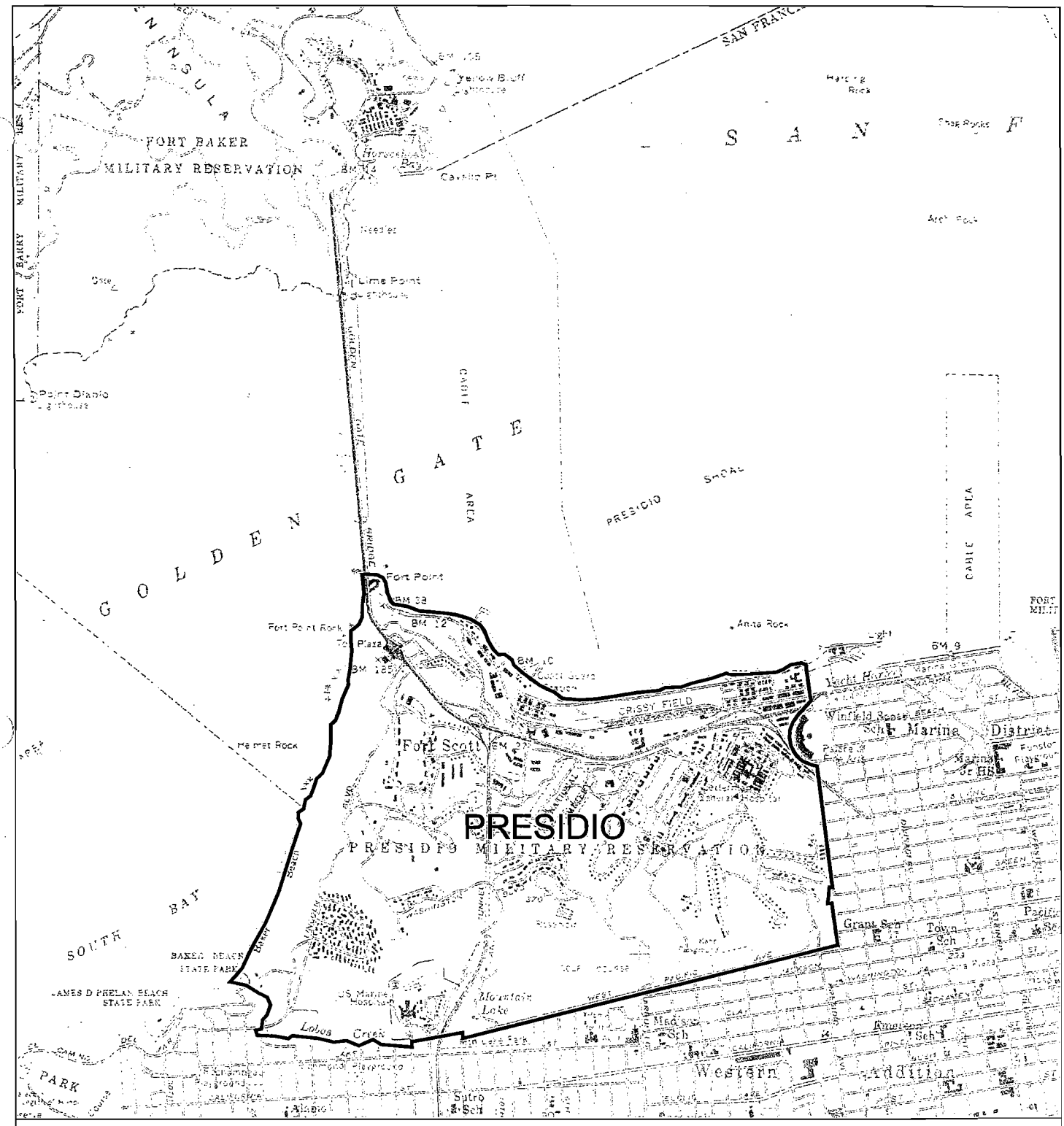
As part of its environmental restoration efforts, the Trust retained Erler & Kalinowski, Inc. ("EKI") to prepare a Revised Final Feasibility Study Report for Main Installation sites ("Revised Final FS Report") at the Presidio. In the process of preparing the Revised Final FS Report, the Trust identified a need to establish cleanup levels for soil, sediment, and groundwater at identified sites to determine if remediation is required, and if so, to what level. This Presidio-wide Cleanup Level Document presents the steps taken to create cleanup levels for Main Installation sites as well as other sites at the Presidio. Figure 2-1 is a vicinity map showing the location of the Presidio; Figure 2-2 shows known CERCLA sites within the Presidio. The list of PCOCs included in this document is based on the chemicals detected in soil, sediment, groundwater, and surface water samples collected at Main Installation and Public Health Service Hospital sites, as included in the database given to the Trust by the Army and as augmented with analytical data collected by the Trust.[1] This list of PCOCs also includes chemicals that have been detected at the Firing Ranges and at petroleum release sites.

[1] Data that were excluded from the database used to create the PCOC list include the following: (a) results from non-representative media (e.g., wipe samples), (b) tentatively identified compounds (TICs), (c) surrogates added by the laboratory during analysis, (d) inorganic chemicals unrelated to chemical releases (e.g., major elements in the earth's crust), (e) common water quality parameters (e.g., hardness), (f) phthalates, which were determined to be laboratory contaminants, and (g) unreliable or rejected data.

The key factors that are used to develop cleanup levels are background metal concentrations, human health exposure, and ecological exposure. Background metals concentrations are based on the predominant soil lithologies encountered within the Presidio. Thus, for any given site, the applicable cleanup level incorporates the planned land use (residential, recreational, institutional, or commercial/industrial), the predominant soil or sediment lithology, and potential ecological species present (including the presence of special-status species). In addition, some cleanup levels, particularly for petroleum hydrocarbons and related constituents, are determined by Presidio-wide Site Cleanup Requirements as adopted in RWQCB Order No. 96–070 ("Order"). The Order allows varying cleanup levels depending on the existing and future use, depth to groundwater, and the Presidio drainage basin.

Chemical-specific ARARs, Presidio-specific risk-based PRGs, and background metals concentrations are combined in Section 7 to develop the Presidio-wide cleanup levels. Also presented in Section 7 is the framework used to identify the specific cleanup levels that will apply to a given Presidio site based on the specific characteristics of an individual site (e.g., human land use, presence of sensitive ecological species, predominant lithology). These site-specific cleanup levels can then be used to identify chemicals of concern ("COCs"), followed by an assessment of required remedial actions.

FIGURES



Reference: U.S.G.S. Topographic Maps, San Francisco North and Point Bonita, Photorevised 1973.

Note:

1. All locations are approximate.

N

0 1/2 1

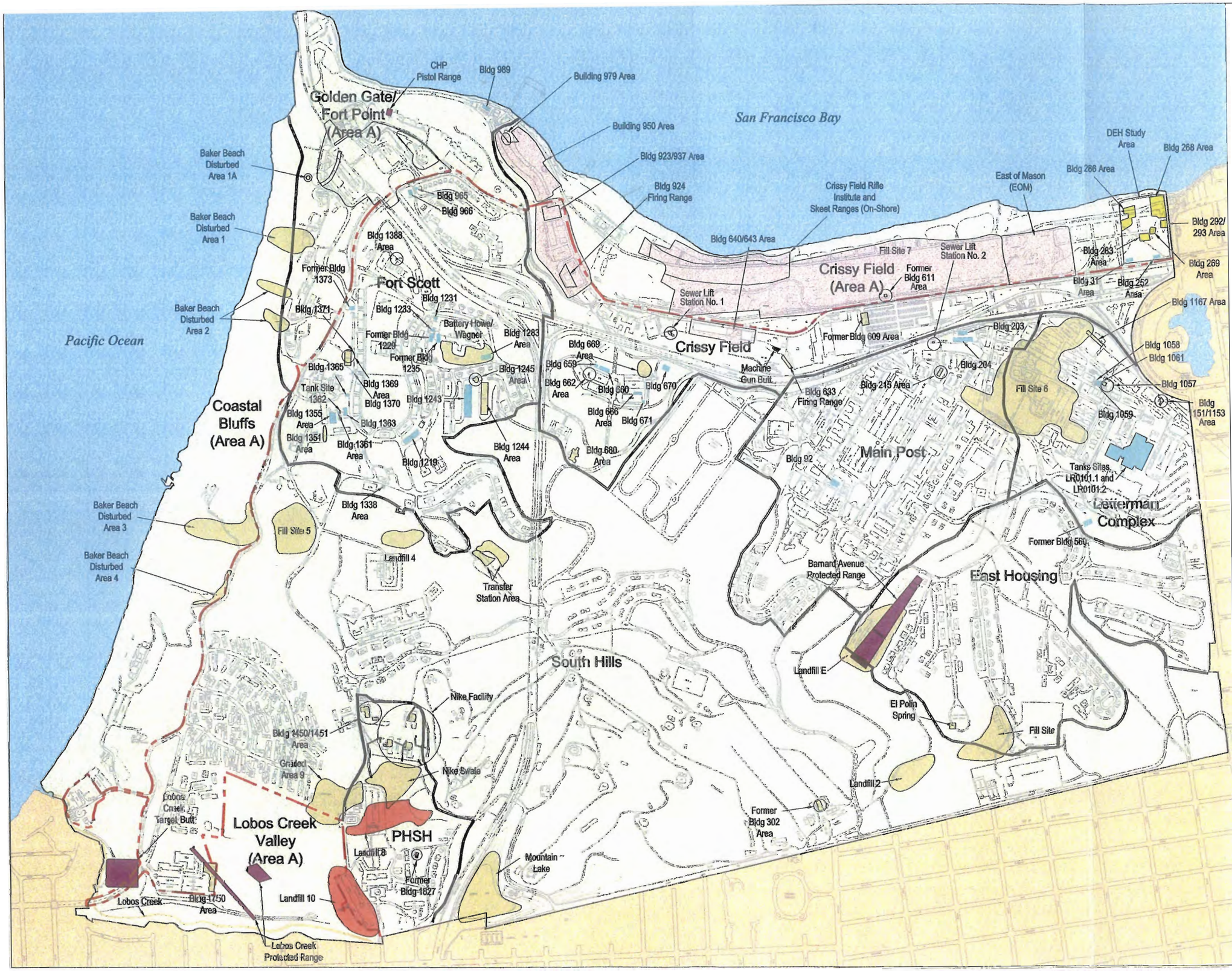
(Approximate Scale in Miles)

Erler & Kalinowski, Inc.

Vicinity Map

Presidio Trust
San Francisco, CA
September 2002
EKI A000003.04

Figure 2–1



N

0 800 1600

(Approximate Scale in Feet)

LEGEND

- Area A/B Boundary
- Presidio Planning Area or District Boundary
- OU1 Public Health Service Hospital Sites
- OU2 Main Installation Sites
- Firing Range Sites
- OU4 Crissy Field Area
- OU5 Directorate of Engineering and Housing
- OU6 Miscellaneous Sites
- OU7 Basewide Cumulative Effects

Notes:

1. All locations are approximate.
2. Basemap developed from site plan provided by the Presidio Trust.
3. PHSH is the Public Health Service Hospital.
4. "OU" is an "Operable Unit".
5. Site boundaries are approximate. For individual tank sites or smaller sites, the associated building is shaded.
6. The Army identified 35 additional potential chemical release sites. These sites are mapped in OU6, but need a site inspection to determine their status.

Erler & Kalinowski, Inc.

Operable Units being Addressed by The Presidio Trust

Presidio Trust
San Francisco, CA
October 2002
EKI A000003.04

Figure 2-2

3. CHEMICAL-SPECIFIC ARARS

3. CHEMICAL-SPECIFIC ARARS

This section identifies some potential chemical-specific ARARs that may be applicable to some Presidio sites. This discussion is not intended to be a complete evaluation of all potential ARARs for all sites at the Presidio; such an evaluation will be included in future decision documents. However, ARARs warrant discussion because the National Oil and Hazardous Substances Pollution Contingency Plan ("NCP") at 40 CFR §300.430(f)(1)(i)(A) provides that releases of hazardous substances at a site be cleaned up to meet ARARs, unless circumstances for a waiver exist. ARARs are used in conjunction with risk-based cleanup goals to establish cleanup levels as part of Remedial Action Objectives ("RAOs") for a site. According to U.S. EPA (1991b), "ARARs represent the minimum that a remedy must attain; it may sometimes be necessary, where there are multiple contaminants with potentially cumulative and synergistic effects, to go beyond what ARARs require to ensure that a remedy is protective."

If available, chemical–specific ARARs were used to establish cleanup levels for water and soil for protection of human health and the environment. Table 3-1 provides a summary of numerical values of potential chemical-specific ARARs for Presidio sites. Not all of these requirements will be an ARAR at every site; other location- or action-specific ARARs may also apply, and, in fact, may be more stringent than the chemical-specific ARARs listed. Section 3.1 addresses potential ARARs in water, seeps, and groundwater, and Section 3.2 addressees potential ARARs in soil. RWQCB Order 96-070 is a specific ARAR for petroleum sites that addresses petroleum hydrocarbons and related constituents in both soil and water; therefore ARARs for petroleum hydrocarbons are presented in Section 3.3. In the development of future decision documents, additional chemical-specific ARARs may be identified and used as cleanup levels.

3.1 POTENTIAL CHEMICAL-SPECIFIC ARARS FOR WATER

For groundwater and surface water, promulgated Maximum Contaminant Levels ("MCLs") or published action levels have been adopted as cleanup levels to protect human health due to groundwater ingestion (U.S. EPA, 2000d). These are listed in Table 3-1. Maximum Contaminant Level Goals ("MCLGs") are the level of a contaminant in drinking water below which there is no known or expected risk to health. MCLGs allow for a margin of safety and are non-enforceable public health goals. MCLGs are also listed in Table 3-1. MCLs are set as close to MCLGs as feasible using the best available treatment technology and taking cost into consideration.

The California Environmental Protection Agency's Office of Environmental Health Hazard Assessment ("OEHHA") has prepared Drinking Water Public Health Goals ("PHGs") for many contaminants in drinking water. In February 1999 OEHHA prepared a PHG for chromium in drinking water, setting a goal of 2.5 µg/L. In November 2001, the chromium PHG was withdrawn by OEHHA because the PHG was calculated using a

study that was determined to have flawed data and should not be used as a basis for health risk assessments. According to OEHHA's webpage, there is uncertainty regarding the carcinogenicity by the oral route. OEHHA is in the process of developing a PHG for hexavalent chromium ("Cr(VI)"). Like MCLGs, PHGs are not enforceable.

Promulgated water quality criteria were applied to existing and planned freshwater surface bodies, and groundwater that recharges surface water or emerges as seeps. Existing surface water bodies at the Presidio include Mountain Lake, Crissy Field wetlands, and Lobos Creek. In addition, Tennessee Hollow and Dragonfly Creek are recognized surface water resources of the Presidio and will be treated as such in applying cleanup levels. Water quality criteria adopted as cleanup levels for surface water and groundwater that recharges surface water at the Presidio are intended to protect freshwater aquatic organisms, marine organisms, and humans who may drink the water and consume fish or other organisms inhabiting the water bodies from chronic exposure to PCOCs. Water quality criteria adopted as cleanup levels for freshwater seeps at the Presidio are intended to protect freshwater aquatic organisms from chronic exposure to PCOCs. Seeps observed at the Presidio are not considered potential habitat that would support fish or other organisms that could be consumed by humans. Water quality criteria used to establish surface water, groundwater recharge to surface water, and seep cleanup levels are listed in Table 3-1 and were obtained from the following sources:

- RWQCB Water Quality Control Plan, San Francisco Bay Basin, ("Basin Plan") amended 16 April 1997.

- Title 40 of the Code of Federal Regulations ("CFR") §131.38, *Establishment of Numerical Criteria for Priority Toxic Pollutants for the State of California*, also known as the California Toxics Rule ("CTR").

3.2 POTENTIAL CHEMICAL-SPECIFIC ARARS FOR SOIL

Chemical-specific ARARs for soil are available for only a limited number of contaminants. Cleanup levels for lead, polychlorinated biphenyls ("PCBs"), and volatile organic compounds ("VOCs") in soil are based on the more stringent of ARARs and risk-based PRGs. Cleanup levels for petroleum hydrocarbons and related constituents in soil and water at the Presidio are derived from ARARs as described below. Cleanup levels for remaining PCOCs in soil are risk-based PRGs or, in the case of metals, background concentrations if naturally occurring levels of metals in soil are greater than PRGs. Background concentrations of metals in serpentinite, chert/shale, Colma Formation, and beach/dune sand are described in Section 6. Serpentinite, Colma Formation, and beach/dune sand are the main lithologies encountered at the Presidio. Chert/shale is believed to have been imported to the Presidio by the Army for use as fill material.

In its *Revised Interim Soil Lead Guidance for CERCLA Sites and RCRA Corrective Action Facilities* (U.S. EPA, 1994), U.S. EPA recommends using a screening level of 400 mg/kg of lead in soil for residential scenarios. The 5 January 2001 *Federal Register*

stated that effective 6 March 2001, the Toxic Substance Control Act ("TSCA") was amended to establish a hazard standard of 400 mg/kg lead in bare residential soil. A cleanup level of 400 mg/kg of lead in soil is being used as a not-to-exceed value for residential areas at the Presidio.[2]

Requirements governing cleanup of PCB-containing soil and wastes were broadened by amendments to TSCA in 1998. As part of these amendments, U.S. EPA added 40 CFR §761.61 to Subpart D of TSCA, which provides cleanup and disposal provisions for PCB-containing soil and other types of remediation wastes. This section of Subpart D sets cleanup levels for high occupancy areas (e.g., residence) at 1 mg/kg of PCBs in soil. The TSCA value of 1 mg/kg for PCBs in soil is compared with the Presidio-specific human health PRGs for PCBs (see Section 4). The more stringent of the ARAR of 1 mg/kg or the Presidio-specific human health PRGs for PCBs is being used as the human health cleanup level.

In December 2001 RWQCB (2001a) released interim final soil and groundwater risk-based screening levels ("RBSLs") for over 100 chemicals commonly found at sites where releases of hazardous substances have occurred. RBSLs are generally not cleanup levels. RBSLs are used to evaluate whether a chemical release may pose a risk at the site that warrants further investigation. In addition, RBSLs can be used, if appropriate, as cleanup levels if site-specific cleanup levels are not available.

For VOCs, the RBSLs were used to incorporate potential risks due to vapor intrusion into indoor air and protection of groundwater due to leaching to groundwater, in addition to direct contact with soil which is addressed by the Presidio-specific human health PRGs developed in Section 4. RBSL values for VOCs for indoor air and potential leaching to groundwater are summarized in Table 3-2.

3.3 POTENTIAL CHEMICAL-SPECIFIC ARARS FOR PETROLEUM HYDROCARBONS

RWQCB issued Order No. 96-070 - *Site Cleanup Requirements for the Cleanup of Petroleum Impacted Soil* to the Army in 1996 (RWQCB, 1996). In this order, the Tennessee Hollow riparian corridor, the Crissy Field wetlands, and a 150-foot buffer zone along the Crissy Field shoreline were identified as sensitive habitats requiring more stringent petroleum hydrocarbon cleanup levels than elsewhere on the Presidio. The area where more stringent cleanup levels apply to the Tennessee Hollow riparian corridor is designated as the freshwater ecological protection zone. The area where more stringent cleanup levels apply to the Crissy Field wetlands and shoreline is designated as the saltwater ecological protection zone.

[2] A Presidio-specific Preliminary Remediation Goal ("PRG") for lead in soil at residential sites has been developed in Section 4. This Presidio-specific PRG will be used as the maximum average lead concentration in soil at residential sites.

The Army conducted several studies and worked closely with RWQCB to develop cleanup levels for petroleum hydrocarbons and related constituents at the Presidio. Human health and ecological cleanup levels for soil and groundwater were developed by Montgomery Watson and presented in its *Fuel Product Action Level Development Report* ("FPALDR"), (Montgomery Watson, 1995). Soil cleanup levels in the FPADLR were subsequently adopted by the RWQCB in Order No. 96-070 for all areas of the Presidio except the freshwater and ecological protection zones. The RWQCB requested that the Army conduct bioassay studies to develop cleanup levels for the saltwater ecological protection zone. International Technology ("IT") Corporation (1997) conducted these studies on behalf of the Army and proposed saltwater and sediment cleanup levels for protection of marine organisms. The Army worked collaboratively with RWQCB to develop cleanup levels for the freshwater protection zone. RWQCB conducted bioassay studies, and Montgomery Watson (1999b) interpreted the results and reviewed toxicological data published in scientific literature, which led to the proposal of freshwater and sediment cleanup levels for protection of freshwater aquatic organisms. Cleanup levels for petroleum hydrocarbons and related constituents developed in connection with Order No. 96-070 have been adopted for the Presidio, and are listed in Table 3-3.

TABLES

TABLE 3-1
NUMERIC VALUES OF POTENTIAL CHEMICAL-SPECIFIC ARARs
FOR WATER AT PRESIDIO SITES (a)

Presidio of San Francisco, California

Potential Chemical of Concern	Clean Water Act					Safe Drinking Water Act		
	RWQCB Basin Plan Surface Water Quality Objectives		California Toxics Rule			Drinking Water Standards		
	Salinity Greater than 5 parts-per-thousand (µg/L); (b)	Salinity Less than 5 parts-per-thousand (µg/L); (b)	Freshwater (µg/L); (c)	Saltwater (µg/L); (c)	Human Health Risk (µg/L); (c)	Maximum Contaminant Levels ("MCLs") (µg/L); (d)	Maximum Contaminant Level Goals ("MCLGs") (µg/L); (d)	Secondary MCLs (µg/L); (d)
Inorganic Chemicals								
Antimony	- (e)	-	-	-	14	6	6	-
Arsenic	36	190	190	36	-	10	-	-
Barium	-	-	-	-	-	1,000	-	-
Beryllium	-	-	-	-	-	4	4	-
Cadmium	9.3	1.1 (f)	1.1 (f)	9.3	-	5	5	-
Trivalent Chromium	-	-	180	-	-	-	-	-
Hexavalent Chromium	50	11	11	50	-	-	-	-
Total Chromium	50	11	11	50	-	50 (g)	-	-
Cobalt	-	-	-	-	-	-	-	-
Copper	4.9	11.8 (f)	7	2.9	1,300	1,300 (h)	-	1,000
Cyanide	5	5.2	5	5.2	700	200	200	-
Lead	5.6	3.2 (f)	3.2 (f)	5.6	-	15 (h)	0	-
Tetraethyl lead	-	-	-	-	-	-	-	-
Mercury	0.025	0.025 (i)	0.025 (i)	0.025	0.05	2	2	-
Molybdenum	-	-	-	-	-	-	-	-
Nickel	8.3	158 (f)	56	7.1	610	100	-	-
Selenium	-	-	5	71	-	50	50	-
Silver	2.3	4.1 (f)	1.2	2.3	-	50 (m)	-	100
Thallium	-	-	-	-	1.7	2	0.5	-
Vanadium	-	-	-	-	-	-	-	-
Zinc	58	106 (f, j)	58	58	-	-	-	5,000
Semivolatile Organic Compounds								
Acenaphthene	-	-	-	-	1,200	-	-	-
Acenaphthylene	-	-	-	-	-	-	-	-
Anthracene	-	-	-	-	9,600	-	-	-
Benzo(a)anthracene	-	-	-	-	0.0044	0.1 (k)	0 (k)	-
Benzo(a)pyrene	-	-	-	-	0.0044	0.2	0	-
Benzo(b)fluoranthene	-	-	-	-	0.0044	0.2 (k)	0 (k)	-
Benzo(g,h,i)perylene	-	-	-	-	-	-	-	-
Benzo(k)fluoranthene	-	-	-	-	0.0044	-	-	-
Benzyl alcohol	-	-	-	-	-	-	-	-
Bis(2-ethylhexyl)phthalate	-	-	-	-	1.8	4	0	-
Chrysene	-	-	-	-	0.0044	-	-	-
Dibenzo(a,h)anthracene	-	-	-	-	0.0044	-	-	-
Dibenzofuran	-	-	-	-	-	-	-	-

TABLE 3-1
NUMERIC VALUES OF POTENTIAL CHEMICAL-SPECIFIC ARARs
FOR WATER AT PRESIDIO SITES (a)

Presidio of San Francisco, California

	Clean Water Act					Safe Drinking Water Act		
	RWQCB Basin Plan Surface Water Quality Objectives		California Toxics Rule			Drinking Water Standards		
Potential Chemical of Concern	Salinity Greater than 5 parts-per-thousand (µg/L); (b)	Salinity Less than 5 parts-per-thousand (µg/L); (b)	Freshwater (µg/L); (c)	Saltwater (µg/L); (c)	Human Health Risk (µg/L); (c)	Maximum Contaminant Levels ("MCLs") (µg/L); (d)	Maximum Contaminant Level Goals ("MCLGs") (µg/L); (d)	Secondary MCLs (µg/L); (d)
emivolatile Organic 'ompounds								
luoranthene	-	-	-	-	300	-	-	-
luorene	-	-	-	-	1,300	-	-	-
ideno(1,2,3-c,d)-pyrene	-	-	-	-	0.0044	-	-	-
-methylnaphthalene	-	-	-	-	-	-	-	-
-methylphenol (p-Cresol)	-	-	-	-	-	-	-	-
aphthalene	-	-	-	-	-	-	-	-
-doctriacontane	-	-	-	-	-	-	-	-
-hentriacontame	-	-	-	-	-	-	-	-
-nitrosodiphenylamine	-	-	-	-	5	-	-	-
-triacontane	-	-	-	-	-	-	-	-
entachlorophenol	-	-	15	7.9	0.28	1	0	-
henanthrene	-	-	-	-	-	-	-	-
henol	-	-	-	-	21,000	1 (m)	-	-
olycyclic aromatic ydrocarbons	0.031	0.031	-	-	-	-	-	-
yrene	-	-	-	-	960	-	-	-
'olatile Organic 'ompounds								
.cetone	-	-	-	-	-	-	-	-
romodichloromethane	-	-	-	-	0.56	80	0	-
-butanone (MEK)	-	-	-	-	-	-	-	-
'arbon disulfide	-	-	-	-	-	-	-	-
'arbon tetrachloride	-	-	-	-	0.25	0.5	0	-
'hlorodibromomethane	-	-	-	-	0.401	80	60	
'hloroform	-	-	-	-	-	80	0	
'hloromethane	-	-	-	-	-	-	-	-
,4-dichlorobenzene	-	-	-	-	400	5	5	5
,2-dichloroethane	-	-	-	-	0.38	0.5	0	-
,1-dichloroethene	-	-	-	-	0.057	6	6	-
-Isopropyltoluene (p-cymene)	-	-	-	-	-	-	-	-
Iethylene chloride	-	-	-	-	4.7	5	0	-
'etrachloroethene	-	-	-	-	0.8	5	0	-
,2,3-trichlorobenzene	-	-	-	-	-	-	-	-
,2,4-trichlorobenzene	-	-	-	-	-	70	70	-
'richloroethene	-	-	-	-	2.7	5	0	-
,1,1-trichloroethane	-	-	-	-	-	200	200	-
'richlorofluoromethane	-	-	-	-	-	150	-	-

TABLE 3-1
NUMERIC VALUES OF POTENTIAL CHEMICAL-SPECIFIC ARARs
FOR WATER AT PRESIDIO SITES (a)

Presidio of San Francisco, California

Potential Chemical of Concern	Clean Water Act					Safe Drinking Water Act		
	RWQCB Basin Plan Surface Water Quality Objectives		California Toxics Rule			Drinking Water Standards		
	Salinity Greater than 5 parts-per-thousand (µg/L); (b)	Salinity Less than 5 parts-per-thousand (µg/L); (b)	Freshwater (µg/L); (c)	Saltwater (µg/L); (c)	Human Health Risk (µg/L); (c)	Maximum Contaminant Levels ("MCLs") (µg/L); (d)	Maximum Contaminant Level Goals ("MCLGs") (µg/L); (d)	Secondary MCLs (µg/L); (d)
PCBs, Pesticides, and Herbicides								
PCBs	-	-	0.014	0.03	0.00017	0.5	0	-
Aldrin	-	-	-	-	0.00013	-	-	-
Chlordane	-	-	0.0043	0.09	0.00057	0.1	0	-
2,4-D	-	-	-	-	-	70	70	-
4,4'-DDD	-	-	-	-	0.00083	-	-	-
4,4'-DDE	-	-	-	-	0.00059	-	-	-
4,4'-DDT	-	-	0.001	0.001	0.00059	-	-	-
Dicamba	-	-	-	-	-	-	-	-
Dieldrin	-	-	0.056	0.0019	0.00014	-	-	0.5 (l)
Endosulfan	-	-	0.056	0.0087	110	-	-	-
Endosulfan Sulfate	-	-	-	-	-	-	-	-
Endrin	-	-	0.036	0.0023	0.76	2	2	-
Endrin Aldehyde	-	-	-	-	-	-	-	-
Endrin Ketone	-	-	-	-	-	-	-	-
Heptachlor	-	-	0.0038	0.0036	0.00021	0.01	0	-
Heptachlor Epoxide	-	-	0.0038	0.0036	0.0001	0.01	0	-
Isodrin	-	-	-	-	-	-	-	-
gamma-BHC (Lindane)	-	-	-	-	0.019	0.2	0.2	-
MCPP	-	-	-	-	-	-	-	-
Methoxychlor	-	-	-	-	-	40	40	-
Petroleum Hydrocarbons and Constituents								
Total TPH	-	-	-	-	-	-	-	-
TPH (as diesel)	-	-	-	-	-	-	-	-
TPH (as gasoline)	-	-	-	-	-	-	-	-
TPH (as fuel oil)	-	-	-	-	-	-	-	-
Benzene	-	-	-	-	1.2	1	0	-
Ethylbenzene	-	-	-	-	3,100	700	700	30 (k)
Toluene	-	-	-	-	6,800	150	-	40 (k)
Total xylenes	-	-	-	-	-	1,750	-	20 (k)
Methyl t-butyl ether (MTBE)	-	-	-	-	-	13	5	-

TABLE 3-1
NUMERIC VALUES OF POTENTIAL CHEMICAL-SPECIFIC ARARs
FOR WATER AT PRESIDIO SITES (a)

Presidio of San Francisco, California

es:

Numeric values for chemical-specific ARARs and TBCs are listed in this table.

µg/L = microgram per liter
mg/L = milligram per liter

Water quality objectives for surface waters are from Table 3-3 and 3-4 of RWQCB *Water Quality Control Plan, San Francisco Bay Basin*, amended 16 April 1997 ("Basin Plan"). Values are for chronic toxicity to aquatic organisms, except for polycyclic aromatic hydrocarbon criteria which are for protection of human health, based on setting the acceptable lifetime risk for cancer to one-in-a-million.

California Toxic Rule water quality criteria listed are freshwater and saltwater aquatic toxicity standards, using 4 days of continuous exposure. Human health standards are for one-in-a-million risk for consumption of water and organisms. Values are from 40 CFR §131.38, *Establishment of Numeric Criteria for Priority Toxic Pollutants for the State of California.*

MCLs, MCLGs, and secondary MCLs are obtained from *U.S. EPA Drinking Water Standards and Health Advisories Table*, Region IX, Drinking Water Office, dated February 2001. If California MCLs are more stringent than federal MCLs, the California values are shown.

Hyphen indicates no value is provided in the reference.

Value listed is a function of hardness. Value shown is based on a hardness of 100 mg/L as calcium carbonate. Hardness concentrations at the Presidio have ranged from 93 to 772 mg/L, with an average of 325 mg/L. The use of 100 mg/L results in conservative values for these metals.

According to the California Environmental Protection Agency's Office of Environmental Health Hazard Assessment ("OEHHA"), there is uncertainty regarding the carcinogenicity of chromium by the oral route.

Values for lead and copper are action levels that require treatment of drinking water.

U.S. EPA water quality criterion for mercury is 0.012 µg/L, which is below typical analytical method reporting limit of 0.025 µg/L. An objective of 0.012 ug/L is desirable.

Zinc value revised in 1997 amendments to RWQCB Basin Plan.

Proposed MCL.

Value corresponds to the California action level.

) Value corresponds to the RWQCB Basin Plan water quality objective for municipal supply.

TABLE 3-2
RISK-BASED SCREENING LEVELS FOR VOCS
AT PRESIDIO SITES (a)

Presidio of San Francisco, California

Potential Chemical of Concern	RWQCB Risk-Based Screening Levels ("RBSLs")			
	Vapor Intrusion		Groundwater Protection (Soil Leaching)	
	Residential Land Use Permitted (mg/kg); (b)	Industrial/ Commercial Land Use (mg/kg); (b)	Residential Land Use Permitted (mg/kg); (c)	Industrial/ Commercial Land Use (mg/kg); (c)
Volatile Organic Compounds				
Acetone	43	140	0.24	0.24
Bromodichloromethane	0.025	0.098	2.7	2.7
2-butanone (MEK)	- (d)	-	3.8	3.8
Carbon disulfide	-	-	-	-
Carbon tetrachloride	0.021	0.074	0.11	0.11
Chlorodibromomethane	-	-	8.3	8.3
Chloroform	0.17	0.58	0.88	0.88
Chloromethane	0.49	1.7	0.42	0.42
1,4-dichlorobenzene	0.13	0.49	0.59	0.59
1,2-dichloroethane	0.04	0.14	0.006	0.006
1,1-dichloroethene	0.018	0.062	1	1
p-Isopropyltoluene (p-cymene)	-	-	-	-
Methylene chloride	0.89	3.1	0.076	0.076
Tetrachloroethene	0.15	0.53	0.8	0.8
1,2,3-trichlorobenzene	-	-	-	-
1,2,4-trichlorobenzene	87	280	15	15
Trichloroethene	0.44	1.5	0.4	0.4
1,1,1-trichloroethane	76	220	8	8
Trichlorofluoromethane	-	-	-	-

Notes:

(a) Numeric values for volatile organic compounds ("VOCs") presented in this table are from *Application of Risk-Based Screening Levels and Decision Making to Sites with Impacted Soil and Groundwater ("RBSLs")*, Regional Water Quality Control Board, San Francisco Bay Region, Interim Final, December 2001. As stated in the text, RBSLs were used only for VOCs to consider leaching to groundwater (groundwater protection) and vapor intrusion into indoor air, in addition to direct contact with soil.

mg/kg = milligram per kilogram

(b) Vapor Intrusion RBSLs represent the soil concentration corresponding to the risk due to vapor intrusion of VOCs from soil into indoor air. Values obtained from Table E-1a from Volume II of the RBSLs. The values assume coarse grain soils.

(c) Groundwater Protection RBSLs are soil cleanup levels based on protection of drinking water resources via the leaching pathway. Values were obtained from Tables A-1 and A-2 from Volume II of the RBSLs. The listed value is from the Groundwater Protection (soil leaching) column, assuming groundwater is a drinking water resource.

(d) Hyphen indicates no value is provided in the reference.

TABLE 3-3
SITE CLEANUP REQUIREMENTS FOR PETROLEUM HYDROCARBONS AND RELATED CONSTITUENTS AT PRESIDIO SITES (a)

Presidio of San Francisco, California

Potential Chemical of Concern	Protection of Human Health			Protection of Ecological Receptors	Soil Cleanup Levels for Crissy Field	
	Residential (mg/kg); (b)	Maintenance (mg/kg); (b)	Recreational (mg/kg); (b)	Terrestrial Receptors (mg/kg); (b)	Greater than 5 feet above Groundwater (mg/kg); (b)	Less than 5 feet above Groundwater (mg/kg); (b)
Inorganic Chemicals						
Lead	- (c)	-	-	50	-	-
Semivolatile Organic Compounds						
Acenaphthene	-	-	-	-	-	-
Acenaphthylene	-	-	-	-	-	-
Anthracene	5,900	17,800	13,800	-	-	1,120
Benzo(a)anthracene	0.43	1.5	1	-	-	23
Benzo(a)pyrene	0.04	0.15	0.1	0.3	-	9
Benzo(b)fluoranthene	0.43	1.5	1	-	-	64
Benzo(g,h,i)perylene	620	1,700	1,400	-	-	19,500
Benzo(k)fluoranthene	0.43	1.5	1	-	-	64
Benzyl alcohol	-	-	-	-	-	-
Bis(2-ethylhexyl)phthalate	-	-	-	-	-	-
Chrysene	4.3	15	10	-	-	151
Dibenzo(a,h)anthracene	-	-	-	-	-	-
Dibenzofuran	-	-	-	-	-	-
Fluoranthene	820	2,300	1,900	-	-	1,160
Fluorene	770	2,300	1,800	-	-	220
Indeno(1,2,3-c,d)-pyrene	-	-	-	-	-	-
2-methylnaphthalene	-	-	-	-	-	-
4-methylphenol (p-Cresol)	-	-	-	-	-	-
Naphthalene	480	2,300	1,100	-	-	140
n-doctriacontane	-	-	-	-	-	-
n-hentriacontame	-	-	-	-	-	-
n-nitrosodiphenylamine	-	-	-	-	-	-
n-triacontane	-	-	-	-	-	-
Pentachlorophenol	-	-	-	-	-	-
Phenanthrene	600	1,700	1,400	-	-	410
Phenol	-	-	-	-	-	-
Polycyclic aromatic hydrocarbons	-	-	-	-	-	-
Pyrene	620	1,700	1,400	-	-	910

TABLE 3-3
SITE CLEANUP REQUIREMENTS FOR PETROLEUM HYDROCARBONS AND RELATED CONSTITUENTS AT PRESIDIO SITES (a)

Presidio of San Francisco, California

Potential Chemical of Concern	Protection of Human Health			Protection of Ecological Receptors	Soil Cleanup Levels for Crissy Field	
	Residential (mg/kg); (b)	Maintenance (mg/kg); (b)	Recreational (mg/kg); (b)	Terrestrial Receptors (mg/kg); (b)	Greater than 5 feet above Groundwater (mg/kg); (b)	Less than 5 feet above Groundwater (mg/kg); (b)
Petroleum Hydrocarbons and Constituents						
Total TPH	-	-	-	-	-	-
TPH (as diesel)	1,380	6,700	3,200	700	15,000	1,950
TPH (as gasoline)	1,030	5,900	2,400	610	5,000	1,690
TPH (as fuel oil)	1,900	9,400	4,500	980	15,000	2,730
Benzene	0.6	5	1.5	40	140	1
Ethylbenzene	840	6,600	1,900	125	60	19
Toluene	530	12,800	1,200	270	420	14
Total xylenes	1,080	109,000	2,500	55	180	4,340
Methyl t-butyl ether (MTBE)	-	-	-	-	-	-

TABLE 3-3
SITE CLEANUP REQUIREMENTS FOR PETROLEUM HYDROCARBONS AND RELATED CONSTITUENTS AT PRESIDIO SITES (a)

Presidio of San Francisco, California

Potential Chemical of Concern	Protection of Water Quality at Detectable Levels		Protection of Water Quality to Drinking Water Standards		Groundwater Quality Goals for Fuel Chemicals (µg/L); (d)
	Greater than 5 feet above Groundwater (mg/kg); (b)	Less than 5 feet above Groundwater (mg/kg); (b)	Greater than 5 feet above Groundwater (mg/kg); (b)	Less than 5 feet above Groundwater (mg/kg); (b)	
Inorganic Chemicals					
Lead	-	-	-	-	-
Semivolatile Organic Compounds					
Acenaphthene	-	-	-	-	-
Acenaphthylene	-	-	-	-	-
Anthracene	-	0.05	-	308	770
Benzo(a)anthracene	-	0.2	-	8	2
Benzo(a)pyrene	-	0.8	-	3	0.2
Benzo(b)fluoranthene	-	0.6	-	23	2
Benzo(g,h,i)perylene	-	2	-	5,040	150
Benzo(k)fluoranthene	-	0.6	-	23	2
Benzyl alcohol	-	-	-	-	-
Bis(2-ethylhexyl)phthalate	-	-	-	-	-
Chrysene	-	0.3	-	54	20
Dibenzo(a,h)anthracene	-	-	-	-	-
Dibenzofuran	-	-	-	-	-
Fluoranthene	-	0.05	-	316	300
Fluorene	-	0.05	-	60	300
Indeno(1,2,3-c,d)-pyrene	-	-	-	-	-
2-methylnaphthalene	-	-	-	-	-
4-methylphenol (p-Cresol)	-	-	-	-	-
Naphthalene	-	0.05	-	9	300
n-doctriacontane	-	-	-	-	-
n-hentriacontame	-	-	-	-	-
n-nitrosodiphenylamine	-	-	-	-	-
n-triacontane	-	-	-	-	-
Pentachlorophenol	-	-	-	-	-
Phenanthrene	-	0.05	-	86	230
Phenol	-	-	-	-	-
Polycyclic aromatic hydrocarbons	-	-	-	-	-
Pyrene	-	0.09	-	241	230

TABLE 3-3
SITE CLEANUP REQUIREMENTS FOR PETROLEUM HYDROCARBONS AND RELATED CONSTITUENTS AT PRESIDIO SITES (a)

Presidio of San Francisco, California

Potential Chemical of Concern	Protection of Water Quality at Detectable Levels		Protection of Water Quality to Drinking Water Standards		Groundwater Quality Goals for Fuel Chemicals (µg/L); (d)
	Greater than 5 feet above Groundwater (mg/kg); (b)	Less than 5 feet above Groundwater (mg/kg); (b)	Greater than 5 feet above Groundwater (mg/kg); (b)	Less than 5 feet above Groundwater (mg/kg); (b)	
Petroleum Hydrocarbons and Constituents					
Total TPH	-	-	-	-	-
TPH (as diesel)	15,000	7	15,000	115	880
TPH (as gasoline)	5,000	7	5,000	100	770
TPH (as fuel oil)	15,000	10	15,000	160	1,200
Benzene	140	0.005	140	0.005	1
Ethylbenzene	60	0.009	60	13	700
Toluene	420	0.005	420	1	150
Total xylenes	180	0.009	180	33	1,750
Methyl t-butyl ether (MTBE)	-	-	-	-	-

TABLE 3-3
SITE CLEANUP REQUIREMENTS FOR PETROLEUM HYDROCARBONS AND RELATED CONSTITUENTS AT PRESIDIO SITES (a)

Presidio of San Francisco, California

Potential Chemical of Concern	Point of Compliance Concentration for Marine Sediment "Saltwater Ecological Protection Zone" (mg/kg); (e)	Point of Compliance Concentrations for Seawater (µg/L); (e)	Point of Compliance Concentrations for Freshwater Sediment "Freshwater Ecological Protection Zone" (mg/kg); (f)	Point of Compliance Concentration for Freshwater (µg/L); (f)
Inorganic Chemicals				
Lead	-	-	-	-
Semivolatile Organic Compounds				
Acenaphthene	-	-	-	-
Acenaphthylene	-	-	-	-
Anthracene	-	-	-	-
Benzo(a)anthracene	-	-	-	-
Benzo(a)pyrene	-	-	-	-
Benzo(b)fluoranthene	-	-	-	-
Benzo(g,h,i)perylene	-	-	-	-
Benzo(k)fluoranthene	-	-	-	-
Benzyl alcohol	-	-	-	-
Bis(2-ethylhexyl)phthalate	-	-	-	-
Chrysene	-	-	-	-
Dibenzo(a,h)anthracene	-	-	-	-
Dibenzofuran	-	-	-	-
Fluoranthene	-	-	-	-
Fluorene	-	-	-	-
Indeno(1,2,3-c,d)-pyrene	-	-	-	-
2-methylnaphthalene	-	-	-	-
4-methylphenol (p-Cresol)	-	-	-	-
Naphthalene	-	-	-	-
n-doctriacontane	-	-	-	-
n-hentriacontame	-	-	-	-
n-nitrosodiphenylamine	-	-	-	-
n-triacontane	-	-	-	-
Pentachlorophenol	-	-	-	-
Phenanthrene	-	-	-	-
Phenol	-	-	-	-
Polycyclic aromatic hydrocarbons	-	-	-	-
Pyrene	-	-	-	-

TABLE 3-3
SITE CLEANUP REQUIREMENTS FOR PETROLEUM HYDROCARBONS AND RELATED CONSTITUENTS AT PRESIDIO SITES (a)

Presidio of San Francisco, California

Potential Chemical of Concern	Point of Compliance Concentration for Marine Sediment "Saltwater Ecological Protection Zone" (mg/kg); (e)	Point of Compliance Concentrations for Seawater (µg/L); (e)	Point of Compliance Concentrations for Freshwater Sediment "Freshwater Ecological Protection Zone" (mg/kg); (f)	Point of Compliance Concentration for Freshwater (µg/L); (f)
Petroleum Hydrocarbons and Constituents				
Total TPH	-	-		
TPH (as diesel)	-	-	-	-
TPH (as gasoline)	11.6	1,200	140	443
TPH (as fuel oil)	144	2,200	-	-
Benzene	50	510	0.79	463
Ethylbenzene	5	43	15	845
Toluene	260	1,000	3	490
Total xylenes	22	130	5.7	318
Methyl t-butyl ether (MTBE)	190	4,400	-	-

TABLE 3-3
SITE CLEANUP REQUIREMENTS FOR PETROLEUM HYDROCARBONS AND RELATED CONSTITUENTS AT PRESIDIO SITES (a)

Presidio of San Francisco, California

tes:

) Numeric values for chemical-specific ARARs and TBCs are listed in this table.

µg/L = microgram per liter
mg/kg = milligram per kilogram

) Values are from Tables 1 through 5 of RWQCB Order No. 96-070, *Site Cleanup Requirements for the Cleanup of Petroleum Impacted Soils, U.S. Army, Presidio of San Francisco, California*, dated 15 May 1996.

) Hyphen indicates no value is provided in the reference.

) Values from Table E-12 of Montgomery Watson *Final Fuel Product Action Level Development Report, Presidio of San Francisco, San Francisco, California,* dated October 1995. Residential exposure scenario was used to determine groundwater cleanup levels listed.

) Values from Table 16 of IT Corporation *Petroleum Hydrocarbon Bioassay and Point-of-Compliance Concentration Determinations*, *Saltwater Ecological Protection Zone, Presidio of San Francisco, California*, dated December 1997.

) Values from Tables 5 and 6 of Montgomery Watson *Development of Point of Compliance Concentrations ("POCCs") for Gasoline in Surface Waters and Sediments of the Proposed Freshwater Stream*, dated May 1999.

4. HUMAN HEALTH RISK-BASED PRGS FOR SOIL

4. HUMAN HEALTH RISK-BASED PRGS FOR SOIL

According to U.S. EPA (1991a), under the NCP, there are two sources that can be used to establish cleanup levels that remedial actions must achieve under a Record of Decision ("ROD") or RAP. These sources consist of chemical-specific ARARs and risk-based PRGs. Chemical-specific ARARs are discussed in Section 3. In the absence of such ARARs, risk-based PRGs have been derived that take into account existing and planned uses at the Presidio. This section presents risk-based human health PRGs for PCOCs. Section 5 presents risk-based ecological PRGs for PCOCs.

4.1 PURPOSE OF RISK-BASED PRGs

U.S. EPA (1991a) defines PRGs as "concentration goals for individual chemicals for specific medium and land use combinations at CERCLA sites." In other words, PRGs are potential cleanup levels that are derived specifically for a site. PRGs take into account the PCOCs that have been identified, the media that have been impacted, most likely future land use where PCOCs have been detected, and the pathways and conditions under which exposure may occur.

Chemical-specific ARARs generally do not exist that adequately consider the scenarios under which humans may be exposed to PCOCs in soil, and ecological receptors may be exposed to PCOCs in soil and sediment at the Presidio. Consequently, site-specific PRGs for protection of human health and the environment to PCOCs in soil and sediment have been derived in this document. The methods used to derive human health and ecological PRGs incorporate comments made by DTSC (2001, 2000b, 2000d) RWQCB (verbal), and other key stakeholders.

4.2 HUMAN HEALTH PRGs FOR SOIL

Chronic exposure to PCOCs may cause non-carcinogenic and carcinogenic effects in humans. PRGs are calculated by establishing an acceptable or target risk level that will protect individuals from the non-carcinogenic and carcinogenic effects of PCOCs. The procedures and assumptions used to derive human health PRGs for soil are discussed in Sections 4.2.1 through 4.2.10.

4.2.1 Potentially Exposed Populations

Children and adults comprise the populations that may be potentially exposed to PCOCs at the Presidio. Children may be exposed through residential or recreational activities. In addition to residential and recreational activities, adults may be exposed as a result of commercial or industrial activities at the Presidio. The recreational or commercial/industrial exposure scenarios should also be protective of populations with short-term exposures, such as tourists or construction workers, respectively. For

example, subsurface utility repairs and earthwork construction typically take a few weeks to one year. Although the ingestion rate for construction and utility workers is commonly assumed to be 480 mg/day (compared with 50 mg/day assumed for the commercial/industrial population), the lifetime soil exposure is significantly lower for the construction worker because the exposure duration is so much shorter (e.g., a few weeks to one year compared with 25 years). Therefore, the PRGs developed for the commercial/industrial exposure scenario should be protective of construction workers and other workers with shorter-term exposures to soil.

Section 7.1.1 discusses the areas of the Presidio where residential, recreational, and commercial/industrial uses are likely to occur and identifies the appropriate cleanup levels based upon anticipated activity patterns that will protect the most sensitive individuals using these areas.

4.2.2 Potential Human Health Exposure Pathways

Metals and polycyclic aromatic hydrocarbons ("PAHs") are the predominant non-petroleum PCOCs in soil at chemical release sites at the Presidio. As shown on Figure 4-1 and discussed in Table 4-1, individuals that come in contact with soil at Presidio sites are likely to be exposed to PCOCs as a result of inadvertently ingesting impacted soil or absorbing chemicals from soil that becomes stuck to their skin. Inhalation of PCOCs is not considered to be a significant exposure pathway. Metals and PAHs are not volatile and inhalation of chemical-containing soil or dust is estimated to result in less than 3 percent of the potential total exposure to PCOCs when compared with the ingestion and dermal absorption pathways.[3] For VOCs, volatilization and vapor intrusion into indoor air is a potentially significant exposure pathway (i.e., for residential and commercial/industrial populations only).

Other potential exposure pathways include consumption of produce grown in gardens at the Presidio, leaching of chemicals in soil to groundwater, and ingestion, inhalation, or absorption of PCOCs that may be present in groundwater or surface water. Of these pathways, leaching to groundwater, ingestion of groundwater, and ingestion of water and fish or other organisms inhabiting surface bodies at the Presidio are considered to be a potentially significant exposure pathways.

The process of chemicals in soil leaching to groundwater is chemical-specific. Metals generally bind strongly to soil and are not prone to significant leaching unless conditions are very acidic. For petroleum compounds and related constituents (including benzene, toluene, ethylbenzene, xylenes, and PAHs), the cleanup levels established in RWQCB Order 96-070 (and as presented in Tables 3-3 and 7-5) include protection of groundwater

[3] EKI calculated the residential PRG for several compounds including and excluding the inhalation pathway. Arsenic was used as a conservative test case because it is significantly more toxic via the inhalation route compared with the oral route (i.e., slope factor of 12 $(mg/kg\text{-}day)^{-1}$ for inhalation versus 1.5 $(mg/kg\text{-}day)^{-1}$ for ingestion). Assuming a fugitive dust concentration of 0.05 mg/m^3 and breathing rates of 10 and 20 m^3/day for children and adults, respectively, the inhalation pathway accounts for 3 percent of the total exposure. For other compounds where the ingestion and inhalation slope factors are the same, the inhalation pathway comprises less than 1 percent of the exposure.

resources via the leaching pathway. Therefore, cleanup levels that consider leaching were derived for VOCs and petroleum compounds and related constituents.

As discussed in Section 7.3.4, the water ingestion and fish or other aquatic organism ingestion pathways are taken into account by adoption of chemical-specific ARARs as cleanup levels. The ARARs being used as cleanup levels include MCLs and aquatic criteria for protection of human health, where applicable. Although MCLs are not explicitly risk-based numbers like MCLGs, they are set as close to MCLGs as feasible using the best available treatment technology and taking cost into consideration. The aquatic criteria for protection of human health are risk-based values that include ingestion of water and consumption of aquatic organisms.

Exposure to PCOCs in homegrown produce, and dermal contact with surface water and seeps are not considered to be significant exposure pathways. Landscaping at the Presidio is maintained by the Trust, and residents and commercial tenants are not permitted to plant vegetation. Consequently, most produce grown at the Presidio would be restricted to plants in containers or in community gardens at locations specifically approved for such use by the Trust. Similarly, no appreciable dermal contact with PCOCs in surface water is expected. Swimming and wading are not allowed in Mountain Lake, Crissy Field wetlands, or Lobos Creek, and it is anticipated that these activities will be restricted in the proposed riparian corridor associated with Tennessee Hollow. Swimming and wading are prohibited in these areas because of possible damage to critical and sensitive habitats, and the need to protect potable supply in the case of Lobos Creek. Although residential and recreational users of the Presidio may have contact with water at seeps, the exposure frequency and duration are anticipated to be very limited.

4.2.3 Non-carcinogen Target Risk Level

As defined by U.S. EPA (1989a), non-carcinogenic effects are organ-specific and are manifested only after reaching a certain chemical dose. As a result, a range of exposures exists from zero to some finite value that can be tolerated with essentially no chance of adverse effects. The upper bound on this tolerance range or "safe dose" is identified as a reference dose ("RfD").

U.S. EPA (1989a) estimates the potential for non-carcinogenic effects by comparing a chronic exposure level (i.e., greater than 7 years) over a specified time period with a reference dose derived for a similar exposure period. This ratio of exposure to toxicity is called the hazard index ("HI"). Consistent with the NCP at 40 CFR §300.430(e)(2)(i)(A)(1), U.S. EPA (1991a) established the standard default non-carcinogenic target risk level to correspond to a HI of unity (i.e., 1). This target risk level is equivalent to the degree of chemical exposure from all significant exposure pathways in a given medium below which it is unlikely for even sensitive populations to experience adverse health effects. A target HI of 1 was used to derive PRGs for soil at the Presidio based upon non-carcinogenic effects.

4.2.4 Carcinogen Target Risk Level

Carcinogenesis, unlike non-carcinogenic effects, is generally thought to be a phenomenon for which risk evaluation based on presumption of a threshold is inappropriate (U.S. EPA, 1989a). For carcinogens, U.S. EPA assumes that a small number of molecular events can evoke changes in a single cell that can lead to uncontrolled cellular proliferation and eventually to a clinical state of disease. This hypothesized mechanism for carcinogenesis is referred to as "non-threshold" because there is not believed to be a level of exposure to such a chemical that does not pose a finite probability, however small, of generating a carcinogenic response. No dose is thought to be risk-free. Therefore, in evaluating cancer risks, a safe dose cannot be estimated.

For carcinogenic effects, U.S. EPA uses a two-part evaluation. In the first part of this evaluation, the chemical is assigned a weight-of-evidence classification, which is related to how convincingly the scientific studies demonstrate that the chemical is carcinogenic to humans. In the second part of this evaluation, a slope factor ("SF") is calculated, which is a measure of the chemical's potency. U.S. EPA (1989a) estimates risks as the incremental probability of an individual developing cancer over a lifetime as a result of exposure to the potential carcinogen. This probability is defined as the incremental or excess lifetime cancer risk. The SF is the 95 percent upper confidence limit on the slope of the low-dose linear portion of the dose-response curve as estimated by the multistage linear model.

The SF directly relates the incremental risk of cancer over a lifetime (i.e., 70 years) to the degree of chemical exposure averaged over a lifetime. U.S. EPA (1991a) established the standard default carcinogenic target risk level to correspond to a one-in-one million (i.e., 10^{-6}) incremental risk of an individual developing cancer over a lifetime as a result of exposure to the potential carcinogen from all significant exposure pathways for a given medium. Consistent with the NCP at 40 CFR §300.430(e)(2)(i)(A)(2), U.S. EPA (1991c) strives for cleanup of Superfund sites that attain a 10^{-4} to 10^{-6} target risk range. A target risk of 10^{-6} was used to derive PRGs for soil at the Presidio based upon carcinogenic effects.

4.2.5 Lead Target Risk Level

Ingested or inhaled lead is distributed primarily to the blood, soft tissue (e.g., bone marrow, liver, and brain), and mineralizing tissue (e.g., bones and teeth) of the body. Lead interferes with normal cell function and with a number of physiologic processes, including damage to the central nervous system, inhibition of the body's ability to make hemoglobin, disruption of the endocrine system that may lead to impaired tooth and bone development, and damage to the kidneys (California Department of Health Services, 1997). The United States Department of Health and Human Services, Agency for Toxic Substances and Disease Registry ("ATSDR") also indicates that lead readily crosses the placenta. According to ATSDR (1995), lead not only affects the viability of the fetus, but development as well. Development consequences of prenatal exposure to low levels of lead include reduced birth weight and premature birth. Reports have shown

lead to be a teratogen and carcinogen in animals. However, studies in humans have failed to show a relationship between lead concentrations and congenital malformations, and the association of lead levels and cancer observed in humans remains uncertain (ATSDR, 1995).

Blood lead concentration is an integrated measure of internal dose resulting from the total exposure of releases of lead at a site and naturally occurring concentrations of lead in the environment. The DTSC has established that the concentration of concern for lead in blood is 10 micrograms per deciliter ("µg/dl") at the 99th percentile, i.e., a one percent chance that blood lead concentrations will be greater than 10 µg/dl (DTSC, 1996). The 99th percentile is believed to be protective because it establishes an upper bound level for lead exposure that is akin to U.S. EPA's reasonable maximum exposure ("RME") approach (U.S. EPA, 1989a).

4.2.6 Human Health Toxicity Values

Following the hierarchy established in DTSC's Preliminary Endangerment Assessment ("PEA") Guidance Manual, toxicity values used to calculate human health PRGs were obtained from the following references in the order listed:

- Carcinogenic slope factors were obtained from California Environmental Protection Agency, Office of Environmental Health Hazard Assessment ("OEHHA") website table entitled *California Cancer Potency Factors*, dated December 2000.

- U.S. EPA's computerized Integrated Risk Information System ("IRIS").

- U.S. EPA's Health Effects Assessment Summary Tables ("HEAST"), dated July 1997.

- U.S. EPA's National Center for Environmental Assessment ("NCEA"), Draft Risk Assessment Issue Papers for individual chemicals.

OEHHA's technical documents and website represent the agency's most current stance on non-carcinogenic and carcinogenic toxicity values. U.S. EPA maintains the IRIS computerized database. Toxicity values on IRIS have undergone review and verification by U.S. EPA program offices prior to publication. Toxicity values were obtained from HEAST if none were available from OEHHA or IRIS. HEAST is not updated as regularly as IRIS and may contain interim toxicity values. NCEA was the final information source consulted. Toxicity values obtained from NCEA have not been verified by U.S. EPA and are considered provisional. The sources for chemical-specific toxicity values used to calculate human health PRGs are presented on the tables in which PRGs are calculated.

No published toxicity values were found for copper, acenaphthylene, benzo(g,h,i)perylene, 2-(4-chloro-o-to(yl)oxy)propionic acid ("MCPP"), phenanthrene,

and 2-methylnaphthalene. Consequently, human health PRGs for these PCOCs could not be calculated. For VOCs and pesticides, which have no published toxicity values, surrogates were used to calculate human health PRGs. The values for 1,2,4-trichlorbenzene were used as a surrogate for 1,2,3-trichlorbenzene, and the values for isopropyl benzene were used as a surrogate for p-isopropyltoluene (also known as p-cymene). The values for endosulfan were used as a surrogate for endosulfan sulfate, the values for endrin were used as a surrogate for endrin aldehyde and endrin ketone, the values for heptachlor were used as a surrogate for heptachlor epoxide, and the values for aldrin were used as a surrogate for isodrin because isodrin is an isomer of aldrin.

4.2.7 Calculation of Human Health PRGs for PCOCs Other than Lead in Soil

Except for lead, PRGs were calculated for PCOCs using the hazard and risk equations based on those presented in DTSC's PEA guidance. PRGs for lead were calculated as described in Section 4.2.10 due to the different toxicological behavior of lead. For other PCOCs, PRGs based on non-carcinogenic effects ("PRG_{nc}") were calculated using the following equation:

$$PRG_{nc} = \frac{RfD \times \text{Target HI of 1}}{\left(\text{Ingestion}_{child} + \text{Dermal}_{child}\right)}$$

PRGs based on carcinogenic effects ("PRG_cs") were calculated using the following equation:

$$PRG_c = \frac{\text{Target Risk Level of } 10^{-6}}{SF \times \left(\text{Ingestion}_{child} + \text{Dermal}_{child} + \text{Ingestion}_{adult} + \text{Dermal}_{adult}\right)}$$

$Ingestion_{child}$, $Dermal_{child}$, $Ingestion_{adult}$, and $Dermal_{adult}$ (i.e., direct contact) are estimates of exposure that may result from swallowing and absorbing PCOCs through the skin of a child and adult, respectively. Exposure to PCOCs for various children and adult populations at the Presidio were estimated by use of the equations listed below:

where:

$$\text{Ingestion}_{child} = \frac{IR_{child} \times FI \times EF \times ED \times 10^{-6}\ kg/mg}{BW_{child} \times AT_c}$$

$$\text{Dermal}_{child} = \frac{SA_{child} \times AF_{child} \times ABS \times EF \times ED \times 10^{-6}\ kg/mg}{BW_{child} \times AT_c}$$

$$\text{Ingestion}_{adult} = \frac{IR_{adult} \times FI \times EF \times ED \times 10^{-6}\ kg/mg}{BW_{adult} \times AT_c}$$

$$\text{Dermal}_{\text{adult}} = \frac{\text{SA}_{\text{adult}} \times \text{AF}_{\text{adult}} \times \text{ABS} \times \text{EF} \times \text{ED} \times 10^{-6}\,\text{kg/mg}}{\text{BW}_{\text{adult}} \times \text{AT}_{\text{c}}}$$

Definitions of the terms or exposure parameters within the equations are presented in Table 4-2.

For VOCs under the residential and commercial/industrial exposure scenarios, the PRGs also incorporate potential risks due to vapor intrusion into indoor air. Carcinogenic and non-carcinogenic PRGs based on the vapor intrusion pathway ("$\text{PRG}_{\text{c-inh}}$" and "$\text{PRG}_{\text{nc-inh}}$") were obtained from Table E-1a of the RWQCB's RBSLs (RWQCB, 2001b).[4] For compounds that do not have tabulated RBSLs, inhalation PRGs were calculated using the Johnson and Ettinger model (Version 2.3, dated March 2001) with the default exposure assumptions and soil parameters used to calculate the RBSLs. The printouts from the Johnson and Ettinger model runs are included in Appendix E.

The PRGs accounting for the direct contact exposure pathways (i.e., dermal contact and ingestion) were combined with those for inhalation using the following equations:

$$\text{PRG}_{\text{c-combined}} = \frac{\text{PRG}_{\text{c}} \times \text{PRG}_{\text{c-inh}}}{\text{PRG}_{\text{c}} + \text{PRG}_{\text{c-inh}}}$$

$$\text{PRG}_{\text{nc-combined}} = \frac{\text{PRG}_{\text{nc}} \times \text{PRG}_{\text{nc-inh}}}{\text{PRG}_{\text{nc}} + \text{PRG}_{\text{nc-inh}}}$$

PRGs for VOCs also need to consider leaching to groundwater ("Groundwater Protection PRGs"). As discussed further in Section 4.2.9, Groundwater Protection PRGs were also obtained from the RWQCB's RBSL document (Table A-1of Volume II) (RWQCB, 2001b).

4.2.8 Human Health Exposure Parameters

In accordance with DTSC PEA Guidance Manual, the same exposure parameter values were used to calculate non-carcinogenic and carcinogenic PRGs except for the averaging time ("AT"). Regarding this parameter, DTSC (1999) states the following:

> AT is 70 yr for cancer risk, but is set equal to 6 years for non-carcinogenic hazard to be consistent with the exposure duration for non-carcinogenic hazards. Thus, all non-carcinogenic exposures are estimated for a child, which are the receptors with the greatest estimated exposures.

[4] The RBSLs generally use default values from the Johnson and Ettinger model. One exception is the indoor air exchange rate. The RBSLs use a residential air exchange rate of 2 per hour, instead of the default of 0.45 per hour, because air exchange rates are anticipated to be higher in the San Francisco Bay Area (i.e., temperate climate and houses with limited insulation). Due to the linear relationship between the calculated soil concentration and the air exchange rate, the difference is only a factor of 4.

As shown in Table 4-2, where available, exposure parameters are default factors obtained from U.S. EPA or DTSC guidance for residential, recreational, and commercial/industrial populations, or are calculated based on published values. Recreational exposure frequency is the only parameter where a default factor does not exist and professional judgement had to be used to estimate a value. The exposure frequency, or number of days per year that an individual may engage in recreational activities (e.g., sightseeing, hiking, picnicking, or participating in athletic or cultural events) at the Presidio is assumed to be 150 days per year (i.e., 3 days per week).

4.2.9 Human Health PRGs for PCOCs Other than Lead in Soil

Tables 4-3, 4-4, and 4-5 summarize the non-carcinogenic and carcinogenic PRGs for residential, recreational, and commercial/industrial exposure at the Presidio, respectively. PRGs proposed as cleanup levels are the lower values of the PRG_{nc} and PRG_{c} for each potential chemical of concern.

For VOCs, the non-carcinogenic and carcinogenic direct contact PRGs calculated in Tables 4-3, 4-4, and 4-5 are carried forward to Table 4-6. In Table 4-6, the indoor air exposure soil concentrations are factored into the PRG_{nc} and PRG_{c} using the formulas described above to account for potential risks due to vapor intrusion into indoor air. The values for $PRG_{nc\text{-}inh}$ and $PRG_{c\text{-}inh}$ (Vapor Intrusion PRGs) were obtained from Table E-1a of the RBSLs, or the Johnson and Ettinger model (Appendix E). The Combined PRGs calculated in Table 4-6 are carried forward to Table 4-7.

In Table 4-7, the Combined PRGs for VOCs are compared to the respective Groundwater Protection PRGs obtained from Tables A-1 or A-2 of the RWQCB's RBSL document (RWQCB, 2001b). The Groundwater Protection PRGs are soil cleanup levels based on protection of drinking water resources via the leaching to groundwater pathway. For VOCs for which groundwater protection numbers are not listed in the RBSL document, Groundwater Protection PRGs were calculated using formulas within the RBSL document. The lower of the Combined PRG or the Groundwater Protection PRG is retained as the human health PRG for the respective VOC for each land use.

As noted above, the Vapor Intrusion PRGs and Groundwater Protection PRGs are from the RWQCB's RBSL document and are not site-specific. Therefore, if VOCs are found at a Presidio site, VOC cleanup levels may be re-calculated to be site-specific. Site-specific factors that could affect the calculation include the type of soil, depth to groundwater, presence of buildings, and the number and types of VOCs present in soil. Any recalculation of PRGs for VOCs would be conducted in conjunction with discussions with regulatory agencies. Other identified COCs at the Presidio generally are not mobile or volatile (e.g., metals, PCBs, and pesticides); therefore, Vapor Intrusion PRGs and Groundwater Protection PRGs were not developed for these other chemical classes.

4.2.10 Human Health PRGs for Lead in Soil

PRGs for residential, recreational and commercial/industrial users of the Presidio were calculated using the DTSC Lead Spread Version 7.0 computer model. PRGs were established such that the lead concentration in the blood of these potentially exposed individuals was less than 10 μg/dl at the 99th percentile, taking into account the intake of lead from releases at Presidio sites, and lead naturally occurring in air, water, food, and soil.

DTSC default factors of 0.028 μg/m^3 and 1.1 kg food/day (at 3.1 μg lead/kg food) were used to account for lead naturally occurring in air and food, respectively, for all populations at the Presidio. The concentration of lead in tap water was established as 2.4 μg/L for residential populations at the Presidio and 15 μg/L for recreational and commercial/industrial users. A value of 2.4 μg/L is the 95 percent upper confidence limit of the average lead concentration measured in tap water at Presidio residences in 1998, 1999, and 2000. The tap water data are included in Appendix A. A value of 15 μg/L is the DTSC default factor, which is based on the Action Level for lead in drinking water.[5] The dietary source of lead assumes that residential, recreational, and commercial/industrial users will not consume produce, if any, grown at impacted sites.[6] A site-specific background concentration of 66 mg/kg of lead was assumed for soil at the Presidio. This concentration reflects the naturally occurring concentration of lead found in serpentinite soil at the Presidio. Naturally occurring or background concentrations of metals in soil and water at the Presidio are discussed in Section 6.

The frequency that residential and recreational users are exposed to naturally occurring or background concentrations of lead in air, water, and food was assumed to be equivalent to the concentrations identified above for 7 days per week. For recreational users, the exposure frequency to background concentrations of lead in soil was assumed to occur 4 days per week (i.e., when those users are assumed to be off-site). Consistent with the assumptions used to calculate PRGs for PCOCs with non-carcinogenic and carcinogenic effects, the exposure frequency to lead in soil and fugitive dust while at the Presidio was taken to be 3 days per week (i.e., 150 days per year) for recreational users and 7 days per week for residential populations. The lead PRG for commercial/industrial users was calculated assuming an exposure frequency of 5 days per week, as specified by DTSC (1996). Exposures of commercial/industrial users to background concentrations of lead in air, water, and food were assumed to be equivalent DTSC default factors. Consistent with the assumptions used to calculate PRGs for other PCOCs, the exposure frequency to lead in soil and fugitive dust while at the Presidio was taken to be 5 days per week for commercial/industrial users.

Table 4-8 summarizes the lead intakes for residential, recreational and commercial/industrial users. As shown in this table, lead concentrations of 370 mg/kg,

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[5] The background level of lead in drinking water for recreational and commercial/industrial users was not established as the site-specific value of 2.4 μg/L because a significant portion of their daily drinking water may come from off-site sources.

[6] Use restrictions prohibiting the in-ground planting of home grown produce are already in place at the Presidio.

500 mg/kg and 3,500 mg/kg in soil at the Presidio potentially cause blood lead to increase to 10 μg/dl in residential, recreational, and commercial/industrial users, respectively, based upon the values of exposure parameters and frequencies assumed. Copies of computer spreadsheets used to calculate PRGs for lead in soil are included in Appendix A. Recreational and commercial/industrial PRGs have been established at 500 mg/kg and 3,500 mg/kg for lead in soil. The residential cleanup level for lead in soil has been established as a not-to-exceed value of 400 mg/kg, based on the chemical-specific ARARs discussed in Section 3.2, and a maximum average concentration of 370 mg/kg, based on the site-specific PRG.

TABLES

TABLE 4-1
EXPOSED POPULATIONS AND EXPOSURE PATHWAYS USED TO DEVELOP PRGs

Presidio of San Francisco, California

Potentially Exposed Populations and Significant Exposure Pathways	Rationale
Residential Use (Children & Adults)	
• Ingestion of Soil • Dermal Contact with Soil	Residential children and adults may be directly exposed to residual chemicals in soil in backyards and areas near houses. Thus, ingestion of soil and dermal contact with soil are considered potentially complete exposure pathways. Ingestion of chemicals in homegrown produce is not considered a significant pathway for residents because landscaping at the Presidio is maintained by the Trust. Residents are not permitted to plant vegetation. Consequently, most produce grown at the Presidio would be in community gardens at locations specifically designated by the Trust.
• Inhalation of VOCs in Indoor Air	The primary non-petroleum potential chemicals of concern ("PCOCs") at the Presidio are metals and polycyclic aromatic hydrocarbons. Inhalation of PCOCs on soil particulates accounts for only 1 to 2 percent of total exposure to PCOCs. Therefore, inhalation of chemicals is not considered to be a significant exposure pathway for non-volatile PCOCs and is not included in the development of preliminary remediation goals ("PRGs"). Inhalation of VOCs via the vapor intrusion pathway is considered a complete pathway.
• Ingestion of Water (Addressed through MCLs as Cleanup Levels)	Exposure to chemicals of concern in groundwater through drinking water is considered a potentially complete pathway and will be addressed by adopting Maximum Contaminant Levels ("MCLs") or action levels as cleanup levels. Swimming and wading are prohibited in Mountain Lake, Crissy Field wetlands, and Lobos Creek. Dermal contact with or incidental ingestion of surface water and sediment is not considered to be a significant exposure pathway for residents. Residents may have periodic contact with water at seeps; however, the exposure is anticipated to be limited because the seeps generally are small and shallow, and difficult to access. Some of the seeps are ephemeral. Contact with water at seeps is not considered to be a significant exposure pathway.

TABLE 4-1
EXPOSED POPULATIONS AND EXPOSURE PATHWAYS USED TO DEVELOP PRGs

Presidio of San Francisco, California

Potentially Exposed Populations and Complete Exposure Pathways	Rationale
Recreational Use (Children & Adults)	
• Ingestion of Soil • Dermal Contact with Soil	Children and adults recreating in open areas of the Presidio may be directly exposed to residual PCOCs. Thus, ingestion of soil and dermal contact with soil are considered potentially complete exposure pathways. The primary non-petroleum PCOCs at the Presidio are metals and polycyclic aromatic hydrocarbons. Inhalation of PCOCs on soil particulates accounts for only 1 to 2 percent of total exposure to PCOCs. Inhalation of non-volatile PCOCs is not considered to be a significant exposure pathway. In addition, recreational users of the Presidio are assumed to be primarily outdoors. Therefore, vapor intrusion of VOCs to indoor air is considered to be an incomplete pathway.
• No Significant Water Exposure Pathways Identified	Swimming and wading are prohibited in Mountain Lake, Crissy Field wetlands, and Lobos Creek. Dermal contact with or incidental ingestion of surface water and sediment is not considered to be a significant exposure pathway for recreational users. Recreational users of the Presidio may have periodic contact with water at seeps; however, the exposure is anticipated to be limited because the seeps generally are small and shallow, and difficult to access. Some of the seeps are ephemeral. Contact with water at seeps is not considered to be a significant exposure pathway.

TABLE 4-1
EXPOSED POPULATIONS AND EXPOSURE PATHWAYS USED TO DEVELOP PRGs

Presidio of San Francisco, California

Potentially Exposed Populations and Complete Exposure Pathways	Rationale
Commercial/Industrial Use (Adults)	
• Ingestion of Soil • Dermal Contact with Soil	Commercial/industrial workers may be directly exposed to residual chemicals at the Presidio. Thus, ingestion of soil and dermal contact with soil are considered potentially complete exposure pathways.
• Inhalation of VOCs in Indoor Air	Inhalation of PCOCs on soil particulates accounts for only 1 to 2 percent of total exposure to PCOCs. Therefore, inhalation of non-volatile PCOCs is not considered a significant exposure pathway. Vapor intrusion of VOCs to indoor air is also considered a complete pathway.
• Ingestion of Water (Addressed through MCLs as Cleanup Levels)	Exposure to PCOCs in groundwater through drinking water is considered a potentially complete exposure pathway and will be addressed by adopting MCLs or action levels as cleanup levels. Commercial/industrial workers are not anticipated to be contacting surface water at the Presidio. Thus, dermal contact with or incidental ingestion of surface water and sediment is not considered to be a complete exposure pathway.

TABLE 4-2
EXPOSURE FACTORS USED TO CALCULATE HUMAN HEALTH PRELIMINARY REMEDIATION GOALS FOR SOIL

Presidio of San Francisco, California

Exposure Parameter	Units	Default or Assumed Value	Reference (a)
Averaging Time (AT)			
Carcinogenic	days	27,375	U.S. EPA, 1997
Non-carcinogenic			
Residential/Recreational	days	2,190	U.S. EPA, 1991; DTSC, 1996
Commercial/Industrial	days	9,125	U.S. EPA, 1991; DTSC, 1996
Exposure Frequency (EF)			
Residential	days/year	350	U.S. EPA, 1991; DTSC, 1996
Recreational	days/year	150	Professional Judgment
Commercial/Industrial	days/year	250	U.S. EPA, 1991; DTSC, 1996
Exposure Duration (ED)			
Residential/Recreational			
Carcinogenic	years	6 (child) + 24 (adult)	U.S. EPA, 1991; DTSC, 1996
Non-carcinogenic	years	6 (child)	U.S. EPA, 1991; DTSC, 1996
Commercial/Industrial			
Carcinogenic and Non-carcinogenic	years	25	U.S. EPA, 1991; DTSC, 1996
Body Weight (BW)			
Adult	kg	70	U.S. EPA, 1991; DTSC, 1996
Child	kg	15	U.S. EPA, 1991; DTSC, 1996
Soil Ingestion Rate (IR)			
Adult - Residential/Recreational	mg/day	100	U.S. EPA, 1997; DTSC, 1996
Child - Residential/Recreational	mg/day	200	U.S. EPA, 1997; DTSC, 1996
Adult - Commercial/Industrial	mg/day	50	U.S. EPA, 1997
Fraction of Soil Ingested (FI)	-	1	U.S. EPA, 1989; DTSC, 1996
Skin Surface Area			
Adult - Residential/Recreational	cm^2/day	5,800 (b)	DTSC, 1999
Child - Residential/Recreational	cm^2/day	2,900 (c)	U.S. EPA, 1998
Adult - Commercial/Industrial	cm^2/day	3,400 (d)	U.S. EPA, 1997
Soil-to-Skin Adherence Factor (AF)	-		
Adult - Residential/Recreational	mg/cm^2	0.23 (e)	U.S. EPA, 1998
Child - Residential/Recreational	mg/cm^2	0.30	U.S. EPA, 1998
Adult - Commercial/Industrial	mg/cm^2	0.12 (f)	U.S. EPA, 1998

TABLE 4-2
EXPOSURE FACTORS USED TO CALCULATE HUMAN HEALTH PRELIMINARY REMEDIATION GOALS FOR SOIL

Presidio of San Francisco, California

Exposure Parameter	Units	Default or Assumed Value	Reference (a)
Skin Absorption Factor (ABS)			
Metals	-	0.01	DTSC, 1999
Arsenic	-	0.03	DTSC, 1999
Cadmium	-	0.001	DTSC, 1999
Polycyclic Aromatic Hydrocarbons	-	0.15	DTSC, 1999
Volatile Organics	-	0.10	DTSC, 1999
Polychlorinated Biphenyls	-	0.15	DTSC, 1999
Pesticides	-	0.05	DTSC, 1999

Notes:

(a) References for exposure parameter values are as follows:

- U.S. EPA. 25 March 1991. *Risk Assessment Guidance for Superfund, Volume 1: Human Health Evaluation Manual, Supplemental Guidance, Standard Default Exposure Factors.* Interim Final. OSWER Directive 9285.6-03.
- U.S. EPA. December 1989. *Risk Assessment Guidance for Superfund, Volume 1: Human Health Evaluation Manual (Part A).* Interim Final. Office of Emergency and Remedial Response. EPA/540/1-89/002.
- U.S. EPA. August 1997. *Exposure Factors Handbook Volume I General Factors: Principles and Applications.* Office of Research and Development. EPA 600/P-95/002F.
- U.S. EPA. May 1998. *Risk Assessment Guidance for Superfund Volume 1: Human Health Evaluation Manual, Supplemental Guidance Dermal Risk Assessment.* Interim Guidance. Office of Emergency Response. NCEA-W-0364.
- DTSC. August 1996. *Supplemental Guidance for Human Health Multimedia Risk Assessments of Hazardous Waste Sites and Permitted Facilities.*
- DTSC. June 1999. *Preliminary Endangerment Assessment Guidance Manual.* Second Printing.

(b) Average skin exposure for men and women's heads, forearms, hands, and lower legs to chemicals of concern in soil while participating in recreational activities. Exposure factor assumes residential and recreational users at the Presidio wear short-sleeved shirts and shorts.

(c) Skin exposure for children's heads, forearms, hands, lower legs, and feet to chemicals of concern in soil. Exposure factor assumes children at the Presidio wear short-sleeved shirts, shorts, and are bare footed.

(d) Average skin exposure for men and women's heads, forearms, and hands to chemicals of concern in soil while performing commercial/industrial activities. Exposure factor assumes workers at the Presidio wear short-sleeved shirts and long pants.

(e) Average of the soil-to-skin adherence factors given for rugby player in wet soil and in dry soil.

(f) Average soil-to-skin adherence factor given for grounds keeper, landscaper, irrigation installer, gardener, archaeologist construction worker, utility worker and heavy equipment operator.

TABLE 4-3
HUMAN HEALTH PRELIMINARY REMEDIATION GOALS FOR SOIL BASED ON RESIDENTIAL USE

Presidio of San Francisco, California

Potential Chemical of Concern	Carcinogenic Oral Slope Factor (mg/kg-day)$^{-1}$	Slope Factor (a)	Non-carcinogenic Oral Reference Dose (mg/kg-day)	Reference Dose (b)	Dermal Absorption Factor (c)	Carcinogenic Risk Based PRG (mg/kg); (d)	Non-carcinogenic Risk Based PRG (mg/kg); (d)	Proposed PRG (mg/kg); (e)
Inorganic Chemicals								
Antimony	- (f)	-	0.0004	IRIS	0.01	-	29	29
Arsenic	1.5	OEHHA	0.0003	IRIS	0.03	0.36	20	0.36
Barium	-	-	0.07	IRIS	0.01	-	5,000	5,000
Beryllium	-	-	0.002	IRIS	0.01	-	140	140
Cadmium	0.38	OEHHA	0.0005	IRIS	0.001	1.7	37	1.7
Chromium (Cr(VI) and Cr(III))	5.3E-04	OEHHA (g)	2	IRIS	0.01	1,200	140,000	1,200
Cobalt	-	-	0.06	NCEA	0.01	-	4,000	4,000
Copper	-	-	(h)	(h)	-	-	-	-
Cyanide	-	-	0.02	IRIS	0.10	-	1,000	1,000
Lead (i)	-	-	-	-	-	-	-	400
Tetraethyl Lead	-	-	0.0000001	IRIS	0.10	-	0.0052	0.0052
Mercury	-	-	0.0003	IRIS	0.01	-	20	20
Molybdenum	-	-	0.0050	IRIS	0.01	-	360	360
Nickel	-	-	0.02	IRIS	0.01	-	1,400	1,400
Selenium	-	-	0.005	IRIS	0.01	-	360	360
Silver	-	-	0.005	IRIS	0.01	-	360	360
Thallium	-	-	0.00008	IRIS (j)	0.01	-	5.7	5.7
Vanadium	-	-	0.009	IRIS	0.01	-	650	650
Zinc	-	-	0.3	IRIS	0.01	-	22,000	22,000
Semivolatile Organic Compounds								
Acenaphthene	-	-	0.06	IRIS	0.15	-	2,700	2,700
Acenaphthylene	-	-	-	-	-	-	-	-
Anthracene	-	-	0.3	IRIS	0.15	-	14,000	14,000
Benzo(a)anthracene	1.2	OEHHA	-	-	0.15	0.27	-	0.27
Benzo(a)pyrene	12	OEHHA	-	-	0.15	0.027	-	0.027

TABLE 4-3
HUMAN HEALTH PRELIMINARY REMEDIATION GOALS FOR SOIL BASED ON RESIDENTIAL USE

Presidio of San Francisco, California

Potential Chemical of Concern	Carcinogenic Oral Slope Factor (mg/kg-day)$^{-1}$	Slope Factor (a)	Non-carcinogenic Oral Reference Dose (mg/kg-day)	Reference Dose (b)	Dermal Absorption Factor (c)	Carcinogenic Risk Based PRG (mg/kg); (d)	Non-carcinogenic Risk Based PRG (mg/kg); (d)	Proposed PRG (mg/kg); (e)
Semivolatile Organic Compounds (cont.)								
Benzo(b)fluoranthene	1.2	OEHHA	-	-	0.15	0.27	-	0.27
Benzo(g,h,i)perylene	-	-	-	-	-	-	-	-
Benzo(k)fluoranthene	1.2	OEHHA	-	-	0.15	0.27	-	0.27
Benzyl Alcohol	-	-	0.3	HEAST	0.15	-	14,000	14,000
Chrysene	0.12	OEHHA	-	-	0.15	2.7	-	2.7
Dibenzo(a,h)anthracene	4.1	OEHHA	-	-	0.15	0.078	-	0.078
Dibenzofuran	-	-	0.02	IRIS	0.15	-	910	910
Fluoranthene	-	-	0.04	IRIS	0.15	-	1,800	1,800
Fluorene	-	-	0.04	IRIS	0.15	-	1,800	1,800
Indeno(1,2,3-c,d)pyrene	1.2	OEHHA	-	-	0.15	0.27	-	0.27
2-methylnaphthalene	-	-	-	-	-	-	-	-
4-methylphenol (p-Cresol)	-	-	0.005	HEAST	0.10	-	260	260
Naphthalene	-	-	0.02	IRIS	0.15	-	910	910
n-Nitrosodiphenylamine	0.009	OEHHA	-	-	0.10	43	-	43
Pentachlorophenol	0.081	OEHHA	0.03	IRIS	0.10	5	1,600	5
Phenanthrene	-	-	-	-	-	-	-	-
Phenol	-	-	0.6	IRIS	0.15	-	27,000	27,000
Pyrene	-	-	0.03	IRIS	0.15	-	1,400	1,400
Volatile Organic Compounds (k)								
Acetone	-	-	0.1	IRIS	0.10	-	5,200	See Table 4-6
2-butanone (MEK)	-	-	0.6	IRIS	0.10	-	31,000	See Table 4-6
Carbon disulfide	-	-	0.1	IRIS	0.10	-	5,200	See Table 4-6
1,4-dichlorobenzene	0.0054	OEHHA	0.03	HEAST	0.10	71	1,600	See Table 4-6
p-Isopropyltoluene (p-cymene)	-	-	0.1	IRIS (l)	0.1	-	5,200	See Table 4-6
Methylene Chloride	0.014	OEHHA	0.06	IRIS	0.10	27	3,100	See Table 4-6

TABLE 4-3
HUMAN HEALTH PRELIMINARY REMEDIATION GOALS FOR SOIL BASED ON RESIDENTIAL USE

Presidio of San Francisco, California

Potential Chemical of Concern	Carcinogenic Oral Slope Factor $(mg/kg\text{-}day)^{-1}$	Slope Factor (a)	Non-carcinogenic Oral Reference Dose (mg/kg-day)	Reference Dose (b)	Dermal Absorption Factor (c)	Carcinogenic Risk Based PRG (mg/kg); (d)	Non-carcinogenic Risk Based PRG (mg/kg); (d)	Proposed PRG (mg/kg); (e)
Volatile Organic Compounds (cont.)								
1,2,3-trichlorobenzene	0.0036	(m)	0.01	(m)	0.1	110	520	See Table 4-6
1,2,4-trichlorobenzene	0.0036	OEHHA	0.01	IRIS	0.1	110	520	See Table 4-6
Trichlorofluoromethane	-	-	0.30	IRIS	0.10	-	16,000	See Table 4-6
1,1,1-trichloroethane	-	-	0.29	NCEA (n)	0.10	-	15,000	See Table 4-6
PCBs, Pesticides, and Herbicides								
PCBs (Aroclor 1254)	2	OEHHA (o)	0.00002	IRIS	0.15	0.16	1.0	0.16
Aldrin	17	OEHHA	0.00003	IRIS	0.05	0.029	1.8	0.029
alpha-BHC	2.7	OEHHA	-	-	0.05	0.180	-	0.18
beta-BHC	1.5	OEHHA	-	-	0.05	0.32	-	0.32
delta-BHC	2.7	(p)	-	-	0.05	0.180	-	0.18
Chlordane	1.3	OEHHA	0.0005	IRIS	0.05	0.37	31	0.37
2,4-D	-	-	0.01	IRIS	0.05	-	620	620
Dicamba	-	-	0.03	IRIS	0.05	-	1,800	1,800
4,4'-DDD	0.24	OEHHA	-	-	0.05	2.0	-	2.0
4,4'-DDE	0.34	OEHHA	-	-	0.05	1.4	-	1.4
4,4'-DDT	0.34	OEHHA	0.0005	IRIS	0.05	1.4	31	1.4
Dieldrin	16	OEHHA	0.00005	IRIS	0.05	0.030	3.1	0.030
Endosulfan	-	-	0.006	IRIS	0.05	-	370	370
Endosulfan Sulfate	-	-	0.006	(q)	0.05	-	370	370
Endrin	-	-	0.0003	IRIS	0.05	-	18	18
Endrin Aldehyde	-	-	0.0003	(q)	0.05	-	18	18
Endrin Ketone	-	-	0.0003	(q)	0.05	-	18	18
gamma-BHC (Lindane)	1.1	OEHHA	0.0003	IRIS	0.05	0.44	18	0.44
Heptachlor	4.1	OEHHA	0.0005	IRIS	0.05	0.12	31	0.12
Heptachlor Epoxide	5.5	OEHHA	0.00001	IRIS	0.05	0.088	1	0.088

TABLE 4-3
HUMAN HEALTH PRELIMINARY REMEDIATION GOALS FOR SOIL BASED ON RESIDENTIAL USE

Presidio of San Francisco, California

Potential Chemical of Concern	Carcinogenic Oral Slope Factor $(mg/kg\text{-}day)^{-1}$	Slope Factor (a)	Non-carcinogenic Oral Reference Dose (mg/kg-day)	Reference Dose (b)	Dermal Absorption Factor (c)	Carcinogenic Risk Based PRG (mg/kg); (d)	Non-carcinogenic Risk Based PRG (mg/kg); (d)	Proposed PRG (mg/kg); (e)
PCBs, Pesticides, and Herbicides (cont.)								
Isodrin	17	(r)	0.00003	(r)	0.05	0.029	-	0.029
MCPP	-	-	-	-	-	-	-	-
Methoxychlor	-	-	0.005	IRIS	0.05	-	310	310

Notes:

(a) Carcinogenic slope factors were obtained from California Environmental Protection Agency, Office of Environmental Health Hazard Assessment ("OEHHA") website table entitled *California Cancer Potency Factors*, dated March 2001. U.S. EPA Integrated Risk Information System ("IRIS") was used as a secondary reference.

(b) Chronic reference doses were obtained from IRIS, U.S. EPA's Health Effects Assessment Summary Tables ("HEAST"), dated July 1997, and U.S. EPA's National Center for Environmental Assessment ("NCEA") Draft Risk Assessment Issue Papers for individual chemicals.

(c) Soil absorption factors obtained from California Environmental Protection Agency, Department of Toxic Substances Control ("DTSC"), *Endangerment Assessment Guidance Manual*, dated June 1999.

(d) Exposure factors used to calculate carcinogenic and non-carcinogenic preliminary remediation goals ("PRGs") are summarized in Table 4-2. PRGs are based upon a carcinogenic target risk level of one-in-one million (i.e., 10^{-6}) incremental risk of an individual developing cancer over a lifetime, and a non-carcinogenic target risk level that corresponds to a hazard index of 1.

(e) Where both carcinogenic and non-carcinogenic PRGs are available, the proposed PRG is the lesser of the two values.

(f) Hyphen indicates that a value is not available or cannot be calculated.

(g) At the Presidio, Cr(VI) comprises 0.0055 to 0.28 percent of the total chromium in serpentinite (Montgomery Watson, 1999). By analogy to the U.S. EPA PRG tables (U.S. EPA, October 2000), OEHHA's oral slope factor of 0.19 $(mg/kg\text{-}d)^{-1}$ for hexavalent chromium was reduced by a factor of 0.0028.

(h) According to HEAST, the toxicity data for copper are inadequate for calculation of an RfD.

(i) The residential cleanup level for lead in soil has been established as a not-to-exceed value of 400 mg/kg, based on chemical-specific ARARs and a maximium average concentration of 370 mg/kg, based on the site-specific PRG. Refer to text for discussion of methodology used to derive the human health PRG for lead.

(j) Reference dose for thallium chloride was used.

TABLE 4-3
HUMAN HEALTH PRELIMINARY REMEDIATION GOALS FOR SOIL BASED ON RESIDENTIAL USE

Presidio of San Francisco, California

Notes (contd):

(k) PRGs for VOCs are adjusted in Tables 4-6 and 4-7, respectively, to account for potential risks due to vapor intrusion into indoor air and potential leaching to groundwater.

(l) Oral reference dose not available for p-isopropyltoluene. The value for isopropylbenzene was used as a surrogate.

(m) Oral slope factors and reference doses not available for 1,2,3-trichlorobenzene. The values for 1,2,4-trichlorobenzene were used as a surrogate.

(n) In the absence of an oral chronic reference dose or oral slope factor, the respective inhalation value was used.

(o) OEHHA's California Cancer Potency Factor table lists a slope factor of 5 $(mg/kg\text{-}day)^{-1}$ for PCBs. However, OEHHA's Consolidated Table of OEHHA/ARB Approved Risk Assessment Health Values (dated 13 September 2001) and IRIS list the oral slope factor for PCBs as 2 $(mg/kd\text{-}day)^{-1}$. Based on discussions with Laurie Monserrat and David Siegel with OEHHA, the oral slope factor of 2 $(mg/kg\text{-}day)^{-1}$ is the most current value and would be accepted in risk assessments reviewed by OEHHA.

(p) An oral slope factor was not available for delta-BHC. The respective slope factor for alpha-BHC is used.

(q) Oral reference doses were not available for Endosulfin Sulfate, Endrin Aldehyde, or Endrin Ketone. The respective reference doses for Endosulfin is used for Endosulfin Sulfate, and Endrin is used for Endrin Aldehyde and Endrin Ketone.

(r) Isodrin is an isomer of aldrin. Oral slope factor and reference dose for aldrin were used to calculate isodrin PRGs.

TABLE 4-4
HUMAN HEALTH PRELIMINARY REMEDIATION GOALS FOR SOIL BASED ON RECREATIONAL USE

Presidio of San Francisco, California

Potential Chemical of Concern	Carcinogenic Oral Slope Factor $(mg/kg\text{-}day)^{-1}$	Slope Factor (a)	Non-carcinogenic Oral Reference Dose (mg/kg-day)	Reference Dose (b)	Dermal Absorption Factor (c)	Carcinogenic Risk Based PRG (mg/kg); (d)	Non-carcinogenic Risk Based PRG (mg/kg); (d)	Proposed PRG (mg/kg); (e)
Inorganic Chemicals								
Antimony	- (f)	-	0.0004	IRIS	0.01	-	70	70
Arsenic	1.5	OEHHA	0.0003	IRIS	0.03	0.88	48	0.88
Barium	-	-	0.07	IRIS	0.01	-	12,000	12,000
Beryllium	-	-	0.002	IRIS	0.01	-	350	350
Cadmium	0.38	OEHHA	0.0005	IRIS	0.001	4.2	91	4.2
Chromium (Cr(VI) and Cr(III))	5.3E-04	OEHHA (g)	2	IRIS	0.01	2,800	350,000	2,800
Cobalt	-	-	0.06	NCEA	0.01	-	10,000	10,000
Copper	-	-	(h)	(h)	-	-	-	-
Cyanide	-	-	0.02	IRIS	0.10	-	2,500	2,500
Lead (i)	-	-	-	-	-	-	-	500
Tetraethyl Lead	-	-	0.0000001	IRIS	0.10	-	0.013	0.013
Mercury	-	-	0.0003	IRIS	0.01	-	52	52
Molybdenum	-	-	0.0050	IRIS	0.01	-	870	870
Nickel	-	-	0.02	IRIS	0.01	-	3,500	3,500
Selenium	-	-	0.005	IRIS	0.01	-	870	870
Silver	-	-	0.005	IRIS	0.01	-	870	870
Thallium	-	-	0.00008	IRIS (j)	0.01	-	14	14
Vanadium	-	-	0.009	IRIS	0.01	-	1,600	1,600
Zinc	-	-	0.3	IRIS	0.01	-	52,000	52,000
Semivolatile Organic Compounds								
Acenaphthene	-	-	0.06	IRIS	0.15	-	6,600	6,600
Acenaphthylene	-	-	-	-	-	-	-	-
Anthracene	-	-	0.3	IRIS	0.15	-	33,000	33,000
Benzo(a)anthracene	1.2	OEHHA	-	-	0.15	0.65	-	0.65
Benzo(a)pyrene	12	OEHHA	-	-	0.15	0.065	-	0.065

TABLE 4-4
HUMAN HEALTH PRELIMINARY REMEDIATION GOALS FOR SOIL BASED ON RECREATIONAL USE

Presidio of San Francisco, California

Potential Chemical of Concern	Carcinogenic Oral Slope Factor (mg/kg-day)$^{-1}$	Slope Factor (a)	Non-carcinogenic Oral Reference Dose (mg/kg-day)	Reference Dose (b)	Dermal Absorption Factor (c)	Carcinogenic Risk Based PRG (mg/kg); (d)	Non-carcinogenic Risk Based PRG (mg/kg); (d)	Proposed PRG (mg/kg); (e)
Semivolatile Organic Compounds (cont.)								
Benzo(b)fluoranthene	1.2	OEHHA	-	-	0.15	0.65	-	0.65
Benzo(g,h,i)perylene	-	-	-	-	-	-	-	-
Benzo(k)fluoranthene	1.2	OEHHA	-	-	0.15	0.65	-	0.65
Benzyl Alcohol	-	-	0.3	HEAST	0.10	-	38,000	38,000
Chrysene	0.12	OEHHA	-	-	0.15	6.5	-	6.5
Dibenzo(a,h)anthracene	4.1	OEHHA	-	-	0.15	0.19	-	0.19
Dibenzofuran	-	-	0.02	IRIS	0.15	-	2,200	2,200
Fluoranthene	-	-	0.04	IRIS	0.15	-	4,400	4,400
Fluorene	-	-	0.04	IRIS	0.15	-	4,400	4,400
Indeno(1,2,3-c,d)pyrene	1.2	OEHHA	-	-	0.15	0.65	-	0.65
2-methylnaphthalene	-	-	-	-	-	-	-	-
4-methylphenol (p-Cresol)	-	-	0.005	HEAST	0.10	-	640	640
Naphthalene	-	-	0.02	IRIS	0.15	-	2,200	2,200
n-nitrosodiphenylamine	0.009	OEHHA	-	-	0.10	104	-	104
Pentachlorophenol	0.081	OEHHA	0.03	IRIS	0.10	12	3,800	12
Phenanthrene	-	-	-	-	-	-	-	-
Phenol	-	-	0.60	IRIS	0.10	-	76,000	76,000
Pyrene	-	-	0.03	IRIS	0.15	-	3,300	3,300
Volatile Organic Compounds (k)								
Acetone	-	-	0.1	IRIS	0.10	-	13,000	See Table 4-6
2-butanone (MEK)	-	-	0.6	IRIS	0.10	-	76,000	See Table 4-6
Carbon disulfide	-	-	0.1	IRIS	0.10	-	13,000	See Table 4-6
1,4-dichlorobenzene	0.0054	OEHHA	0.03	HEAST	0.10	173	3,800	See Table 4-6
p-Isopropyltoluene (p-cymene)	-	-	0.1	IRIS (l)	0.1	-	13,000	See Table 4-6
Methylene Chloride	0.014	OEHHA	0.06	IRIS	0.10	67	7,600	See Table 4-6

TABLE 4-4
HUMAN HEALTH PRELIMINARY REMEDIATION GOALS FOR SOIL BASED ON RECREATIONAL USE

Presidio of San Francisco, California

Potential Chemical of Concern	Carcinogenic Oral Slope Factor $(mg/kg\text{-}day)^{-1}$	Slope Factor (a)	Non-carcinogenic Oral Reference Dose (mg/kg-day)	Reference Dose (b)	Dermal Absorption Factor (c)	Carcinogenic Risk Based PRG (mg/kg); (d)	Non-carcinogenic Risk Based PRG (mg/kg); (d)	Proposed PRG (mg/kg); (e)
Volatile Organic Compounds (cont.)								
1,2,3-trichlorobenzene	0.0036	(m)	0.01	(m)	0.1	260	1,300	See Table 4-6
1,2,4-trichlorobenzene	0.0036	OEHHA	0.01	IRIS	0.1	260	1,300	See Table 4-6
Trichlorofluoromethane	-	-	0.30	IRIS	0.10	-	38,000	See Table 4-6
1,1,1-trichloroethane	-	-	0.29	NCEA (n)	0.10	-	37,000	See Table 4-6
PCBs, Pesticides, and Herbicides								
PCBs (Aroclor 1254)	2	OEHHA (o)	0.00002	IRIS	0.15	0.39	2.2	0.39
Aldrin	17	OEHHA	0.00003	IRIS	0.05	0.07	4.5	0.07
alpha-BHC	2.7	OEHHA	-	-	0.05	0.44	-	0.44
beta-BHC	1.5	OEHHA	-	-	0.05	0.79	-	0.79
delta-BHC	2.7	(p)	-	-	0.05	0.44	-	0.44
Chlordane	1.3	OEHHA	0.0005	IRIS	0.05	0.91	75	0.91
2,4-D	-	-	0.01	IRIS	0.05	-	1,500	1,500
Dicamba	-	-	0.03	IRIS	0.05	-	4,500	4,500
4,4'-DDD	0.24	OEHHA	-	-	0.05	4.9	-	4.9
4,4'-DDE	0.34	OEHHA	-	-	0.05	3.5	-	3.5
4,4'-DDT	0.34	OEHHA	0.0005	IRIS	0.05	3.5	75	3.5
Dieldrin	16	OEHHA	0.00005	IRIS	0.05	0.074	7.5	0.074
Endosulfan	-	-	0.006	IRIS	0.05	-	900	900
Endosulfan Sulfate	-	-	0.006	(q)	0.05	-	900	900
Endrin	-	-	0.0003	IRIS	0.05	-	45	45
Endrin Aldehyde	-	-	0.0003	(q)	0.05	-	45	45
Endrin Ketone	-	-	0.0003	(q)	0.05	-	45	45
gamma-BHC (Lindane)	1.1	OEHHA	0.0003	IRIS	0.05	1.1	45	1.1
Heptachlor	4.1	OEHHA	0.0005	IRIS	0.05	0.29	75	0.29
Heptachlor Epoxide	5.5	OEHHA	0.00001	IRIS	0.05	0.21	2	0.21

TABLE 4-4
HUMAN HEALTH PRELIMINARY REMEDIATION GOALS FOR SOIL BASED ON RECREATIONAL USE

Presidio of San Francisco, California

Potential Chemical of Concern	Carcinogenic Oral Slope Factor $(mg/kg\text{-}day)^{-1}$	Slope Factor (a)	Non-carcinogenic Oral Reference Dose (mg/kg-day)	Reference Dose (b)	Dermal Absorption Factor (c)	Carcinogenic Risk Based PRG (mg/kg); (d)	Non-carcinogenic Risk Based PRG (mg/kg); (d)	Proposed PRG (mg/kg); (e)
PCBs, Pesticides, and Herbicides (cont.)								
Isodrin	17	(r)	0.00003	(r)	0.05	0.069	4	0.069
MCPP	-	-	-	-	-	-	-	-
Methoxychlor	-	-	0.005	IRIS	0.05	-	750	750

Notes:

(a) Carcinogenic slope factors were obtained from California Environmental Protection Agency, Office of Environmental Health Hazard Assessment ("OEHHA") website table entitled *California Cancer Potency Factors*, dated March 2001. U.S. EPA Integrated Risk Information System ("IRIS") was used as a secondary reference.

(b) Chronic reference doses were obtained from IRIS, U.S. EPA's Health Effects Assessment Summary Tables ("HEAST"), dated July 1997, and U.S. EPA's National Center for Environmental Assessment ("NCEA") Draft Risk Assessment Issue Papers for individual chemicals.

(c) Soil absorption factors obtained from California Environmental Protection Agency, Department of Toxic Substances Control ("DTSC"), *Endangerment Assessment Guidance Manual*, dated June 1999.

(d) Exposure factors used to calculate carcinogenic and non-carcinogenic preliminary remediation goals ("PRGs") are summarized in Table 4-2. PRGs are based upon a carcinogenic target risk level of one-in-one million (i.e., 10^{-6}) incremental risk of an individual developing cancer over a lifetime, and a non-carcinogenic target risk level that corresponds to a hazard index of 1.

(e) Where both carcinogenic and non-carcinogenic PRGs are available, the proposed PRG is the lesser of the two values.

(f) Hyphen indicates that a value is not available or cannot be calculated.

(g) At the Presidio, Cr(VI) comprises 0.0055 to 0.28 percent of the total chromium in serpentinite (Montgomery Watson, 1999). By analogy to the U.S. EPA PRG tables (U.S. EPA, October 2000), OEHHA's oral slope factor of 0.19 $(mg/kg\text{-}d)^{-1}$ for hexavalent chromium was reduced by a factor of 0.0028.

(h) According to HEAST, the toxicity data for copper are inadequate for calculation of an RfD.

(i) PRG calculated through use of DTSC Lead Spread Version 7.0 (beta test version) computer model.

(j) Reference dose for thallium chloride was used.

TABLE 4-4
HUMAN HEALTH PRELIMINARY REMEDIATION GOALS FOR SOIL BASED ON RECREATIONAL USE

Presidio of San Francisco, California

Notes (contd):

(k) PRGs for VOCs are adjusted in Tables 4-6 and 4-7, respectively, to account for potential risks due to vapor intrusion into indoor air and potential leaching to groundwater.

(l) Oral reference dose not available for p-isopropyltoluene. The value for isopropylbenzene was used as a surrogate.

(m) Oral slope factors and reference doses not available for 1,2,3-trichlorobenzene. The values for 1,2,4-trichlorobenzene were used as a surrogate.

(n) In the absence of an oral chronic reference dose or oral slope factor, the respective inhalation value was used.

(o) OEHHA's California Cancer Potency Factor table lists a slope factor of 5 $(mg/kg\text{-}day)^{-1}$ for PCBs. However, OEHHA's Consolidated Table of OEHHA/ARB Approved Risk Assessment Health Values (dated 13 September 2001) and IRIS list the oral slope factor for PCBs as 2 $(mg/kd\text{-}day)^{-1}$. Based on discussions with Laurie Monserrat and David Siegel with OEHHA, the oral slope factor of 2 $(mg/kg\text{-}day)^{-1}$ is the most current value and would be accepted in risk assessments reviewed by OEHHA.

(p) An oral slope factor was not available for delta-BHC. The respective slope factor for alpha-BHC is used.

(q) Oral reference doses were not available for Endosulfin Sulfate, Endrin Aldehyde, or Endrin Ketone. The respective reference doses for Endosulfin is used for Endosulfin Sulfate, and Endrin is used for Endrin Aldehyde and Endrin Ketone.

(r) Isodrin is an isomer of aldrin. Oral slope factor and reference dose for aldrin were used to calculate isodrin PRGs.

TABLE 4-5
HUMAN HEALTH PRELIMINARY REMEDIATION GOALS FOR SOIL BASED ON COMMERCIAL/INDUSTRIAL USE

Presidio of San Francisco, California

Potential Chemical of Concern	Carcinogenic Oral Slope Factor (mg/kg-day)$^{-1}$	Slope Factor (a)	Non-carcinogenic Oral Reference Dose (mg/kg-day)	Reference Dose (b)	Dermal Absorption Factor (c)	Carcinogenic Risk Based PRG (mg/kg); (d)	Non-carcinogenic Risk Based PRG (mg/kg); (d)	Proposed PRG (mg/kg); (e)
Inorganic Chemicals								
Antimony	- (f)	-	0.0004	IRIS	0.01	-	760	760
Arsenic	1.5	OEHHA	0.0003	IRIS	0.03	3.3	490	3.3
Barium	-	-	0.07	IRIS	0.01	-	130,000	130,000
Beryllium	-	-	0.002	IRIS	0.01	-	3,800	3,800
Cadmium	0.38	OEHHA	0.0005	IRIS	0.001	16	1,000	16
Chromium (Cr(VI) and Cr(III))	5.3E-04	OEHHA (g)	2	IRIS	0.01	11,000	3,800,000	11,000
Cobalt	-	-	0.06	NCEA	0.01	-	110,000	110,000
Copper	-	-	(h)	(h)	-	-	-	-
Cyanide	-	-	0.02	IRIS	0.10	-	23,000	23,000
Lead (i)	-	-	-	-	-	-	-	3,500
Tetraethyl Lead	-	-	0.0000001	IRIS	0.10	-	0.11	0.11
Mercury	-	-	0.0003	IRIS	0.01	-	570	570
Molybdenum	-	-	0.0050	IRIS	0.01	-	9,400	9,400
Nickel	-	-	0.02	IRIS	0.01	-	38,000	38,000
Selenium	-	-	0.005	IRIS	0.01	-	9,400	9,400
Silver	-	-	0.005	IRIS	0.01	-	9,400	9,400
Thallium	-	-	0.00008	IRIS (j)	0.01	-	150	150
Vanadium	-	-	0.009	IRIS	0.01	-	17,000	17,000
Zinc	-	-	0.3	IRIS	0.01	-	570,000	570,000
Semivolatile Organic Compounds								
Acenaphthene	-	-	0.06	IRIS	0.15	-	55,000	55,000
Acenaphthylene	-	-	-	-	-	-	-	-
Anthracene	-	-	0.3	IRIS	0.15	-	280,000	280,000
Benzo(a)anthracene	1.2	OEHHA	-	-	0.15	2.3	-	2.3
Benzo(a)pyrene	12	OEHHA	-	-	0.15	0.23	-	0.23

TABLE 4-5
HUMAN HEALTH PRELIMINARY REMEDIATION GOALS FOR SOIL BASED ON COMMERCIAL/INDUSTRIAL USE

Presidio of San Francisco, California

Potential Chemical of Concern	Carcinogenic Oral Slope Factor (mg/kg-day)$^{-1}$	Slope Factor (a)	Non-carcinogenic Oral Reference Dose (mg/kg-day)	Reference Dose (b)	Dermal Absorption Factor (c)	Carcinogenic Risk Based PRG (mg/kg); (d)	Non-carcinogenic Risk Based PRG (mg/kg); (d)	Proposed PRG (mg/kg); (e)
Semivolatile Organic Compounds (cont.)								
Benzo(b)fluoranthene	1.2	OEHHA	-	-	0.15	2.3	-	2.3
Benzo(g,h,i)perylene	-	-	-	-	-	-	-	-
Benzo(k)fluoranthene	1.2	OEHHA	-	-	0.15	2.3	-	2.3
Benzyl Alcohol	-	-	0.3	HEAST	0.15	-	280,000	280,000
Chrysene	0.12	OEHHA	-	-	0.15	23	-	23
Dibenzo(a,h)anthracene	4.1	OEHHA	-	-	0.15	0.67	-	0.67
Dibenzofuran	-	-	0.02	IRIS	0.15	-	18,000	18,000
Fluoranthene	-	-	0.04	IRIS	0.15	-	37,000	37,000
Fluorene	-	-	0.04	IRIS	0.15	-	37,000	37,000
Indeno(1,2,3-c,d)pyrene	1.2	OEHHA	-	-	0.15	2.3	-	2.3
2-methylnaphthalene	-	-	-	-	-	-	-	-
4-methylphenol (p-Cresol)	-	-	0.005	HEAST	0.10	-	5,600	5,600
Naphthalene	-	-	0.02	IRIS	0.15	-	18,000	18,000
n-nitrosodiphenylamine	0.009	OEHHA	-	-	0.10	380	-	380
Pentachlorophenol	0.081	OEHHA	0.03	IRIS	0.10	42	34,000	42
Phenanthrene	-	-	-	-	-	-	-	-
Phenol	-	-	0.6	IRIS	0.15	-	550,000	550,000
Pyrene	-	-	0.03	IRIS	0.15	-	28,000	28,000
Volatile Organic Compounds (k)								
Acetone	-	-	0.1	IRIS	0.10	-	110,000	See Table 4-6
2-butanone (MEK)	-	-	0.6	IRIS	0.10	-	680,000	See Table 4-6
Carbon disulfide	-	-	0.1	IRIS	0.10	-	110,000	See Table 4-6
1,4-dichlorobenzene	0.0054	OEHHA	0.03	HEAST	0.10	630	34,000	See Table 4-6
p-Isopropyltoluene (p-cymene)	-	-	0.1	IRIS (l)	0.1	-	110,000	See Table 4-6
Methylene Chloride	0.014	OEHHA	0.06	IRIS	0.10	240	68,000	See Table 4-6

TABLE 4-5
HUMAN HEALTH PRELIMINARY REMEDIATION GOALS FOR SOIL BASED ON COMMERCIAL/INDUSTRIAL USE

Presidio of San Francisco, California

Potential Chemical of Concern	Carcinogenic Oral Slope Factor $(mg/kg\text{-}day)^{-1}$	Slope Factor (a)	Non-carcinogenic Oral Reference Dose (mg/kg-day)	Reference Dose (b)	Dermal Absorption Factor (c)	Carcinogenic Risk Based PRG (mg/kg); (d)	Non-carcinogenic Risk Based PRG (mg/kg); (d)	Proposed PRG (mg/kg); (e)
Volatile Organic Compounds (cont.)								
1,2,3-trichlorobenzene	0.0036	(m)	0.01	(m)	0.1	940	11,000	See Table 4-6
1,2,4-trichlorobenzene	0.0036	OEHHA	0.01	IRIS	0.1	940	11,000	See Table 4-6
Trichlorofluoromethane	-	-	0.30	IRIS	0.10	-	338,000	See Table 4-6
1,1,1-trichloroethane	-	-	0.29	NCEA (n)	0.10	-	330,000	See Table 4-6
PCBs, Pesticides, and Herbicides								
PCBs (Aroclor 1254)	2	OEHHA (o)	0.00002	IRIS	0.15	1.4	18	1.4
Aldrin	17	OEHHA	0.00003	IRIS	0.05	0.26	44	0.26
alpha-BHC	2.7	OEHHA	-	-	0.05	1.6	-	1.6
beta-BHC	1.5	OEHHA	-	-	0.05	2.9	-	2.9
delta-BHC	2.7	(p)	-	-	0.05	1.6	-	1.6
Chlordane	1.3	OEHHA	0.0005	IRIS	0.05	3.4	730	3.4
2,4-D	-	-	0.01	IRIS	0.05	-	15,000	15,000
Dicamba	-	-	0.03	IRIS	0.05	-	44,000	44,000
4,4'-DDD	0.24	OEHHA	-	-	0.05	18	-	18
4,4'-DDE	0.34	OEHHA	-	-	0.05	13	-	13
4,4'-DDT	0.34	OEHHA	0.0005	IRIS	0.05	13	730	13
Dieldrin	16	OEHHA	0.00005	IRIS	0.05	0.27	73	0.27
Endosulfan	-	-	0.006	IRIS	0.05	-	8,700	8,700
Endosulfan Sulfate	-	-	0.006	(q)	0.05	-	8,700	8,700
Endrin	-	-	0.0003	IRIS	0.05	-	440	440
Endrin Aldehyde	-	-	0.0003	(q)	0.05	-	440	440
Endrin Ketone	-	-	0.0003	(q)	0.05	-	440	440
gamma-BHC (Lindane)	1.1	OEHHA	0.0003	IRIS	0.05	4.0	440	4.0
Heptachlor	4.1	OEHHA	0.0005	IRIS	0.05	1.1	730	1.1
Heptachlor Epoxide	5.5	OEHHA	0.00001	IRIS	0.05	0.79	19	0.79

TABLE 4-5

HUMAN HEALTH PRELIMINARY REMEDIATION GOALS FOR SOIL BASED ON COMMERCIAL/INDUSTRIAL USE

Presidio of San Francisco, California

Potential Chemical of Concern	Carcinogenic Oral Slope Factor $(mg/kg\text{-}day)^{-1}$	Slope Factor (a)	Non-carcinogenic Oral Reference Dose (mg/kg-day)	Reference Dose (b)	Dermal Absorption Factor (c)	Carcinogenic Risk Based PRG (mg/kg); (d)	Non-carcinogenic Risk Based PRG (mg/kg); (d)	Proposed PRG (mg/kg); (e)
PCBs, Pesticides, and Herbicides (cont.)								
Isodrin	17	(r)	0.00003	(r)	0.05	0.26	44	0.26
MCPP	-	-	-	-	-	-	-	-
Methoxychlor	-	-	0.005	IRIS	0.05	-	7,300	7,300

Notes:

(a) Carcinogenic slope factors were obtained from California Environmental Protection Agency, Office of Environmental Health Hazard Assessment ("OEHHA") website table entitled *California Cancer Potency Factors*, dated March 2001. U.S. EPA Integrated Risk Information System ("IRIS") was used as a secondary reference.

(b) Chronic reference doses were obtained from IRIS, U.S. EPA's Health Effects Assessment Summary Tables ("HEAST"), dated July 1997, and U.S. EPA's National Center for Environmental Assessment ("NCEA") Draft Risk Assessment Issue Papers for individual chemicals.

(c) Soil absorption factors obtained from California Environmental Protection Agency, Department of Toxic Substances Control ("DTSC"), *Endangerment Assessment Guidance Manual*, dated June 1999.

(d) Exposure factors used to calculate carcinogenic and non-carcinogenic preliminary remediation goals ("PRGs") are summarized in Table 4-2. PRGs are based upon a carcinogenic target risk level of one-in-one million (i.e., 10^{-6}) incremental risk of an individual developing cancer over a lifetime, and a non-carcinogenic target risk level that corresponds to a hazard index of 1.

(e) Where both carcinogenic and non-carcinogenic PRGs are available, the proposed PRG is the lesser of the two values.

(f) Hyphen indicates that a value is not available or cannot be calculated.

(g) At the Presidio, Cr(VI) comprises 0.0055 to 0.28 percent of the total chromium in serpentinite (Montgomery Watson, 1999). By analogy to the U.S. EPA PRG tables (U.S. EPA, October 2000), OEHHA's oral slope factor of 0.19 $(mg/kg\text{-}d)^{-1}$ for hexavalent chromium was reduced by a factor of 0.0028.

(h) According to HEAST, the toxicity data for copper are inadequate for calculation of an RfD.

(i) PRG calculated through use of DTSC Lead Spread Version 7.0 (beta test version) computer model.

(j) Reference dose for thallium chloride was used.

TABLE 4-5
HUMAN HEALTH PRELIMINARY REMEDIATION GOALS FOR SOIL BASED ON COMMERCIAL/INDUSTRIAL USE

Presidio of San Francisco, California

Notes (contd):

(k) PRGs for VOCs are adjusted in Tables 4-6 and 4-7, respectively, to account for potential risks due to vapor intrusion into indoor air and potential leaching to groundwater.

(l) Oral reference dose not available for p-isopropyltoluene. The value for isopropylbenzene was used as a surrogate.

(m) Oral slope factors and reference doses not available for 1,2,3-trichlorobenzene. The values for 1,2,4-trichlorobenzene were used as a surrogate.

(n) In the absence of an oral chronic reference dose or oral slope factor, the respective inhalation value was used.

(o) OEHHA's California Cancer Potency Factor table lists a slope factor of 5 $(mg/kg\text{-}day)^{-1}$ for PCBs. However, OEHHA's Consolidated Table of OEHHA/ARB Approved Risk Assessment Health Values (dated 13 September 2001) and IRIS list the oral slope factor for PCBs as 2 $(mg/kd\text{-}day)^{-1}$. Based on discussions with Laurie Monserrat and David Siegel with OEHHA, the oral slope factor of 2 $(mg/kg\text{-}day)^{-1}$ is the most current value and would be accepted in risk assessments reviewed by OEHHA.

(p) An oral slope factor was not available for delta-BHC. The respective slope factor for alpha-BHC is used.

(q) Oral reference doses were not available for Endosulfin Sulfate, Endrin Aldehyde, or Endrin Ketone. The respective reference doses for Endosulfin is used for Endosulfin Sulfate, and Endrin is used for Endrin Aldehyde and Endrin Ketone.

(r) Isodrin is an isomer of aldrin. Oral slope factor and reference dose for aldrin were used to calculate isodrin PRGs.

TABLE 4-6
DEVELOPMENT OF HUMAN HEALTH PRELIMINARY REMEDIATION GOALS FOR VOLATILE ORGANIC COMPOUNDS IN SOIL AT THE PRESIDIO OF SAN FRANCISCO (INCLUDES VAPOR INTRUSION PATHWAY)

Presidio of San Francisco, California

CARCINOGENIC	Carcinogenic Direct Contact PRGs (a)			Carcinogenic Vapor Intrusion PRGs ($PRG_{c\text{-}inh}$) (b)		Combined Carcinogenic PRGs (c)		
Potential Chemical of Concern	Residential (mg/kg)	Recreational (mg/kg)	Comm./Indust. (mg/kg)	Residential (mg/kg)	Comm./Indust. (mg/kg)	Residential (mg/kg)	Recreational (mg/kg)	Comm./Indust. (mg/kg)
Acetone	-	-	-	-	-	-	-	-
2-butanone (MEK)	-	-	-	-	-	-	-	-
Carbon disulfide	-	-	-	-	-	-	-	-
1,4-dichlorobenzene	71	173	630	0.13	0.49	0.13	173	0.49
p-Isopropyltoluene (p-cymene)	-	-	-	-	-	-	-	-
Methylene Chloride	27	67	240	0.89	3.1	0.86	67	3.1
1,2,3-trichlorobenzene (d)	110	260	940	87	280	49	260	216
1,2,4-trichlorobenzene	110	260	940	87	280	49	260	216
Trichlorofluoromethane	-	-	-	-	-	-	-	-
1,1,1-trichloroethane	-	-	-	-	-	-	-	-

NON-CARCINOGENIC	Non-carcinogenic Direct Contact PRGs (a)			Non-carcinogenic Vapor Intrusion PRGs ($PRG_{nc\text{-}inh}$) (e)		Combined Non-carcinogenic PRGs (c)		
Potential Chemical of Concern	Residential (mg/kg)	Recreational (mg/kg)	Comm./Indust. (mg/kg)	Residential (mg/kg)	Comm./Indust. (mg/kg)	Residential (mg/kg)	Recreational (mg/kg)	Comm./Indust. (mg/kg)
Acetone	5,200	13,000	110,000	43	140	43	13,000	140
2-butanone (MEK)	31,000	76,000	680,000	596	1,980	585	76,000	1,974
Carbon disulfide	5,200	13,000	110,000	266	676	253	13,000	672
1,4-dichlorobenzene	1,600	3,800	34,000	485	1,580	372	3,800	1,510
p-Isopropyltoluene (p-cymene)	5,200	13,000	110,000	533	848	483	13,000	842
Methylene Chloride	3,100	7,600	68,000	1,140	3,320	958	7,600	3,165
1,2,3-trichlorobenzene (d)	520	1,300	11,000	462	1,520	245	1,300	1,335
1,2,4-trichlorobenzene	520	1,300	11,000	462	1,520	245	1,300	1,335
Trichlorofluoromethane	16,000	38,000	338,000	40	116	40	38,000	116
1,1,1-trichloroethane	15,000	37,000	330,000	76	220	76	37,000	220

TABLE 4-6
DEVELOPMENT OF HUMAN HEALTH PRELIMINARY REMEDIATION GOALS FOR VOLATILE ORGANIC COMPOUNDS IN SOIL AT THE PRESIDIO OF SAN FRANCISCO (INCLUDES VAPOR INTRUSION PATHWAY)

Presidio of San Francisco, California

Notes:

(a) Direct Contact Preliminary Remediation Goals ("PRGs") for volatile organic compounds ("VOCs") were calculated in Tables 4-3, 4-4, and 4-5 for residential, recreational, and commercial/industrial human health land use, respectively. The direct contact PRGs do not include potential risks due to vapor intrusion into indoor air.

(b) Carcinogenic Vapor Intrusion PRGs represent the soil concentration corresponding to a lifetime incremental cancer risk of 10^{-6} due to vapor intrusion of VOCs from soil into indoor air. Values obtained from Table E-1a from Volume II, of *Application of Risk-Based Screening Levels and Decision Making to Sites with Impacted Soil and Groundwater ("RBSLs"),* Regional Water Quality Control Board, San Francisco Bay Region, Interim Final, December 2001. The value assumes coarse grained soils. Recreational populations are assumed to be outdoors; this pathway is assumed to be incomplete for recreational users.

(c) Combined carcinogenic and non-carcinogenic PRGs incorporating the Vapor Intrusion PRGs were calculated using the formula shown in the text. These values are carried forward for use in calculation of final human health PRGs in subsequent tables. Vapor intrusion of VOCs into indoor air is not anticipated for recreational land uses. Therefore, the recreational PRGs were not modified to account for vapor intrusion.

(d) Values for 1,2,4-trichlorobenzene were used as a surrogate for 1,2,3-trichlorobenzene.

(e) Non-carcinogenic Vapor Intrusion PRGs represent the soil concentration corresponding to a hazard index of 1 due to vapor intrusion of VOCs from soil into indoor air. Values obtained from Table E-1a from Volume II of the RBSLs. The value assumes coarse grained soils. RBSLs were not available for 2-butanone, carbon disulfide, 1,4-dichlorobenzene (non-carcinogenic), p-isopropyltoluene, trichloroflouromethane, and 1,2,4-trichlorobenzene (non-carcinogenic). Vapor Intrusion PRGs for these VOCs were calculated using the Johnson & Ettinger model (Version 2.3, March 2001), with the same exposure assumptions and soil parameters as used for the development of the RBSLs. Recreational populations are assumed to be outdoors; this pathway is assumed to be incomplete for recreational users.

TABLE 4-7
HUMAN HEALTH PRELIMINARY REMEDIATION GOALS FOR VOLATILE ORGANIC COMPOUNDS IN SOIL AND SEDIMENT AT THE PRESIDIO OF SAN FRANCISCO

Presidio of San Francisco, California

Potential Chemical of Concern	Combined Carcinogenic PRGs (a)			Combined Non-carcinogenic PRGs (a)			Groundwater Protection PRGs for Surface Soil (b)		Proposed Human Health PRGs (c)		
	Residential (mg/kg)	Recreational (mg/kg)	Comm./Indust. (mg/kg)	Residential (mg/kg)	Recreational (mg/kg)	Comm./Indust. (mg/kg)	Residential (mg/kg)	Comm./Indust. (mg/kg)	Residential (mg/kg)	Recreational (mg/kg)	Comm./Indust. (mg/kg)
Acetone	-	-	-	43	13,000	140	0.24	0.24	0.24	0.24	0.24
2-butanone (MEK)	-	-	-	585	76,000	1,974	3.8	3.8	3.8	3.8	3.8
Carbon disulfide	-	-	-	253	13,000	672	200	200	200	200	200
1,4-dichlorobenzene	0.13	173	0.49	372	3,800	1,510	0.59	0.59	0.13	0.59	0.49
p-Isopropyltoluene (p-cymene)	-	-	-	483	13,000	842	133	133	133	133	133
Methylene Chloride	0.86	67	3.1	958	7,600	3,165	0.076	0.076	0.076	0.076	0.076
1,2,3-trichlorobenzene (d)	49	260	216	245	1,300	1,335	15	15	15	15	15
1,2,4-trichlorobenzene	49	260	216	245	1,300	1,335	15	15	15	15	15
Trichlorofluoromethane	-	-	-	40	38,000	116	80	80	40	80	80
1,1,1-trichloroethane	-	-	-	76	37,000	220	8.0	8.0	8.0	8.0	8.0

Notes:

(a) Combined carcinogenic and non-carcinogenic Preliminary Remediation Goals ("PRGs") for volatile organic compounds ("VOCs") are carried forward from Table 4-6. The PRGs for residential and commercial/industrial human health land use incorporate potential risks due to vapor intrusion into indoor air. Vapor intrusion of VOCs into indoor air is not anticipated for recreational uses.

(b) Groundwater Protection PRGs are soil cleanup levels based on protection of drinking water resources via the leaching pathway. Values were obtained from Tables A-1 and A-2 from Volume II of the *Application of Risk-Based Screening Levels and Decision Making to Sites with Impacted Soil and Groundwater ("RBSLs")*, Regional Water Quality Control Board, San Francisco Bay Region, Interim Final, December 2001. The listed value is from the Groundwater Protection (soil leaching) column, assuming groundwater is a drinking water resource. Groundwater protection RBSLs were not available for carbon disulfide, p-isopropyltoluene, or trichlorofluoromethane; groundwater protection values were calculated for these compounds using formulas in the RBSL guidance. For these calculations, the common maximum contaminant level ("MCL") for trichlorofluoromethane and toluene (as a surrogate for p-isopropyltoluene) of 150 µg/L was used as the target groundwater concentration for both chemicals. The U.S. EPA tap water PRG (November 2000) was used as the target groundwater concentration for carbon disulfide (1,000 µg/L), as no target groundwater concentration is identified in Table 7-6. Because the Vapor Intrusion and Groundwater Protection PRGs are not site-specific, if VOCs are found at Presidio sites, VOC cleanup levels may be re-calculated to be site-specific. Such values would be calculated in conjunction with discussions with regulatory agencies.

(c) The proposed PRG is the more stringent (smallest) of the applicable values in each land use category. Although the RWQCB's RBSL document does not provide numbers for leaching to groundwater under a recreational land use scenario, the protection of groundwater resources in recreational areas is appropriate. Therefore, the Groundwater Protection PRGs are retained as the proposed PRGs for recreational land uses since these values are more stringent than the other human health values and are appropriate for protecting groundwater resources in recreational areas of the Presidio.

(d) Values for 1,2,4-trichlorobenzene were used as a surrogate for 1,2,3-trichlorobenzene.

TABLE 4-8
LEAD INTAKE SUMMARY FOR RESIDENTIAL, RECREATIONAL, AND COMMERCIAL/INDUSTRIAL USERS (a)

Presidio of San Francisco, California

Potentially Exposed Population	Exposure Frequency (days/week)	Exposure Media/Lead Concentration					Blood Lead (f) (µg/dl)
		Air (b) (µg/m^3)	Water (b) (µg/L)	Food Intake (c) (kg/day)	Background Soil (d) (mg/kg)	Presidio Soil (e) (mg/kg)	
Residential (child)	7 (Presidio)	0.028	2.4	1.9	0	**370**	10
Recreational (child)	7 (Background)	0.028	15	1.1	0	0	4.6
	4 (Background)	0	0	0	66	0	0.8
	3 (Presidio)	0	0	0	0	**500**	4.6
							10
Commercial/Industrial (adult)	5 (Presidio)	0.028	15	1.9	0	**3,500**	10

Notes:

(a) Lead concentration in blood calculated using California Environmental Protection Agency, Department of Toxic Substances Control ("DTSC") Lead Spread Version 7.0 (beta test version) computer model.

(b) Air, water and food intake concentrations are based on DTSC default factors, except for lead in residential tap water. A value of 2.4 ug/L is based on the 95% upper confidence limit of the average lead concentration measured in residential tap water at the Presidio in 1998, 1999, and 2000 (see data in Appendix A).

(c) Food intake is based on DTSC default factor. The lead concentration in food is assumed to be 3.1 µg/kg, which is also a DTSC default factor.

(d) Background concentrations of lead in soil at the Presidio are used for background in Lead Spread. A value of 66 mg/kg of lead corresponds to the background concentration in serpentinite, which is the maximum background concentration calculated by EKI for the four lithologies at the Presidio.

TABLE 4-8

LEAD INTAKE SUMMARY FOR RESIDENTIAL, RECREATIONAL, AND COMMERCIAL/INDUSTRIAL USERS (a)

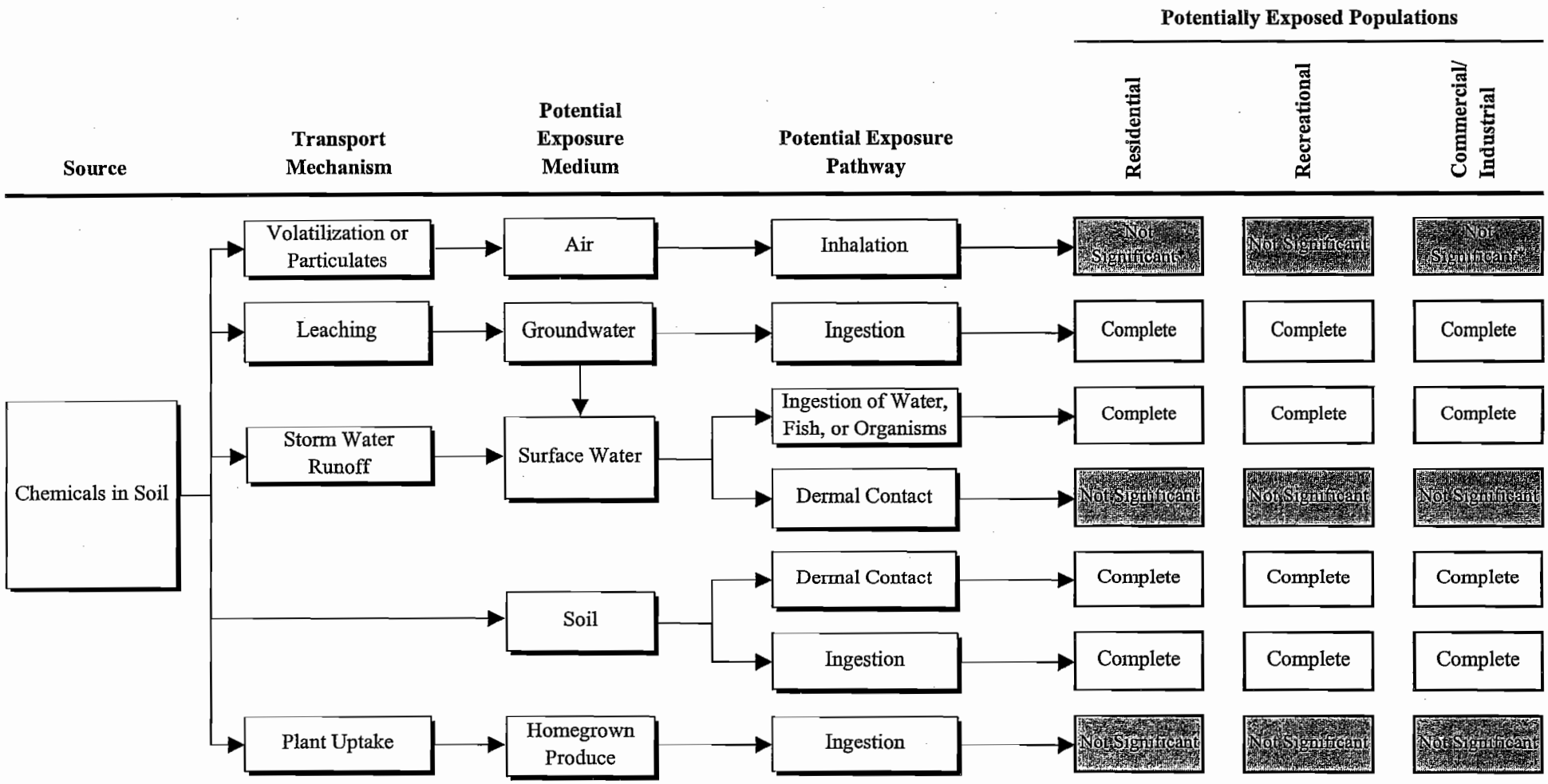
Presidio of San Francisco, California

Notes (continued):

(e) The concentration of lead in Presidio soil corresponds to the value that results in a cumulative blood lead concentration of 10 µg/dl. This value is the proposed cleanup level for the scenario indicated.

(f) See Appendix A for the computer spreadsheets in which blood lead concentration is calculated.

FIGURES



Legend

Complete — Pathway Complete or Potentially Complete. Pathway Has Been Quantitatively Evaluated.

Not Significant — Pathway Complete or Potentially Complete; Exposure is Not Considered Significant. Pathway Has Not Been Evaluated Quantitatively.

Not Complete — Pathway is Not Considered Complete.

*For volatile organic compounds, volatilization to indoor air is considered to be a complete pathway. For non-volatile compounds this pathway is not signficant.

Potential Human Health Exposure Pathways

Presidio of San Francisco, California

Erler & Kalinowski, Inc.

October 2002

Figure 4-1

5. ECOLOGICAL PRGS FOR SOIL AND SEDIMENT

5. ECOLOGICAL PRGS FOR SOIL AND SEDIMENT

Human health PRGs for PCOCs in soil were developed in Section 4. This section presents the development of ecological PRGs for PCOCs in soil and sediment. As discussed in Section 5.10, the Trust received comments from DTSC on the ecological PRGs for soil, as developed in Sections 5.1 through 5.8. These sections present the methodology used by the Trust to develop ecological PRGs for PCOCs other than lead. Section 5.10 presents the selection of the final ecological PRGs for soil based on DTSC's comments.

5.1 DERIVATION OF ECOLOGICAL PRGs FOR SOIL AND SEDIMENT

Derivation of ecological cleanup levels or performance of ecological risk assessments differ from their human health counterparts in that the objectives of ecological cleanup levels are site-specific. In contrast, the goals of human health cleanup levels are prescribed (i.e., reduce incremental carcinogenic risk to 10^{-6} to 10^{-4} and limit the non-carcinogenic HI below 1). The numerical values of human health cleanup levels change only as a result of varying activities that may be performed at a given site. Recognizing this important distinction between ecological and human health cleanup levels and risk assessments, U.S. EPA (1998b) states the following:

> The wide use and important advantages of ecological risk assessments do not mean they are the sole determinants of management decisions; risk managers consider many factors. Legal mandates and political, social, and economic considerations may lead risk managers to make decisions that are more or less protective. Reducing risk to the lowest level may be too expensive or not technically feasible. Thus, although ecological risk assessments provide critical information to risk managers, they are only part of the environmental-decision making process.

The resources to be protected and the objectives of ecological cleanup levels must be clearly established to ensure that remedial actions implemented at identified sites truly benefit the ecosystems found at the Presidio. For example, overly conservative ecological cleanup levels may cause greater harm than less stringent criteria if the cleanup levels result in remedial actions that destroy or substantially alter the habitats of the plants and wildlife that the cleanup levels are attempting to preserve. Ecological PRGs for soil and sediment at the Presidio have been derived independently of potential remedial actions to accomplish the following objectives:

- Maintain and permit enhancement of habitats as described in the *General Management Plan Amendment*, ("GMPA") (NPS, 1994), the *Vegetation Management Plan,* ("VMP") (NPS and Trust, 2001), and the *Presidio Trust*

Management Plan, Land Use Policies for Area B of the Presidio of San Francisco, ("PTMP") (Trust, 2002).

- Sustain populations of plants and soil fauna, wildlife, and aquatic life present at the Presidio.

- Protect individual plants and animals of rare, or threatened or endangered ("special status") species.

These objectives are consistent with the goals of remedial actions performed under Superfund. U.S. EPA (1999a) states the following regarding cleanup measures intended to protect the environment:

> Superfund remedial actions generally should not be designed to protect organisms on an individual basis (the exception being designated protected status resources, such as listed or candidate threatened and endangered species or treaty-protected species that could be exposed to site releases), but to protect local populations and communities of biota. Levels that are expected to protect local populations and communities can be estimated by extrapolating from effects on individuals and groups of individuals using a lines-of-evidence approach.

The Army conducted an ecological risk assessment as part of the RI (Dames & Moore, 1997b) and the results obtained were used to develop ecological PRGs for PCOCs in the FS (Dames & Moore, 1997a). Concerns expressed by regulatory agencies, organizations, and individuals regarding the manner in which the Army performed its ecological risk assessment caused the Trust to reexamine risks to ecological receptors and recalculate PRGs building upon the work completed by the Army.

Ms. Bridgette DeShields, formerly of Harding ESE and currently with Blasland, Bouck and Lee, Inc., was retained to review the Army's ecological risk assessment and to derive ecological PRGs for soil and sediment at the Presidio. The approach employed by Harding ESE to derive ecological PRGs paralleled the method used to derive PRGs in the Army's FS. For PCOCs other than lead, this method involved conducting the following two major steps:

(1) Develop toxicity benchmark values ("TBVs") that represent a range of potential adverse effects to indicator plant and wildlife species that may be exposed to PCOCs.

(2) Adopt these TBVs as acceptable concentrations or PRGs for PCOCs in soil and sediment, or use the TBVs in standard risk equations to calculate PRGs that are protective of indicator plant and wildlife species.

Multiple PRGs for PCOCs at Presidio sites were obtained because a range of TBVs was developed and more than one indicator species was considered. PRGs were further

assessed to obtain a single value for each PCOC to safeguard non-special status species and a single value for each PCOC to safeguard special status species. Non-special status species PRGs were selected to protect populations of ecological receptors, whereas special status species PRGs were chosen to protect individuals. PRGs for lead were evaluated differently because the widely varying toxicity values for lead do not lend themselves well to derivation of PRGs by the method used for other PCOCs. PRGs for lead were recalculated by use of the Monte Carlo method as was done by the Army.

Although PRGs were derived employing similar methods to those of the Army, the methods were revised to address comments made by DTSC, U.S. EPA and other regulatory agencies and organizations. Special status species were considered separately, toxicity values and exposure factors were updated to reflect more recent guidance and published literature, and errors in calculations performed by the Army were corrected. Procedures and assumptions used by Harding ESE to derive ecological PRGs for soil and sediment are discussed in Sections 5.2 through 5.9.

5.2 POTENTIALLY EXPOSED SPECIES

The Presidio has both higher quality habitat areas (e.g., native plant communities, forests, Mountain Lake, Lobos Creek, Crissy Field wetlands) and lower quality habitat areas (e.g., paved streets and parking lots or designed landscapes such as lawns and ornamental plantings). Generally, plants and animals requiring protection are associated with higher quality habitat areas. These higher quality habitat areas include both terrestrial and aquatic habitats.

5.2.1 Plants

The GMPA recognized the need for a plan to address vegetation at the Presidio. In response to this need, the Trust and NPS prepared the VMP, dated May 2001. The purpose of the VMP is to provide a management framework for protecting, enhancing, restoring, and rehabilitating native and planted vegetation at the Presidio. Members of the California Native Plant Society (Skinner and Pavlik, 1994), NPS (1995), and biologists retained by NPS (Jones & Stokes Associates, Inc., 1997) have identified the following twelve (12) native plant communities:

- Foredune
- Bluff scrub
- Coastal scrub
- Serpentine chaparral
- Live oak riparian forest
- Riparian scrub
- Dune scrub
- Coastal prairie
- Serpentine grassland
- Freshwater marsh and seep
- Arroyo willow riparian forest
- Live oak woodland

Table 5–1 summarizes special status plant species identified in the VMP as being present at the Presidio. Section 7.1.2 describes the Presidio sites where special status plant species have been observed or may be reintroduced under the VMP. Figure 7-3 identifies planned vegetation types at the Presidio, based on the VMP and PTMP.

5.2.2 Wildlife

A number of avian and mammalian species, as well as invertebrates, amphibians, and reptiles, utilize the higher quality habitat areas within the Presidio. Special status animal species considered by the Army in the RI were obtained from Jones & Stokes Associates, Inc. *Presidio of San Francisco Forest Management Plan*, dated 1994. Jones & Stokes Associates identified potential occurring special status animal species based upon the wildlife that are associated with varying types of habitats found at the Presidio. Table 5–2 summarizes special status animal species that may exist at the Presidio. Potential special status animal species are generally limited to birds.

5.2.3 Indicator Plant and Wildlife Species

Indicator species are routinely selected to conduct an ecological risk assessment. The reason for choosing a subset of potentially occurring species to determine risk at or PRGs for a site is to avoid repetition in the analysis that would make the ecological risk assessment or derivation of PRGs more difficult to perform and understand.

Indicator species are chosen to represent various ecological trophic levels (e.g., primary producer, primary consumer, and higher level consumer) to provide for complete food chain modeling. Species considered more likely to be exposed to site-related chemicals are selected over other species to represent receptors throughout the entire trophic levels. Availability of published exposure factors (e.g., body weight, surface area, dietary ingestion rate, soil ingestion rate) and toxicological information are also considered in determining indicator species. In some instances, more than one species is selected from a receptor group to adequately represent trophic levels. In the case of certain receptor groups, such as plants, soil invertebrates, aquatic plants and invertebrates, amphibians, and fish, indicator species are not identified; rather, an indicator group is selected. For example, aquatic life represents aquatic plants and invertebrates, amphibians, and fish.

5.2.3.1 Non-special Status Indicator Species

The following receptors were chosen as indicator species for non-special status species at the Presidio based on the criteria presented in Section 5.2.3, procedures followed by the Army in selecting its indicator species (Dames & Moore, 1997b), review of U.S. EPA (1992c, 1997a, 1998b) guidance, and discussions with regulatory agency staff:

- Terrestrial habitats:
  - ◊ Plants and soil fauna (e.g., soil invertebrates)
  - ◊ American robin (insectivorous bird)

- ◊ Mourning dove (herbivorous bird)
- ◊ Western harvest mouse (omnivorous mammal)
- ◊ Valley pocket gopher (herbivorous mammal)
- ◊ Raccoon (carnivorous mammal)
- ◊ Peregrine falcon (carnivorous bird that ingests birds)
- ◊ Red-tailed hawk (carnivorous bird that ingests mammals)

- Aquatic habitats:
  - ◊ Aquatic life (e.g., aquatic plants and invertebrates, amphibians, and fish)
  - ◊ Mallard duck (herbivorous, dabbling duck)
  - ◊ Western sandpiper (insectivorous, wading bird)

5.2.3.2 Special Status Indicator Species

The following receptors were chosen as indicator species for special status species at the Presidio:

- Terrestrial habitats:
  - ◊ Plants and soil fauna
  - ◊ Peregrine falcon
  - ◊ Red-tailed hawk
- Aquatic habitats:
  - ◊ Mallard duck
  - ◊ Western sandpiper

Potential ecological exposure pathways to PCOCs for both non-special status and special status species in terrestrial and aquatic habitats at Presidio sites are discussed in Section 5.3.

5.3 POTENTIAL ECOLOGICAL EXPOSURE PATHWAYS

Figures 5-1 and 5-2 illustrate the complete and potentially complete exposure pathways for each of the receptor types for terrestrial and aquatic habitats at the Presidio. Aquatic habitat includes both freshwater and marine (or estuarine) areas. Some complete or potentially complete pathways may be considered less significant due to: (1) low levels of contaminants, (2) low exposure frequency, or (3) low contribution to the overall risks in comparison to other pathways. According to U.S. EPA (1997a), complete or potentially complete exposure pathways should be evaluated quantitatively. Pathways considered less significant and that require more uncertain assumptions to be made do not warrant further evaluation.

5.3.1 Terrestrial Habitats

For plants and soil fauna (i.e., soil invertebrates), one or more complete exposure pathways are shown on Figure 5-1. Route-specific exposures shown on Figure 5-1 are not directly quantified for these species in an ecological risk assessment. Published TBVs for exposure of plants and soil fauna to PCOCs are expressed as concentrations, as opposed to doses, and generally encompass all potential exposure pathways. Therefore, exposures of plants and soil fauna to PCOCs are taken into account by use of published TBVs and not through the quantification of route-specific exposures.

For birds and mammals, pathways considered complete include ingestion of contaminated soil and food items, dermal contact with PCOCs, and inhalation of particulates and VOCs. Dermal contact and inhalation pathways are considered less significant than ingestion pathways. U.S. EPA (2000c) has examined the contributions that dermal contact of PCOCs, inhalation of particulates, and inhalation of VOCs make to chemical doses received by birds and mammals. Dermal contact and inhalation of particulate pathways have been found to contribute less than 1 percent (and often less than 0.001 percent) of the total dose. Similarly, U.S. EPA (2000c) has determined that inhalation of VOCs typically represents 1 percent of the total dose, but may contribute more under certain circumstances. Although VOCs are PCOCs at some Presidio sites, VOCs are infrequently detected at low concentrations that do not meet the conditions under which evaluation of this pathway is recommended (e.g., broadly distributed VOCs in soil and groundwater within areas where animals are burrowing). Consequently, inhalation of particulates and VOCs are not included in derivation of ecological PRGs for Presidio sites. Ecological PRGs consider ingestion of contaminated soil and food items, and dermal contact of PCOCs. The dermal contact pathway was retained, not because it is believed that this pathway contributes significantly to total dose, but due to the fact that this pathway was quantitatively evaluated in the risk assessment presented in the Army's RI (Dames & Moore, 1997b).

5.3.2 Aquatic Habitats

For aquatic life, one or more complete exposure pathways are shown on Figure 5-2. As is the case of plants and soil fauna, route-specific exposures shown on Figure 5-2 are not directly quantified for aquatic life in an ecological risk assessment; rather, risks are assessed through use of TBVs or sediment quality criteria. Exposures of wildlife to PCOCs in surface water are also not directly quantified. Aquatic life TBVs and sediment quality criteria are generally considered protective of wildlife exposures to PCOCs in surface water as well.

Ecological PRGs for birds and mammals were calculated by quantitatively evaluating ingestion of contaminated soil and food items, and dermal contact of PCOCs. Inhalation exposure pathways are not routinely assessed for aquatic habitats because VOCs do not generally bind to sediments and half-lives of these compounds are generally short in surface water. In addition, as discussed in Section 5.3.1, inhalation pathways generally do not significantly contribute to the overall risk.

5.4 ECOLOGICAL TARGET RISK LEVEL

Ecological PRGs developed for Presidio sites are intended to maintain and permit enhancement of habitats at the Presidio that will support local communities of biota. As such, the PRGs for non-special status species have been chosen to protect wildlife populations that may occur at the Presidio. While recognizing DTSC's (2000b) comment that studies of population dynamics have not been made, the objective to safeguard non-special status species populations, as opposed to individuals, is supported by U.S. EPA guidance (1999a).

Upon identifying TBVs that pose no significant risk to ecological receptors under consideration, the "safe" dose from all complete exposure pathways is the dose that results in a hazard quotient ("HQ") of unity (i.e., 1):

$$HQ = \frac{\text{Dose}}{\text{TBV}}$$

In contrast to ecological PRGs for non-special status species, ecological PRGs for special status species are intended to protect individual plants and animals of rare, or threatened or endangered species. The toxicity values for developing PRGs for both non-special status and special status species are discussed in Section 5.5.

5.5 ECOLOGICAL TOXICITY VALUES

For non-special status species, ecological PRGs for PCOCs other than lead have been derived through adoption of published TBVs and sediment quality guidelines, or calculation of risk-based concentrations that are judged to be protective of non-special status species. The ecological PRGs for lead for non-special status and special status species were derived using the Monte Carlo method, as explained in Section 5.9. Ecological PRGs for special status species were determined by evaluating reported no-observed-effects-concentrations ("NOECs") and TBV values for the indicator species and employing professional judgment to select those values that will reasonably safeguard special status species that have been observed or may exist at the Presidio.

TBVs were developed from toxicity values presented in the Army's RI, and the results of a recent literature search and the application of safety or uncertainty factors, where appropriate. The Army developed both low and high toxicity values because its review of scientific literature returned numerous toxicity values for each PCOC and indicator species evaluated.

The most conservative (i.e., lowest) value for a given chemical and indicator species was termed the TBV_{low}. TBV_{low} values are based on no-observed-adverse-effect-levels ("NOAELs") or NOEC if reported. Uncertainty factors were applied to toxicity data for

PCOCs for which NOAELs and NOECs were unavailable in an effort to estimate doses that pose no risk to individuals or populations. Exposure concentrations or doses at or below the TBV_{low} are considered to result in no significant adverse effects to the indicator species.

According to the Army, the TBV_{high} was developed to represent the upper bound of "acceptable or safe daily intakes". Where BTAG high toxicity values (PRC, 1997) were used, the TBV_{high} is considered a level of high concern to regulatory agencies and natural resource trustees. Because the TBV_{high} was often a lowest-observed-adverse-effect level ("LOAEL"), it is more correct to indicate that exposure doses below the TBV_{high} may be within the acceptable range. Exposure concentrations at or above the TBV_{high} may result in significant adverse effects on individuals or populations of ecological receptors.

The range of values between the TBV_{low} and the TBV_{high} is considered a "gray zone" where risks are possible but significant risks are unlikely. Toxicity values presented in the Army's RI were used to derive PRGs by the Trust with the following exceptions:

- Updated TBVs for plants, soil invertebrates, and aquatic life were obtained from the references consulted by the Army.
- A literature review was performed and more current TBVs were used for wildlife indicator species if warranted.
- Errors in the calculation of TBVs for wildlife, mostly due to transcription errors or misapplication of uncertainty factors, were corrected.
- Additional uncertainty factors were applied to TBVs based on studies of mortality endpoints that were used in the Army's RI.
- TBVs were developed for chemicals not considered in the Army's RI.

Summarized in Tables 5–3 and 5–4 are TBVs and uncertainty factors for chemicals not considered in the Army's RI. Revised TBV_{low} and TBV_{high} values for non-special status indicator species are listed in Table 5–5 for plants and Table 5–6 for wildlife.

5.5.1 Plants and Soil Fauna

The United States Department of Energy ("DOE") Oak Ridge National Laboratory ("ORNL") documents are the primary references consulted by both the Army and Trust for plant and invertebrate TBVs. The recommended benchmark values in the ORNL documents were used as the TBV_{low} values in the Army's RI. The lowest lowest-observed-effects-concentration ("LOEC") values in the ORNL documents were adopted as the TBV_{high} values in the Army's RI. The Trust reviewed current versions of the ORNL documents (Efroymson, 1997) and updated TBVs as appropriate. TBVs in Tables 5–5 and 5–6 that are boxed and shown in bold are updated values, or values for chemicals not considered in the Army's RI. Updated values do not vary greatly from the

original values. For example, TBV_{low} for cadmium increased from 3 to 4 mg/kg. The TBV_{low} of 5 mg/kg for chromium was chosen based on toxicity tests using different forms of chromium reported in the ORNL documents. Toxicity values for plants and invertebrates were unavailable for many PCOCs, including several chemicals not considered in the Army's RI. The majority of the chemicals without plant and invertebrate TBVs are VOCs, SVOCs, and pesticides. These chemicals are most often not highly toxic to plants. Although some VOCs, SVOCs, and pesticides have been shown to be toxic to invertebrates, risks from these chemicals are typically governed by wildlife receptors for which TBVs are generally available.

5.5.2 Wildlife

A variety of references were used to develop TBVs for wildlife species in the Army's RI including the following:

- Toxicity values listed in governmental computerized databases, such as the National Library of Medicine Toxicity Data Network ("TOXNET") and the National Institute for Occupational Safety and Health Registry of Toxic Effects of Chemical Substances ("RTECS").

- Laboratory toxicology studies for various chemicals reported by U.S. EPA and ORNL, or published in *Environmental Toxicology and Chemistry*.

- U.S. EPA's Great Lakes Water Quality Initiative Criteria Documents for the Protection of Wildlife: DDT, Mercury, 2,3,7,8 TCDD, and PCBs, dated 1995.

- Donker, M.H., H.E. van Capelleveen, and N.M. van Straalen. 1993. *Metal Contamination Affects Size-structure and Life-history Dynamics in Isopod Field Populations*. Ecotoxicology of Metals in Invertebrates.

- U.S. EPA Region IX Biological Technical Advisory Group ("BTAG") draft TBVs, which have since been formalized (PRC Environmental Management, 1997).

Extensive effort was put forth by the Army to gather toxicity information and to develop TBVs for wildlife. Updating TBVs for wildlife in the Army's RI involved comparing the values in the Army's RI to more recently published TBVs, correcting errors, and reevaluating the Army's values that were based upon mortality endpoints. Errors in the calculation of TBVs for wildlife, mostly due to transcription errors or misapplication of uncertainty factors, were minor and had little effect on TBV values used to calculate risk-based PRGs by the Trust. For example, using the correct uncertainty factors for the red-tailed hawk changed the TBV_{low} for mercury from 0.04 to 0.08 mg/kg-day. Uncertainty factors ("UFs") developed by the Army are shown in the table below. UFs were used to convert all toxicity endpoints to chronic NOAELs based on sensitive endpoints (e.g., growth, reproduction, development). TBV_{low} and TBV_{high} values that were based on mortality endpoints were divided by an additional uncertainty factor of 10.

TBV_{high} values derived by the Army for silver, thallium, chlordane, and gamma-BHC (i.e., lindane) were divided by this additional uncertainty factor.

Uncertainty Factors Used in the Calculation of TBV_{low} values (a)

Type of UF	UF	Comments
Study Duration	5	Converts acute to chronic
	2	Converts subchronic to chronic
Endpoint	2	Converts from less to more sensitive endpoint
	5	Converts LOAEL to NOAEL
	10	Converts LD50 to NOAEL (Army)
	10	Additional factor 10 for mortality endpoints (LD50s) was applied to both the TBV_{low} and TBV_{high} by the Trust
Intertaxon	3	Converts between species in same family, different genus
	4	Converts between species in same order, different families
	5	Converts between species in different orders
	10	Converts between species in different orders with an additional factor of 2 for special-status species (raptors)

(a) Uncertainty factors were those developed by the Army, except where noted.

TBV_{low} and TBV_{high} values were developed for chemicals not considered in the Army RI using similar methods, including application of uncertainty factors used in the Army's RI, as appropriate. Chemicals not considered in the Army's RI for which TBVs were derived consist of tetraethyl lead, 4-methylphenol, n-nitrosodiphenylamine, pentachlorophenol, phenol, acetone, 2-butanone, 1,4-dichlorobenzene, carbon disulfide, methylene chloride, 1,1,1-trichloroethane, toluene (which was used as a surrogate for p-isopropyltoluene), and methoxychlor. Additionally, mammalian data were added for heptachlor/heptachlor epoxide, which was not included in the Army's RI.

The Army also did not consider acenaphthene, acenapthylene, benzo(a)anthracene, benzo(b)fluoranthene, dibenzofuran, benzo(k)fluoranthene, benzo(g,h,i)perylene, dibenzo(a,h)anthracene, indeno(1,2,3-cd)pyrene, 2-methylnaphthalene, phenanthrene, and pyrene, which are PAHs. Because only one set of toxicity values is available for PAHs, this same set was applied to each of these PAHs. Similarly, the TBV for endosulfan was used as a surrogate for endosulfan sulfate, the TBV for endrin was used

as a surrogate for endrin aldehyde and endrin ketone, the TBV for heptachlor was used as a surrogate for heptachlor epoxide, the TBV for beta-BHC was used as a surrogate for alpha- and delta-BHC, and the TBV for aldrin was used as a surrogate for isodrin because isodrin is an isomer of aldrin. Only studies on mortality endpoints were available to calculate TBV_{high} values for benzyl alcohol, aldrin, chlordane, gamma-BHC, heptachlor, heptachlor epoxide, isodrin, and methoxychlor. TBV_{high} values for these chemicals were divided by an additional uncertainty factor of 10, consistent with the revisions made to TBV_{high} values derived by the Army based upon mortality endpoints.

No published toxicity values were found for trichlorofluoromethane, 2,4-D, dicamba, and MCPP. Consequently, ecological PRGs for these PCOCs could not be calculated.

5.5.3 Aquatic Life

TBVs for aquatic life were developed for both freshwater and marine aquatic habitats. Aquatic life TBVs are based upon sediment quality guidelines. Potentially relevant sediment quality guidelines for freshwater sediments include the following:

- **Canadian Sediment Quality Guidelines**: The Canadian Council of Ministers of the Environment (1999) has issued interim sediment quality guidelines ("ISQGs") and probable effect levels ("PELs") for chemicals in sediment. These levels have been developed employing the approach that NOAA (1999) used to derive sediment criteria in its *Screening Quick Reference Tables*. Chemical concentrations in sediment below the LEL are unlikely to result in adverse effects, concentrations between the LEL and PEL may result in adverse effects, and concentrations above the PEL are likely to result in adverse effects.

- **Consensus-Based Threshold Effects Concentration ("TEC") and Probable Effects Concentration ("PEC"):** MacDonald et al. (2000) developed freshwater sediment quality guidelines for 28 chemicals. These guidelines reflect the toxicity of chemicals in sediment when they occur in mixtures with other chemicals and provide a basis for classifying sediment as potentially harmful. For each chemical considered by MacDonald et al., a TEC and PEC have been developed. Similar to the Canadian sediment quality guidelines, chemical concentrations in sediment below the TEC are unlikely to result in adverse effects, concentrations between the TEC and PEC may result in adverse effects, and concentrations above the PEC are likely to result in adverse effects.

- **U.S. EPA Sediment Quality Criteria ("SQC") and Sediment Quality Benchmarks ("SQB"):** U.S. EPA (1996a, 1995a) developed SQC and SQB values based on the equilibrium partitioning ("EqP") method. These values are considered protective of aquatic life.

Sediment quality guidelines for marine sediments include the following:

- **NOAA Effects Range Low (ER-L) and Effects-Range Median (ER-M):** NOAA (Long et al., 1995) developed effects-based screening benchmarks using data for chemical concentrations in coastal marine and estuarine environments collected throughout the United States annually. Concentrations observed or predicted from these studies associated with biological effects are ranked; the lower 10th percentile values are the ER-Ls and the median values are the ER-Ms.
- **U.S. EPA SQC and SQB**: (U.S. EPA (1996a, 1995a) developed SQC and SQB values based on the EqP method. These values are considered protective of aquatic life.

Sediment quality criteria or PRGs for aquatic life are summarized in Tables 5–7 and 5–8, respectively, for freshwater and marine habitats.

5.6 CALCULATION OF ECOLOGICAL PRGS FOR PCOCS OTHER THAN LEAD IN SOIL AND SEDIMENT

As discussed in Section 5.3, PRGs for plants, soil fauna, and aquatic life are not calculated. PRGs for these receptor groups are instead based upon published TBVs or sediment quality guidelines for the PCOCs under consideration that encompass all exposure pathways. To calculate wildlife PRGs for Presidio sites, standard risk equations were rearranged to solve for the concentration term. The general equation employed to calculate PRGs for protection of wildlife species at the Presidio is as follows:

$$PRG = \frac{\text{Target HQ of } 1 \times TBV \times BW}{Intake_{soil/sed\ ingestion} + Intake_{food\ ingestion} + Intake_{dermal}}$$

where:

HQ	=	Hazard quotient equal to 1
TBV	=	Toxicity benchmark value (mg/kg-day)
BW	=	Body weight (kg)
$Intake_i$	=	Intake (or dose) from pathway *i* (kg/day)

The intake from soil and sediment ("soil/sed") ingestion is equivalent to the total dietary ingestion rate multiplied by the fraction of soil and sediment in the diet:

$$Intake_{soil/sed\ ingestion} = DIR \times F_{soil/sed}$$

where:

DIR	=	Daily ingestion rate (kg/day)
$F_{soil/sed}$	=	Fraction of soil and sediment in diet (unitless)

The intake from food ingestion is the sum of the ingestion for each food item, which is estimated by multiplying the dietary ingestion rate by the fraction of the diet that consists of the particular food item and by the bioaccumulation factor of the food item:

$$\text{Intake}_{\text{food ingestion}} = \Sigma\ \text{DIR} \times F_i \times \text{BAF}_i$$

where:

F_i	=	Fraction of diet that consists of food item *i* (unitless)
BAF_i	=	Bioaccumulation factor for food item *i* (unitless)

Intake from dermal contact is expressed as follows:

$$\text{Intake}_{\text{dermal}} = \text{SA} \times \text{AF} \times \text{ABS} \times \text{CF}$$

where:

SA	=	Surface area of species (cm^2)
AF	=	Soil adherence factor (mg/cm^2)
ABS	=	Absorption factor (chemical-specific)
CF	=	Conversion factor (converts units from mg to kg)

The Army used the above general equations to create formulas for calculating PRGs for specific wildlife species. Formulas for terrestrial habitat indicator species (i.e., American robin, mourning dove, western harvest mouse, valley pocket gopher, raccoon, peregrine falcon, red-tailed hawk) and aquatic habitat indicator species (i.e., mallard duck, western sandpiper) are included in Appendix B of the Army's FS (Dames & Moore, 1997a). The formulas in Appendix B of the Army's FS were modified by the Trust to recalculate ecological PRGs for Presidio sites. Modifications to the formulas involved adjusting the ingestion of food items pathway to be consistent with the exposure pathways described in Section 5.3, and removing the area use factors ("AUFs"). The AUF is the ratio of the area of the site to the area of the home range of the species evaluated. AUFs were removed because the PRGs developed apply to all Presidio sites and do not correspond to the area of a specific site. Modified formulas used by the Trust to recalculate ecological PRGs for Presidio sites are listed in Table 5–9.

5.7 ECOLOGICAL EXPOSURE PARAMETERS

Table 5–10 summarizes the factors assumed for the exposure parameters in the formulas used to recalculate PRGs. Home ranges in Table 5–10 are presented for information only. Exposure factors are identical to those presented in the Army's FS except for adjustment to some dietary ingestion rates as noted below. When available, upper-bound (i.e., 95th percentile) values were used to be protective.

- **Body weight (BW):** 95th percentile values assumed by the Army were used. These values were compared to values in DTSC (2000a) Ecotox computerized database and were found to be comparable.

- **Surface area (SA):** 95th percentile values assumed by the Army were used.

- **Dietary ingestion rate (DIR):** 95th percentile values assumed by the Army were used except that values previously expressed on a wet weight basis (i.e., American robin, western harvest mouse, and red-tailed hawk) were converted to a dry weight basis. This conversion was necessary because all other exposure factors (e.g., fraction of soil in diet, BAF) are expressed on a dry weight basis. Dietary ingestion rates were converted using the equation $DIR_{dry} = DIR_{wet} \times (1 - \text{percent water content in food})$ and average moisture contents from Sample and Suter (1994).

Values assumed for dietary composition and bioaccumulation factors ("BAF") are discussed in Sections 5.7.1 and 5.7.2.

5.7.1 Dietary Composition

The formulas for recalculating PRGs for specific wildlife species are based upon the following dietary fractions:

- American robin: 100 percent of diet is invertebrates ($F_{inv} = 1$)

- Mourning dove: 100 percent of diet is plants ($F_{plant} = 1$)

- Western harvest mouse: 50 percent of diet is plants ($F_{plant} = 0.5$) and 50 percent is invertebrates ($F_{inv} = 0.5$)

- Valley pocket gopher: 100 percent of diet is plants ($F_{plant} = 1$)

- Raccoon: 50 percent of diet is invertebrates ($F_{inv} = 0.5$) and 50 percent is herbivorous birds ($F_{bird} = 0.5$)[7]

- Peregrine falcon: 50 percent of diet is herbivorous birds ($F_{bird1} = 0.5$) and 50 percent is insectivorous birds ($F_{bird2} = 0.5$)

- Red-tailed hawk: 50 percent of diet is herbivorous mammals ($F_{mam1} = 0.5$) and 50 percent is insectivorous mammals ($F_{mam2} = 0.5$)

[7] Although raccoons are more likely to ingest plant material and some small mammals, the use of the herbivorous bird BAF (BAF for plants times BAF for birds) is conservative and encompasses a similar magnitude of exposure.

- Mallard duck: 100 percent of diet is plants ($F_{plant} = 1$)

- Western sandpiper: 100 percent of diet is invertebrates ($F_{inv} = 1$).

5.7.2 Bioaccumulation Factors

Metals, PCBs, pesticides, and herbicides are recognized to be bioaccumulative. BAFs used by the Trust to recalculate ecological PRGs are summarized in Table 5–11. If available, BAFs for PCOCs were obtained from ORNL documents (Bechtel Jacobs Company L.L.C, 1998; Sample, et al., 1998a, 1998b). U.S. EPA generally accepts BAFs from ORNL for use in performing ecological risk assessments. ORNL BAFs for plants, soil invertebrates, and wildlife were available for most bioaccumulative PCOCs. If no BAFs from ORNL were available for PCOCs, BAFs included in the Army's RI were assumed instead. The BAF for lead was used as a surrogate for tetraethyl lead. The BAF for dieldrin was used as a surrogate for aldrin and isodrin. The BAF for heptachlor was used as a surrogate for heptachlor epoxide, and 4,4'-DDT was used as a surrogate for 4,4'-DDD and 4,4'-DDE. For pesticides and herbicides that do not have reported BAFs, assumptions were made for these values based on the magnitude of BAFs reported in literature for other pesticides and herbicides.

Plants do not bioaccumulate pesticides and herbicides to any significant extent. Therefore, the BAF was assumed to be zero for plants without pesticide and herbicide literature-reported values. Pesticide and herbicide BAFs were assumed to be 3 for invertebrates, 1 for birds, and 0.5 and 0.1 for omnivorous and herbivorous mammals based on the range of literature-reported values for chlordane, dieldrin, heptachlor, and 4,4'-DDT.

5.8 ECOLOGICAL PRGS FOR PCOCS OTHER THAN LEAD IN SOIL AND SEDIMENT

Ecological PRGs for PCOCs other than lead in soil and sediment for non-special status species and special status species are described in Sections 5.8.1 and 5.8.2. PRGs for lead in soil and sediment for non-special status species and special status species are described in Section 5.9.

5.8.1 Non-special Status Species PRGs

PRGs for soil based on TBV_{low} and TBV_{high} values are presented in Tables 5-12 and 5-13, respectively. Potential ecological PRGs for soil are compiled in Table 5-14. For each PCOC, Table 5-14 contain the PRG_{low} and PRG_{high} values for plants and soil fauna, and the lowest wildlife PRGs recalculated using the TBV_{low} from Table 5–5 and TBV_{high} from Table 5–6. The arithmetic means of the PRGs for plants and soil fauna, and the arithmetic mean PRGs for wildlife were computed for each PCOC. Selecting the lower of the arithmetic means of plants and soil fauna PRGs, and wildlife PRGs determined the soil PRG proposed to safeguard populations of non-special status species. The arithmetic

means are considered protective because they are computed from PRG_{low} and PRG_{high} values that are based on TBVs that span the range of no significant adverse effects to the upper bound of acceptable or safe daily intakes, as discussed in Section 5.5.

A similar approach to that used to develop ecological PRGs for soil was used to derive ecological PRGs for sediment. Sediment quality criteria were compared to risk-based PRGs calculated for the mallard duck and western sandpiper to determine whether sediment quality criteria or risk-based PRGs should be proposed as cleanup levels for PCOCs. Mallard duck and western sandpiper are considered representative species for both freshwater and marine aquatic areas onsite. Although mallard duck is more of a freshwater species, it is similar to diving ducks that may be present in marine aquatic areas (e.g., scoters, lesser scaup, etc.). Sediment quality criteria for aquatic life are presented in Tables 5–7 and 5–8. Potential PRGs for sediment calculated from the TBV_{low} and TBV_{high} values for the mallard duck and western sandpiper are summarized in Table 5-15. The PRGs for aquatic life, and the mallard duck, and western sandpiper were considered together to select potential sediment PRGs for each PCOC. The lowest values defining the range of PRGs developed for these indicator species (i.e., aquatic life, mallard duck, western sandpiper) of aquatic habitats are presented in Tables 5-16 and 5-17, respectively, for freshwater and marine habitats. The arithmetic mean of these lowest values was computed for each PCOC and is the proposed sediment PRG for protection of non-special status species.

5.8.2 Special Status Species PRGs

As described in Section 5.8.1, proposed PRGs in Tables 5-14, 5-16, and 5-17 are anticipated to be protective of populations of ecological receptors. However, these PRGs may not be protective of individual special status species, especially where the difference between the PRG_{low} and PRG_{high} values used to calculate the mean is great. For PCOCs where the difference between the TBV_{low} and TBV_{high} values for the species governing the level of cleanup is greater than one order of magnitude, a separate evaluation was conducted to develop alternate PRGs that are intended to safeguard special status species. For plants, special status species PRGs had to be developed for several metals. For raptors and shorebirds, which serve as wildlife indicator species for terrestrial and aquatic habitats, special status species PRGs had to be developed for several metals, as well as pesticides, and herbicides. The non-special status species PRGs for all other PCOCs and indicator species (i.e., aquatic life) are considered protective of special status species.

For plants, NOECs were compiled from the references consulted for non-special status plant species. However, the low and high values used to develop special status species PRGs encompassed the entire range of NOECs and excluded LOECs. The 5th, 10th, and 25th percentiles, and arithmetic means of the NOEC values were computed, as summarized in Table 5-18. The 25th percentile of NOECs for each metal is proposed as the alternate special status species PRG because this percentile includes NOECs obtained from studies on a variety of soil types and species, including species that are taxonomically similar to those at the Presidio.

The alternate special status species PRGs for raptors and shorebirds are established from the PRGs for the peregrine falcon and western sandpiper, respectively, because the PRGs for these birds are the lowest of the special status indicator species evaluated for terrestrial and aquatic habitats. PRG_{low} and PRG_{high} values were computed from TBVs compiled from the references consulted for non-special status wildlife species. The 5th, 10th, and 25th percentiles, and arithmetic means of the PRG_{low} and PRG_{high} values were calculated for each metal, pesticide, and herbicide that a special status species PRG needed to be derived. Tables 5-19 and 5-20 summarize these statistics and the toxicity endpoints of the studies on which the computed PRGs are founded. The following hierarchy was used to select the proposed PRG for special status raptors:

- The 5th percentile was used where the difference between PRG_{low} and PRG_{high} values for non-special status species is two orders of magnitude or greater.

- The 10th percentile was used where the difference between PRG_{low} and PRG_{high} values for non-special status species is between one and two orders of magnitude.

Except for 4,4'-DDT, no further adjustment was required to calculate special status PRGs because TBVs obtained from studies of mortality endpoints had previously been divided by an uncertainty factor of 10 to calculate PRGs for non-special status species. TBV_{low} and TBV_{high} values for 4,4'-DDT were adjusted based upon TBVs developed from studies on eggshell thinning.

Soil PRGs for special status plant (Table 5-18) and wildlife species (Table 5-19) were compared to soil PRGs proposed for non-special status plant and wildlife species (Table 5-14). This comparison is presented in Table 5-21. Special status species PRGs that are lower than non-special status PRGs are proposed as soil PRGs for special status species. Non-special status PRGs may be lower for some of the PCOCs evaluated because (1) the non-special status species evaluated may have higher exposure to chemicals than the special status species (e.g., American robin vs. peregrine falcon), or (2) the toxicity value for a non-special status species for a particular chemical is lower (e.g., mammal vs. bird toxicity values). For these PCOCs, no value is presented in Table 5-21 for the alternate PRG for special status species.

Similarly, sediment PRGs for special status wildlife species (Table 5-20) were compared to sediment PRGs proposed for non-special status aquatic life and wildlife species (Table 5-16). These comparisons are presented in Tables 5-22 and 5-23, respectively, for freshwater and marine habitats. Special status species PRGs that are lower than non-special status PRGs are proposed as sediment PRGs for special status species.

5.9 ECOLOGICAL PRGS FOR LEAD IN SOIL AND SEDIMENT

The Army evaluated separately the potential ecological risks of lead in Appendix U of the Army's RI. Available plant and wildlife toxicity information for lead varies up to five orders of magnitude. In fact, inserting U.S. EPA Region IX BTAG lead toxicity values

(PRC, 1997) in the formulas listed in Table 5–9 generates an ecological PRG that is considerably less than naturally occurring lead concentrations in Presidio soil based upon BTAG's low toxicity value, and generates an ecological PRG greater than 2,000 mg/kg based upon BTAG's high toxicity value. Therefore, establishing an ecological PRG for lead by computing the arithmetic mean of PRGs derived from TBV_{low} and TBV_{high} values may not be appropriate.

The Army used a probabilistic approach to derive a cleanup level for lead. The approach used is often termed the Monte Carlo method because of the type of computer modeling employed. The Monte Carlo method takes into account the variability of toxicity values and exposure factors. Instead of using single point estimates for TBVs and exposure factors (e.g., body weight, dietary ingestion rate), the entire distributions of values are input into a computer simulation model. The model randomly selects each of these distributions for values to be incorporated into the risk equations, thereby generating a distribution of acceptable concentrations or PRGs.

The Army performed the Monte Carlo method for plants and the American robin. Plants were selected because of the need to protect special status plant species at the Presidio. The American robin was chosen because the robin has some of the lowest PRGs of the wildlife indicator species evaluated. DTSC (2000b) provided comments to the Trust on the manner in which the Army performed the Monte Carlo method to derive PRGs for lead. In response to these comments, the Trust made the following modifications to the Monte Carlo method to recalculate ecological PRGs for lead in soil at the Presidio:

- For plants, only toxicity data for non-mortality endpoints (e.g., reduction in shoot or root growth) were used and the data were fitted to a distribution.

- For the American robin, exposure factors were revised, as discussed in Section 5.7, updated TBVs for lead from U.S. EPA Region IX BTAG were used (PRC, 1997), the gastrointestinal tract absorption of lead was changed from 10 to 26 percent, and a dermal absorption factor of 0.01 for lead was used, as suggested by DTSC (2000b).

- A total of 10,000 iterations was used in each Monte Carlo computer model simulation instead of 1,000 iterations used by the Army.

- The 50th percentile lead concentrations to safeguard plants and the American Robin were compared to determine the proposed PRG for lead in soil to protect non-special status species as opposed to the 90th percentile values used by the Army.

- The 25th percentile lead concentration to safeguard plants is proposed as the PRG for lead in soil to protect special status species.

Crystal Ball™ was used to perform the Monte Carlo method computer simulations. Copies of input parameters and Monte Carlo method output using Crystal Ball™ are included as Appendix B.

5.9.1 Non-special Status Species PRGs

The Monte Carlo method produced 50th percentile concentrations of 324 mg/kg of lead to protect plants and 297 mg/kg of lead to protect the American robin. Consequently, a PRG of 300 mg/kg for lead in soil is proposed for protection of both non-special status plant and animal species.

PRGs of 82 and 132 mg/kg for lead in sediment from freshwater and marine habitats, respectively, are proposed for protection of non-special status aquatic life and wildlife species. For freshwater habitats, this concentration is based upon the arithmetic mean of the lowest sediment quality value for aquatic life of 35.7 mg/kg and the highest sediment quality value of 128 mg/kg for lead (Table 5–7). For marine habitats, this concentration is based on the arithmetic mean of the lowest sediment quality value for aquatic life of 46.7 mg/kg and the highest sediment quality value of 218 mg/kg for lead (Table 5–8). The Monte Carlo method was not conducted for indicator wildlife species of aquatic habitats because the range of values of sediment quality value for lead varied by less than an order of magnitude and because of the fact that sediment quality value for aquatic life are generally considered protective of wildlife exposures to PCOCs in surface water as well.

5.9.2 Special Status Species PRGs

A PRG of 160 mg/kg for lead in soil is proposed for protection of both special status plant and animal species based upon the 25th percentile concentration of 157 mg/kg of lead to protect plants generated by the Monte Carlo method. The PRGs of 82 and 132 mg/kg for lead in sediment are believed to be protective of special status aquatic life and wildlife species as well as non-special status species.

5.10 DTSC REVIEW OF ECOLOGICAL PRGS FOR SOIL

The DTSC reviewed the ecological PRGs developed using the protocol described above and provided the Trust with written comments in October 2001 (DTSC, 2001) and verbal comments during the first few months of 2002. The DTSC was primarily concerned that (1) the special status species PRGs for soil developed by the Trust may not be fully protective of special status species and (2) when there was a large difference between the PRG_{low} and PRG_{high}, the arithmetic mean PRG may not be fully protective of non-special status species. Based on discussions with the DTSC, the Trust made the following changes to the ecological cleanup levels:

- The areas of the Presidio where non-special status species PRGs would be applied were renamed "buffer zone" areas because these areas are generally adjacent to

special status species areas and developed areas of the Presidio where ecological PRGs are not applicable (see Section 7.1.2 and Figure 7-2). Proposed soil PRGs for these buffer zone areas were redefined as the lowest value of (1) the special status species PRG identified in Table 5-21, (2) the arithmetic mean of the PRG_{low} and PRG_{high} for plant and soil fauna, (3) the arithmetic mean of the PRG_{low} and PRG_{high} wildlife PRGs, or (4) 5 mg/kg for pesticides or herbicides for which not enough toxicological data exists to calculate a PRG_{low} and PRG_{high} (i.e., 2,4-D, Dicamba, and MCPP).

- Special status species PRGs were redefined as the lower value of (1) the PRG_{low} for plant and soil fauna or (2) the PRG_{low} for wildlife, unless the PRG_{low} is less than the laboratory method detection limit as specified in the *Presidio-wide Quality Assurance Project Plan, Sampling and Analysis Plan* ("QAPP/SAP") (TTEMI, 2001). In such cases, the method detection limit was established as the special status species PRG. If no PRG could be calculated for pesticides or herbicides due to a lack of toxicological data (i.e., 2,4-D, Dicamba, and MCPP), the special status species PRG was established as the method detection limit. For mercury, the special status species PRG was established as two times the typical method detection limit.

These revised ecological PRGs are shown in Table 5-24, which summarizes the ecological PRGs for PCOCs in soil at the Presidio. These PRGs are incorporated into the selection of applicable cleanup levels at the Presidio, as described in Section 7.

TABLES

TABLE 5-1
SPECIAL STATUS PLANT SPECIES AT THE PRESIDIO OF SAN FRANCISCO (a)

Presidio of San Francisco, California

Common Name	Scientific Name	Basis for Special Status Listing
Coast rock cress	*Arabis blepharophylla*	List 4 Species: Plants of Limited Distribution (b)
Raven's manzanita	*Arctostaphylos hookeri* var. *ravenii*	Federal and California Endangered Species (c); (d); List 1B Species: Rare, Threatened, or Endangered Species in California or Elsewhere (b)
San Francisco spineflower	*Chorizanthe cuspidata* var. *cuspidata*	List 1B Species: Rare, Threatened, or Endangered Species in California or Elsewhere (b)
Franciscan thistle	*Cirsium andrewsii*	Proposed List 1B Species: Rare, Threatened, or Endangered Species in California or Elsewhere (b)
Presidio clarkia	*Clarkia franciscana*	Federal and California Endangered Species (c); (d); List 1B Species: Rare, Threatened, or Endangered Species in California or Elsewhere (b)
San Francisco wallflower	*Erysimum franciscanum*	List 4 Species: Plants of Limited Distribution (b)
Dune gilia	*Gilia capitata* ssp. *chamissonis*	Proposed List 1B Species: Rare, Threatened, or Endangered Species in California or Elsewhere (b)
San Francisco gum plant	*Grindelia hirsutula* var. *maritima*	List 1B Species: Rare, Threatened, or Endangered Species in California or Elsewhere (b)
Marin dwarf flax	*Hesperolinon congestum*	Federal and California Threatened Species (c); (d); List 1B Species: Rare, Threatened, or Endangered Species in California or Elsewhere (b)
San Francisco lessingia	*Lessingia germanorum* var. *germanorum*	Federal and California Endangered Species (c); (d); List 1B Species: Rare, Threatened, or Endangered Species in California or Elsewhere (b)
San Francisco campion	*Silene verecunda* ssp. *verecunda*	List 1B Species: Rare, Threatened, or Endangered Species in California or Elsewhere (b)
San Francisco owl's clover	*Tryphysaria floribunda*	List 1B Species: Rare, Threatened, or Endangered Species in California or Elsewhere (b)
California sea-blight	*Suaeda californica*	Federal and California Endangered Species (c)

TABLE 5-1
SPECIAL STATUS PLANT SPECIES AT THE PRESIDIO OF SAN FRANCISCO (a)

Presidio of San Francisco, California

Notes:

(a) Special status plant species identified at the Presidio of San Francisco are compiled from Department of Interior, National Park Service and Presidio Trust *Vegetation Management Plan and Environmental and Assessment Staff Report,* dated October 2000, finalized May 2001.

(b) Skinner, M.W. and B.M. Pavlik. 1994. *Inventory of Rare and Endangered Vascular Plants of California*. 5th Edition. California Native Plant Society.

(c) Title 50 of Code of Federal Regulations §17.12.

(d) California Department of Fish and Game. September 1995. *Endangered, Threatened, or Rare Plants of California*. Natural Heritage Division, Plant Conservation Program, Sacramento, California.

TABLE 5-2
POTENTIAL OCCURRING SPECIAL STATUS WILDLIFE SPECIES AT THE PRESIDIO OF SAN FRANCISCO (a)

Presidio of San Francisco, California

Common Name	Scientific Name	Basis for Special Status Listing
Double-crested cormorant	*Phalacrocorax auritus*	California Species of Concern (c)
Western snowy plover	*Charadrius alexandrius nivosus*	Federal Threatened Species (b); California Species of Concern (c)
Loggerhead shrike	*Lanius ludovicianus*	California Species of Concern (c)
Long-billed curlew	*Numenius americanus*	Federal and California Species of Concern (b); (c)
California gull	*Larus californicus*	California Species of Concern (c)
Saltmarsh common yellowthroat	*Geothylpos trichas sinuosa*	Federal and California Species of Concern (b); (c)
Elegant tern	*Sterna elegans*	California Species of Concern (c)
California least tern	*Sterna antillarum browni*	Federal and California Endangered Species (b); (c)
Vaux's swift	*Chaetura vauxi*	California Species of Concern (c)
California yellow warbler	*Dendroica petechia brewsteri*	California Species of Concern (c)
Willow flycatcher	*Empidonax trailli*	California Endangered Species (c)
White-tailed kite	*Elanus caeruleus*	California Fully Protected Species (c)
Bald eagle	*Haliaeetus leucocephalus*	Proposed Delisting from Federal Endangered Species Act (b); California Endangered and Fully Protected Species (c)
Northern harrier	*Circus cyaneus*	California Species of Concern (c)
Sharp-shinned hawk	*Accipiter striatus*	California Species of Concern (c)
Northern goshawk	*Accipiter gentilis*	California Species of Concern (c)

TABLE 5-2

POTENTIAL OCCURRING SPECIAL STATUS WILDLIFE SPECIES AT THE PRESIDIO OF SAN FRANCISCO (a)

Presidio of San Francisco, California

Common Name	Scientific Name	Basis for Special Status Listing
Swainson's hawk	*Buteo swainsoni*	California Threatened Species (c)
Ferruginous hawk	*Buteo regalis*	Federal and California Species of Concern (b); (c)
Golden eagle	*Aquila chrysaetos*	California Fully Protected Species (c)
Prairie falcon	*Falco mexicanus*	California Species of Concern (c)
Cooper's hawk	*Accipiter cooperi*	California Species of Concern (c)
Merlin	*Falco columbarius*	California Species of Concern (c)
Peregrine falcon	*Falco peregrinus anatum*	Delisted from Federal Endangered Species Act (b); California Endangered Species (c)
Common loon	*Gavia inmer*	California Species of Concern (c)
American white pelican	*Pelecanus erythrorhynchos*	California Species of Concern (c)
California brown pelican	*Pelecanus occidentalis californicus*	Federal and California Endangered Species (b); (c)
Harlequin duck	*Histrionicus histrionicus*	California Species of Concern (c)
Osprey	*Pandion haliaetus*	California Species of Concern (c)
Marbled murrelet	*Brachyramphus marmoratus*	Federal Threatened Species (b); California Endangered Species (c)
Yuma myotis	*Myotis yumanensis*	Federal and California Species of Concern (b); (c)

Notes:

(a) Potential occurring special status animal species identified at the Presidio of San Francisco are compiled from Jones & Stokes Associates, Inc. *Draft Presidio of San Francisco Forest Management Plan*, dated 1994. Jones & Stokes Associates identified potential occurring special status animal species based upon the animals that are associated with varying types of habitats found at the Presidio.

(b) Title 50 of Code of Federal Regulations §1711-12

(c) California Fish and Game Code §§3511, 4700, 5050, and 3503.5.

TABLE 5-3
DEVELOPMENT OF TOXICITY BENCHMARK VALUES FOR CHEMICALS NOT INCLUDED IN ARMY REMEDIAL INVESTIGATION (a)

Presidio of San Francisco, California

Potential Chemical of Concern	TBV-Low (mg/kg-day)	TBV-high (mg/kg-day)	Species	Study Endpoint UF	Study Duration UF	NOAEL (mg/kg-day)	LOAEL (mg/kg-day)	Study Description	Reference	Comment
Inorganic Chemicals										
Beryllium	48.5	485	poultry	5	2	- (b)	485	Caused ricketts in poultry and other livestock at 0.5% of diet. Use 0.097 kg/kg-day from Wiseman (1987) to convert.	Friberg et al, 1979.	Study used in Army RI.
	21.3	42.5	rat	2	1	-	42.5	Mild weight loss, 2 year study. Estimated with 0.085 gm/gm-day (Groton, et al, 1991.)	WHO, 1999.	Long term study; clear endpoint; study used in Army RI.
Cyanide	68.7	-	rat	1	1	68.7	-	Chronic, gestation and lactation; reproduction, oral in diet.	Sample et al, 1996.	Used potassium cyanide.
Molybdenum	3.5	35.3	poultry	1	1	3.5	35.3	LOAEL reduced embryonic viability; 21 day study	Sample et al., 1996	Reproductive endpoint.
	0.26	2.6	mouse	1	1	0.26	2.6	LOAEL for reduced reproductive success; 3 generation study	Sample et al, 1996.	Long-term study.
Tetraethyl Lead	12	170	rat	1	1	12	170	NOAEL for mortality and growth.	Azar et al, 1973.	Study used in Army RI.
	1.13	11.3	quail	1	1	1.13	11.3	Egg hatching success.	Sample et al, 1996.	Long-term study.

TABLE 5-3

DEVELOPMENT OF TOXICITY BENCHMARK VALUES FOR CHEMICALS NOT INCLUDED IN ARMY REMEDIAL INVESTIGATION (a)

Presidio of San Francisco, California

Potential Chemical of Concern	TBV-Low (mg/kg-day)	TBV-high (mg/kg-day)	Species	Study Endpoint UF	Study Duration UF	NOAEL (mg/kg-day)	LOAEL (mg/kg-day)	Study Description	Reference	Comment
Semi Volatile Oragnic Compounds										
Benzyl Alcohol	2	100	bird	10	5	-	100	LD_{50} study.	RTECS, 1996.	Study used in Army RI.
	20.8	1,040	rabbit	10	5	-	1,040	LD_{50} study.	RTECS, 1996.	Study used in Army RI.
4-methylphenol (p-Cresol)	219.2	-	mink	1	1	219.2	-	6 months, reproduction, oral in diet.	Sample et al, 1996.	Used o-cresol.
n-nitrosodiphenylamine	200	-	rat	1	1	200	-	100 week, systemic.	ATSDR, 1999.	
Pentachlorophenol	0.24	2.4	rat	1	1	-	-	Reduction in survival and growth during gestation.	Sample et al, 1996.	Study used in Army RI.
Phenol	30	-	rat	2	1	60	-	NOAEL, chronic, oral study demonstrating decreased fetal weight.	U.S. EPA, 2000.	
Volatile Organic Compounds										
Acetone	100	500	rat	1	1	100	500	90 day NOAEL & LOAEL; liver & kidney damage; oral intubation.	Sample et al, 1996.	Study used in Army RI.
2-butanone (MEK)	50	100	rat	1	1	50	-	NOAEL for methyl isobutyl ketone for body weight, food consumption, organ weight, histopathology, morbidity, clinical chemistry, hematology for 13 week study.	WHO, 1990.	Study used in Army RI.

TABLE 5-3
DEVELOPMENT OF TOXICITY BENCHMARK VALUES FOR CHEMICALS NOT INCLUDED IN ARMY REMEDIAL INVESTIGATION (a)

Presidio of San Francisco, California

Potential Chemical of Concern	TBV-Low (mg/kg-day)	TBV-high (mg/kg-day)	Species	Study Endpoint UF	Study Duration UF	NOAEL (mg/kg-day)	LOAEL (mg/kg-day)	Study Description	Reference	Comment
Volatile Organic Compounds (cont.)										
Carbon disulfide	11	110	rat	1	1	11	110	NOAEL for fetal toxicty/malformations; entire gesation period (22 days).	IRIS, 2001.	Calculated from oral dose.
1,4-dichlorobenzene	25	50	mouse, rat	1	1	25	50	NOEL, subchronic oral study, endpoints of body weight, survival, histopathology, hematology, organ weight range from 25-125 mg/kg bw/d.	CEPA, 1993.	Less extrapolation than using the inhalation study from Army RI.
Methylene Chloride	5.85	50	rat	1	1	5.85	50	Histological effects on liver.	Sample et al, 1996.	
Toluene (as a surrogate for p-isopropyltoluene)	26	260	mouse	1	1	26	260	LOAEL for reduced fetal weights; dosed during	Sample et al, 1996.	
1,1,1-trichloroethane	114	5,700	rabbit, rat, guinea pig	10	5	-	5,700	LD_{50} study.	CEPA, 1993.	Study used in Army RI.
PCBs, Pesticides, and Herbicides										
Aldrin	0.5	5	mallard duck	5	2	-	5	LOAEL for mortality in a 30-day study.	Hudson et al, 1984.	Study used in Army RI.
	0.2	1	rat	1	1	0.2	1	Reproduction, duration less than 1year, oral in diet.	Sample et al, 1996.	Study used in Army RI.
alpha-BHC	0.563	2.25	japanese quail	1	1	0.563	2.25	Chronic, 90-day, reproduction, oral in diet	Sample et al, 1996.	Used beta-BHC.

TABLE 5-3
DEVELOPMENT OF TOXICITY BENCHMARK VALUES FOR CHEMICALS NOT INCLUDED IN ARMY REMEDIAL INVESTIGATION (a)

Presidio of San Francisco, California

Potential Chemical of Concern	TBV-Low (mg/kg-day)	TBV-high (mg/kg-day)	Species	Study Endpoint UF	Study Duration UF	NOAEL (mg/kg-day)	LOAEL (mg/kg-day)	Study Description	Reference	Comment
PCBs, Pesticides, and Herbicides (cont.)										
alpha-BHC	4	20	rat	1	1	4	20	13 weeks; growth, blood chemistry, organ histology, oral in diet.	Sample et al, 1996.	Used beta-BHC.
beta-BHC	0.563	2.25	japanese quail	1	1	0.563	2.25	Chronic, 90-day, reproduction, oral in diet	Sample et al, 1996.	Study used in Army RI.
	4	20	rat	1	1	4	20	13 weeks (subchronic); growth, blood chemistry, organ histology, oral in diet.	Sample et al, 1996.	Study used in Army RI.
delta-BHC	0.563	2.25	japanese quail	1	1	0.563	2.25	Chronic, 90-day, reproduction, oral in diet.	Sample et al, 1996.	Used beta-BHC.
	4	20	rat	1	1	4	20	13 weeks; growth, blood chemistry, organ histology, oral in diet.	Sample et al, 1996.	Used beta-BHC.
Endosulfan / Endosulfan Sulfate	10	-	gray partridge	1	1	10	-	4 weeks, chronic; reproduction; oral in diet.	Sample et al, 1996.	Study used in Army RI.
	1.5	-	rat	1	1	1.5	-	30 days; reproduction, blood chemistry; oral intubation.	Sample et al, 1996.	Study used in Army RI.

TABLE 5-3
DEVELOPMENT OF TOXICITY BENCHMARK VALUES FOR CHEMICALS NOT INCLUDED IN ARMY REMEDIAL INVESTIGATION (a)

Presidio of San Francisco, California

Potential Chemical of Concern	TBV-Low (mg/kg-day)	TBV-high (mg/kg-day)	Species	Study Endpoint UF	Study Duration UF	NOAEL (mg/kg-day)	LOAEL (mg/kg-day)	Study Description	Reference	Comment
PCBs, Pesticides, and Herbicides (cont.)										
Endrin / Endrin Aldehyde / Endrin Ketone	0.032	0.2	mallard duck	1	1	0.0315	0.189	NOAEL for reproductive effects in a 12 week study; dietary level 0.5 ppm. 3 ppm decreased embryo survival, and decreased male body weight by 4.5%; convert with 0.063 g/g -day from U.S. EPA (1993).	Roylance et al, 1985.	Long term study; relates to assessment endpoints; study used in Army RI.
	0.184	0.92	mouse	5	1	-	0.92	120 days, chronic; reproduction; oral in diet.	Sample et al, 1996.	Study used in Army RI.
Heptachlor / Heptachlor Epoxide	0.2	1	mink	5	1	-	1	181 days, chronic; reproduction; oral in diet.	Sample et al, 1996.	Mammal data.
Isodrin	0.5	5	mallard duck	5	2	-	5	LOAEL for mortality in a 30-day study.	Hudson et al., 1984	Used aldrin.
	0.2	1	rat	1	1	0.2	1	Reproduction, duration less than 1year, oral in diet.	Sample et al, 1996.	Used aldrin.
Methoxychlor	40	2,000	mallard duck, sharp tailed grouse, California quail	10	5	-	200	LD_{50} exceeded 2,000 mg/kg bw for all species.	Hudson et al., 1984	
	4	8	rat	1	1	4	8	11 month, chronic, reproduction; oral in diet.	Sample et al, 1996.	Study used in Army RI.

TABLE 5-3

DEVELOPMENT OF TOXICITY BENCHMARK VALUES FOR CHEMICALS NOT INCLUDED IN ARMY REMEDIAL INVESTIGATION (a)

Presidio of San Francisco, California

Notes:

(a) Abbreviations used in this table are as follows:

ATSDR	Agency for Toxic Substances and Disease Registry
CEPA	Canada Environmental Protection Agency
IRIS	Integrated Risk Information System
LOAEL	lowest-observed-adverse-effect-level
mg/kg-day	milligrams per kilogram body weight per day
NOAEL	no-observed-adverse-effect-level
ORNL	Oak Ridge National Laboratory
RI	Remedial Investigation
RTECS	Registry of Toxic Effects of Chemical Substances
TBV	toxicity benchmark value
UF	uncertainty factor
U.S. EPA	United States Environmental Protection Agency
WHO	World Health Organization

(b) Hyphen indicates information was not available.

(c) References listed in this table are as follows:

- Azar, A., H.J. Trochimowicz, and M.E. Maxfield. 1973. *Review of Lead Studies in Animals Carried Out at Haskell Laboratory - Two-Year Feeding Study and Response to Hemorrhage Study.* International Symposium. Environmental Health Aspects of Lead.
- Canada Environmental Protection Agency. 1993. *1,2-Dichlorobenzene, Priority Substances List Assessment Report*. Health Canada, Ottawa, Canada: Canada Communications Group Publishing.
- Dames & Moore. January 1997. *Final Remedial Investigation Report, Presidio Main Installation, Presidio of San Franscisco*.
- Friberg, L., G.F. Nordberg, and V.B. Vouk. 1979. *Handbook of Toxicology of Metals*. Elsevier/North Holland Biomedical Press.
- Groten, J.P., E.J. Sinkeldam, J. B. Luten, and P.J. Van Bladeren. 1991. *Comparison of the Toxicity of Inorganic and Liver-Incorporated Cadmium: A Four Week Feeding Study in Rats.* Food and Chemical Toxicology. Vol. 28, pp. 435-442.
- Hudson, R., R.K. Tucker, and M.A. Haegele. 1984. *Handbook of Toxicity of Pesticides to Wildlife (2nd ed.)*. United States Fish and Wildlife Service. Res. Publ. 153.
- Roylance, K.J., C.D. Jorgensen, G.M. Booth, and M.W. Carter. 1985. *Effects of Dietary Endrin on Reproduction of Mallard Ducks*. Archives of Env. Contam. and Tox. Vol. 14. pp. 705-711.
- Sample, B.E., D.M. Opresko, and G.W. Suter I.I. June 1996. *Toxicological Benchmarks for Wildlife: 1996 Revision*. Oak Ridge National Laboratory.

TABLE 5-3
DEVELOPMENT OF TOXICITY BENCHMARK VALUES FOR CHEMICALS NOT INCLUDED IN ARMY REMEDIAL INVESTIGATION (a)

Presidio of San Francisco, California

Notes:

- United States Department of Health and Human Services. 1999. *Toxicological Profile for N-Nitrosodiphenylamine*. Agency for Toxic Substances and Disease Registry.
- U.S. EPA. 2000. Integrated Risk Information System Computerized Database. www.epa.gov/ngispgm3/iris/subst/.
- U.S. EPA. 1993. *Wildlife Exposure Factors Handbook, Volumes I and II*. Office of Research and Development. EPA/600/R-93/187 (a and b).
- Wiseman, J. 1987. *Feeding of Non-Ruminant Livestock*. Butterworths
- World Health Organization. 1999. *Beryllium; Environmental Health Criteria 106*. Geneva, Switzerland.

TABLE 5-4
UNCERTAINTY FACTORS USED FOR CHEMICALS NOT INCLUDED IN ARMY REMEDIAL INVESTIGATION

Presidio of San Francisco, California

Potential Chemical of Concern	Toxicity Data (a)			Uncertainty Factors (Dimensionless); (a)								
	Species Data are Based	TBV_{low} (mg/kg-day)	TBV_{high} (mg/kg-day)	American Robin	Mourning Dove	Western Harvest Mouse	Valley Pocket Gopher	Raccoon	Peregrine Falcon	Red-tailed Hawk	Mallard Duck	Western Sandpiper
Inorganic Chemicals												
Beryllium	poultry	48.5	485	5	5	- (b)	-	-	10	5	5	5
	rat	21.3	42.5	-	-	3	4	5	-	-	-	-
Cyanide	rat	68.7	68.7	-	-	3	4	5	-	-	-	-
Molybdenum	poultry	3.5	35.3	5	5	10	5	5	5	-	-	-
	mouse	0.26	2.6	-	-	-	-	-	-	3	4	5
Tetraethyl Lead	rat	12	170	-	-	3	4	5	-	-	-	-
	quail	1.13	11.3	5	5	-	-	-	10	5	5	5
Semivolatile Organic Compounds												
Benzyl Alcohol	bird	2	100	5	5	-	-	-	10	5	5	5
	rabbit	20.8	1,040	-	-	5	5	5	-	-	-	-
4-methylphenol (p-Cresol)	mink	219.2	219.2	-	-	5	5	4	-	-	-	-
n-nitrosodiphenylamine	rat	200	200	-	-	3	4	5	-	-	-	-
Pentachlorophenol	rat	0.24	2.4	-	-	3	4	5	-	-	-	-
Phenol	rat	30	30	-	-	3	4	5	-	-	-	-
Volatile Organic Compounds												
Acetone	rat	100	500	-	-	3	4	5	-	-	-	-
2-butanone (MEK)	rat	50	100	-	-	3	4	5	-	-	-	-

TABLE 5-4
UNCERTAINTY FACTORS USED FOR CHEMICALS NOT INCLUDED IN ARMY REMEDIAL INVESTIGATION

Presidio of San Francisco, California

Potential Chemical of Concern	Toxicity Data (a)			Uncertainty Factors (Dimensionless); (a)								
	Species Data are Based	TBV_{low} (mg/kg-day)	TBV_{high} (mg/kg-day)	American Robin	Mourning Dove	Western Harvest Mouse	Valley Pocket Gopher	Raccoon	Peregrine Falcon	Red-tailed Hawk	Mallard Duck	Western Sandpiper
Volatile Organic Compounds (cont.)												
1,4-dichlorobenzene	mouse, rat	25	50	-	-	3	4	5	-	-	-	-
Carbon disulfide	rat	11	110	-	-	3	4	5	-	-	-	-
Methylene Chloride	rat	5.85	50	-	-	3	4	5	-	-	-	-
Toluene (as a surrogate for p-isopropyltoluene)	mouse	26	260	-	-	3	4	5	-	-	-	-
1,1,1-trichlorothane	rabbit rat, guinea pig	114	5,700	-	-	3	4	5	-	-	-	-
PCBs, Pesticides, and Herbicides												
Aldrin	mallard duck	0.5	5	5	5	-	-	-	10	5	1	5
	rat	0.2	1	-	-	3	4	5	-	-	-	-
alpha-BHC	japanese quail	0.563	2.25	5	5	-	-	-	10	5	5	5
	rat	4	20	-	-	3	4	5	-	-	-	-
beta-BHC	japanese quail	0.563	2.25	5	5	-	-	-	10	5	5	5
	rat	4	20	-	-	3	4	5	-	-	-	-

TABLE 5-4
UNCERTAINTY FACTORS USED FOR CHEMICALS NOT INCLUDED IN ARMY REMEDIAL INVESTIGATION

Presidio of San Francisco, California

Potential Chemical of Concern	Toxicity Data (a)			Uncertainty Factors (Dimensionless); (a)								
	Species Data are Based	TBV_{low} (mg/kg-day)	TBV_{high} (mg/kg-day)	American Robin	Mourning Dove	Western Harvest Mouse	Valley Pocket Gopher	Raccoon	Peregrine Falcon	Red-tailed Hawk	Mallard Duck	Western Sandpiper
PCBs, Pesticides, and Herbicides (cont.)												
delta-BHC	japanese quail	0.563	2.25	5	5	-	-	-	10	5	5	5
	rat	4	20	-	-	3	4	5	-	-	-	-
	rat	1.5	1.5	-	-	3	4	5	-	-	-	-
Endrin / Endrin Aldehyde / Endrin Ketone	mallard duck	0.032	0.2	5	5	-	-	-	10	5	1	5
	mouse	0.184	0.92	-	-	3	4	5	-	-	-	-
Heptachlor/Heptachlor Epoxide	mink	0.2	0.5	-	-	5	5	4	-	-	-	-
Isodrin	mallard duck	0.5	5	5	5	-	-	-	10	5	1	5
	rat	0.2	1	-	-	3	4	5	-	-	-	-
Methoxychlor	mallard duck, sharp tailed grouse, California quail	40	2,000	5	5	-	-	-	10	5	1	5
	rat	4	8	-	-	3	4	5	-	-	-	-

Notes:

(a) Toxicity values are obtained from studies described in Table 5-3; uncertainty factors are discussed in Section 5.5.

(b) Hyphen indicates information was not available.

TABLE 5-5
LOW TOXICITY BENCHMARK VALUES FOR NON-SPECIAL STATUS PLANT AND WILDLIFE SPECIES

Presidio of San Francisco, California

Potential Chemical of Concern	Plants and Soil Fauna TBV_{low} (mg/kg)	Wildlife TBV_{low} (mg/kg-day); (a)								
		American Robin	Mourning Dove	Western Harvest Mouse	Valley Pocket Gopher	Raccoon	Peregrine Falcon	Red-tailed Hawk	Mallard Duck	Western Sandpiper
Inorganic Chemicals										
Antimony	5	- (b)	-	0.59	0.45	0.36	-	-	-	-
Arsenic	10	2.8	2.8	1.27	0.95	0.76	1.4	2.8	14	2.8
Barium	500	19.4	19.4	11.9	8.9	7.12	9.7	19.4	19.4	19.4
Beryllium	**10**	**9.7**	**9.7**	**7.1**	**5.33**	**4.26**	**4.85**	**9.7**	**9.7**	**9.7**
Cadmium	**4**	0.08	0.08	0.06	0.06	0.06	0.04	0.08	0.4	0.08
Chromium	**5**	0.26	0.26	4	4	5	0.13	0.26	0.26	0.32
Cobalt	20	101	101	0.8	0.6	0.48	50.4	101	252	101
Copper	50	11.1	11.1	26.7	26.7	1.97	5.53	11.1	11.1	11.1
Cyanide	-	-	-	**22.9**	**17.2**	**13.7**	-	-	-	-
Lead (c)										
Tetraethyl Lead	-	**0.23**	**0.23**	**4**	**3**	**19.8**	**0.11**	**0.23**	**0.23**	**0.23**
Mercury	0.3	0.0	0.0	0.26	0.2	0.16	0.04	**0.1**	**0.1**	**0.1**
Molybdenum	-	**0.7**	**0.7**	**0.087**	**0.065**	**0.052**	**0.35**	**0.7**	**0.7**	**0.7**
Nickel	**30**	3.49	3.49	10.5	7.9	3	1.75	3.49	3.49	3.49
Selenium	1	0.13	0.13	0.04	0.03	0.02	0.07	0.13	0.13	0.13
Silver	2	**0.349**	**0.349**	21.7	16.3	13	**0.175**	**0.349**	**0.349**	**0.349**
Thallium	1	**0.009**	**0.009**	0.1	0.08	0.06	**0.005**	**0.009**	**0.009**	**0.009**
Vanadium	2	0.1	0.1	0.02	0.01	0.01	0.05	0.1	0.1	0.1
Zinc	50	7.56	7.56	56.7	42.5	34	3.78	7.56	37.8	7.56

TABLE 5-5

LOW TOXICITY BENCHMARK VALUES FOR NON-SPECIAL STATUS PLANT AND WILDLIFE SPECIES

Presidio of San Francisco, California

Potential Chemical of Concern	Plants and Soil Fauna TBV_{low} (mg/kg)	Wildlife TBV_{low} (mg/kg-day); (a)								
		American Robin	Mourning Dove	Western Harvest Mouse	Valley Pocket Gopher	Raccoon	Peregrine Falcon	Red-tailed Hawk	Mallard Duck	Western Sandpiper
Semivolatile Organic Compounds										
Acenaphthene	**30**	-	-	**0.33**	**0.25**	**0.20**	-	-	-	-
Acenaphthylene	**30**	-	-	**0.33**	**0.25**	**0.20**	-	-	-	-
Anthracene	30	-	-	0.33	0.25	0.2	-	-	-	-
Benzo(a)anthracene	**30**	-	-	**0.33**	**0.25**	**0.20**	-	-	-	-
Benzo(a)pyrene	**30**	-	-	**0.33**	**0.25**	**0.20**	-	-	-	-
Benzo(b)fluoranthene	**30**	-	-	**0.33**	**0.25**	**0.20**	-	-	-	-
Benzo(g,h,i)perylene	**30**	-	-	**0.33**	**0.25**	**0.20**	-	-	-	-
Benzo(k)fluoranthene	**30**	-	-	**0.33**	**0.25**	**0.20**	-	-	-	-
Benzyl Alcohol	-	**0.04**	**0.04**	**0.416**	**0.416**	**0.416**	**0.02**	**0.04**	**0.04**	**0.04**
Chrysene	30	-	-	0.33	0.25	0.2	-	-	-	-
Dibenzo(a,h)anthrancene	**30**	-	-	**0.33**	**0.25**	**0.20**	-	-	-	-
Dibenzofuran	-	-	-	-	-	-	-	-	-	-
Fluoranthene	30	-	-	0.33	0.25	0.2	-	-	-	-
Fluorene	30	-	-	0.33	0.25	0.2	-	-	-	-
Ideno(1,2,3-cd)pyrene	**30**	-	-	**0.33**	**0.25**	**0.20**	-	-	-	-
2-methylnaphthalene	**30**	-	-	**0.33**	**0.25**	**0.20**	-	-	-	-
4-methylphenol (p-Cresol)	**50**	-	-	**43.8**	**43.8**	**54.8**	-	-	-	-
Naphthalene	30	-	-	0.33	0.25	0.2	-	-	-	-
n-nitrosodiphenylamine	**20**	-	-	**66.7**	**50**	**40**	-	-	-	-
Pentachlorophenol	**3**	-	-	**0.08**	**0.06**	**0.05**	-	-	-	-
Phenanthrene	**30**	-	-	**0.33**	**0.25**	**0.20**	-	-	-	-
Phenol	**30**	-	-	**10**	**7.5**	**6**	-	-	-	-
Pyrene	**30**	-	-	**0.33**	**0.25**	**0.20**	-	-	-	-

TABLE 5-5
LOW TOXICITY BENCHMARK VALUES FOR NON-SPECIAL STATUS PLANT AND WILDLIFE SPECIES

Presidio of San Francisco, California

Potential Chemical of Concern	Plants and Soil Fauna TBV_{low} (mg/kg)	Wildlife TBV_{low} (mg/kg-day); (a)								
		American Robin	Mourning Dove	Western Harvest Mouse	Valley Pocket Gopher	Raccoon	Peregrine Falcon	Red-tailed Hawk	Mallard Duck	Western Sandpiper
Volatile Organic Compounds										
Acetone	-	-	-	**33.3**	**25**	**20**	-	-	-	-
2-Butanone (MEK)	-	-	-	**16.7**	**12.5**	**10**	-	-	-	-
Carbon disulfide	-	-	-	**3.67**	**2.75**	**2.20**	-	-	-	-
1,4-dichlorobenzene	**20**	-	-	**8.33**	**6.25**	**5**	-	-	-	-
p-isopropyltoluene (p-cymene) (d)	**200**	-	-	**8.7**	**6.5**	**5.20**	-	-	-	-
Methylene Chloride	-	-	-	**1.67**	**1.25**	**1.00**	-	-	-	-
1,2,3-trichlorobenzene	**20**	-	-	-	-	-	-	-	-	-
1,2,4-trichlorobenzene	**20**	-	-	-	-	-	-	-	-	-
Trichlorofluoromethane	-	-	-	-	-	-	-	-	-	-
1,1,1-trichloroethane	-	-	-	**38**	**28.5**	**22.8**	-	-	-	-
PCBs, Pesticides, and Herbicides										
PCBs (Aroclor 1254)	40	0.04	0.04	0.11	0.09	0.07	0.02	0.04	0.04	0.04
Aldrin	-	**0.01**	**0.01**	**0.07**	**0.05**	**0.04**	**0.005**	**0.01**	**0.05**	**0.01**
alpha-BHC	-	**0.113**	**0.113**	**1.33**	**1**	**0.8**	**0.0563**	**0.113**	**0.113**	**0.113**
beta-BHC	-	**0.113**	**0.113**	**1.33**	**1**	**0.8**	**0.0563**	**0.113**	**0.113**	**0.113**
delta-BHC	-	**0.113**	**0.113**	**1.33**	**1**	**0.8**	**0.0563**	**0.113**	**0.113**	**0.113**
Chlordane	-	**0.027**	**0.021**	0.24	0.24	0.24	**0.011**	**0.021**	**0.021**	**0.021**
2,4-D	-	-	-	-	-	-	-	-	-	-
Dicamba	-	-	-	-	-	-	-	-	-	-
4,4'-DDD	40	0.06	0.06	2.83	2.13	1.7	0.04	0.1	0.06	0.06
4,4'-DDE	40	0.12	0.12	2.83	2.13	1.7	0.06	0.12	0.12	0.12
4,4'-DDT	40	0.01	0.01	2.83	2.13	1.7	**0.04**	**0.1**	**0.06**	**0.06**
Dieldrin	50	0.1	0.1	0.09	0.07	0.01	0.05	0.1	0.1	0.1
Endosulfan	-	**2**	**2**	**0.5**	**0.375**	**0.3**	**1**	**2**	**2**	**2**
Endosulfan Sulfate (e)	-	**2**	**2**	**0.5**	**0.375**	**0.3**	**1**	**2**	**2**	**2**

TABLE 5-5

LOW TOXICITY BENCHMARK VALUES FOR NON-SPECIAL STATUS PLANT AND WILDLIFE SPECIES

Presidio of San Francisco, California

Potential Chemical of Concern	Plants and Soil Fauna TBV_{low} (mg/kg)	Wildlife TBV_{low} (mg/kg-day); (a)								
		American Robin	Mourning Dove	Western Harvest Mouse	Valley Pocket Gopher	Raccoon	Peregrine Falcon	Red-tailed Hawk	Mallard Duck	Western Sandpiper
PCBs, Pesticides, and Herbicides (cont.)										
Endrin	-	**0.0064**	**0.0064**	**0.06**	**0.046**	**0.0368**	**0.0032**	**0.0064**	**0.032**	**0.0064**
Endrin Aldehyde (e)	-	**0.0064**	**0.0064**	**0.06**	**0.046**	**0.0368**	**0.0032**	**0.0064**	**0.032**	**0.0064**
Endrin Ketone (e)	-	**0.0064**	**0.0064**	**0.06**	**0.046**	**0.0368**	**0.0032**	**0.0064**	**0.032**	**0.0064**
gamma-BHC (Lindane)	-	**0.019**	**0.019**	**2.7**	**2.0**	**1.6**	**0.01**	**0.019**	**0.019**	**0.019**
Heptachlor	-	**0.019**	**0.019**	**0.04**	**0.04**	**0.05**	**0.01**	**0.019**	**0.019**	**0.019**
Heptachlor Epoxide	-	**0.019**	**0.019**	**0.04**	**0.04**	**0.05**	**0.01**	**0.019**	**0.019**	**0.019**
Isodrin (f)	-	**0.01**	**0.01**	**0.067**	**0.05**	**0.04**	**0.005**	**0.01**	**0.05**	**0.01**
MCPP	-	-	-	-	-	-	-	-	-	-
Methoxychlor	-	**0.8**	**0.8**	**1.33**	**1**	**0.8**	**0.4**	**0.8**	**4**	**0.8**

Notes:

(a) Toxicity values that are boxed and shown in bold have been updated and differ from those assumed by the Army in Dames & Moore, *Final Feasibility Study Report, Presidio Main Installation*, dated May 1997. Updated values have been obtained from United States Department of Energy Oak Ridge National Laboratory documents prepared by R.A. Efroymson, M.E. Will, G.W. Suter II, and A.C. Wooten entitled *Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants, 1997 Revision*, dated November 1997. Low toxicity values incorporate uncertainty factors, as discussed in Section 5.5.

(b) Hyphen indicates information was not available.

(c) United States Environmental Protection Agency Region IX Biological Technical Advisory Group toxicity benchmark values for lead vary up to five orders of magnitude. As described in the text, the Preliminary Remediation Goals for lead in soil were developed by use of the Monte Carlo method.

(d) Values for toluene were used for isopropyltoluene.

(e) Values for Endosulfan were used for Endosulfan Sulfate. Values for Endrin were used for Endrin Aldehyde and Endrin Ketone.

(f) Isodrin is an isomer of Aldrin. Values for Aldrin were used for Isodrin.

TABLE 5-6
HIGH TOXICITY BENCHMARK VALUES FOR NON-SPECIAL STATUS PLANT AND WILDLIFE SPECIES

Presidio of San Francisco, California

Potential Chemical of Concern	Plants and Soil Fauna TBV_{high} (mg/kg)	Wildlife TBV_{high} (mg/kg-day); (a)								
		American Robin	Mourning Dove	Western Harvest Mouse	Valley Pocket Gopher	Raccoon	Peregrine Falcon	Red-tailed Hawk	Mallard Duck	Western Sandpiper
Inorganic Chemicals										
Antimony	5	- (b)	-	1.78	1.78	1.78	-	-	-	-
Arsenic	224	42	42	22.5	22.5	22.5	42	42	42	42
Barium	500	194	194	71.2	71.2	71.2	194	194	194	194
Beryllium	**10**	**485**	**485**	**42.5**	**42.5**	**42.5**	**485**	**485**	**485**	**485**
Cadmium	100	2	2	24.3	24.3	24.3	2	2	2	2
Chromium	200	2.56	2.56	40	40	40	2.56	2.56	2.56	2.56
Cobalt	75	2,520	2,520	12	12	12	2,520	2,520	2,520	2,520
Copper	400	72.7	72.7	40	40	13	72.7	72.7	72.7	72.7
Cyanide	-	-	-	**68.7**	**68.7**	**68.7**	-	-	-	-
Lead (c)										
Tetraethyl Lead	-	**11.3**	**11.3**	**170**	**170**	**170**	**11.3**	**11.3**	**11.3**	**11.3**
Mercury	10	12.5	12.5	3.9	3.9	3.9	12.5	12.5	12.5	12.5
Molybdenum	-	**35.3**	**35.3**	**2.6**	**2.6**	**2.6**	**35.3**	**35.3**	**35.3**	**35.3**
Nickel	500	87.3	87.3	158	158	158	87.3	87.3	87.3	87.3
Selenium	70	1.32	1.32	0.57	0.57	0.57	1.32	1.32	1.32	1.32
Silver	2	**8.73**	**8.73**	130	130	130	**8.73**	**8.73**	**8.73**	**8.73**
Thallium	1	**2.37**	**2.37**	3	3	3	**2.37**	**2.37**	**2.37**	**2.37**
Vanadium	20	0.485	0.485	20	20	20	0.485	0.485	0.485	0.485
Zinc	864	189	189	340	340	340	189	189	189	189

TABLE 5-6
HIGH TOXICITY BENCHMARK VALUES FOR NON-SPECIAL STATUS PLANT AND WILDLIFE SPECIES

Presidio of San Francisco, California

Potential Chemical of Concern	Plants and Soil Fauna TBV_{high} (mg/kg)	Wildlife TBV_{high} (mg/kg-day); (a)								
		American Robin	Mourning Dove	Western Harvest Mouse	Valley Pocket Gopher	Raccoon	Peregrine Falcon	Red-tailed Hawk	Mallard Duck	Western Sandpiper
Semivolatile Organic Compounds										
Acenaphthene	**50**	-	-	**10**	**10**	**10**	-	-	-	-
Acenaphthylene	**50**	-	-	**10**	**10**	**10**	-	-	-	-
Anthracene	50	-	-	10	10	10	-	-	-	-
Benzo(a)anthracene	**50**	-	-	**10**	**10**	**10**	-	-	-	-
Benzo(a)pyrene	50	-	-	10	10	10	-	-	-	-
Benzo(b)fluoranthene	**50**	-	-	**10**	**10**	**10**	-	-	-	-
Benzo(g,h,i)perylene	**50**	-	-	**10**	**10**	**10**	-	-	-	-
Benzo(k)fluoranthene	**50**	-	-	**10**	**10**	**10**	-	-	-	-
Benzyl Alcohol	-	**10**	**10**	**104**	**104**	**104**	**10**	**10**	**10**	**10**
Chrysene	50	-	-	10	10	10	-	-	-	-
Dibenzo(a,h)anthrancene	**50**	-	-	**10**	**10**	**10**	-	-	-	-
Dibenzofuran	-	-	-	-	-	-	-	-	-	-
Fluoranthene	50	-	-	10	10	10	-	-	-	-
Fluorene	50	-	-	10	10	10	-	-	-	-
Indeno(1,2,3-cd)pyrene	**50**	-	-	**10**	**10**	**10**	-	-	-	-
2-methylnaphthalene	**50**	-	-	**10**	**10**	**10**	-	-	-	-
4-methylphenol (p-Cresol)	**50**	-	-	**219**	**219**	**219**	-	-	-	-
Naphthalene	50	-	-	10	10	10	-	-	-	-
n-nitrosodiphenylamine	**109**	-	-	**200**	**200**	**200**	-	-	-	-
Pentachlorophenol	**4**	-	-	**2.4**	**2.4**	**2.4**	-	-	-	-
Phenanthrene	**50**	-	-	**10**	**10**	**10**	-	-	-	-
Phenol	**188**	-	-	**30**	**30**	**30**	-	-	-	-
Pyrene	**50**	-	-	**10**	**10**	**10**	-	-	-	-

TABLE 5-6
HIGH TOXICITY BENCHMARK VALUES FOR NON-SPECIAL STATUS PLANT AND WILDLIFE SPECIES

Presidio of San Francisco, California

Potential Chemical of Concern	Plants and Soil Fauna TBV_{high} (mg/kg)	Wildlife TBV_{high} (mg/kg-day); (a)								
		American Robin	Mourning Dove	Western Harvest Mouse	Valley Pocket Gopher	Raccoon	Peregrine Falcon	Red-tailed Hawk	Mallard Duck	Western Sandpiper
Volatile Organic Compounds										
Acetone	-	-	-	**500**	**500**	**500**	-	-	-	-
2-Butanone (MEK)	-	-	-	**100**	**100**	**100**	-	-	-	-
Carbon disulfide	-	-	-	**110**	**110**	**110**	-	-	-	-
1,4-dichlorobenzene	**128**	-	-	**50**	**50**	**50**	-	-	-	-
p-isopropyltoluene (p-cymene) (d)	**1,000**	-	-	**87**	**65**	**52**	-	-	-	-
Methylene Chloride	-	-	-	**125**	**125**	**125**	-	-	-	-
1,2,3-trichlorobenzene	**115**	-	-	-	-	-	-	-	-	-
1,2,4-trichlorobenzene	**127**	-	-	-	-	-	-	-	-	-
Trichlorofluoromethane	-	-	-	-	-	-	-	-	-	-
1,1,1-trichloroethane	-	-	-	**5,700**	**5,700**	**5,700**	-	-	-	-
PCBs, Pesticides, and Herbicides										
PCBs (Aroclor 1254)	240	1.8	1.8	1.7	1.7	1.7	1.8	1.8	1.8	1.8
Aldrin	-	**0.5**	**0.5**	**1**	**1**	**1**	**0.5**	**0.5**	**0.5**	**0.5**
alpha-BHC	-	**20**	**20**	**2.25**	**2.25**	**2.25**	**20**	**20**	**20**	**20**
beta-BHC	-	**20**	**20**	**2.25**	**2.25**	**2.25**	**20**	**20**	**20**	**20**
delta-BHC	-	**20**	**20**	**2.25**	**2.25**	**2.25**	**20**	**20**	**20**	**20**
Chlordane	-	**0.213**	**0.213**	10.4	10.4	10.4	**0.213**	**0.213**	**0.213**	**0.213**
2,4-D	-	-	-	-	-	-	-	-	-	-
Dicamba	-	-	-	--	-	-	-	-	-	-
4,4'-DDD	200	3	3	43	43	43	**3**	3	3	3
4,4'-DDE	200	3	3	43	43	43	3	3	3	3
4,4'-DDT	200	3	3	43	43	43	**3**	3	3	3
Dieldrin	100	1.25	1.25	0.31	0.31	2.6	1.25	1.25	1.25	1.25
Endosulfan	-	**10**	**10**	**1.5**	**1.5**	**1.5**	**10**	**10**	**10**	**10**
Endosulfan Sulfate (e)	-	**10**	**10**	**1.5**	**1.5**	**1.5**	**10**	**10**	**10**	**10**

TABLE 5-6

HIGH TOXICITY BENCHMARK VALUES FOR NON-SPECIAL STATUS PLANT AND WILDLIFE SPECIES

Presidio of San Francisco, California

Potential Chemical of Concern	Plants and Soil Fauna TBV_{high} (mg/kg)	Wildlife TBV_{high} (mg/kg-day); (a)								
		American Robin	Mourning Dove	Western Harvest Mouse	Valley Pocket Gopher	Raccoon	Peregrine Falcon	Red-tailed Hawk	Mallard Duck	Western Sandpiper
PCBs, Pesticides, and Herbicides (cont.)										
Endrin	-	**0.92**	**0.92**	**2**	**2**	**2**	**0.92**	**0.92**	**0.92**	**0.92**
Endrin Aldehyde (e)	-	**0.92**	**0.92**	**2**	**2**	**2**	**0.92**	**0.92**	**0.92**	**0.92**
Endrin Ketone (e)	-	**0.92**	**0.92**	**2**	**2**	**2**	**0.92**	**0.92**	**0.92**	**0.92**
gamma-BHC (Lindane)	-	**3**	**3**	**8**	**8**	**8**	**3**	**3**	**3**	**3**
Heptachlor	-	**208**	**208**	**1**	**1**	**1**	**208**	**208**	**208**	**208**
Heptachlor Epoxide	-	**208**	**208**	**1**	**1**	**1**	**208**	**208**	**208**	**208**
Isodrin (f)	-	**0.5**	**0.5**	**1**	**1**	**1**	**0.5**	**0.5**	**0.5**	**0.5**
MCPP	-	-	-	-	-	-	-	-	-	-
Methoxychlor	-	**200**	**200**	**8**	**8**	**8**	**200**	**200**	**200**	**200**

Notes:

(a) Toxicity values that are boxed and shown in bold have been updated and differ from those assumed by the Army in Dames & Moore, *Final Feasibility Report, Presidio Main Installation*, dated May 1997. Updated values have been obtained from United States Department of Energy Oak Ridge National Laboratory documents prepared by R.A. Efroymson, M.E. Will, G.W. Suter II, and A.C. Wooten entitled *Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants, 1997 Revision*, dated November 1997.
With the exception of the factor of 10 used for toxicity values based on mortality endpoints, high toxicity values do not incorporate the use of uncertainty factors (see Section 5.5).

(b) Hyphen indicates information was not available.

(c) United States Environmental Protection Agency Region IX Biological Technical Advisory Group toxicity benchmark values vary up to five orders of magnitude. As described in the text, the Preliminary Remediation Goals for lead in soil were developed by use of the Monte Carlo method.

(d) Values for toluene were used for isopropyltoluene.

(e) Values for Endosulfan were used for Endosulfan Sulfate. Values for Endrin were used for Endrin Aldehyde and Endrin Ketone.

(f) Isodrin is an isomer of Aldrin. Values for Aldrin were used for Isodrin.

TABLE 5-7
SEDIMENT QUALITY CRITERIA FOR AQUATIC LIFE (FRESHWATER)

Presidio of San Francisco, California

Potential Chemical of Concern	Sediment Quality Criteria (mg/kg)							
	CCME ISQG (a)	CCME PEL (a)	Consensus Based TEC (b)	Consensus Based PEC (b)	U.S. EPA SQC (c)	U.S. EPA SQB (c)	Lowest Criterion	Highest Criterion
Inorganic Chemicals								
Antimony	- (d)	-	-	-	-	-	-	-
Arsenic	5.9	17	9.79	33	-	-	5.9	33
Barium	-	-	-	-	-	-	-	-
Beryllium	-	-	-	-	-	-	-	-
Cadmium	0.6	3.5	0.99	4.98	-	-	0.6	4.98
Chromium	37.3	90	43.4	111	-	-	37.3	111
Cobalt	50 (e)	-	-	-	-	-	50	50
Copper	35.7	197	31.6	149	-	-	31.6	197
Cyanide	0.0001 (e)	-	-	-	-	-	0.0001	0.0001
Lead	35.7	91.3	35.8	128	-	-	35.7	128
Tetraethyl Lead	-	-	-	-	-	-	-	-
Mercury	0.17	0.486	0.18	1.06	-	-	0.17	1.06
Molybdenum	-	-	-	-	-	-	-	-
Nickel	16 (e)	75 (e)	22.7	48.6	-	-	16	75
Selenium	-	-	-	-	-	-	-	-
Silver	0.5 (e)	-	-	-	-	-	0.5	0.5
Thallium	-	-	-	-	-	-	-	-
Vanadium	-	-	-	-	-	-	-	-
Zinc	123	315	121	459	-	-	121	459

TABLE 5-7

SEDIMENT QUALITY CRITERIA FOR AQUATIC LIFE (FRESHWATER)

Presidio of San Francisco, California

Potential Chemical of Concern	Sediment Quality Criteria (mg/kg)							
	CCME ISQG (a)	CCME PEL (a)	Consensus Based TEC (b)	Consensus Based PEC (b)	U.S. EPA SQC (c)	U.S. EPA SQB (c)	Lowest Criterion	Highest Criterion
Semivolatile Organic Compounds								
Acenaphthene	0.00671	0.0889	-	-	0.62	-	0.00671	0.62
Acenaphthylene	0.00587	0.128	-	-	-	-	0.00587	0.128
Anthracene	0.0469	0.245	0.0572	0.845	-	-	0.0469	0.845
Benzo(a)anthracene	0.0317	0.385	0.108	1.05	-	-	0.0317	1.05
Benzo(a)pyrene	0.0319	0.782	0.15	1.45	-	-	0.0319	1.45
Benzo(b)fluoranthene	0.24 (e,f)	1.34 (e,f)	-	-	-	-	0.24	1.34
Benzo(g,h,i)perylene	0.17 (e)	0.32 (e)	-	-	-	-	0.17	0.32
Benzo(k)fluoranthene	0.24 (f)	1.34 (f)	-	-	-	-	0.24	1.34
Benzyl Alcohol	-	-	-	-	-	-	-	-
Chrysene	0.0571	0.862	0.166	1.29	-	-	0.0571	1.29
Dibenzo(a,h)anthrancene	0.00622	0.135	0.033	-	-	-	0.00622	0.135
Dibenzofuran	-	-	-	-	-	2	2	2
Fluoranthene	0.111	2.355	0.423	2.23	2.9	-	0.111	2.9
Fluorene	0.0212	0.144	0.0774	0.536	-	0.54	0.0212	0.54
Indeno(1,2,3-cd)pyrene	0.2	0.32	-	-	-	-	0.2	0.32
2-methylnaphthalene	0.0202	0.201	-	-	-	-	0.0202	0.201
4-methylphenol (p-Cresol)	-	-	-	-	-	-	-	-
Naphthalene	0.0346	0.391	0.176	0.561	-	0.48	0.0346	0.561
n-nitrosodiphenylamine	-	-	-	-	-	-	-	-
Pentachlorophenol	-	-	-	-	-	-	-	-
Phenanthrene	0.0419	0.515	0.204	1.17	0.85	-	0.0419	1.17
Phenol	-	-	-	-	-	-	-	-
Pyrene	0.053	0.875	0.195	1.52	-	-	0.053	1.52

TABLE 5-7
SEDIMENT QUALITY CRITERIA FOR AQUATIC LIFE (FRESHWATER)

Presidio of San Francisco, California

Potential Chemical of Concern	Sediment Quality Criteria (mg/kg)							
	CCME ISQG (a)	CCME PEL (a)	Consensus Based TEC (b)	Consensus Based PEC (b)	U.S. EPA SQC (c)	U.S. EPA SQB (c)	Lowest Criterion	Highest Criterion
Volatile Organic Compounds								
Acetone	-	-	-	-	-	-	-	-
2-Butanone (MEK)	-	-	-	-	-	-	-	-
Carbon disulfide	-	-	-	-	-	-	-	-
p-isopropyltoluene (p-cymene)	-	-	-	-	-	-	-	-
1,4-dichlorobenzene	-	-	-	-	-	0.35	0.35	0.35
Methylene Chloride	-	-	-	-	-	-	-	-
1,2,3-trichlorobenzene	-	-	-	-	-	-	-	-
1,2,4-trichlorobenzene	-	-	-	-	-	-	-	-
Trichlorofluormethane	-	-	-	-	-	-	-	-
1,1,1-trichloroethane	-	-	-	-	-	0.17	0.17	0.17
PCBs, Pesticides, and Herbicides								
PCBs (Arochlor 1254)	0.06	0.34	0.0598	0.676	-	-	0.0598	0.676
Aldrin	0.002 (e)	0.008 (e)	-	-	-	-	0.002	0.008
alpha-BHC	0.006 (e)	0.01 (e)	-	-	-	-	0.006	0.01
beta-BHC	0.005 (e)	0.021 (e)	-	-	-	-	0.005	0.021
delta-BHC	0.003 (e)	0.012 (e)	-	-	-	-	0.003	0.012
Chlordane	0.0045	0.00887	0.00324	0.0176	-	-	0.00324	0.0176
2,4-D	-	-	-	-	-	-	-	-
Dicamba	-	-	-	-	-	-	-	-
4,4'-DDD	0.00354	0.00851	0.00488	0.028	-	-	0.00354	0.028
4,4'-DDE	0.00142	0.00675	0.00316	0.0313	-	-	0.00142	0.0313
4,4'-DDT	0.00119	0.00477	0.00416	0.0629	-	-	0.00119	0.0629
Dieldrin	0.00285	0.00667	0.0019	0.0618	0.052	-	0.0019	0.0618
Endosulfan	-	-	-	-	-	0.0054	0.0054	0.0054
Endosulfan Sulfate (g)	-	-	-	-	-	0.0054	0.0054	0.0054

SEDIMENT QUALITY CRITERIA FOR AQUATIC LIFE (FRESHWATER)

Presidio of San Francisco, California

Potential Chemical of Concern	Sediment Quality Criteria (mg/kg)							
	CCME ISQG (a)	CCME PEL (a)	Consensus Based TEC (b)	Consensus Based PEC (b)	U.S. EPA SQC (c)	U.S. EPA SQB (c)	Lowest Criterion	Highest Criterion
PCBs, Pesticides, and Herbicides (cont.)								
Endrin	0.00267	0.0624	0.00222	0.207	0.02	-	0.00222	0.207
Endrin Aldehyde (g)	0.00267	0.0624	0.00222	0.207	0.02	-	0.00222	0.207
Endrin Ketone (g)	0.00267	0.0624	0.00222	0.207	0.02	-	0.00222	0.207
gamma-BHC (Lindane)	0.00094	0.00138	0.00237	0.00499	-	0.0037	0.00094	0.00499
Heptachlor	0.0006	0.00274	0.00247	0.016	-	-	0.0006	0.016
Heptachlor Epoxide	0.0006	0.00274	0.00247	0.016	-	-	0.0006	0.016
Isodrin	0.002 (h)	0.008 (h)	-	-	-	-	0.002	0.008
MCPP	-	-	-	-	-	-	-	-
Methoxychlor	-	-	-	-	-	0.019	0.019	0.019

Notes:

(a) Unless otherwise noted, interim sediment quality guidelines ("ISQG") and probable effect levels ("PELs") obtained from Canadian Council of Ministers of the Environment *Canadian Sediment Quality Guidelines for the Protection of Aquatic Life*, dated 1999.

(b) Consensus-based threshold effects concentrations ("TECs") and probable effects concentrations ("PECs") obtained from MacDonald, D.M., C.G. Ingersoll, and T.A. Berger *Development and Evaluation of Consensus-Based Sediment Quality Guidelines for Freshwater Ecosystems*, dated 2000.

(c) Sediment quality criteria ("SQC") and sediment quality benchmarks ("SQB") obtained from U.S. EPA *Ecotox Thresholds*, dated 1996 and U.S. EPA. *Ecological Screening Values*, dated 1995.

(d) Hyphen indicates sediment quality criterion not found.

(e) Value from Persuad, D., R. Jaagumagi, and A. Hayton *Guidelines for the Protection and Management of Aquatic Sediment Quality in Ontario*, dated August 1993 or U.S. EPA (1996).

(f) Value for benzo(k)fluoroanthene obtained from Persuad, et al (1993). Value for benzo(k)fluoroanthene used for benzo(b)fluoroanthene.

(g) Values for Endosulfan were used for Endosulfan Sulfate. Values for Endrin were used for Endrin Aldehyde and Endrin Ketone.

(h) Isodrin is an isomer of aldrin. Value listed is for aldrin.

TABLE 5-8
SEDIMENT QUALITY CRITERIA FOR AQUATIC LIFE (MARINE)

Presidio of San Francisco, California

Potential Chemical of Concern	Sediment Quality Criteria (mg/kg)					
	ER-L (a)	ER-M (a)	U.S. EPA SQC (b)	U.S. EPA SQB (b)	Lowest Criterion	Highest Criterion
Inorganic Chemicals						
Antimony	2	25	- (c)	-	2	25
Arsenic	8.2	70	-	-	8.2	70
Barium	-	-	-	-	-	-
Beryllium	-	-	-	-	-	-
Cadmium	1.2	9.6	-	-	1.2	9.6
Chromium	81	370	-	-	81	370
Cobalt	-	-	-	-	-	-
Copper	34	270	-	-	34	270
Cyanide	-	-	-	-	-	-
Lead	46.7	218	-	-	46.7	218
Tetraethyl Lead	-	-	-	-	-	-
Mercury	0.15	0.71	-	-	0.15	0.71
Molybdenum	-	-	-	-	-	-
Nickel	20.9	51.6	-	-	20.9	51.6
Selenium	-	-	-	-	-	-
Silver	1	3.7	-	-	1	3.7
Thallium	-	-	-	-	-	-
Vanadium	-	-	-	-	-	-
Zinc	150	410	-	-	150	410

TABLE 5-8

SEDIMENT QUALITY CRITERIA FOR AQUATIC LIFE (MARINE)

Presidio of San Francisco, California

Potential Chemical of Concern	Sediment Quality Criteria (mg/kg)					
	ER-L (a)	ER-M (a)	U.S. EPA SQC (b)	U.S. EPA SQB (b)	Lowest Criterion	Highest Criterion
Semivolatile Organic Compounds						
Acenaphthene	0.016	0.5	0.62	-	0.016	0.62
Acenaphthylene	0.044	0.64	-	-	0.044	0.64
Anthracene	0.0853	1.1	-	-	0.0853	1.1
Benzo(a)anthracene	0.261	1.6	-	-	0.261	1.6
Benzo(a)pyrene	0.43	1.6	-	-	0.43	1.6
Benzo(b)fluoranthene	-	-	-	-	-	-
Benzo(g,h,i)perylene	-	-	-	-	-	-
Benzo(k)fluoranthene	-	-	-	-	-	-
Benzyl Alcohol	-	-	-	-	-	-
Chrysene	0.384	2.8	-	-	0.384	2.8
Dibenzo(a,h)anthrancene	0.0634	0.26	-	-	0.0634	0.26
Dibenzofuran	-	-	-	2	2	2
Fluoranthene	0.6	5.1	2.9	-	0.6	5.1
Fluorene	0.019	0.54	-	0.54	0.019	0.54
Indeno(1,2,3-cd)pyrene	-	-	-	-	-	-
2-methylnaphthalene	0.07	0.67	-	-	0.07	0.67
4-methylphenol (p-Cresol)	-	-	-	-	-	-
Naphthalene	0.16	2.1	-	0.48	0.16	2.1
n-nitrosodiphenylamine	-	-	-	-	-	-
Pentachlorophenol	-	-	-	-	-	-
Phenanthrene	0.24	1.5	0.85	-	0.24	1.5
Phenol	-	-	-	-	-	-
Pyrene	0.665	2.6	-	-	0.665	2.6

TABLE 5-8
SEDIMENT QUALITY CRITERIA FOR AQUATIC LIFE (MARINE)

Presidio of San Francisco, California

Potential Chemical of Concern	Sediment Quality Criteria (mg/kg)					
	ER-L (a)	ER-M (a)	U.S. EPA SQC (b)	U.S. EPA SQB (b)	Lowest Criterion	Highest Criterion
Volatile Organic Compounds						
Acetone	-	-	-	-	-	-
2-Butanone (MEK)	-	-	-	-	-	-
Carbon disulfide	-	-	-	-	-	-
1,4-dichlorobenzene	-	-	-	0.35	0.35	0.35
p-isopropyltoluene (p-cymene) (d)	-	-	-	0.67	0.67	0.67
Methylene Chloride	-	-	-	-	-	-
1,2,3-trichlorobenzene (e)	-	-	-	9.2	9.2	9.2
1,2,4-trichlorobenzene	-	-	-	9.2	9.2	9.2
Trichlorofluormethane	-	-	-	-	-	-
1,1,1-trichloroethane	-	-	-	0.17	0.17	0.17
PCBs, Pesticides, and Herbicides						
PCBs (Arochlor 1254)	0.0227 (f)	0.18 (f)	-	-	0.0227	0.18
Aldrin	-	-	-	-	-	-
alpha-BHC	0.00032 (g,h)	0.00099 (g,h)	-	-	0.00032	0.00099
beta-BHC	0.00032 (g,h)	0.00099 (g,h)	-	-	0.00032	0.00099
delta-BHC	0.00032 (g,h)	0.00099 (g,h)	-	-	0.00032	0.00099
Chlordane	0.0005	0.006	-	-	0.0005	0.006
2,4-D	-	-	-	-	-	-
Dicamba	-	-	-	-	-	-
4,4'-DDD	0.002	0.02	-	-	0.002	0.02
4,4'-DDE	0.0022	0.027	-	-	0.0022	0.027
4,4'-DDT	0.001	0.007	-	-	0.001	0.007
Dieldrin	0.00002	0.008	0.052	-	0.00002	0.052
Endosulfan	-	-	-	0.0054	0.0054	0.0054
Endosulfan Sulfate (i)	-	-	-	0.0054	0.0054	0.0054

TABLE 5-8
SEDIMENT QUALITY CRITERIA FOR AQUATIC LIFE (MARINE)

Presidio of San Francisco, California

Potential Chemical of Concern	Sediment Quality Criteria (mg/kg)					
	ER-L (a)	ER-M (a)	U.S. EPA SQC (b)	U.S. EPA SQB (b)	Lowest Criterion	Highest Criterion
PCBs, Pesticides, and Herbicides (cont.)						
Endrin	0.00002	0.045	0.02	-	0.00002	0.045
Endrin Aldehyde (i)	0.00002	0.045	0.02	-	0.00002	0.045
Endrin Ketone (i)	0.00002	0.045	0.02	-	0.00002	0.045
gamma-BHC (Lindane)	0.00032 (g)	0.00099 (g)	-	0.0037	0.00032	0.0037
Heptachlor	-	-	-	-	-	-
Heptachlor Epoxide	-	-	-	-	-	-
Isodrin	-	-	-	-	-	-
MCPP	-	-	-	-	-	-
Methoxychlor	0.019	-	-	0.019	0.019	0.019

Notes:

(a) Effects Range-Low ("ER-L") and Effects Range-Medium ("ER-M") obtained from U.S. EPA *Sediment Classification Methods Compendium*, dated 1992; except where noted.

(b) Sediment quality criteria ("SQC") and sediment quality benchmarks ("SQB") obtained from U.S. EPA *Ecotox Thresholds*, dated *1996 and U.S. EPA. Ecological Screening Values*, dated 1995.

(c) Hyphen indicates sediment quality criterion not found.

(d) Values for toluene were used for isopropyltoluene.

(e) Values for 1,2,4-trichlorobenzene were used for 1,2,3-trichlorobenzene.

(f) Value listed is for total PCBs.

(g) Florida Department of Environmental Protection Threshold Effects Level (TEL) and Probable Effects Level (PEL) (MacDonald, 1994). dated 1990 and normalized to 1 percent total organic carbon.

(h) Value listed is for gamma-BHC.

(i) Values for Endosulfan were used for Endosulfan Sulfate. Values for Endrin were used for Endrin Aldehyde and Endrin Ketone.

TABLE 5-9
FORMULAS FOR CALCULATION OF WILDLIFE PRELIMINARY REMEDIATION GOALS FOR SOIL AND SEDIMENT AT THE PRESIDIO OF SAN FRANCISCO

Presidio of San Francisco, California

$$PRG_{\text{American robin}} = \frac{HQ \times TBV \times BW}{(F_{soil/sed} \times DIR) + (CF \times SA \times AF \times ABS) + (BAF_{inv} \times DIR)}$$

$$PRG_{\text{Mourning dove}} = \frac{HQ \times TBV \times BW}{(F_{soil/sed} \times DIR) + (CF \times SA \times AF \times ABS) + (BAF_{pl} \times DIR)}$$

$$PRG_{\text{Western harvest mouse}} = \frac{HQ \times TBV \times BW}{(F_{soil/sed} \times DIR) + (CF \times SA \times AF \times ABS) + (((BAF_{pl} \times 0.5) + (BAF_{inv} \times 0.5)) \times DIR)}$$

$$PRG_{\text{Pocket gopher}} = \frac{HQ \times TBV \times BW}{(F_{soil/sed} \times DIR) + (CF \times SA \times AF \times ABS) + (BAF_{pl} \times DIR)}$$

$$PRG_{\text{Red-tailed hawk}} = \frac{HQ \times TBV \times BW}{(F_{soil/sed} \times DIR) + (CF \times SA \times AF \times ABS) + ((BAF_{mam} \times BAF_{pl} \times 0.5) + (BAF_{mam} \times BAF_{inv} \times 0.5)) \times DIR)}$$

TABLE 5-9
FORMULAS FOR CALCULATION OF WILDLIFE PRELIMINARY REMEDIATION GOALS FOR SOIL AND SEDIMENT AT THE PRESIDIO OF SAN FRANCISCO

Presidio of San Francisco, California

$$PRG_{\text{Peregrine falcon}} = \frac{HQ \times TBV \times BW}{(F_{soil/sed} \times DIR) + (CF \times SA \times AF \times ABS) + (((BAF_{bird} \times BAF_{pl} \times 0.5) + (BAF_{bird} \times BAF_{inv} \times 0.5)) \times DIR)}$$

$$PRG_{\text{Raccoon}} = \frac{HQ \times TBV \times BW}{(F_{soil/sed} \times DIR) + (CF \times SA \times AF \times ABS) + (((BAF_{bird} \times BAF_{pl} \times 0.5) + (BAF_{inv} \times BAF_{inv} \times 0.5)) \times DIR)}$$

$$PRG_{\text{Mallard duck}} = \frac{HQ \times TBV \times BW}{(F_{soil/sed} \times DIR) + (CF \times SA \times AF \times ABS) + (BAF_{pl} \times DIR)}$$

$$PRG_{\text{Western sandpiper}} = \frac{HQ \times TBV \times BW}{(F_{soil/sed} \times DIR) + (CF \times SA \times AF \times ABS) + (BAF_{inv} \times DIR)}$$

TABLE 5-9
FORMULAS FOR CALCULATION OF WILDLIFE PRELIMINARY REMEDIATION GOALS FOR SOIL AND SEDIMENT AT THE PRESIDIO OF SAN FRANCISCO

Presidio of San Francisco, California

where:

ABS	=	Absorption factor (chemical-specific)
AF	=	Soil adherence factor (mg/cm^2)
BAF_{inv}	=	Bioaccumulation factor for invertebrates (unitless)
BAF_{pl}	=	Bioaccumulation factor for plants (unitless)
BW	=	Body weight (kg)
CF	=	Conversion factor (converts units from mg to kg)
DIR	=	Dietary ingestion rate (kg/day)
$F_{soil/sed}$	=	Fraction of soil and sediment in diet (unitless)
HQ	=	Hazard quotient equal to 1
PRG	=	Preliminary remediation goal
SA	=	Surface area (cm^2)
TBV	=	Toxicity benchmark value (mg/kg-day)

TABLE 5-10
WILDLIFE EXPOSURE FACTORS (a)

Presidio of San Francisco, California

Receptor	Surface Area (cm^2)	Body Weight (kg)	Normalized Dietary Ingestion Rate (kg/kg-day)	Dietary Ingestion Rate (kg/day)	Basis of Dietary Ingestion Rate	Converted Dietary Ingestion Rate (kg/day); (b)	Soil Ingestion (Fraction of Diet)	Soil Ingestion Rate (kg/day)	Home Range (hectares)
American Robin	206	0.085	1.457	0.1235	weight weight	0.0499	0.103	0.00514	0.4
Mourning Dove	385	0.166	0.200	0.0332	dry weight	0.0332	0.103	0.00342	0.24
Western Harvest Mouse	93	0.029	0.372	0.0108	weight weight	0.0044	0.024	0.00010	0.4
Valley Pocket Gopher	161	0.306	0.061	0.0187	dry weight	0.0187	0.024	0.00044	0.1
Raccoon	3979	7.264	0.017	0.1235	dry weight	0.1235	0.094	0.01161	2122
Peregrine Falcon	279	0.135	0.290	0.0392	dry weight	0.0392	0.028	0.00110	192
Red-tailed Hawk	1208	1.231	0.109	0.1342	weight weight	0.0426	0.028	0.00119	1663
Mallard Duck	1205	1.243	0.053	0.0659	dry weight	0.0659	0.033	0.00217	608
Western Sandpiper	140	0.047	0.122	0.0057	dry weight	0.0057	0.282	0.00160	0.25

Notes:

(a) Unless otherwise noted, wildlife exposure factors are the same as those assumed by the Army in Dames & Moore, *Final Feasibility Study Report, Presidio Main Installation*, dated May 1997.

(b) Dietary ingestion rates were converted to a dry weight basis using the equation DIRdry = DIRwet x (1 - percent water in food) and average moisture contents from Sample, B.E. and G.W. Suter, I.I. 1994. *Estimating Exposure of Terrestrial Wildlife to Contaminants*. Oak Ridge National Laboratory, United States Department of Energy. ES/ER/TM-125.

TABLE 5-11
PLANT AND WILDLIFE BIOACCUMULATION FACTORS

Presidio of San Francisco, California

Potential Chemical of Concern	Bioaccumulation Factor (unitless); (a)				
	Plant	Soil Invertebrate	Bird	Mammal	
				Omnivore	Herbivore
Inorganic Chemicals					
Cadmium	**0.586**	**7.708**	0.002	**0.1217**	**0.1258**
Copper	**0.124**	**0.515**	0.001	**0.1272**	**0.1086**
Lead	**0.0389**	**0.266**	0.0003	**0.0659**	**0.0522**
Mercury	**0.652**	**1.693**	1.214	**0.0543**	**0.0239**
Selenium	**0.672**	**0.985**	0.013	**0.2062**	**0.155**
Zinc	**0.366**	**3.201**	0.001	0.55772	**0.50429**
Semivolatile Organic Compounds					
Polycyclic Aromtaic Hydrocarbons	0	0	0	0	0
PCBs, Pesticides, and Herbicides					
PCBs	0.01	**6.667**	0.227	1.43	1.43
Aldrin	**0.03**	**4.29**	**0.477**	**0.02**	**0.02**
alpha-BHC (b)	**0**	**3**	**1**	**0.5**	**0.1**
beta-BHC (b)	**0**	**3**	**1**	**0.5**	**0.1**
delta-BHC (b)	**0**	**3**	**1**	**0.5**	**0.1**
Chlordane	0.02	5	0.352	0.04	0.04
Dicamba (b)	**0**	**3**	**1**	**0.5**	**0.1**
4,4'-DDD	**0.01**	**1.98**	**0.905**	**0.45**	**0.45**
4,4'-DDE	**0.01**	**1.98**	**0.905**	**0.45**	**0.45**
4,4'-DDT	0.01	1.98	0.905	0.45	0.45
Dieldrin	0.03	4.29	0.477	0.02	0.02
Endosulfan (b)	**0**	**3**	**1**	**0.5**	**0.1**
Endosulfan Sulfate (b)	**0**	**3**	**1**	**0.5**	**0.1**
Endrin (b)	**0**	**3**	**1**	**0.5**	**0.1**
Endrin Aldehyde (b)	**0**	**3**	**1**	**0.5**	**0.1**
Endrin Ketone (b)	**0**	**3**	**1**	**0.5**	**0.1**
gamma-BHC (b)	**0**	**3**	**1**	**0.5**	**0.1**
Heptachlor	0.086	1.67	2.25	0.11	0.11
Heptachlor Epoxide	**0.086**	**1.67**	**2.25**	**0.11**	**0.11**
Isodrin (c)	**0.03**	**4.29**	**0.477**	**0.02**	**0.02**
MCPP (b)	**0**	**3**	**1**	**0.5**	**0.1**
Methoxychlor (b)	**0**	**3**	**1**	**0.5**	**0.1**

TABLE 5-11
PLANT AND WILDLIFE BIOACCUMULATION FACTORS

Presidio of San Francisco, California

ıtes:

.) Unless otherwise noted, bioaccumulation factors that are boxed and shown in bold have been updated and differ from those assumed by the Army in Dames & Moore, *Final Feasibility Study Report, Presidio Main Installation*, dated May 1997. Updated values have been obtained from the following United States Department of Energy Oak Ridge National Laboratory documents:

- Bechtel Jacobs Company L.L.C. September 1998. *Empirical Models for Uptake of Inorganic Chemicals from Soil to Plants.* United States Department of Energy Oak Ridge National Laboratory. BJC/OR-133.
- Sample, B.E., et al. February 1998. *Development and Validation of Bioaccumulation Models for Earthworms*. Energy. ES/ER/TM-220.
- Sample, B.E., et al. February 1998. *Development and Validation of Bioaccumulation Models for Small Mammals*. United States Department of United States Department of Energy ES/ER/TM-219.

Calculation of BAFs for chemicals without literature based BAFs

	Bioaccumulation Factor (unitless)				
		Soil		Mammal	
Potential Chemical of Concern	Plant	Invertebrate	Bird	Omnivore	Herbivore
Pesticides/herbicides with BAFs					
Dieldrin	0.03	4.29	0.477	0.02	0.02
Chlordane	0.02	5	0.352	0.04	0.04
4,4'-DDT	0.01	1.98	0.905	0.45	0.45
Heptachlor	0.086	1.67	2.25	0.11	0.11
Statistics					
Range	0.01-0.09	1.67-5	0.35-2.25	0.02-0.45	0.02-0.45
Median	0.025	3.135	0.691	0.075	0.075
Assumed BAFs (for chemicals with no literature BAF)	**0 (a)**	**3 (b)**	**1 (c)**	**0.5 (d)**	**0.1 (e)**

(a) Assumed to be 0 based on BAFs for other pesticides all below 0.1.
(b) Assumed to be 3 based on median BAF for other pesticides of 3.1.
(c) Assumed to be 1 based on median BAF for other pesticides of 0.7.
(d) Assumed to be 0.5 based on median BAF for other pesticides of 0.075 and conservative assumption that omnivores should have a higher BAF.
(e) Assumed to be 0.1 based on median BAF for other pesticides of 0.075.

) No literature-reported bioaccumulation factors were found. Bioaccumulation factors listed for potential chemical of concern are assumed values based on the range of literature-reported values for chlordane, dieldrin, heptachlor, and 4,4'-DDT.

) Isodrin is an isomer of Aldrin. Values for Aldrin were used for Isodrin.

TABLE 5-12
SOIL PRELIMINARY REMEDIATION GOALS FOR NON-SPECIAL STATUS PLANT AND WILDLIFE SPECIES BASED ON LOW TOXICITY BENCHMARK VALUES

Presidio of San Francisco, California

Potential Chemical of Concern	Plants and Soil Fauna PRG_{low} (mg/kg)	Soil Preliminary Remediation Goal for Protection of Wildlife (mg/kg)							
		American Robin	Mourning Dove	Western Harvest Mouse	Valley Pocket Gopher	Raccoon	Peregrine Falcon	Red-tailed Hawk	Wildlife Minimum PRG Value
Inorganic Chemicals									
Antimony	5	- (a)	-	162	309	225	-	-	162
Arsenic	10	46	135	343	647	471	171	2,804	46
Barium	500	320	940	3,264	6,109	4,440	1,192	19,819	320
Beryllium	10	160	470	1,953	3,655	2,657	596	9,910	160
Cadmium	4	0.017	0.58	0.1	2	0.89	4	4	0.017
Chromium	5	4	13	1,100	2,746	3,118	16	266	4
Cobalt	20	1,663	4,886	220	412	299	6,191	102,977	220
Copper	50	30	243	517	2,957	329	672	4,715	30
Cyanide	-	-	-	6,298	11,789	8,569	-	-	6,298
Lead (b)	-	-	-	-	-	-	-	-	-
Tetraethyl Lead	-	1	8	151	783	5,111	13	175	1
Mercury	0.3	0.038	0.26	1.45	4.85	7.04	0.095	28.18	0.038
Molybdenum	-	12	34	24	44	32	43	701	12
Nickel	30	58	169	2,896	5,422	1,871	215	3,565	58
Selenium	1	0.2	0.84	0.31	0.71	2	6	21	0.2
Silver	2	6	17	5,960	11,154	8,107	21	357	6
Thallium	1	0.15	0.44	28	55	37	1	9	0.15
Vanadium	2	2	5	6	7	6	6	102	2
Zinc	50	4	81	209	1,787	1,180	437	216	4

TABLE 5-12

SOIL PRELIMINARY REMEDIATION GOALS FOR NON-SPECIAL STATUS PLANT AND WILDLIFE SPECIES BASED ON LOW TOXICITY BENCHMARK VALUES

Presidio of San Francisco, California

Potential Chemical of Concern	Plants and Soil Fauna PRG_{low} (mg/kg)	Soil Preliminary Remediation Goal for Protection of Wildlife (mg/kg)							
		American Robin	Mourning Dove	Western Harvest Mouse	Valley Pocket Gopher	Raccoon	Peregrine Falcon	Red-tailed Hawk	Wildlife Minimum PRG Value
Semivolatile Organic Compounds									
Acenaphthene	30	-	-	84	166	121	-	-	84
Acenaphthylene	30	-	-	84	166	121	-	-	84
Anthracene	30	-	-	84	166	121	-	-	84
Benzo(a)anthracene	30	-	-	84	166	121	-	-	84
Benzo(a)pyrene	30	-	-	84	166	121	-	-	84
Benzo(b)fluoranthene	30	-	-	84	166	121	-	-	84
Benzo(g,h,i)perylene	30	-	-	84	166	121	-	-	84
Benzo(k)fluoranthene	30	-	-	84	166	121	-	-	84
Benzyl Alcohol	-	0.66	2	106	277	252	2	37	0.66
Chrysene	30	-	-	84	166	121	-	-	84
Dibenzo(a,h)anthrancene	30	-	-	84	166	121	-	-	84
Dibenzofuran	-	-	-	-	-	-	-	-	-
Fluoranthene	30	-	-	84	166	121	-	-	84
Fluorene	30	-	-	84	166	121	-	-	84
Indeno(1,2,3-cd)pyrene	30	-	-	84	166	121	-	-	84
2-methylnaphthalene	30	-	-	84	166	121	-	-	84
4-methylphenol (p-Cresol)	50	-	-	11,167	29,145	33,156	-	-	11,167
Naphthalene	30	-	-	84	166	121	-	-	84
n-nitrosodiphenylamine	20	-	-	16,981	33,240	24,202	-	-	16,981
Pentachlorophenol	3	-	-	22	41	30	-	-	22
Phenanthrene	30	-	-	84	166	121	-	-	84
Phenol	30	-	-	2,547	4,986	3,630	-	-	2,547
Pyrene	30	-	-	84	166	121	-	-	84

TABLE 5-12
SOIL PRELIMINARY REMEDIATION GOALS FOR NON-SPECIAL STATUS PLANT AND WILDLIFE SPECIES BASED ON LOW TOXICITY BENCHMARK VALUES

Presidio of San Francisco, California

Potential Chemical of Concern	Plants and Soil Fauna PRG_{low} (mg/kg)	Soil Preliminary Remediation Goal for Protection of Wildlife (mg/kg)							
		American Robin	Mourning Dove	Western Harvest Mouse	Valley Pocket Gopher	Raccoon	Peregrine Falcon	Red-tailed Hawk	Wildlife Minimum PRG Value
Volatile Organic Compounds									
Acetone	-	-	-	8,490	16,620	12,101	-	-	8,490
2-Butanone (MEK)	-	-	-	4,245	8,310	6,050	-	-	4,245
Carbon disulfide	-	-	-	934	1,828	1,331	-	-	934
1,4-dichlorobenzene	20	-	-	2,123	4,155	3,025	-	-	2,123
p-isopropyltoluene (p-cymene) (d)	200	-	-	2,207	4,321	3,146	-	-	2,207
Methylene Chloride	-	-	-	459	858	624	-	-	459
1,2,3-trichlorobenzene	20	-	-	-	-	-	-	-	-
1,2,4-trichlorobenzene	20	-	-	-	-	-	-	-	-
Trichlorfluoromethane	-	-	-	-	-	-	-	-	-
1,1,1-trichloroethane	-	-	-	9,679	18,947	13,795	-	-	9,679
PCBs, Pesticides, and Herbicides									
PCBs (Aroclor 1254)	40	0.01	2	0.22	43	1	0.09	0.24	0.01
Aldrin	-	0.004	0.37	0.2	15	1	0.02	4	0.004
alpha-BHC	-	0.062	5	6	665	29	0.13	18	0.062
beta-BHC	-	0.062	5	6	665	29	0.13	18	0.062
delta-BHC	-	0.062	5	6	665	29	0.13	18	0.062
Chlordane	-	0.009	0.85	0.63	88	5	0.04	5	0.009
2,4-D	-	-	-	-	-	-	-	-	-
Dicamba	-	-	-	-	-	-	-	-	-
4,4'-DDD	40	0.049	3	18	1,007	92	0.14	6	0.049
4,4'-DDE	40	0.098	5	18	1,007	92	0.22	7	0.098
4,4'-DDT	40	0.008	0.44	18	1,007	92	0.14	6	0.008
Dieldrin	50	0.039	4	0.27	21	0.26	0.16	39	0.039
Endosulfan	-	1.1	96	2	249	11	2	320	1.1
Endosulfan Sulfate (d)	-	1.1	96	2	249	11	2	320	1.1

TABLE 5-12

SOIL PRELIMINARY REMEDIATION GOALS FOR NON-SPECIAL STATUS PLANT AND WILDLIFE SPECIES BASED ON LOW TOXICITY BENCHMARK VALUES

Presidio of San Francisco, California

Potential Chemical of Concern	Plants and Soil Fauna PRG_{low} (mg/kg)	Soil Preliminary Remediation Goal for Protection of Wildlife (mg/kg)							
		American Robin	Mourning Dove	Western Harvest Mouse	Valley Pocket Gopher	Raccoon	Peregrine Falcon	Red-tailed Hawk	Wildlife Minimum PRG Value
PCBs, Pesticides, and Herbicides (cont.)									
Endrin	-	0.004	0.31	0.3	31	1	0.007	1	0.004
Endrin Aldehyde (d)	-	0.004	0.31	0.3	31	1	0.007	1	0.004
Endrin Ketone (d)	-	0.004	0.31	0.3	31	1	0.007	1	0.004
gamma-BHC (Lindane)	-	0.010	0.91	12	1,330	59	0.023	3	0.010
Heptachlor	-	0.018	0.50	0.29	6	3	0.017	4	0.017
Heptachlor Epoxide	-	0.018	0.5	0.29	6	3	0.017	4	0.017
Isodrin	-	0.004	0.37	0.2	15	1	0.016	4	0.004
MCPP	-	-	-	-	-	-	-	-	-
Methoxychlor	-	0.44	38	6	665	29	0.9	128	0.44

Notes:

(a) Hyphen indicates that Preliminary Remediation Goal ("PRG") could not be calculated due to lack of toxicity information.

(b) PRG for lead was calculated through use of the Monte Carlo method. Refer to text for discussion of methodology used to derive the PRG for lead.

(c) Values for toluene were used for isopropyltoluene.

(d) Values for Endosulfan were used for Endosulfan Sulfate. Values for Endrin were used for Endrin Aldehyde and Endrin Ketone.

TABLE 5-13
SOIL PRELIMINARY REMEDIATION GOALS FOR NON-SPECIAL STATUS PLANT AND WILDLIFE SPECIES BASED ON HIGH TOXICITY BENCHMARK VALUES

Presidio of San Francisco, California

Potential Chemical of Concern	Plants and Soil Fauna PRG_{high} (mg/kg)	Soil Preliminary Remediation Goal for Protection of Wildlife (mg/kg)							
		American Robin	Mourning Dove	Western Harvest Mouse	Valley Pocket Gopher	Raccoon	Peregrine Falcon	Red-tailed Hawk	Wildlife Minimum PRG Value
Inorganic Chemicals									
Antimony	5	- (a)	-	490	1,222	1,110	-	-	490
Arsenic	224	692	2,031	6,080	15,333	13,937	5,133	42,064	692
Barium	500	3,200	9,404	19,581	48,870	44,403	23,831	198,190	3,200
Beryllium	10	8,000	23,510	11,688	29,171	26,505	59,578	495,476	8,000
Cadmium	100	0.44	15	38.80	653	362	190	108	0.44
Chromium	200	42	124	11,001	27,455	24,946	314	2,615	42
Cobalt	75	41,567	122,156	3,300	8,237	7,484	309,559	2,574,431	3,300
Copper	400	200	1,599	775	4,435	2,173	8,824	30,975	200
Cyanide	-	-	-	18,894	47,154	42,844	-	-	18,894
Lead (b)	-	-	-	-	-	-	-	-	-
Tetraethyl Lead	-	52	398	6,408	44,391	43,989	1,386	8,578	52
Mercury	10	12	83	22	95	172	30	4,402	12
Molybdenum	-	582	1,710	703	1,770	1,610	4,310	35,400	582
Nickel	500	1,440	4,232	43,453	108,448	98,536	10,724	89,186	1,440
Selenium	70	2	9	4	13	57	117	210	2
Silver	2	144	423	35,752	89,230	81,074	1,072	8,919	144
Thallium	1	39	115	825	2,059	1,871	291	2,421	39
Vanadium	20	8	24	5,500	13,728	12,473	60	495	8
Zinc	864	97	2,014	1,253	14,297	11,799	21,830	5,390	97

TABLE 5-13

SOIL PRELIMINARY REMEDIATION GOALS FOR NON-SPECIAL STATUS PLANT AND WILDLIFE SPECIES BASED ON HIGH TOXICITY BENCHMARK VALUES

Presidio of San Francisco, California

Potential Chemical of Concern	Plants and Soil Fauna PRG_{high} (mg/kg)	Soil Preliminary Remediation Goal for Protection of Wildlife (mg/kg)							
		American Robin	Mourning Dove	Western Harvest Mouse	Valley Pocket Gopher	Raccoon	Peregrine Falcon	Red-tailed Hawk	Wildlife Minimum PRG Value
Semivolatile Organic Compounds									
Acenaphthene	50	-	-	2,547	6,648	6,050	-	-	2,547
Acenaphthylene	50	-	-	2,547	6,648	6,050	-	-	2,547
Anthracene	50	-	-	2,547	6,648	6,050	-	-	2,547
Benzo(a)anthracene	50	-	-	2,547	6,648	6,050	-	-	2,547
Benzo(a)pyrene	50	-	-	2,547	6,648	6,050	-	-	2,547
Benzo(b)fluoranthene	50	-	-	2,547	6,648	6,050	-	-	2,547
Benzo(g,h,i)perylene	50	-	-	2,547	6,648	6,050	-	-	2,547
Benzo(k)fluoranthene	50	-	-	2,547	6,648	6,050	-	-	2,547
Benzyl Alcohol	-	164	480	26,490	69,139	62,924	1,201	9,371	164.36
Chrysene	50	-	-	2,547	6,648	6,050	-	-	2,547
Dibenzo(a,h)anthrancene	50	-	-	2,547	6,648	6,050	-	-	2,547
Dibenzofuran	-	-	-	-	-	-	-	-	-
Fluoranthene	50	-	-	2,547	6,648	6,050	-	-	2,547
Fluorene	50	-	-	2,547	6,648	6,050	-	-	2,547
Indeno(1,2,3-cd)pyrene	50	-	-	2,547	6,648	6,050	-	-	2,547
2-methylnaphthalene	50	-	-	2,547	6,648	6,050	-	-	2,547
4-methylphenol (p-Cresol)	50	-	-	55,782	145,591	132,504	-	-	55,782
Naphthalene	50	-	-	2,547	6,648	6,050	-	-	2,547
n-nitrosodiphenylamine	109	-	-	50,942	132,960	121,008	-	-	50,942
Pentachlorophenol	4	-	-	660	1,647	1,497	-	-	660
Phenanthrene	50	-	-	2,547	6,648	6,050	-	-	2,547
Phenol	188	-	-	7,641	19,944	18,151	-	-	7,641
Pyrene	50	-	-	2,547	6,648	6,050	-	-	2,547

TABLE 5-13
SOIL PRELIMINARY REMEDIATION GOALS FOR NON-SPECIAL STATUS PLANT AND WILDLIFE SPECIES BASED ON HIGH TOXICITY BENCHMARK VALUES

Presidio of San Francisco, California

Potential Chemical of Concern	Plants and Soil Fauna PRG_{high} (mg/kg)	Soil Preliminary Remediation Goal for Protection of Wildlife (mg/kg)							
		American Robin	Mourning Dove	Western Harvest Mouse	Valley Pocket Gopher	Raccoon	Peregrine Falcon	Red-tailed Hawk	Wildlife Minimum PRG Value
Volatile Organic Compounds									
Acetone	-	-	-	127,356	332,399	302,520	-	-	127,356
2-Butanone (MEK)	-	-	-	25,471	66,480	60,504	-	-	25,471
Carbon disulfide	-	-	-	28,018	73,128	66,554	-	-	28,018
1,4-dichlorobenzene	128	-	-	12,736	33,240	30,252	-	-	12,736
p-isopropyltoluene (p-cymene) (c)	1,000	-	-	22,075	43,212	31,462	-	-	22,075
Methylene Chloride	-	-	-	34,377	85,798	77,956	-	-	34,377
1,2,3-trichlorobenzene	115	-	-	-	-	-	-	-	-
1,2,4-trichlorobenzene	127	-	-	-	-	-	-	-	-
Trichlorfluoromethane	-	-	-	-	-	-	-	-	-
1,1,1-trichloroethane	-	-	-	1,451,858	3,789,347	3,448,730	-	-	1,451,858
PCBs, Pesticides, and Herbicides									
PCBs (Aroclor 1254)	240	0.45	79	3	812	29	8	10.83	0.45
Aldrin	-	0.19	19	3	300	26	2	195	0.19
alpha-BHC	-	11	960	10	1,496	83	45	740	10
beta-BHC	-	11	960	10	1,496	83	45	740	10
delta-BHC	-	11	960	10	1,496	83	45	740	10
Chlordane	-	0.071	9	27	3,818	235	0.81	47	0.071
2,4-D	-	-	-	-	-	-	-	-	-
Dicamba	-	-	-	-	-	-	-	-	-
4,4'-DDD	200	2	131	280	20,339	2,317	11	181	2
4,4'-DDE	200	2	131	280	20,339	2,317	11	181	2
4,4'-DDT	200	2	131	280	20,339	2,317	11	181	2
Dieldrin	100	0.48	47	0.94	93	68	4	488	0.48
Endosulfan	-	5	480	7	997	55	23	370	5
Endosulfan Sulfate (d)	-	5	480	7	997	55	23	370	5

TABLE 5-13

SOIL PRELIMINARY REMEDIATION GOALS FOR NON-SPECIAL STATUS PLANT AND WILDLIFE SPECIES BASED ON HIGH TOXICITY BENCHMARK VALUES

Presidio of San Francisco, California

Potential Chemical of Concern	Plants and Soil Fauna PRG_{high} (mg/kg)	Soil Preliminary Remediation Goal for Protection of Wildlife (mg/kg)							
		American Robin	Mourning Dove	Western Harvest Mouse	Valley Pocket Gopher	Raccoon	Peregrine Falcon	Red-tailed Hawk	Wildlife Minimum PRG Value
PCBs, Pesticides, and Herbicides (cont.)									
Endrin	-	0.50	44	9	1,330	74	2	34	0.50
Endrin Aldehyde (d)	-	0.50	44	9	1,330	74	2	34	0.50
Endrin Ketone (d)	-	0.50	44	9	1,330	74	2	34	0.50
gamma-BHC (Lindane)	-	2	144	35	5,318	295	7	111	2
Heptachlor	-	199	5,467	7	148	57	358	47,169	7
Heptachlor Epoxide	-	199	5,467	7	148	57	358	47,169	7
Isodrin (e)	-	0.19	19	3	300	26	2	195	0.19
MCPP	-	-	-	-	-	-	-	-	-
Methoxychlor	-	110	9,598	35	5,318	295	451	7,401	35

Notes:

(a) Hyphen indicates that Preliminary Remediation Goal ("PRG") could not be calculated due to lack of toxicity information.

(b PRG for lead was calculated through use of the Monte Carlo method. Refer to text for discussion of methodology used to derive the PRG for lead.

(c) Values for toluene were used for isopropyltoluene.

(d Values for Endosulfan were used for Endosulfan Sulfate. Values for Endrin were used for Endrin Aldehyde and Endrin Ketone.

(e) Isodrin is an isomer of Aldrin. Values for Aldrin were used for Isodrin.

TABLE 5-14
SOIL PRELIMINARY REMEDIATION GOALS FOR NON-SPECIAL STATUS PLANT AND WILDLIFE SPECIES

Presidio of San Francisco, California

Potential Chemical of Concern	Summary of Plant and Soil Fauna PRGs (mg/kg); (a)			Summary of Wildlife PRGs (mg/kg); (a)			Proposed Soil PRG (mg/kg); (b)
	PRG_{low}	PRG_{high}	Arithmetic Mean	PRG_{low}	PRG_{high}	Arithmetic Mean	
Inorganic Chemicals							
Antimony	5	5	5	162	490	326	5
Arsenic	10	224	117	46	692	369	120
Barium	500	500	500	320	3,200	1,760	500
Beryllium	10	10	10	160	8,000	4,080	10
Cadmium	4	100	52	0.017	0.44	0.23	0.23
Chromium	5	200	103	4	42	23	23
Cobalt	20	75	48	220	3,300	1,760	48
Copper	50	400	225	30	200	115	120
Cyanide	- (c)	-	-	6,298	18,894	12,596	13,000
Lead (d)							300
Tetraethyl Lead	-	-	-	1	52	27	27
Mercury	0.3	10	5.15	0.038	12	6	5.2
Molybdenum	-	-	-	11.5	582	297	300
Nickel	30	500	265	58	1,440	749	270
Selenium	1	70	35.5	0.20	2	1	1.1
Silver	2	2	2	6	144	75	2
Thallium	1	1	1	0.15	39	20	1
Vanadium	2	20	11	2	8	5	5
Zinc	50	864	457	4	97	51	50

TABLE 5-14

SOIL PRELIMINARY REMEDIATION GOALS FOR NON-SPECIAL STATUS PLANT AND WILDLIFE SPECIES

Presidio of San Francisco, California

Potential Chemical of Concern	Summary of Plant and Soil Fauna PRGs (mg/kg); (a)			Summary of Wildlife PRGs (mg/kg); (a)			Proposed Soil PRG (mg/kg); (b)
	PRG_{low}	PRG_{high}	Arithmetic Mean	PRG_{low}	PRG_{high}	Arithmetic Mean	
Semivolatile Organic Compounds							
Acenaphthene	30	50	40	84	2,547	1,316	40
Acenaphthylene	30	50	40	84	2,547	1,316	40
Anthracene	30	50	40	84	2,547	1,316	40
Benzo(a)anthracene	30	50	40	84	2,547	1,316	40
Benzo(a)pyrene	30	50	40	84	2,547	1,316	40
Benzo(b)fluoranthene	30	50	40	84	2,547	1,316	40
Benzo(g,h,i)perylene	30	50	40	84	2,547	1,316	40
Benzo(k)fluoranthene	30	50	40	84	2,547	1,316	40
Benzyl Alcohol	-	-	-	1	164	83	83
Chrysene	30	50	40	84	2,547	1,316	40
Dibenzo(a,h)anthrancene	30	50	40	84	2,547	1,316	40
Dibenzofuran	-	-	-	-	-	-	-
Fluoranthene	30	50	40	84	2,547	1,316	40
Fluorene	30	50	40	84	2,547	1,316	40
Indeno(1,2,3-cd)pyrene	30	50	40	84	2,547	1,316	40
2-methylnaphthalene	30	50	40	84	2,547	1,316	40
4-methylphenol (p-Cresol)	50	50	50	11,167	55,782	33,474	50
Naphthalene	30	50	40	84	2,547	1,316	40
n-nitrosodiphenylamine	20	109	65	16,981	50,942	33,962	65
Pentachlorophenol	3	4	3.5	22	660	341	3.5
Phenanthrene	30	50	40	84	2,547	1,316	40
Phenol	30	188	109	2,547	7,641	5,094	109
Pyrene	30	50	40	84	2,547	1,316	40

TABLE 5-14
SOIL PRELIMINARY REMEDIATION GOALS FOR NON-SPECIAL STATUS PLANT AND WILDLIFE SPECIES

Presidio of San Francisco, California

Potential Chemical of Concern	Summary of Plant and Soil Fauna PRGs (mg/kg); (a)			Summary of Wildlife PRGs (mg/kg); (a)			Proposed Soil PRG (mg/kg); (b)
	PRG_{low}	PRG_{high}	Arithmetic Mean	PRG_{low}	PRG_{high}	Arithmetic Mean	
Volatile Organic Compounds							
Acetone	-	-	-	8,490	127,356	67,923	68,000
2-butanone (MEK)	-	-	-	4,245	25,471	14,858	15,000
Carbon disulfide	-	-	-	934	28,018	14,476	14,476
1,4-dichlorobenzene	20	128	74	2,123	12,736	7,429	74
p-isopropyltoluene (p-cymene) (e)	200	1000	600	2,207	22,075	12,141	600
Methylene Chloride	-	-	-	459	34,377	17,418	17,000
1,2,3-trichlorobenzene	20	115	67.5	-	-	-	67.5
1,2,4-trichlorobenzene	20	127	73.5	-	-	-	73.5
Trichlorofluoromethane	-	-	-	-	-	-	-
1,1,1-trichloroethane	-	-	-	9,679	1,451,858	730,768	730,000
PCBs, Pesticides, and Herbicides							
PCBs (Arochlor 1254)	40	240	140	0.010	0.45	0.23	0.23
Aldrin	-	-	-	0.0039	0.19	0.1	0.1
alpha-BHC	-	-	-	0.062	10	4.9	4.9
beta-BHC	-	-	-	0.062	10	4.9	4.9
delta-BHC	-	-	-	0.062	10	4.9	4.9
Chlordane	-	-	-	0.0090	0.071	0.04	0.04
2,4-D	-	-	-	-	-	-	-
Dicamba	-	-	-	-	-	-	-
4,4'-DDD	40	200	120	0.049	2	1.2	1.2
4,4'-DDE	40	200	120	0.098	2	1.3	1.3
4,4'-DDT	40	200	120	0.0082	2	1.2	1.2
Dieldrin	50	100	75	0.039	0.48	0.26	0.26
Endosulfan	-	-	-	1.1	5.5	3.3	3.3
Endosulfan Sulfate (f)	-	-	-	1.1	5.5	3.3	3.3

TABLE 5-14

SOIL PRELIMINARY REMEDIATION GOALS FOR NON-SPECIAL STATUS PLANT AND WILDLIFE SPECIES

Presidio of San Francisco, California

Potential Chemical of Concern	Summary of Plant and Soil Fauna PRGs (mg/kg); (a)			Summary of Wildlife PRGs (mg/kg); (a)			Proposed Soil PRG (mg/kg); (b)
	PRG_{low}	PRG_{high}	Arithmetic Mean	PRG_{low}	PRG_{high}	Arithmetic Mean	
PCBs, Pesticides, and Herbicides							
Endrin	-	-	-	0.004	0.50	0.25	0.25
Endrin Aldehyde (f)	-	-	-	0.004	0.50	0.25	0.25
Endrin Ketone (f)	-	-	-	0.004	0.50	0.25	0.25
gamma-BHC (Lindane)	-	-	-	0.010	2	0.83	0.83
Heptachlor	-	-	-	0.017	7	3.7	3.7
Heptachlor Epoxide	-	-	-	0.017	7	3.7	3.7
Isodrin (g)	-	-	-	0.0039	0.19	0.1	0.1
MCPP	-	-	-	-	-	-	-
Methoxychlor	-	-	-	0.44	35	18	18

Notes:

(a) Listed in this table are the low and high Preliminary Remediation Goals ("PRGs") values for plants and soil fauna, and the lowest wildlife PRGs recalculated using TBV_{low} values from Table 5-12 and TBV_{high} values from Table 5-13.

(b) The soil PRG proposed for protection of non-special status species is the lower of the arithmetic means of plants and soil fauna PRGs, and wildlife PRGs.

(c) Hyphen indicates that PRG could not be calculated due to lack of toxicity information.

(d) Values for toluene were used for isopropyltoluene.

(e) PRG for lead was calculated through use of the Monte Carlo method. Refer to text for discussion of methodology used to derive the PRG for lead.

(f) Values for Endosulfan were used for Endosulfan Sulfate. Values for Endrin were used for Endrin Aldehyde and Endrin Ketone.

(g) Isodrin is an isomer of Aldrin. Values for Aldrin were used for Isodrin.

TABLE 5-15
SEDIMENT PRELIMINARY REMEDIATION GOALS FOR NON-SPECIAL STATUS WILDLIFE SPECIES

Presidio of San Francisco, California

Potential Chemical of Concern	Sediment PRG for Wildlife Based on TBV_{low} (mg/kg); (a)		Sediment PRG for Wildlife Based on TBV_{high} (mg/kg); (a)	
	Mallard Duck	Western Sandpiper	Mallard Duck	Western Sandpiper
Inorganic Chemicals				
Antimony	- (a)	-	-	-
Arsenic	7,874	81	23,621	1,219
Barium	11,031	564	110,309	5,639
Beryllium	5,515	282	275,774	14,097
Cadmium	12	0.082	61	2
Chromium	148	9	1,456	74
Cobalt	143,289	2,930	1,432,886	73,246
Copper	1,328	114	8,721	748
Cyanide	-	-	-	-
Lead (b)				
Tetraethyl Lead	60	3	2,958	169
Mercury	2	0.33	344	52
Molybdenum	394	20.3	19,900	1,020
Nickel	1,984	101	49,639	2,537
Selenium	3	0.84	35	8.5
Silver	198	10	4,964	254
Thallium	5	0.26	1,348	69
Vanadium	57	3	276	14
Zinc	1,787	18	8,933	445
Semivolatile Organic Compounds				
Acenaphthene	-	-	-	-
Acenaphthylene	-	-	-	-
Anthracene	-	-	-	-
Benzo(a)anthracene	-	-	-	-
Benzo(a)pyrene	-	-	-	-
Benzo(b)fluoranthene	-	-	-	-
Benzo(g,h,i)perylene	-	-	-	-
Benzo(k)fluoranthene	-	-	-	-
Benzyl Alcohol	22	1	5,417	288
Chrysene	-	-	-	-
Dibenzo(a,h)anthrancene	-	-	-	-
Dibenzofuran	-	-	-	-
Fluoranthene	-	-	-	-
Fluorene	-	-	-	-

TABLE 5-15
SEDIMENT PRELIMINARY REMEDIATION GOALS FOR NON-SPECIAL STATUS WILDLIFE SPECIES

Presidio of San Francisco, California

Potential Chemical of Concern	Sediment PRG for Wildlife Based on TBV_{low} (mg/kg); (a)		Sediment PRG for Wildlife Based on TBV_{high} (mg/kg); (a)	
	Mallard Duck	Western Sandpiper	Mallard Duck	Western Sandpiper
Semivolatile Organic Compounds (cont.)				
Indeno(1,2,3-cd)pyrene	-	-	-	-
2-methylnaphthalene	-	-	-	-
4-methylphenol (p-Cresol)	-	-	-	-
Naphthalene	-	-	-	-
n-nitrosodiphenylamine	-	-	-	-
Pentachlorophenol	-	-	-	-
Phenanthrene	-	-	-	-
Phenol	-	-	-	-
Pyrene	-	-	-	-
Volatile Organic Compounds				
Acetone	-	-	-	-
2-butanone (MEK)	-	-	-	-
Carbon disulfide	-	-	-	-
1,4-dichlorobenzene	-	-	-	-
p-isopropyltoluene (p-cymene)	-	-	-	-
Methylene Chloride	-	-	-	-
1,2,3-trichlorobenzene	-	-	-	-
1,2,4-trichlorobenzene	-	-	-	-
Trichlorfluoromethane	-	-	-	-
1,1,1-trichloroethane	-	-	-	-
PCBs, Pesticides, and Herbicides				
PCBs (Arochlor 1254)	17	0.047	770	2
Aldrin	15	0.018	146	0.90
alpha-BHC	61	0.28	10,835	50
beta-BHC	61	0.28	10,835	50
delta-BHC	61	0.28	10,835	50
Chlordane	7	0.033	73	0.33
2,4-D	-	-	-	-
Dicamba	-	-	-	-
4,4'-DDD	25	0.22	1,263	11
4,4'-DDE	51	0.43	1,263	11
4,4'-DDT	25	0.22	1,263	11
Dieldrin	29	0.18	364	2
Endosulfan	1,083	5	5,417	25
Endosulfan Sulfate (c)	1,083	5	5,417	25

TABLE 5-15
SEDIMENT PRELIMINARY REMEDIATION GOALS FOR NON-SPECIAL STATUS WILDLIFE SPECIES

Presidio of San Francisco, California

Potential Chemical of Concern	Sediment PRG for Wildlife Based on TBV_{low} (mg/kg); (a)		Sediment PRG for Wildlife Based on TBV_{high} (mg/kg); (a)	
	Mallard Duck	Western Sandpiper	Mallard Duck	Western Sandpiper
PCBs, Pesticides, and Herbicides (cont.)				
Endrin	17	0.016	498	2
Endrin Aldehyde (c)	17	0.016	498	2
Endrin Ketone (c)	17	0.016	498	2
gamma-BHC (Lindane)	10	0.048	1,625	7
Heptachlor	3	0.080	32,480	873
Heptachlor Epoxide	3	0.080	32,480	873
Isodrin (d)	15	0.018	146	0.90
MCPP	-	-	-	-
Methoxychlor	2,167	2	108,349	500

Notes:

(a) Hyphen indicates that Preliminary Remediation Goal ("PRG") could not be calculated due to lack of toxicity information.

(b) Refer to text for discussion of methodology used to derive the the PRG for lead.

(c) Values for Endosulfan were used for Endosulfan Sulfate. Values for Endrin were used for Endrin Aldehyde and Endrin Ketone.

(d) Isodrin is an isomer of Aldrin. Values for Aldrin were used for Isodrin.

TABLE 5-16
SEDIMENT PRELIMINARY REMEDIATION GOALS FOR NON-SPECIAL STATUS AQUATIC LIFE AND WILDLIFE SPECIES (FRESHWATER)

Presidio of San Francisco, California

Potential Chemical of Concern	Range of Sediment PRGs (mg/kg); (a)		Proposed Sediment PRG (b) (mg/kg)
	PRG_{low}	PRG_{high}	
Inorganic Chemicals			
Antimony	- (c)	-	-
Arsenic	6	33	19
Barium	564	5,639	3,100
Beryllium	282	14,097	7,200
Cadmium	0.082	2	1.1
Chromium	9	74	42
Cobalt	50	50	50
Copper	32	197	114
Cyanide	-	-	-
Lead	35.7	128	82
Tetraethyl Lead	3	169	86
Mercury	0.17	1.06	0.62
Molybdenum	20.3	1,020	522
Nickel	16	75	46
Selenium (d)	0.4	38	4.5
Silver	0.5	0.5	0.5
Thallium	0.26	69	35
Vanadium	3	14	9
Zinc	18	445	230
Semivolatile Organic Compounds			
Acenaphthene	0.0067	0.62	0.31
Acenaphthylene	0.0059	0.13	0.067
Anthracene	0.047	0.85	0.45
Benzo(a)anthracene	0.032	1.05	0.54
Benzo(a)pyrene	0.032	1.45	0.74
Benzo(b)fluoranthene	0.24	1.34	0.79
Benzo(g,h,i)perylene	0.17	0.32	0.25
Benzo(k)fluoranthene	0.24	1.34	0.79
Benzyl Alcohol	1	288	145
Chrysene	0.057	1.29	0.67
Dibenzo(a,h)anthrancene	0.0062	0.135	0.071
Dibenzofuran	2	2	2
Fluoranthene	0.11	2.9	1.5
Fluorene	0.021	0.54	0.28

TABLE 5-16
SEDIMENT PRELIMINARY REMEDIATION GOALS FOR NON-SPECIAL STATUS AQUATIC LIFE AND WILDLIFE SPECIES (FRESHWATER)

Presidio of San Francisco, California

Potential Chemical of Concern	Range of Sediment PRGs (mg/kg); (a)		Proposed Sediment PRG (b) (mg/kg)
	PRG_{low}	PRG_{high}	
Semivolatile Organic Compounds (cont.)			
Indeno(1,2,3-cd)pyrene	0.2	0.32	0.26
2-methylnaphthalene	0.02	0.20	0.11
4-methylphenol (p-Cresol)	-	-	-
Naphthalene	0.03	0.56	0.3
n-nitrosodiphenylamine	-	-	-
Pentachlorophenol	-	-	-
Phenanthrene	0.042	1.2	0.61
Phenol	-	-	-
Pyrene	0.053	1.5	0.79
Volatile Organic Compounds			
Acetone	-	-	-
2-butanone (MEK)	-	-	-
Carbon disulfide	-	-	-
1,4-dichlorobenzene	0.35	0.35	0.35
p-isopropyltoluene (p-cymene)	-	-	-
Methylene Chloride	-	-	-
1,2,3-trichlorobenzene	-	-	-
1,2,4-trichlorobenzene	-	-	-
Methylene Chloride	-	-	-
Trichlorfluoromethane	-	-	-
1,1,1-trichloroethane	0.17	0.17	0.17
PCBs, Pesticides, and Herbicides			
PCBs (Arochlor 1254)	0.047	0.68	0.36
Aldrin	0.002	0.008	0.005
alpha-BHC	0.006	0.01	0.008
beta-BHC	0.005	0.021	0.013
delta-BHC	0.003	0.012	0.0075
Chlordane	0.0032	0.018	0.01
2,4-D	-	-	-
Dicamba	-	-	-
4,4'-DDD	0.0035	0.028	0.016
4,4'-DDE	0.0014	0.031	0.016
4,4'-DDT	0.0012	0.063	0.032
Dieldrin	0.0019	0.062	0.032
Endosulfan	0.0054	0.0054	0.0054
Endosulfan Sulfate (e)	0.0054	0.0054	0.0054

TABLE 5-16
SEDIMENT PRELIMINARY REMEDIATION GOALS FOR NON-SPECIAL STATUS AQUATIC LIFE AND WILDLIFE SPECIES (FRESHWATER)

Presidio of San Francisco, California

Potential Chemical of Concern	Range of Sediment PRGs (mg/kg); (a)		Proposed Sediment PRG (b) (mg/kg)
	PRG_{low}	PRG_{high}	
PCBs, Pesticides, and Herbicides (cont.)			
Endrin	0.0022	0.207	0.1
Endrin Aldehyde (e)	0.0022	0.207	0.1
Endrin Ketone (e)	0.0022	0.207	0.1
gamma-BHC (Lindane)	0.0009	0.005	0.003
Heptachlor	0.0006	0.016	0.0083
Heptachlor Epoxide	0.0006	0.016	0.0083
Isodrin (f)	0.002	0.008	0.005
MCPP	-	-	-
Methoxychlor	0.019	0.019	0.019

Notes:

(a) The sediment quality criteria for aquatic life (Table 5-17), and the Preliminary Remediation Goals ("PRGs") for the mallard duck and western sandpiper (Table 5-15) were considered together to select potential sediment PRGs for each potential chemical of concern ("PCOC"). The lowest values defining the range of PRGs developed for these indicator species of aquatic habitats are listed.

(b) Proposed sediment PRG for protection of non-special status species is the arithmetic mean of the range of PRGs listed in this table for aquatic life, and the mallard duck and western sandpiper.

(c) Hyphen indicates that PRG could not be calculated due to lack of toxicity information.

(d) PRG_{low} is the United States Fish and Wildlife Service recommended no-observed-adverse-effect-level developed in Skorupa J.P., S.P. Morman, and J.S. Sefchick-Edwards. March 1996. *Guidelines for Interpreting Selenium Exposures of Biota Associated with Nonmarine Aquatic Habitats*. Sacramento Field Office.

(e) Values for Endosulfan were used for Endosulfan Sulfate. Values for Endrin were used for Endrin Aldehyde and Endrin Ketone.

(f) Isodrin is an isomer of Aldrin. Values for Aldrin were used for Isodrin.

TABLE 5-17
SEDIMENT PRELIMINARY REMEDIATION GOALS FOR NON-SPECIAL STATUS AQUATIC LIFE AND WILDLIFE SPECIES (MARINE)

Presidio of San Francisco, California

Potential Chemical of Concern	Range of Sediment PRGs (mg/kg); (a)		Proposed Sediment PRG (b) (mg/kg)
	PRG_{low}	PRG_{high}	
Inorganic Chemicals			
Antimony	2	25	14
Arsenic	8.2	70	39
Barium	564	5,639	3,100
Beryllium	282	14,097	7,200
Cadmium	1.2	2	1.6
Chromium	9	74	42
Cobalt	2,930	73,246	38,088
Copper	34	270	152
Cyanide	-	-	-
Lead	46.7	218	132
Tetraethyl Lead	3	169	86
Mercury	0.15	0.71	0.43
Molybdenum	20.3	1,020	522
Nickel	20.9	51.6	36
Selenium (d)	0.4	8.5	4.5
Silver	1	3.7	2.4
Thallium	0.26	69	35
Vanadium	3	14	8.5
Zinc	18	410	214
Semivolatile Organic Compounds			
Acenaphthene	0.016	0.62	0.32
Acenaphthylene	0.044	0.64	0.34
Anthracene	0.0853	1.1	0.59
Benzo(a)anthracene	0.261	1.6	0.93
Benzo(a)pyrene	0.43	1.6	1.0
Benzo(b)fluoranthene	-	-	-
Benzo(g,h,i)perylene	-	-	-
Benzo(k)fluoranthene	-	-	-
Benzyl Alcohol	1.2	288	145
Chrysene	0.384	2.8	1.6
Dibenzo(a,h)anthrancene	0.0634	0.26	0.16
Dibenzofuran	2.0	2.0	2.0
Fluoranthene	0.6	5.1	2.9
Fluorene	0.019	0.54	0.28

TABLE 5-17
SEDIMENT PRELIMINARY REMEDIATION GOALS FOR NON-SPECIAL STATUS AQUATIC LIFE AND WILDLIFE SPECIES (MARINE)

Presidio of San Francisco, California

Potential Chemical of Concern	Range of Sediment PRGs (mg/kg); (a)		Proposed Sediment PRG (b) (mg/kg)
	PRG_{low}	PRG_{high}	
Semivolatile Organic Compounds (cont.)			
Indeno(1,2,3-cd)pyrene	-	-	-
2-methylnaphthalene	0.07	0.67	0.37
4-methylphenol (p-Cresol)	-	-	-
Naphthalene	0.16	2.1	1.1
n-nitrosodiphenylamine	-	-	-
Pentachlorophenol	-	-	-
Phenanthrene	0.24	1.5	0.87
Phenol	-	-	-
Pyrene	0.665	2.6	1.6
Volatile Organic Compounds			
Acetone	-	-	-
2-butanone (MEK)	-	-	-
Carbon disulfide	-	-	-
1,4-dichlorobenzene	0.35	0.35	0.35
p-isopropyltoluene (p-cymene) (e)	0.67	0.67	0.67
Methylene Chloride	-	-	-
1,2,3-trichlorobenzene (f)	9.2	9.2	9.2
1,2,4-trichlorobenzene	9.2	9.2	9.2
Methylene Chloride	-	-	-
Trichlorfluoromethane	-	-	-
1,1,1-trichloroethane	0.17	0.17	0.17
PCBs, Pesticides, and Herbicides			
PCBs (Arochlor 1254)	0.0227	0.18	0.10
Aldrin	0.018	0.90	0.46
alpha-BHC	0.00032	0.00099	0.0007
beta-BHC	0.00032	0.00099	0.0007
delta-BHC	0.00032	0.00099	0.0007
Chlordane	0.0005	0.006	0.003
2,4-D	-	-	-
Dicamba	-	-	-
4,4'-DDD	0.002	0.02	0.011
4,4'-DDE	0.0022	0.027	0.015
4,4'-DDT	0.001	0.007	0.004
Dieldrin	0.00002	0.052	0.026
Endosulfan	0.0054	0.0054	0.005
Endosulfan Sulfate (g)	0.0054	0.0054	0.005

TABLE 5-17
SEDIMENT PRELIMINARY REMEDIATION GOALS FOR NON-SPECIAL STATUS AQUATIC LIFE AND WILDLIFE SPECIES (MARINE)

Presidio of San Francisco, California

Potential Chemical of Concern	Range of Sediment PRGs (mg/kg); (a)		Proposed Sediment PRG (b) (mg/kg)
	PRG_{low}	PRG_{high}	
PCBs, Pesticides, and Herbicides			
Endrin	0.00002	0.045	0.023
Endrin Aldehyde (g)	0.00002	0.045	0.023
Endrin Ketone (g)	0.00002	0.045	0.023
gamma-BHC (Lindane)	0.00032	0.0037	0.002
Heptachlor	0.080	873	437
Heptachlor Epoxide	0.080	873	437
Isodrin (h)	0.018	0.90	0.46
MCPP	-	-	-
Methoxychlor	0.019	0.019	0.019

Notes:

(a) The sediment quality criteria for aquatic life (Table 5-8), and the Preliminary Remediation Goals ("PRGs") for the mallard duck and western sandpiper (Table 5-15) were considered together to select potential sediment PRGs for each potential chemical of concern ("PCOC"). The lowest values defining the range of PRGs developed for these indicator species of aquatic habitats are listed.

(b) Proposed sediment PRG for protection of non-special status species is the arithmetic mean of the range of PRGs listed in this table for aquatic life, and the mallard duck and western sandpiper.

(c) Hyphen indicates sediment quality criterion not found.

(d) PRG_{low} is the United States Fish and Wildlife Service recommended no-observed-adverse-effect-level developed in Skorupa J.P., S.P. Morman, and J.S. Sefchick-Edwards. March 1996. *Guidelines for Interpreting Selenium Exposures of Biota Associated with Nonmarine Aquatic Habitats*. Sacramento Field Office.

(e) Values for toluene were used for isopropyltoluene.

(f) Values for 1,2,4-trichlorobenzene were used for 1,2,3-trichlorobenzene.

(g) Values for Endosulfan were used for Endosulfan Sulfate. Values for Endrin were used for Endrin Aldehyde and Endrin Ketone.

(h) Isodrin is an isomer of Aldrin. Values for Aldrin were used for Isodrin.

SOIL PRELIMINARY REMEDIATION GOALS FOR SPECIAL STATUS PLANT SPECIES BASED ON NO-OBSERVED-EFFECTS-CONCENTRATIONS

Presidio of San Francisco, California

Potential Chemical of Concern	Toxicity Benchmarks (a)		No-Observed-Effects-Concentration (mg/kg); (b); (c)						Proposed Alternate PRG for Special Status Plant Species
					Summary Statistics				
	TBV_{low} (mg/kg)	TBV_{high} (mg/kg)	Low	High	5th Percentile	10th Percentile	25th Percentile	Arithmetic Mean	
Inorganic Chemicals									
Arsenic	10	224	10	224	21	31	**64**	117	64
Cadmium	4	100	1	50	3	6	**13**	26	13
Chromium	5	200	1	150	8	16	**38**	76	38
Lead (d)									160
Mercury	0.3	10	0.3	10	0.8	1.3	**2.7**	5.2	3
Nickel	30	500	5	270	18	32	**71**	138	71

Notes:

(a) Preliminary Remediation Goals ("PRGs") may not be protective of individual special status species, especially where the difference between the PRG_{low} and PRG_{high} values used to calculate the mean is great. PRGs for special status plant species were developed for potential chemicals of concern where the difference between the low and high toxicity benchmark values ("TBVs") for the species governing determination of the cleanup levels is more than one order of magnitude. TBV_{low} values from Table 5-12 and TBV_{high} values from Table 5-13 are included for reference.

(b) No-observed-effects-concentrations ("NOECs") were compiled from the references consulted for non-special status plant species. However, the low and high values used to develop special status species PRGs encompassed the entire range of NOECs and excluded lowest-observed-effects-concentrations ("LOECs"). The 5th, 10th, and 25th percentiles, and arithmetic means of the NOEC values were computed, as summarized in this table. The 25th percentile of NOECs for each metal is proposed as the PRG because this percentile includes NOECs obtained from studies on a variety of soil types and species, including species that are taxonomically similar to those at the Presidio.

(c) Values that are boxed and shown in bold are proposed as PRG for rare, or threatened or endangered plant (i.e., special status) species.

(d) Special status species PRG for lead was calculated through use of the Monte Carlo method. Refer to text for discussion of methodology used to derive special status species PRG for lead.

TAB 5-19
SOIL PRELIMINARY REMEDIATION GOALS FOR SPECIAL STATUS WILDLIFE SPECIES BASED ON TOXICITY BENCHMARK VALUES

Presidio of San Francisco, California

Potential Chemical of Concern	PRGs for Peregine Falcon (a)		Summary Statistics for Peregrine Falcon (mg/kg); (b); (c)					Proposed Alternate PRG for Special Status Wildlife Species
	PRG_{low} (mg/kg)	PRG_{high} (mg/kg)	5th Percentile	10th Percentile	25th Percentile	Arithmetic Mean	Toxicity Endpoint of Study	
Inorganic Chemicals								
Arsenic	170	5,130	418	**666**	1,410	2,650	Protective	666
Lead (d)								
Mercury	0.095	29.7	**1.6**	3.1	7.5	15	Protective	1.58
Nickel	215	10,700	**739**	1,264	2,836	5,458	Protective	739
Selenium	6.21	117	**11.7**	17	34	62	Protective	12
Silver	21.5	1,070	**74**	126	284	546	Based on mortality/10	74
Thallium	0.614	291	**15**	30	73	146	Based on mortality/10	15
PCBs, Pesticides, and Herbicides								
PCBs (Aroclor 1254)	0.09	8	**0.490**	0.88	2.1	4.0	Protective	0.49
Aldrin	0.016	2	**0.097**	0.18	0.42	0.82	Based on mortality/10	0.097
alpha-BHC	0.13	45	**2.4**	4.6	11	23	Protective	2.4
beta-BHC	0.13	45	**2.4**	4.6	11	23	Protective	2.4
delta-BHC	0.13	45	**2.4**	4.6	11	23	Protective	2.4
Chlordane	0.04	0.81	0.080	**0.12**	0.23	0.42	Based on mortality/10	0.12
4,4'-DDD	0.14	4	0.34	**0.53**	1.12	2.10	Protective; adjusted for endpoint	0.53
4,4'-DDE	0.22	4	0.42	**0.61**	1.18	2.15	Protective; adjusted for endpoint	0.61
4,4'-DDT	0.14	4	0.34	**0.53**	1.12	2.10	Protective; adjusted for endpoint	0.53
Dieldrin			0.36	**0.55**	1.14	2.12	Low partially based on mortality	0.55
Endrin	0.007	2	**0.11**	0.21	0.5	1.0	Protective	0.11
Endrin Aldehyde (e)	0.007	2	**0.11**	0.21	0.5	1.0	Protective	0.11
Endrin Ketone (e)	0.007	2	**0.11**	0.21	0.5	1.0	Protective	0.11
gamma-BHC	0.023	7	**0.37**	0.72	1.8	3.5	Based on mortality/10	0.37
Heptachlor	0.017	358	**18**	36	90	179	Based on mortality/10	18
Heptachlor Epoxide	0.017	358	**18**	36	90	179	Based on mortality/10	18
Isodrin (f)	0.016	2	**0.097**	0.18	0.42	0.82	Based on mortality/10	0.097
Methoxychlor	0.9	451	**23**	46	113	226	Based on mortality/10	26

Notes:

(a) Soil Preliminary Remediation Goals ("PRGs") for non-special status plant and animal species listed in Table 5-14.

(b) PRGs for special status wildlife species are established from the PRG_{low} and PRG_{high} values for the peregrine falcon because the PRGs for this bird are the lowest of the avian indicator species evaluated for terrestrial habitats. PRG concentrations were computed from TBVs compiled from the references consulted for non-special status wildlife species. The 5th percentile is proposed as the PRG where the difference between PRG_{low} and PRG_{high} values for non-special status species is two orders of magnitude or greater. The 10th percentile is proposed as the PRG where the difference between PRG_{low} and PRG_{high} values for non-special status species is between one and two orders of magnitude.

(c) Values that are boxed and shown in bold are proposed as PRG for rare, or threatened or endangered wildlife (i.e., special status) species.

(d) Special status species PRG for lead was calculated through use of the Monte Carlo method. Refer to text for discussion of methodology used to derive special status species PRG for lead.

(e) Values for Endrin were used for Endrin Aldehyde and Endrin Ketone.

(f) Isodrin is an isomer of Aldrin. Values for Aldrin were used for Isodrin.

TAE 5-20

SEDIMENT PRELIMINARY REMEDIATION GOALS FOR SPECIAL STATUS WILDLIFE SPECIES BASED ON TOXICITY BENCHMARK VALUES

Presidio of San Francisco, California

Potential Chemical of Concern	PRGs for Western Sandpiper (a)		Summary Statistics for Western Sandpiper (mg/kg); (b); (c)					Proposed PRG for Special Status Wildlife Species
	PRG_{low} (mg/kg)	PRG_{high} (mg/kg)	5th Percentile	10th Percentile	25th Percentile	Arithmetic Mean	Toxicity Endpoint of Study	
Inorganic Chemicals								
Arsenic	81	1,220	138	**195**	366	651	Protective	195
Lead (d)								
Mercury	0.33	52	**2.9**	5.5	13.2	26	Protective	2.9
Nickel	101	2,540	223	**345**	711	1,321	Protective	345
Selenium	0.84	9	1.2	**1.6**	3	5	Protective	1.6
Silver	10	254	**22**	34	71	132	Based on mortality/10	22
Thallium	0.26	69	**3.7**	7	17	35	Based on mortality/10	3.7
PCBs, Pesticides, and Herbicides								
PCBs (Aroclor 1254)	0.047	2	**0.14**	**0.24**	0.54	1.0	Protective	0.14
Aldrin	0.018	1	0.061	**0.1**	0.23	0.45	Based on mortality/10	0.1
alpha-BHC	0.28	50	**2.8**	5.3	13	25	Protective	2.8
beta-BHC	0.28	50	**2.8**	5.3	13	25	Protective	2.8
delta-BHC	0.28	50	**2.8**	5.3	13	25	Protective	2.8
Chlordane	0.03	0.33	0.048	**0.062**	0.11	0.18	Based on mortality/10	0.062
4,4'-DDD	0.22	11	0.75	**1.3**	2.9	5.6	Protective; adjusted for endpoint	1.3
4,4'-DDE	0.44	11	0.96	**1.5**	3.1	5.7	Protective; adjusted for endpoint	1.5
4,4'-DDT	0.22	11	0.75	**1.3**	2.9	5.6	Protective; adjusted for endpoint	1.3
Dieldrin	0.179	2	0.28	**0.39**	0.69	1.21	Low partially based on mortality	0.39
Endrin	0.016	2	**0.12**	0.21	0.51	1.0	Protective	0.12
Endrin Aldehyde (e)	0.016	2	**0.12**	0.21	0.51	1.0	Protective	0.12
Endrin Ketone (e)	0.016	2	**0.12**	0.21	0.51	1.0	Protective	0.12
gamma-BHC	0.049	7	**0.4**	0.74	1.8	3.5	Based on mortality/10	0.4
Heptachlor	0.08	873	44	87	218	437	Based on mortality/10	44
Heptachlor Epoxide	0.08	873	44	87	218	437	Based on mortality/10	44
Isodrin (f)	0.018	1	**0.1**	0.10	0.23	0.45	Based on mortality/10	0.1
Methoxychlor	2	500	**27**	52	127	251	Based on mortality/10	27

SEDIMENT PRELIMINARY REMEDIATION GOALS FOR SPECIAL STATUS WILDLIFE SPECIES BASED ON TOXICITY BENCHMARK VALUES

Presidio of San Francisco, California

Notes:

(a) Sediment Preliminary Remediation Goals ("PRGs") for non-special status plant and animal species listed in Table 5-15.

(b) PRGs for special status wildlife species are established from the PRG_{low} and PRG_{high} values for the western sandpiper because the PRGs for this bird are the lowest of the avian indicator species evaluated for aquatic habitats. PRG concentrations were computed from TBVs compiled from the references consulted for non-special status wildlife species. The 5th percentile is proposed as the PRG where the difference between PRG_{low} and PRG_{high} values for non-special status species is two orders of magnitude or greater. The 10th percentile is proposed as the PRG where the difference between PRG_{low} and PRG_{high} values for non-special status species is between one and two orders of magnitude.

(c) Values that are boxed and shown in bold are proposed as PRG for rare, or threatened or endangered wildlife (i.e., special status) species.

(d) A special status species PRG for lead was not calculated because the sediment quality criteria for aquatic life is protective of aquatic life, including special status species. Refer to text for discussion of methodology used to derive special status species PRG for lead.

(e) Values for Endrin were used for Endrin Aldehyde and Endrin Ketone.

(f) Isodrin is an isomer of Aldrin. Values for Aldrin were used for Isodrin.

TABLE 5-21
COMPARISON OF SOIL PRELIMINARY REMEDIATION GOALS OF NON-SPECIAL STATUS AND SPECIAL STATUS SPECIES

Presidio of San Francisco, California

Potential Chemical of Concern	Plant and Soil Fauna PRGs (mg/kg); (a)		Wildlife PRGs (mg/kg); (b)		Alternate PRGs for Special Status Species (mg/kg); (c)
	Non-Special Status	Special Status	Non-Special Status	Special Status	
Inorganic Chemicals					
Arsenic	117	64	369	666	64
Lead (d)					160
Mercury	5.2	2.7	5.9	1.6	1.6
Nickel	265	71	749	739	71
Selenium	36	- (e)	1.1	12	
Silver	2	-	749	74	
Thallium	1	-	196	15	
PCBs, Pesticides, and Herbicides					
PCBs (Aroclor 1254)	40	240	0.23	0.49	
Aldrin	-	-	0.1	0.097	0.097
alpha-BHC	-	-	4.9	2.4	2.4
beta-BHC	-	-	4.9	2.4	2.4
delta-BHC	-	-	4.9	2.4	2.4
Chlordane	-	-	0.04	0.12	
4,4'-DDD	120	-	1.25	0.53	0.53
4,4'-DDE	120	-	1.27	0.61	0.61
4,4'-DDT	120	-	1.23	0.53	0.53
Dieldrin	75	-	0.26	0.55	
Endrin	-	-	0.25	0.11	0.11
Endrin Aldehyde (f)	-	-	0.25	0.11	0.11
Endrin Ketone (f)	-	-	0.25	0.11	0.11
gamma-BHC	-	-	0.83	0.37	0.37

TABLE 5-21

COMPARISON OF SOIL PRELIMINARY REMEDIATION GOALS OF NON-SPECIAL STATUS AND SPECIAL STATUS SPECIES

Presidio of San Francisco, California

Potential Chemical of Concern	Plant and Soil Fauna PRGs (mg/kg); (a)		Wildlife PRGs (mg/kg); (b)		Alternate PRGs for Special Status Species (mg/kg); (c)
	Non-Special Status	Special Status	Non-Special Status	Special Status	
PCBs, Pesticides, and Herbicides (contd)					
Heptachlor	-	-	3.7	18	
Heptachlor Epoxide	-	-	3.7	18	
Isodrin (g)	-	-	0.1	0.097	0.097
Methoxychlor	-	-	18	26	

Notes:

(a) Preliminary Remediation Goals ("PRGs") for non-special status and special status plant and soil fauna species compiled from Table 5-14 and Table 5-18, respectively.

(b) PRGs for non-special status and special status wildlife species compiled from Table 5-14 and Table 5-19, respectively.

(c) PRGs for special status species that are proposed as soil/sediment Alternate PRGs for special status species. Receptors that are not special status species may have lower PRGs because of higher exposure or different sensitivity to potential chemicals of concern ("PCOCs"). For PCOCs where special status PRGs are not the lowest PRGs no value is presented for the Alternate PRGs for special status species.

(d) Special status species PRG for lead was calculated through use of the Monte Carlo method. Refer to text for discussion of methodology used to derive special status species PRG for lead.

(e) Hyphen indicates that PRG could not be calculated due to lack of toxicity information.

(f) Values for Endrin were used for Endrin Aldehyde and Endrin Ketone.

(g) Isodrin is an isomer of Aldrin. Values for Aldrin were used for Isodrin.

TABLE 5-22
COMPARISON OF SEDIMENT PRELIMINARY REMEDIATION GOALS OF NON-SPECIAL STATUS AND SPECIAL STATUS SPECIES (FRESHWATER)

Presidio of San Francisco, California

Potential Chemical of Concern	Aquatic Life and Wildlife PRGs (mg/kg); (a)		Special Status PRGs Proposed for Use as Cleanup Levels (b) (mg/kg)
	Non-Special Status	Special Status	
Inorganic Chemicals			
Arsenic	19	195	
Lead (c)	82		
Mercury	0.6	2.9	
Nickel	46	345	
Selenium	4.5	1.6	1.6
Silver	1	22	
Thallium	35	3.7	3.7
PCBs, Pesticides, and Herbicides			
PCBs (Aroclor 1254)	0.36	0.14	0.14
Aldrin	0.005	0.1	
alpha-BHC	0.008	2.8	
beta-BHC	0.013	2.8	
delta-BHC	0.0075	2.8	
Chlordane	0.01	0.062	
4,4'-DDD	0.016	1.3	
4,4'-DDE	0.016	1.5	
4,4'-DDT	0.032	1.3	
Dieldrin	0.032	0.39	
Endrin	0.1	0.12	
Endrin Aldehyde (d)	0.1	0.12	
Endrin Ketone (d)	0.1	0.12	
gamma-BHC	0.003	0.4	
Heptachlor	0.0083	44	
Heptachlor Epoxide	0.0083	44	
Isodrin (e)	0.005	0.1	
Methoxychlor	0.019	27	

Notes:

(a) Preliminary Remediation Goals ("PRGs") for non-special status and special status aquatic life and wildlife species compiled from Table 5-16 and Table 5-20, respectively.

(b) PRGs for special status species that are proposed as soil/sediment PRGs for special status species. Receptors that are not special status species may have lower PRGs because of higher exposure or different sensitivity to potential chemicals of concern ("PCOCs"). For PCOCs where special status PRGs are not the lowest PRGs, soil/sediment PRGs for non-special status species will be applied as cleanup levels and considered protective of special status species as well.

(c) Refer to text for discussion of methodology used to derive sediment PRG for lead.

(d) Values for Endrin were used for Endrin Aldehyde and Endrin Ketone.

(e) Isodrin is an isomer of Aldrin. Values for Aldrin were used for Isodrin.

TABLE 5-23
COMPARISON OF SEDIMENT PRELIMINARY REMEDIATION GOALS OF NON-SPECIAL STATUS AND SPECIAL STATUS SPECIES (MARINE)

Presidio of San Francisco, California

Potential Chemical of Concern	Aquatic Life and Wildlife PRGs (mg/kg); (a)		Special Status PRGs Proposed for Use as Cleanup Levels (b) (mg/kg)
	Non-Special Status	Special Status	
Inorganic Chemicals			
Arsenic	39	195	
Lead (c)	132		
Mercury	0.43	2.9	
Nickel	36	345	
Selenium	4.5	1.6	1.6
Silver	2.4	22	
Thallium	35	3.7	3.7
PCBs, Pesticides, and Herbicides			
PCBs (Aroclor 1254)	0.10	0.14	
Aldrin	0.46	0.1	0.1
alpha-BHC	0.0007	2.8	
beta-BHC	0.0007	2.8	
delta-BHC	0.0007	2.8	
Chlordane	0.0033	0.062	
4,4'-DDD	0.011	1.3	
4,4'-DDE	0.015	1.5	
4,4'-DDT	0.004	1.3	
Dieldrin	0.026	0.39	
Endrin	0.023	0.12	
Endrin Aldehyde (d)	0.023	0.12	
Endrin Ketone (d)	0.023	0.12	
gamma-BHC	0.002	0.4	
Heptachlor	437	44	44
Heptachlor Epoxide	437	44	44
Isodrin (e)	0.46	0.1	0.1
Methoxychlor	0.019	27	

Notes:

(a) Preliminary Remediation Goals ("PRGs") for non-special status and special status aquatic life and wildlife species compiled from Table 5-17 and Table 5-20, respectively.

(b) PRGs for special status species that are proposed as soil/sediment PRGs for special status species. Receptors that are not special status species may have lower PRGs because of higher exposure or different sensitivity to potential chemicals of concern ("PCOCs"). For PCOCs where special status PRGs are not the lowest PRGs, soil/sediment PRGs for non-special status species will be applied as cleanup levels and considered protective of special status species as well.

(c) Refer to text for discussion of methodology used to derive sediment PRG for lead.

(d) Values for Endrin were used for Endrin Aldehyde and Endrin Ketone.

(e) Isodrin is an isomer of Aldrin. Values for Aldrin were used for Isodrin.

TABLE 5-24
SUMMARY OF ECOLOGICAL PRELIMINARY REMEDIATION GOALS FOR NON-PETROLEUM COMPOUNDS IN SOIL

Presidio of San Francisco, California

Potential Chemical of Concern	Summary of Plant and Soil Fauna PRGs (mg/kg); (a)			Summary of Wildlife PRGs (mg/kg); (a)			Proposed Alternate PRGs (mg/kg); (b)	Proposed Buffer Zone PRGs (mg/kg); (c)	Proposed Special Status PRGs (mg/kg); (d)
	PRG_{low}	PRG_{high}	Arithmetic Mean	PRG_{low}	PRG_{high}	Arithmetic Mean			
Inorganic Chemicals									
Antimony	5	5	5	162	490	326	- (e)	5	5
Arsenic	10	224	117	46	692	369	64	64	10
Barium	500	500	500	320	3,200	1,760	-	500	320
Beryllium	10	10	10	160	8,000	4,080	-	10	10
Cadmium	4	100	52	0.017	0.44	0.23	-	0.23	0.017
Chromium	5	200	103	4	42	23	-	23	4
Cobalt	20	75	48	220	3,300	1,760	-	48	20
Copper	50	400	225	30	200	115	-	120	30
Cyanide	-	-	-	6,298	18,894	12,596	-	13,000	6,300
Lead (f)	-	-	-	-	-	-	-	300	160
Tetraethyl Lead	-	-	-	1.1	52	27	-	27	1.1
Mercury	0.3	10	5.15	0.038	12	6	1.6	1.6	0.4 (g)
Molybdenum	-	-	-	11.5	582	297	-	300	12
Nickel	30	500	265	58	1,440	749	71	71	30
Selenium	1	70	35.5	0.20	2	1	-	1.1	0.2
Silver	2	2	2	6	144	75	-	2	2
Thallium	1	1	1	0.15	39	20	-	1	0.15
Vanadium	2	20	11	2	8	5	-	5	2
Zinc	50	864	457	4	97	51	-	50	4
Semivolatile Organic Compounds									
Acenaphthene	30	50	40	84	2,547	1,316	-	40	30
Acenaphthylene	30	50	40	84	2,547	1,316	-	40	30
Anthracene	30	50	40	84	2,547	1,316	-	40	30
Benzo(a)anthracene	30	50	40	84	2,547	1,316	-	40	30
Benzo(a)pyrene	30	50	40	84	2,547	1,316	-	40	30

TABLE 5-24

SUMMARY OF ECOLOGICAL PRELIMINARY REMEDIATION GOALS FOR NON-PETROLEUM COMPOUNDS IN SOIL

Presidio of San Francisco, California

Potential Chemical of Concern	Summary of Plant and Soil Fauna PRGs (mg/kg); (a)			Summary of Wildlife PRGs (mg/kg); (a)			Proposed Alternate PRGs (mg/kg); (b)	Proposed Buffer Zone PRGs (mg/kg); (c)	Proposed Special Status PRGs (mg/kg); (d)
	PRG_{low}	PRG_{high}	Arithmetic Mean	PRG_{low}	PRG_{high}	Arithmetic Mean			
Semivolatile Organic Compounds									
Benzo(b)fluoranthene	30	50	40	84	2,547	1,316	-	40	30
Benzo(g,h,i)perylene	30	50	40	84	2,547	1,316	-	40	30
Benzo(k)fluoranthene	30	50	40	84	2,547	1,316	-	40	30
Benzyl Alcohol	-	-	-	1	164	83	-	40 (h)	1
Chrysene	30	50	40	84	2,547	1,316	-	40	30
Dibenzo(a,h)anthracene	30	50	40	84	2,547	1,316	-	40	30
Dibenzofuran	-	-	-	-	-	-	-	-	-
Fluoranthene	30	50	40	84	2,547	1,316	-	40	30
Fluorene	30	50	40	84	2,547	1,316	-	40	30
Indeno(1,2,3-cd)pyrene	30	50	40	84	2,547	1,316	-	40	30
2-methylnaphthalene	30	50	40	84	2,547	1,316	-	40	30
4-methylphenol (p-Cresol)	50	50	50	11,167	55,782	33,474	-	50	50
Naphthalene	30	50	40	84	2,547	1,316	-	40	30
n-nitrosodiphenylamine	20	109	65	16,981	50,942	33,962	-	65	20
Pentachlorophenol	3	4	3.5	22	660	341	-	3.5	3
Phenanthrene	30	50	40	84	2,547	1,316	-	40	30
Phenol	30	188	109	2,547	7,641	5,094	-	109	30
Pyrene	30	50	40	84	2,547	1,316	-	40	30

TABLE 5-24
SUMMARY OF ECOLOGICAL PRELIMINARY REMEDIATION GOALS FOR NON-PETROLEUM COMPOUNDS IN SOIL

Presidio of San Francisco, California

Potential Chemical of Concern	Summary of Plant and Soil Fauna PRGs (mg/kg); (a)			Summary of Wildlife PRGs (mg/kg); (a)			Proposed Alternate PRGs (mg/kg); (b)	Proposed Buffer Zone PRGs (mg/kg); (c)	Proposed Special Status PRGs (mg/kg); (d)
	PRG_{low}	PRG_{high}	Arithmetic Mean	PRG_{low}	PRG_{high}	Arithmetic Mean			
Volatile Organic Compounds									
Acetone	-	-	-	8,490	127,356	67,923	-	68,000	8,500
2-butanone (MEK)	-	-	-	4,245	25,471	14,858	-	15,000	4,200
Carbon disulfide	-	-	-	934	28,018	14,476	-	14,000	934
1,4-dichlorobenzene	20	128	74	2,123	12,736	7,429	-	74	20
p-isopropyltoluene (p-cymene)	200 (i)	1,000 (i)	600 (i)	2,207 (i)	22,075 (i)	12,141 (i)	-	600 (i)	200 (i)
Methylene Chloride	-	-	-	459	34,377	17,418	-	17,000	459
1,2,3-trichlorobenzene (j)	20	115	67.5	-	-	-	-	68	20
1,2,4-trichlorobenzene	20	127	73.5	-	-	-	-	74	20
Trichlorofluoromethane	-	-	-	-	-	-	-	-	-
1,1,1-trichloroethane	-	-	-	9,679	1,451,858	730,768	-	730,000	9,700
PCBs, Pesticides, and Herbicides									
PCBs (Arochlor 1254)	40	240	140	0.010	0.45	0.23	-	0.23	*0.033*
Aldrin	-	-	-	0.0039	0.19	0.1	0.097	0.1	0.0039
alpha-BHC	-	-	-	0.062	9.8	4.9	2.4	2.4	0.062
beta-BHC	-	-	-	0.062	9.8	4.9	2.4	2.4	0.062
delta-BHC	-	-	-	0.062	9.8	4.9	2.4	2.4	0.062
Chlordane	-	-	-	0.0090	0.071	0.04	-	0.04	0.0090
2,4-D	-	-	-	-	-	-	-	5	*0.025*
Dicamba	-	-	-	-	-	-	-	5	*0.01*
4,4'-DDD	40	200	120	0.049	2.4	1.2	0.53	0.53	0.049
4,4'-DDE	40	200	120	0.098	2.4	1.3	0.61	0.61	0.098
4,4'-DDT	40	200	120	0.0082	2.4	1.2	0.53	0.53	0.0082
Dieldrin	50	100	75	0.039	0.48	0.26	-	0.26	0.039
Endosulfan	-	-	-	1.1	5.5	3.3	-	3.3	1.1

TABLE 5-24

SUMMARY OF ECOLOGICAL PRELIMINARY REMEDIATION GOALS FOR NON-PETROLEUM COMPOUNDS IN SOIL

Presidio of San Francisco, California

Potential Chemical of Concern	Summary of Plant and Soil Fauna PRGs (mg/kg); (a)			Summary of Wildlife PRGs (mg/kg); (a)			Proposed Alternate PRGs (mg/kg); (b)	Proposed Buffer Zone PRGs (mg/kg); (c)	Proposed Special Status PRGs (mg/kg); (d)
	PRG_{low}	PRG_{high}	Arithmetic Mean	PRG_{low}	PRG_{high}	Arithmetic Mean			
PCBs, Pesticides, and Herbicides									
Endosulfan Sulfate (j)	-	-	-	1.1	5.5	3.3	-	3.3	1.1
Endrin	-	-	-	0.0035	0.50	0.25	0.11	0.11	*0.004*
Endrin Aldehyde (j)	-	-	-	0.0035	0.50	0.25	0.11	0.11	*0.004*
Endrin Ketone (j)	-	-	-	0.0035	0.50	0.25	0.11	0.11	*0.004*
gamma-BHC (Lindane)	-	-	-	0.010	1.6	0.8	0.37	0.37	0.010
Heptachlor	-	-	-	0.017	7.4	3.7	-	3.7	0.017
Heptachlor Epoxide	-	-	-	0.017	7.4	3.7	-	3.7	0.017
Isodrin (j)	-	-	-	0.0039	0.19	0.1	0.097	0.1	0.0039
MCPP	-	-	-	-	-	-	-	-	*5.0*
Methoxychlor	-	-	-	0.44	35	18	-	18	0.44

Notes:

(a) Listed in these columns are the following: (1) the plant and soil fauna represent the low and high Preliminary Remediation Goals ("PRGs") from Tables 5-12 and 5-13; (2) the wildlife PRG_{low} represents the lowest of the wildlife PRG_{low} from Table 5-12; and (3) the wildlife PRG_{high} represents the lowest of the wildlife PRG_{high} from Table 5-13.

(b) Alternate PRGs for special status species were developed by the Trust for PCOCs which have a large difference (greater than one order of magnitude) between PRG_{low} and PRG_{high}. These values were obtained from Table 5-21.

(c) The buffer zone PRG proposed for protection of non-special status species is the lowest of the arithmetic mean of plant and soil fauna PRGs, the arithmetic mean of wildlife PRGs, the Alternate PRG for special status species, or 5 mg/kg for pesticides or herbicides for which not enough toxicological data exist to calculate a PRG_{low} and PRG_{high} (i.e., 2,4-D, Dicamba, and MCPP).

(d) Values are proposed as soil PRGs for protection of special status species. The special status PRG, as used in this document, is established as the lower value of (1) the PRG_{low} for plant and soil fauna or (2) the PRG_{low} for wildlife, unless the PRG_{low} is less than the laboratory method detection limit. Italics indicates that the laboratory detection limit exceeds the PRG_{low}, and thus the detection limit is selected as the PRG. The laboratory detection limit is also used as the special status PRG for pesticides and herbicides for which not enough toxicological data exist to calculate ecological PRGs.

TABLE 5-24

SUMMARY OF ECOLOGICAL PRELIMINARY REMEDIATION GOALS FOR NON-PETROLEUM COMPOUNDS IN SOIL

Presidio of San Francisco, California

Notes:

(e) Hyphen indicates that PRG could not be calculated due to lack of applicable toxicity data in available literature, or no value is appropriate based on the Trust's assessment of alternate PRGs for special status species.

(f) Ecological PRGs for lead were calculated through use of the Monte Carlo method. Refer to text for discussion of methodology used to derive the ecological PRGs for lead.

(g) Mercury level for special status species is based on risk management concerns and is established at 2 times the typical method detection limit.

(h) For benzyl alcohol, the buffer zone PRG was decreased from the wildlife arithmetic mean PRG to be more in line with the other semivolatile organic compounds.

(i) Toluene was used as a surrogate for isopropyltoluene.

(j) Values for Endosulfan were used for Endosulfan Sulfate, values for Endrin were used for Endrin Aldehyde and Endrin Ketone.
Isodrin is an isomer of Aldrin; values for Aldrin were used for Isodrin.

FIGURES

Source	Transport Mechanism	Potential Exposure Medium	Potential Exposure Pathway	Potential Exposed Ecological Receptors of Terrestrial Habitats: Plants	Soil Invertebrates	Insectivorus Birds	Herbivorous Birds	Omnivorous Mammal	Herbivorous Mammal	Carnivorous Mammal	Carnivorous Birds
Chemicals in Soil	Volatilization or Particulates	Air	Inhalation	Not Complete	Not Complete	Not Significant	Not Significant	Not Significant	Not Significant	Not Significant	Not Significant
			Dermal Contact	Complete	Complete	Complete	Complete	Complete	Complete	Complete	Complete
	Plant Uptake	Plant Tissue	Ingestion	Not Complete	Complete	Not Complete	Complete	Complete	Complete	Not Complete	Not Complete
	Animal Uptake	Animal Tissue	Ingestion	Not Complete	Complete	Complete	Not Complete	Complete	Not Complete	Complete	Complete
			Ingestion	Not Complete	Complete	Complete	Complete	Complete	Complete	Complete	Complete

Legend

Complete	Pathway Complete or Potentially Complete. Pathway Has Been Quantitatively Evaluated.
Not Significant	Pathway Complete or Potentially Complete; Exposure is Not Considered Significant. Pathway Has Not Been Evaluated Quantitatively.
Not Complete	Pathway is Not Considered Complete.

Harding ESE

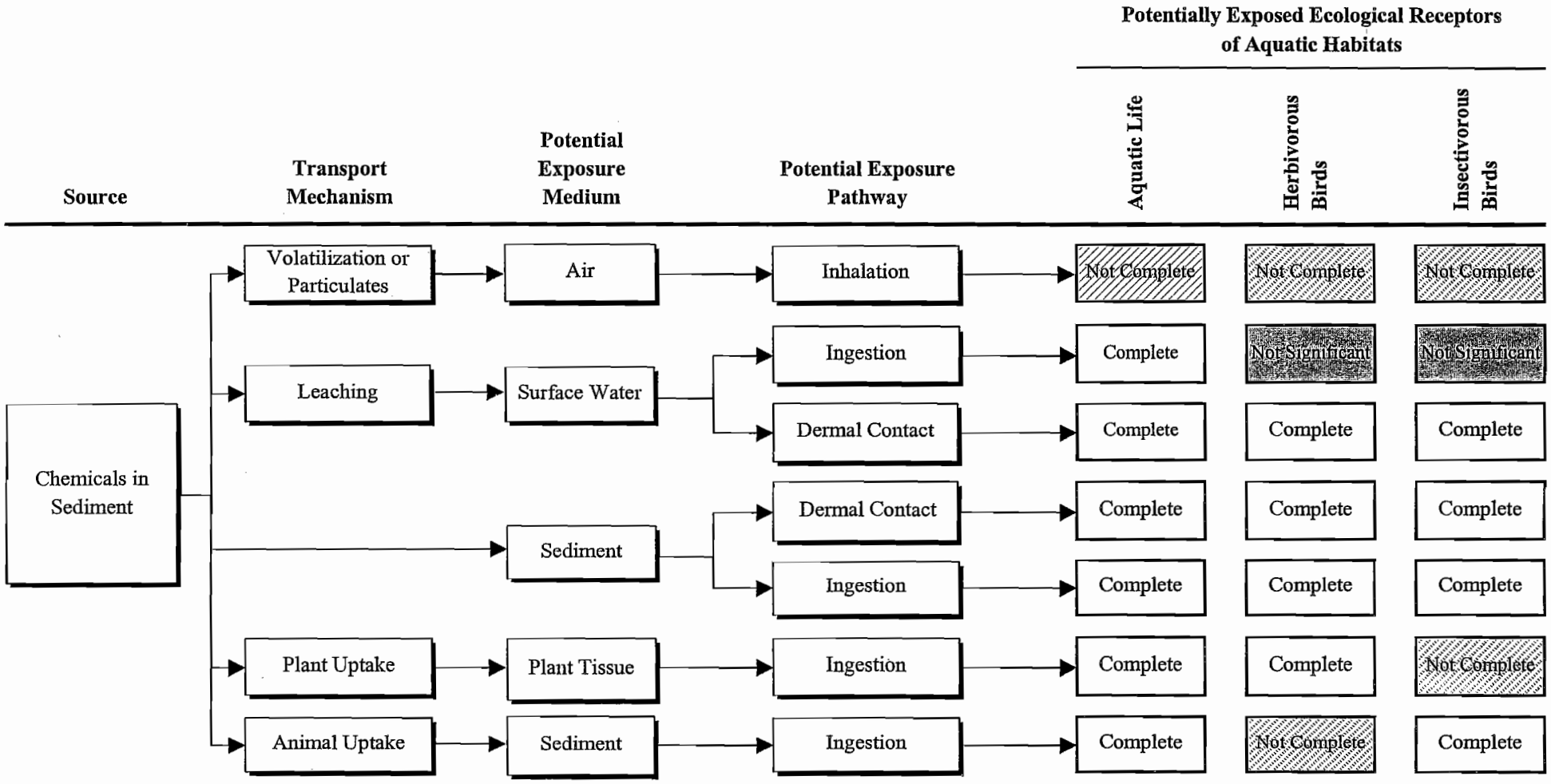
Potential Ecological Chemical Exposure Pathways for Terrestrial Habitats

Presidio of San Francisco, California

Erler & Kalinowski, Inc.

October 2002

Figure 5-1



Legend

Complete — Pathway Complete or Potentially Complete. Pathway Has Been Quantitatively Evaluated.

Not Significant — Pathway Complete or Potentially Complete; Exposure is Not Considered Significant. Pathway Has Not Been Evaluated Quantitatively.

Not Complete — Pathway is Not Considered Complete.

Harding ESE

Potential Ecological Chemical Exposure Pathways for Aquatic Habitats

Presidio of San Francisco, California

Erler & Kalinowski, Inc.

October 2002

Figure 5-2

6. BACKGROUND CONCENTRATIONS OF METALS IN SOIL AND WATER AT THE PRESIDIO

6. BACKGROUND CONCENTRATIONS OF METALS IN SOIL AND WATER AT THE PRESIDIO

Under 22 CCR §66261.24, DTSC lists seventeen metals (i.e., antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, lead, mercury, molybdenum, nickel, selenium, silver, thallium, vanadium, and zinc) that may pose human health and ecological risks if present in waste at sufficiently high concentrations. U.S. EPA (1999b) has established PRGs for these metals in soil and water based upon available toxicological data. However, identification of a release is complicated by the fact that all of these metals are naturally occurring (i.e., at background levels) in soil, sediment, groundwater, and surface water. Background metal concentrations were assessed because it is impractical to remediate releases of metals to less than naturally occurring concentrations. Background concentrations of metals derived in this section have been incorporated into cleanup levels presented in Section 7 to assist in distinguishing between releases of metals at Presidio sites and naturally occurring concentrations of metals in soil and water at the Presidio.

6.1 PRESIDIO GEOLOGY

Studies conducted by the Army (Dames & Moore, 1997b; IT Corporation, 1999; Montgomery Watson, 1999a, 1998a, 1996, 1995; Argonne National Laboratory, 1989) and others (Schlocker, 1974) have identified serpentinite, Colma Formation, and beach/dune sand as the three primary lithologies or soil types at the Presidio. Serpentinite is bedrock unit, part of the Franciscan Formation, whereas the Colma Formation and the beach/dune sands are unconsolidated sediments deposited on top of bedrock. These three primary units were distinguished in borehole logging performed by the Army and considered as distinct geochemically in its assessment of background metals. Based upon mapping performed by the USGS (Schloker, 1974), the generalized surface distribution of serpentinite, Colma Formation, and beach/dune sand is shown on Figure 6-1. This figure is a geological map; each contact has not been field verified at each site. Actual field observations at a particular site will be used to determine site-specific lithology.

Five other secondary geologic units occur at the Presidio in sufficient volumes to be discernible on the 1:24,000-scale USGS geologic map (Schloker, 1974). These units consist of four Franciscan Formation bedrock units (which were not distinguished by the Army in borehole logs nor in the background metals assessment) and Artificial Fill. In detail, the bedrock units are Sheared Rock, Jurassic/Cretaceous Sedimentary Rocks, Greenstone, and Chert/Shale. The Sheared Rock unit is a mixed bedrock unit. It is made up of a soft, highly sheared, clayey matrix of serpentinite, shale, or both, in which occur coherent blocks of Jurassic/Cretaceous Sedimentary Rock and serpentinite. The Jurassic/Cretaceous Sedimentary Rocks is a bedrock unit that is made up of interbedded sandstones, shales, and occasional conglomerates. Greenstone is a bedrock unit made up of dark green meta-basalt that occurs interbedded with the Jurassic/Cretaceous

Sedimentary Rocks and the Chert/Shale. Chert/Shale is a bedrock unit made up of alternating beds of hard, red-brown chert and softer, red-brown shale. It occurs interbedded with greenstone and Jurassic/Cretaceous Sedimentary Rocks. At the Presidio, both Greenstone and Chert/Shale are exposed in minor outcrops only along the Coastal Bluffs. Artificial Fill is an all-inclusive term for unconsolidated material artificially placed for engineering purposes. It includes material probably excavated from local sources at the Presidio as well as material brought in from Fort Baker/Marin Peninsula or dredged from San Francisco Bay.

Although these soil types can be found separately at the Presidio, they are often commingled due to natural events or human activity. As shown on Figure 6-1, landslide deposits and soil reside as fill in ravines at the Fort Scott, Presidio Hill, and Presidio Forest planning areas. These deposits are likely to be derived from any of the three soil types, individually or mixed together. Dames & Moore (1997b) indicates that the landslide deposits and soil in these ravines are generally thin, but may be as thick as 150 feet at some locations. In addition, Artificial Fill is common at the Presidio and may include any or all of the Presidio rock and soil types as well as material brought in from off-site.

The main significance of the secondary geologic units is that, with the exception of Chert/Shale, they have not been characterized geochemically in terms of background metals. Hence, if encountered during remedial activities, these units may have background metals "signatures" that differ from the primary soil types and therefore, can be confused with contamination. For example, Greenstone will typically show higher background levels of chromium, nickel, copper, and vanadium than many other rocks or soils.

The characteristics of the three primary soil types, serpentinite, Colma Formation, and beach/dune sand, are discussed further in Sections 6.1.1 through 6.1.3. Chert/Shale, which have been used as fill and base rock at Crissy Field and other locations at the Presidio, is discussed in Section 6.1.4 because this material is also likely to be encountered during implementation of remedial actions. Greenstone is discussed in Section 6.1.5 because it seems to be present in some fill and, therefore, may be encountered during remedial actions. The actual site-specific lithology will be determined in the field through sampling.

6.1.1 Serpentinite

Serpentinite is an ultramafic rock (i.e., a rock composed mostly of magnesium and iron minerals) that is associated with the Franciscan Formation at the Presidio. It is made up of varying proportions of the three magnesium silicate serpentine minerals, antigorite, chrysotile (a form of asbestos), and lizardite. Serpentinite intrusives and coherent blocks of hard rock in a matrix of intensely sheared shale and serpentinite comprise the outcrops or exposed bedrock observed in the remainder of the Presidio (Schlocker, 1974). Serpentinite is a distinctive greenish gray to bluish gray crumbly rock that tends to form

poorly developed soils with a wide range of grain sizes. It is geochemically distinctive in that it typically contains high concentrations of chromium, nickel, and cobalt.

6.1.2 Colma Formation

The Colma Formation overlies bedrock in the south and southeast portions of the Presidio. The Colma Formation consists of unconsolidated fine to medium sand with moderate amounts of silt and clay. Dames & Moore (1997b) notes that these unconsolidated deposits are generally yellow to reddish brown, but can be gray to black at some locations. Schlocker (1974) reports that the Colma Formation may range in thickness from 75 to 300 feet. The Colma Formation overlies Franciscan Formation lithologies (e.g., serpentinite, Jurassic/Cretaceous Sedimentary Rocks, etc.) and may in turn be covered by geologically younger beach/dune sand. In terms of background metals, the Colma Formation is geochemically very similar to the beach/dune sand.

6.1.3 Beach/Dune Sand

Beach and dune sand comprises the bulk of the exposed deposits in the southwest portion, and along the ocean and bay fronts of the Presidio. These deposits are highly permeable, clean, well-sorted sand that are yellowish brown to light gray in color. Schlocker (1974) reports that the thickness of beach/dune sand deposits are typically on the order of 100 feet. Beach and dune sand overlie the Franciscan and Colma Formations. In terms of background metals, beach/dune sand is very similar to the Colma Formation.

6.1.4 Chert/Shale

Investigations and remedial actions conducted at Crissy Field find that reddish brown chert and shale have been placed as fill in the upper 2 feet of ground throughout much of this area. Chert/shale has also been used as fill and base rock at other areas of the Presidio. As noted by Schlocker (1974), only minor outcrops of chert are present at the Presidio, and only in the relatively inaccessible Coastal Bluffs planning area. Based upon a study conducted for the Army, IT Corporation believes that the chert/shale found at Crissy Field was imported to the Presidio. IT Corporation (1999) states:

> Although the specific source is presently unknown, it is possible that the quickest, easiest and cheapest source was the Marin Peninsula chert, barged in as fill probably for the 1915 Panama-Pacific International Exposition. The similarities between the Presidio chert and shale and the southern Marin Peninsula chert and shale...would tend to support this possibility.

Chert/shale is a dark reddish brown rock with regularly alternating layers of chert and shale. Individual layers of chert and shale observed in outcrops generally vary from a fraction of an inch to several inches thick. These thin layers or bands cause the two rock types to become intimately mixed together when imported and placed as fill. The reddish

brown shale associated with the chert is a distinctly different lithology from the gray-green sheared shale sometimes associated with serpentinite.

6.1.5 Greenstone

Greenstone is a dark greenish gray to gray olive colored basaltic rock found associated with chert/shale and/or Jurassic/Cretaceous sedimentary rocks of the Franciscan Formation. When it occurs as a submarine pillow lava, greenstone can develop curving, slickensided surfaces that resemble serpentinite. It appears to be present in fill at Graded Area 9 and the Transfer Station sites where it has been erroneously logged as serpentinite. The locations of these sites are shown on Figure 2-2. Greenstone is not specifically mapped on Figure 6-1. Greenstone is geochemically similar to serpentinite in that it naturally contains higher concentrations of chromium and nickel than other geologic units at the Presidio. Greenstone is geochemically distinctive relative to serpentinite in that the concentrations of nickel and chromium are in the hundreds of mg/kg instead of thousands of mg/kg and greenstone typically contains several hundred mg/kg vanadium. Schloker (1974) reports greenstone analyses from the northern San Francisco Quadrangle that range from 15 to 300 mg/kg chromium, 150 to 300 mg/kg nickel, and 150 to 300 mg/kg vanadium.

6.2 APPROACH TO DEVELOPING BACKGROUND METALS CONCENTRATIONS IN SOIL

Evaluation of background metals in soil included development of a DTSC-approved approach to evaluate background metals concentrations, evaluation of the existing soil metal data set, determining screening levels of metals in soil, and determining threshold levels of metals in soil. These topics are discussed in Sections 6.2.1 through 6.2.4.

6.2.1 Regulatory Guidelines

During preparation of the Revised Final Feasibility Study for Main Installation Sites, the Trust received feedback from the DTSC regarding the approach for evaluating background metals at the Presidio. The DTSC expressed an interest in promoting consistency among base closure sites throughout California. The principal features of the background metals evaluation approach were as follows:

- The probability of "false negatives", i.e., erroneously concluding that significant contamination is not present when it actually is present, should be made as small as possible.

- Evaluating background metals concentrations at the Presidio should be a two-tiered statistical process involving definition of "screening" levels and "threshold" levels. Screening levels are used to determine PCOCs and threshold levels are used to define COCs.

- Only site-specific background data should be used to determine both screening levels and threshold levels (i.e., regional data would not be appropriate to establish background concentrations).

- For a given metal, there should be separate screening and threshold levels for each of the primary soil types encountered at the Presidio.

- In order to make valid estimates of screening and threshold metals levels, a minimum statistical mass must be present, i.e., there should be at least 20 background samples for each soil type.

- When there are insufficient background samples, i.e., samples specifically collected to be representative of background conditions, selected site sample data may be used to supplement the background data set if the DTSC and other stakeholders concur that the supplemental data represent background.

6.2.2 Background Metals Data Set

The Army compiled limited background soil data as part of its RI (Dames & Moore, 1997b) and subsequent studies (IT Corporation, 1999, Montgomery Watson, 1999a). The U.S. EPA's National Enforcement Investigations Center ("NEIC") (1997b) has also analyzed background soil samples collected at the Presidio. The aggregate suite of background samples included 16 beach/dune sand, 11 Colma Formation, 10 serpentinite, and 49 Chert/Shale samples. These data sets are presented in Appendix C.

According to the DTSC guidelines discussed above, three of the four soil types were not represented by a sufficient number of samples to reasonably estimate background screening or threshold levels. In order to avoid the considerable expense and schedule delay involved in collecting additional samples as part of a supplemental background metals study, the DTSC agreed to the inclusion of selected site data in the background data set. The selection of these additional data is described below.

The Trust searched the RI database provided by the Army/Montgomery Watson and retrieved soil samples classified as beach/dune, Colma Formation, or serpentinite. The retrieved data were then progressively screened according to the following scheme:

- Samples that were grossly misclassified were excluded, e.g., Colma or beach/dune samples with high levels of chromium, nickel, and cobalt.

- Samples with obvious contamination were excluded.

- Samples with suspect analyses or laboratory quality assurance/quality control ("QA/QC") problems were excluded.

- Site samples collected from the surface to 0.5 feet below ground surface ("bgs") were excluded because of the potential for general surface contamination and difficulty in accurately classifying topsoil.

- Samples from landfill sites were excluded unless they were collected at least 2 feet below the bottom of the fill.

- Samples collected from sites with known metals contamination were excluded if the samples were collected from 2 feet bgs or less.

- All Fill Site 7 data were excluded due to the presence of hydraulically placed fill.

- All RI samples from the Building 900's and 600's Series sites were excluded due to possible metals contamination and the presence of mixed soil types (e.g., serpentinite fragments in beach/dune material).

Because of the paucity of serpentinite samples, two small sets of data were added to the serpentinite background data set. One set consisted of five soil samples reported by Montgomery Watson in their *Fuel Product Action Level Development Report* ("FPALDR") (1995) that were unclassified as to soil type but which appeared to be serpentinite on the basis of their chromium and nickel concentrations. The second set consisted of three serpentinite bedrock samples collected by Montgomery Watson during the 1998 excavation for petroleum-impacted soil at the Presidio Golf Course clubhouse and reported in their *Hexavalent Chromium in Serpentinite Bedrock and Groundwater in Upland Areas* study (1999a).

The resulting sets of site-derived background data were combined with the RI background data sets into revised background data sets by soil type. The revised background data sets were then evaluated in a joint meeting of the Trust, DTSC, and other stakeholders. The primary evaluation tool used to check the revised background data sets was the bivariate scatterplot (e.g., Figures 6-2 and 6-3) which showed the relationships between metals that are potential contaminants and major elements which are not considered potential contaminants (e.g., iron, aluminum, magnesium, and manganese). Data that were clearly "outliers" from the main mass or trend of data were eliminated, e.g., a single high barium result shown in Figure 6-2 or the cluster of anomalous cobalt data shown in Figure 6-3. The full set of background metals scatterplots is reported in a Technical Memorandum (EKI, 2001).

The outcome of this process was revised background data sets (shown in Tables C–1 through C–4 in Appendix C) that were agreed to by the stakeholders and which contained sufficient samples for statistically estimating background screening and threshold levels.

6.2.3 Determining Metals Screening (PCOC) Levels

According to the DTSC, the main reason for establishing "screening" levels for metals is to build in an evaluation step that would help prevent "false negatives", i.e., situations

wherein it is concluded that no contamination is present when, in fact, it is present. Phrased another way, the screening level step is meant to answer the question, "Are we at the edge of a plume or release?"

The means for accomplishing this goal was to set the screening level very conservatively in a statistical sense, i.e., at the 95% upper confidence level of 80th percentile of the data distribution[8]. The meaning of this terminology is shown graphically on Figure 6-4. The generic metal concentrations presented on Figure 6-4 are shown with a logarithmic scale because the background metals data are best described by logarithmic distributions. A specific screening level example, i.e., chromium in beach/dune sand, is shown on Figure 6-5.

The 80th percentile method for defining the screening level could not be meaningfully applied in those situations wherein 50% or more of the results for a particular metal were below detection limits, e.g., antimony. For these instances, the screening level was defined as the most commonly encountered detection limit.

The process of defining screening levels summarized above was followed and the results discussed in a meeting of the Trust, DTSC, and other stakeholders. The consensus screening levels agreed to by the stakeholders are summarized for serpentinite, Colma Formation, beach/dune, and chert/shale in Tables 6-1 through 6-4, respectively.

The screening levels presented in Tables 6-1 through 6-4 are used to identify which metals at a given site are PCOCs. In other words, if a metal concentration exceeds the screening level for the soil type at the site, then that metal is retained as a PCOC.

6.2.4 Determining Metals Threshold (COC) Levels

The objective of threshold levels evaluation is to define concentration levels (by metal and soil type) above which soil sample metals results would reasonably be considered indicative of contamination and therefore retained as a chemical of concern for the selected site.

As with the screening levels, the threshold levels were defined statistically. The threshold level for a particular metal and soil type was usually defined as the 95% upper confidence limit of the 95th percentile of the data distribution[9]. The meaning of this terminology is shown graphically on Figure 6-4, and an example showing the threshold level for chromium in beach/dune soil is shown on Figure 6-6.

As with the screening levels, threshold levels could not be derived statistically when there were 50% or more results below detection limits. In these instances, the threshold level

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[8] Because of the small number of samples in the background metals data set, the DTSC and the Trust agreed to define the screening and threshold levels for serpentinite soils as the 80th and the 95th percentiles, respectively, of the data distributions (rather than the 95% upper confidence limit of those percentiles).

[9] Because of the small number of samples in the background metals data set, the DTSC and the Trust agreed to define the screening and threshold levels for serpentinite soils as the 80th and the 95th percentiles, respectively, of the data distributions (rather than the 95% upper confidence limit of those percentiles).

was defined as the greater of either the maximum concentration detected or the most common detection limit[10]. Background threshold levels derived as described above were reviewed in a meeting of the Trust, DTSC, and other stakeholders. The consensus threshold levels agreed to by the stakeholders are summarized for serpentinite, Colma Formation, beach/dune, and chert/shale in Tables 6-1 through 6-4, respectively.

The threshold levels presented in Tables 6-1 through 6-4 and summarized in Table 6-5 represent the Trust's best estimate of background metals concentrations based on available data. Additional data collected during Presidio remedial activities may indicate the need to modify these estimates. Furthermore, these threshold levels are not cleanup levels; rather, the threshold should be compared to cleanup levels to determine if a specific cleanup level should be established as the background threshold. In particular, if the PRG is less than the background, the cleanup level is established as the background threshold because it is not practical or possible to clean up to concentrations below background.

6.2.5 Summary of Background Threshold Data

Table 6-5 summarizes the background threshold levels by metal and the soil type at each site. The soil type will be determined in the field based on lithologic logs. In addition, the derivation of each threshold is indicated, i.e., 95% UCL, maximum detection, or common detection limit. To provide a larger frame of reference, background metals data from regional sources are summarized in Table 6–6.

6.3 PRESIDIO HYDROGEOLOGY

The Army evaluated the hydrogeology of the Presidio in detail as part of preparation of the FPALDR (Montgomery Watson, 1995). Three groundwater basins that are hydraulically isolated from each other by the bedrock topography have been identified. As shown on Figure 6-7, these groundwater basins consist of the Lobos Creek, Coastal Bluffs, and Marina Groundwater Basins. The shallow depths to bedrock in the entire Coastal Bluffs Groundwater Basin, and in portions of the Lobos Creek and Marina Groundwater Basins indicate that significant amounts of groundwater are not present in these areas and their use as potable supply is limited. Further, the Crissy Field Groundwater Area in the Marina Groundwater Basin (Figure 6-7) is tidally influenced. Saltwater intrusion restricts groundwater use in this area.

Groundwater with the highest likelihood of being developed as potable supply is found in portions of the Presidio where thick sand deposits enhance the infiltration and storage of water in the subsurface. The Army identified three locations where groundwater may be a significant resource. These areas consist of the Lobos Creek Groundwater Area in the

[10] The "common detection limit" is the reporting limit typically achieved by analytical laboratories that have analyzed soil samples at the Presidio. These common detection limits were identified in a series of meetings with the Trust, DTSC, and other stakeholders.

Lobos Creek Groundwater Basin, and the West Valley and Northeastern Groundwater Areas in the Marina Groundwater Basin, as shown on Figure 6-7.

6.4 BACKGROUND CONCENTRATIONS OF METALS IN SURFACE WATER, SEEPS, AND GROUNDWATER

Low concentrations of metals in surface water, seeps, and groundwater have been identified as PCOCs at several Presidio sites where such samples have been collected. The occurrence of these metals in the majority of surface water, seep, and groundwater monitoring well samples are likely to be naturally occurring. However, except for chromium, background water quality has not been sufficiently characterized to confirm that the metals are naturally occurring. U.S. EPA (1997b, 1997f) and the Army (Montgomery Watson, 1999a, 1998b) conducted studies of chromium in bedrock, and dissolved and hexavalent chromium in surface water and groundwater. The results of these studies indicate that dissolved chromium is widespread at low concentrations in surface water and groundwater throughout the Presidio. This occurrence is suggestive of natural, rather than anthropogenic sources of chromium.

6.4.1 Hypothesis that Serpentinite is a Natural Source of Chromium in Water

Chromium exists in two valence states or forms. One form is trivalent chromium, which can also be expressed as Cr(III), and the other form is hexavalent chromium, which can also be expressed as Cr(VI). Under ambient conditions, such as those found at the Presidio, trivalent chromium is insoluble and not detected in water, but present in soil as a precipitate or solid. In contrast, hexavalent chromium is soluble and found dissolved in water under ambient conditions. The solubility and toxicological properties of hexavalent chromium are the reasons that this form of chromium is of greater environmental concern than trivalent chromium.

Dissolved chromium is a very good surrogate for hexavalent chromium because of the differing solubility of trivalent and hexavalent chromium in water. As such, dissolved chromium can be assumed to be hexavalent chromium. Seep and groundwater monitoring well locations from which water samples were collected and analyzed for dissolved chromium are shown on Figure 6-8.

High, naturally occurring concentrations of chromium are associated with serpentinite (Kreckeberg, 1984). As shown in Table 6-1, the background threshold concentration of chromium in serpentinite has been determined to be 1,700 mg/kg. In comparison, the naturally occurring or background threshold chromium concentration in the Colma Formation and beach/dune sand at the Presidio has been determined to be 140 mg/kg and 120 mg/kg, respectively (Tables 6-2 and 6-3). Given that serpentinite is a natural source of chromium, it has been hypothesized that dissolved chromium (i.e., hexavalent chromium) measured in seeps and groundwater at the Presidio is due to the presence of chromium in serpentinite. The Army performed studies to confirm this hypothesis. Representatives of U.S. EPA, DTSC, San Francisco State University, NPS, Presidio

Trust, and community members of the RAB provided significant input to the development of the studies. Montgomery Watson, on behalf of the Army, conducted these studies in 1998 and 1999 (1999a).

6.4.2 Evidence that Serpentinite is a Natural Source of Chromium in Water

As discussed in Sections 6.4.2.1 through 6.4.2.4, the results of the Army's studies support the hypothesis that chromium measured in groundwater is naturally occurring. Results of these studies are included in Appendix D.

6.4.2.1 Background Groundwater Geochemistry

Five monitoring wells were constructed in upland locations considered representative of background conditions (Montgomery Watson, 1999a). Locations of these wells were selected with input from the agencies and organizations that collaborated on development of the Army's studies. The wells, UBR01GW01, UBR02GW01, UBR02GW02, UBR03GW01, and UBR03GW02 (Figure 6-8), were constructed in locations that are up gradient of the direction of groundwater flow from potential anthropogenic sources of chromium. Groundwater samples collected from the three wells screened within the serpentinite contained dissolved or hexavalent chromium ranging from 25 to 100 μg/L (Appendix D). The groundwater conditions in these wells were alkaline (with measured pH values ranging from 8.3 to 9.1) and oxidizing (with measured Eh values ranging from 308 to 423 mV). These conditions are favorable for producing stable concentrations of hexavalent chromium in upland groundwater created by leaching and/or interaction of groundwater with serpentinite bedrock.

6.4.2.2 Serpentinite Geochemistry

Samples of serpentinite bedrock collected during monitoring well construction in upland locations were analyzed for hexavalent chromium (Montgomery Watson, 1999a). Hexavalent chromium was detected in these samples at concentrations ranging from 0.064 mg/kg to 0.602 mg/kg. In addition, the aqueous extracts of serpentinite bedrock were moderately alkaline (with measured pH values ranging from 8 to 8.5) and oxidizing (with measured Eh values ranging from 421 to 454 mV) (Appendix D). These conditions are favorable for leaching and/or creating hexavalent chromium from serpentinite through interaction with infiltrating surface water or contact with groundwater.

6.4.2.3 Leaching Test Results

Serpentinite samples collected during monitoring well construction in upland locations were subjected to leaching tests to evaluate whether hexavalent chromium could be leached from bedrock under different conditions (Montgomery Watson, 1999a). Hexavalent chromium was measured in leachate from the serpentinite samples (Appendix D).

6.4.2.4 Occurrence of Dissolved Chromium in Groundwater Throughout the Presidio

The occurrence and distribution of hexavalent chromium in groundwater at the Presidio appears to result from the fact that hexavalent chromium is present in serpentinite bedrock at the Presidio and/or can be created from serpentinite through interaction with infiltrating surface water or contact with groundwater. Hexavalent chromium can be leached and/or generated from serpentinite by various complex reactions because the geochemical conditions, including pH and Eh, are favorable for producing stable concentrations of hexavalent chromium in surface water and groundwater. Conversion of dissolved hexavalent chromium to insoluble trivalent chromium likely occurs in areas where geochemical conditions are reducing in nature, either from naturally occurring organic matter (e.g., bay muds at Crissy Field) or anthropogenic organic matter (e.g., petroleum hydrocarbons at Nike Facility). Thus, the presence of serpentinite and oxidizing conditions, and the lack of organic matter, produce conditions whereby hexavalent chromium is stable in groundwater.

Chromium has been measured in groundwater samples, and in some cases, seep samples collected from Building 215, Fill Site 6, Battery Howe/Wagner, Landfill 8, Landfill 10, Landfill E, Fill Site 1, Nike Facility, Landfill 2, Landfill 4 and Fill Site 5 (Table 6-7 and Figure 6-8). In addition, chromium has been detected in groundwater samples collected from other areas of the Presidio, including background locations (UBR monitoring wells) and wells constructed in the Tennessee Hollow, which are situated a significant distant from known chemical release sites. Serpentinite has been observed in at least one monitoring well at each of these sites or areas with the exceptions of Building 215, Fill Site 6, and Landfill 4.

6.4.3 Further Assessment Required to Confirm Other Metals in Water are Naturally Occurring

Based upon the Army's study results, hexavalent chromium in groundwater in upland areas of the Presidio appears to be naturally occurring. In its letter, dated 13 July 2000, DTSC agreed that hexavalent chromium is naturally occurring in areas where groundwater contacts serpentinite. DTSC (2000c) has stated that further assessment of the occurrence of hexavalent chromium is required for areas where serpentinite is not present or is not directly down gradient from the flow of groundwater through serpentinite. DTSC is interested in understanding the background concentrations of chromium in water that result from contact with other soil types, and whether these background chromium concentrations would be expected to be higher than potential cleanup levels, as is the case of chromium concentrations in water that contacts serpentinite.

The findings of investigations and studies conducted by the Army clearly indicate that hexavalent chromium is naturally occurring in surface water and groundwater at Battery Howe/Wagner, Landfill 8, Landfill 10, Landfill E, Fill Site 1, Nike Facility, Landfill 2, and Fill Site 5. Hexavalent chromium in groundwater at the Building 215 Area and Fill Site 6 is also likely to be naturally occurring but further assessment is required due to the

proximity of these areas to Crissy Field. It is probable that groundwater containing hexavalent chromium has migrated through upland serpentinite to the Building 215 Area and Fill Site 6. The Colma and Beach/Dune Formations beneath Fill Site 6 and Building 215 consist largely of sands and other material generally poor in naturally occurring organic material. With the exception of releases of petroleum hydrocarbons at the nearby Building 1065 and Building 1027 Areas, there are no reducing agents in the saturated zone beneath Fill Site 6 and Building 215. Consequently, hexavalent chromium formed at upland locations and transported in groundwater to Fill Site 6 and Building 215 is chemically stable. No sources of hexavalent chromium have been identified at these areas and the chromium concentrations are consistent with this type of transport mechanism.

Similar to hexavalent chromium, low concentrations of other metals, such as barium, cadmium, copper, lead, mercury, nickel, selenium, and zinc, are detected in surface water, seep, and groundwater samples collected at Presidio sites. The low concentrations at which these metals are detected and their distribution in surface water, seeps, and groundwater throughout the Presidio suggest that these metals are also naturally occurring. However, this finding cannot be confirmed based upon available data. Analytical results of background metal concentrations in surface water and groundwater have not been obtained for all Presidio sites. It may be appropriate to collect additional data in the vicinity of sites where metals have been identified as COCs in water to demonstrate that the metals are naturally occurring and do not derive from historic chemical releases.

TABLES

TABLE 6-1
SUMMARY OF BACKGROUND DATA, SCREENING LEVELS, AND THRESHOLD LEVELS -- SERPENTINITE SOIL (a)

Presidio of San Francisco, California

Metal	Background Data Summary			Screening Level (mg/kg)				Threshold Level (mg/kg)				
	Number of Detections	Total Samples	Maximum Detected (mg/kg)	Detection Limit	80th Percentile	95% UCL of 80th Percentile	Trust Screening Level	Detection Limit	Maximum Detected	95th Percentile	95% UCL of 95th Percentile	Trust Threshold Level
Antimony	0	8	NM (b)	3.0	-- (d)	--	3.0	3.0	NA	--	--	3.0
Arsenic	8	12	4.1	NA (c)	2.5	4.7	2.5	NA	NA	5.4	12	5.4
Barium	15	16	149	NA	100	180	100	NA	NA	230	510	230
Beryllium	6	14	1.1	0.50	--	--	0.50	0.50	1.1	--	--	1.1
Cadmium	4	12	1.9	0.80	--	--	0.80	0.80	1.9	--	--	1.9
Chromium	22	22	1700 (e)	NA	1,300	1,500	1,300	NA	NA	1,700	2,200	1,700
Cobalt	18	18	165	NA	140	160	140	NA	NA	170	200	170
Copper	22	22	65	NA	48	68	18	NA	NA	85	140	85
Lead	11	15	77	NA	21	49	21	NA	NA	66	200	66
Mercury	2	9	0.069	0.20	--	--	0.20	0.20	0.069	--	--	0.20
Molybdenum	0	4	NM	2.0	--	--	2.0	2.0	NA	--	--	2.0
Nickel	22	22	4,300	NA	3,100	3,900	3,100	NA	NA	4,500	6,100	4,500
Selenium	0	7	NM	0.5	--	--	0.5	0.5	NA	--	--	0.5
Silver	1	10	1.7	1.0	--	--	1.0	1.0	1.7	--	--	1.7
Thallium	4	8	0.077	1.0	--	--	1.0	1.0	0.077	--	--	1.0
Vanadium	22	22	84	NA	51	64	51	NA	NA	74	100	74
Zinc	22	22	140	NA	86	120	86	NA	NA	160	250	160

Notes:

(a) Column headings have the following meanings:

Detection Limit: A typical detection limit is included when there were insufficient data to calculate an 80th percentile or a 95th percentile (e.g., no detections or fewer than 50% detections).

80th Percentile: The concentration corresponding to the 80th percentile of the lognormal data distribution calculated for data sets with a frequency of detection greater than 50%. Because of the small number of samples in the background data set, DTSC and the Trust agreed to use the 80th percentile to establish screening levels for serpentinite soils.

95% UCL of 80th Percentile: The concentration corresponding to the 95% upper confidence level ("UCL") of the 80th percentile of the lognormal data distribution.

Trust Screening Level: Screening level for classification of corresponding metal as a potential chemical of concern.

Maximum: Maximum concentration detected in background samples of this lithology (threshold level when there are fewer than 50% detections).

95th Percentile: The concentration corresponding to the 95th percentile of the lognormal data distribution calculated for data sets with a frequency of detection greater than 50%. Because of the small number of samples in the background data set, DTSC and the Trust agreed to use the 95th percentile to establish threshold levels for serpentinite soils.

95% UCL of 95th Percentile: The concentration corresponding to the 95% UCL of the 95th percentile of the lognormal data distribution.

Trust Threshold Level: Threshold level for classification of corresponding metal as a chemical of concern.

(b) NM means not measured; there were no data above applicable laboratory reporting limits.

(c) NA means not applicable; there were sufficient data to estimate a data distribution so the detection limit or maximum detected concentration are not screening or threshold levels.

(d) A double hyphen ("--") indicates that there were insufficient data above laboratory reporting limits to estimate a data distribution.

(e) Hexavalent chromium has been measured in serpentinite at the Presidio at concentrations ranging from 0.064 to 0.602 mg/kg (Montgomery Watson, 1999a).

TABLE 6-2
SUMMARY OF BACKGROUND DATA, SCREENING LEVELS, AND THRESHOLD LEVELS -- COLMA FORMATION SOIL (a)

Presidio of San Francisco, California

	Background Data Summary			Screening Level (mg/kg)				Threshold Level (mg/kg)				
Metal	Number of Detections	Total Samples	Maximum Detected (mg/kg)	Detection Limit	80th Percentile	95% UCL of 80th Percentile	Trust Screening Level	Detection Limit	Maximum Detected	95th Percentile	95% UCL of 95th Percentile	Trust Threshold Level
Antimony	0	8	NM (b)	3.0	-- (d)	--	3.0	3.0	NA	--	--	3.0
Arsenic	13	20	5.0	NA (c)	3.1	3.9	3.9	NA	NA	4.5	6.2	6.2
Barium	36	36	180	NA	77	99	99	NA	NA	130	180	180
Beryllium	17	32	0.68	NA	0.33	0.46	0.46	NA	NA	0.64	0.99	0.99
Cadmium	5	28	0.49	0.80	--	--	0.80	0.80	0.49	--	--	0.80
Chromium	36	36	150	NA	81	95	95	NA	NA	110	140	140
Cobalt	36	36	19	NA	14	16	16	NA	NA	18	21	21
Copper	36	36	81	NA	18	24	24	NA	NA	33	49	49
Lead	32	35	8.2	NA	4.5	5.2	5.2	NA	NA	6.1	7.5	7.5
Mercury	3	19	0.12	0.20	--	--	0.20	0.20	0.12	--	--	0.20
Molybdenum	0	0	NM	2.0	--	--	2.0	2.0	NA	--	--	2.0
Nickel	35	35	120	NA	72	83	83	NA	NA	96	110	110
Selenium	2	12	0.46	0.5	--	--	0.5	0.50	0.46	--	--	0.50
Silver	0	12	NM	1.0	--	--	1.0	1.0	NA	--	--	1.0
Thallium	0	6	NM	1.0	--	--	1.0	1.0	NA	--	--	1.0
Vanadium	35	35	85	NA	53	62	62	NA	NA	73	90	90
Zinc	36	36	62	NA	38	43	43	NA	NA	50	60	60

Notes:

(a) Column headings have the following meanings:

Detection Limit: A typical detection limit is included when there were insufficient data to calculate an 80th percentile or a 95th percentile (e.g., no detections or fewer than 50% detections).

80th Percentile: The concentration corresponding to the 80th percentile of the lognormal data distribution calculated for data sets with a frequency of detection greater than 50%.

95% UCL of 80th Percentile: The concentration corresponding to the 95% upper confidence level ("UCL") of the 80th percentile of the lognormal data distribution.

Trust Screening Level: Screening level for classification of corresponding metal as a potential chemical of concern.

Maximum: Maximum concentration detected in background samples of this lithology (threshold level when there are fewer than 50% detections).

95th Percentile: The concentration corresponding to the 95th percentile of the lognormal data distribution calculated for data sets with a frequency of detection greater than 50%.

95% UCL of 95th Percentile: The concentration corresponding to the 95% UCL of the 95th percentile of the lognormal data distribution.

Trust Threshold Level: Threshold level for classification of corresponding metal as a chemical of concern.

(b) NM means not measured; there were no data above applicable laboratory reporting limits.

(c) NA means not applicable; there were sufficient data to estimate a data distribution so the detection limit or maximum detected concentration are not screening or threshold levels.

(d) A double hyphen ("--") indicates that there were insufficient data above laboratory reporting limits to estimate a data distribution.

TABLE 6-3

SUMMARY OF BACKGROUND DATA, SCREENING LEVELS, AND THRESHOLD LEVELS -- BEACH/DUNE SOIL (a)

Presidio of San Francisco, California

	Background Data Summary			Screening Level (mg/kg)				Threshold Level (mg/kg)				
Metal	Number of Detections	Total Samples	Maximum Detected (mg/kg)	Detection Limit	80th Percentile	95% UCL of 80th Percentile	Trust Proposed Screening Level	Detection Limit	Maximum Detected	95th Percentile	95% UCL of 95th Percentile	Trust Proposed Threshold Level
Antimony	0	11	NM (b)	3.0	-- (d)	--	3.0	3.0	NA	--	--	3.0
Arsenic	55	69	6.0	NA (c)	3.4	3.9	3.9	NA	NA	5	5.9	5.9
Barium	63	70	250	NA	43	54	54	NA	NA	87	120	120
Beryllium	37	56	1.3	NA	0.44	0.52	0.52	NA	NA	0.70	0.89	0.89
Cadmium	3	32	1.7	0.80	--	--	0.80	0.80	1.7	--	--	1.7
Chromium	75	75	140	NA	72	81	81	NA	NA	100	120	120
Cobalt	62	71	24	NA	10	11	11	NA	NA	14	16	16
Copper	61	70	57	NA	17	21	21	NA	NA	33	43	43
Lead	66	83	89	NA	16	21	21	NA	NA	39	57	57
Mercury	11	65	0.65 (e)	0.20	--	--	0.20	0.20	0.11	--	--	0.20
Molybdenum	0	1	NM	2.0	--	--	2.0	2.0	NA	--	--	2.0
Nickel	70	70	83	NA	43	48	48	NA	NA	60	70	70
Selenium	5	31	4.3 (e)	0.5	--	--	0.5	0.50	0.75	--	--	0.75
Silver	5	39	0.86	1.0	--	--	1.0	1.0	0.86	--	--	1.0
Thallium	1	19	0.37	1.0	--	--	1.0	1.0	0.37	--	--	1.0
Vanadium	71	71	100	NA	52	59	59	NA	NA	77	92	92
Zinc	61	69	93	NA	37	42	42	NA	NA	55	66	66

Notes:

(a) Column headings have the following meanings:

Detection Limit: A typical detection limit is included when there were insufficient data to calculate an 80th percentile or a 95th percentile (e.g., no detections or fewer than 50% detections).

80th Percentile: The concentration corresponding to the 80th percentile of the lognormal data distribution calculated for data sets with a frequency of detection greater than 50%.

95% UCL of 80th Percentile: The concentration corresponding to the 95% upper confidence level ("UCL") of the 80th percentile of the lognormal data distribution.

Trust Screening Level: Screening level for classification of corresponding metal as a potential chemical of concern.

Maximum: Maximum concentration detected in background samples of this lithology (threshold level when there are fewer than 50% detections).

95th Percentile: The concentration corresponding to the 95th percentile of the lognormal data distribution calculated for data sets with a frequency of detection greater than 50%.

95% UCL of 95th Percentile: The concentration corresponding to the 95% UCL of the 95th percentile of the lognormal data distribution.

Trust Threshold Level: Threshold level for classification of corresponding metal as a chemical of concern.

(b) NM means not measured; there were no data above applicable laboratory reporting limits.

(c) NA means not applicable; there were sufficient data to estimate a data distribution so the detection limit or maximum detected concentration are not screening or threshold levels.

(d) A double hyphen ("--") indicates that there were insufficient data above laboratory reporting limits to estimate a data distribution.

(e) The concentration shown was the maximum detected in the data set. DTSC requested that the second highest concentration be used for evaluating the threshold level.

TABLE 6-4
SUMMARY OF BACKGROUND DATA, SCREENING LEVELS, AND THRESHOLD LEVELS -- CHERT/SHALE SOIL (a)

Presidio of San Francisco, California

	Background Data Summary			Screening Level (mg/kg)				Threshold Level (mg/kg)				
Metal	Number of Detections	Total Samples	Maximum Detected (mg/kg)	Detection Limit	80th Percentile	95% UCL of 80th Percentile	Trust Screening Level	Detection Limit	Maximum Detected	95th Percentile	95% UCL of 95th Percentile	Trust Threshold Level
Antimony	0	46	NM (b)	3.0	-- (c)	--	3.0	3.0	NA (d)	--	--	3.0
Arsenic	3	47	15 (e)	2.5	--	--	2.5	NA	3.2	--	--	3.2
Barium	47	47	1100	NA	210	310	310	NA	NA	540	900	900
Beryllium	14	47	0.72	0.20	--	--	0.2	0.20	0.72	--	--	0.72
Cadmium	11	47	1.7	0.80	--	--	0.80	0.80	1.7	--	--	1.7
Chromium	37	47	52	NA	8.7	13	13	NA	NA	24	41	41
Cobalt	33	47	87	NA	9.2	13	13	NA	NA	22	37	37
Copper	47	47	310	NA	90	130	130	NA	NA	220	360	360
Lead	6	47	45	10	--	--	10	10	45	--	--	45
Mercury	1	47	0.036	0.20	--	--	0.20	0.20	0.036	--	--	0.20
Molybdenum	0	46	NM	2.0	--	--	2.0	2.0	NA	--	--	2.0
Nickel	34	47	110	NA	19	27	27	NA	NA	44	71	71
Selenium	0	1 (f)	NM	0.50	--	--	0.5	0.50	NA	--	--	0.50
Silver	0	47	NM	1.0	--	--	1.0	1.0	NA	--	--	1.0
Thallium	0	46	NM	1.0	--	--	1.0	1.0	NA	--	--	1.0
Vanadium	45	47	71	NA	16	23	23	NA	NA	38	61	61
Zinc	43	47	140	NA	27	41	41	NA	NA	73	120	120

Notes:

(a) Column headings have the following meanings:

Detection Limit: A typical detection limit is included when there were insufficient data to calculate an 80th percentile or a 95th percentile (e.g., no detections or fewer than 50% detection

80th Percentile: The concentration corresponding to the 80th percentile of the lognormal data distribution calculated for data sets with a frequency of detection greater than 50%.

95% UCL of 80th Percentile: The concentration corresponding to the 95% upper confidence level ("UCL") of the 80th percentile of the lognormal data distribution.

Trust Screening Level: Screening level for classification of corresponding metal as a potential chemical of concern.

Maximum: Maximum concentration detected in background samples of this lithology (threshold level when there are fewer than 50% detections).

95th Percentile: The concentration corresponding to the 95th percentile of the lognormal data distribution calculated for data sets with a frequency of detection greater than 50%.

95% UCL of 95th Percentile: The concentration corresponding to the 95% UCL of the 95th percentile of the lognormal data distribution.

Trust Threshold Level: Threshold level for classification of corresponding metal as a chemical of concern.

(b) NM means not measured; there were no data above applicable laboratory reporting limits.

(c) NA means not applicable; there were sufficient data to estimate a data distribution so the detection limit or maximum detected concentration are not screening or threshold levels.

(d) A double hyphen ("--") indicates that there were insufficient data above laboratory reporting limits to estimate a data distribution.

(e) The concentration shown was the maximum detected in the data set. DTSC requested that the second highest concentration be used for evaluating the threshold level.

(f) The total number of samples analyzed for selenium was 47. However, 46 of these samples had elevated detection limits and were not considered in the evaluation.

TABLE 6-5
SUMMARY OF BACKGROUND SCREENING AND THRESHOLD DATA, PRESIDIO SOILS

Presidio of San Francisco, California

Metal	Trust Screening and Threshold Levels by Lithology (mg/kg)							
	Serpentinite		Colma		Beach/Dune		Chert/Shale	
	Screening Level	Threshold Level	Screening Level	Threshold Level	Screening Level	Threshold Level	Screening Level	Threshold Level
Antimony	3.0(DL)	3.0(DL)	3.0(DL)	3.0(DL)	3.0(DL)	3.0(DL)	3.0(DL)	3.0(DL)
Arsenic	2.5(80th)	5.4(95th)	3.9(UCL80)	6.2(UCL95)	3.9(UCL80)	5.9(UCL95)	2.5(DL)	3.2(Max)
Barium	100(80th)	230(95th)	99(UCL80)	180(UCL95)	54(UCL80)	120(UCL95)	310(UCL80)	900(UCL95)
Beryllium	0.50(DL)	1.1(Max)	0.46(UCL80)	0.99(UCL95)	0.52(UCL80)	0.89(UCL95)	0.2(DL)	0.72(UCL95)
Cadmium	0.80(DL)	1.9(Max)	0.80(DL)	0.8(DL)	0.80(DL)	1.7(Max)	0.80(DL)	1.7(Max)
Chromium	1,300(80th)	1,700(95th)	95(UCL80)	140(UCL95)	81(UCL80)	120(UCL95)	13(UCL80)	41(UCL95)
Cobalt	140(80th)	170(95th)	16(UCL80)	21(UCL95)	11(UCL80)	16(UCL95)	13(UCL80)	37(UCL95)
Copper	18(80th)	85(95th)	24(UCL80)	49(UCL95)	21(UCL80)	43(UCL95)	130(UCL80)	360(UCL95)
Lead	21(80th)	66(95th)	5.2(UCL80)	7.5(UCL95)	21(UCL80)	57(UCL95)	10(DL)	45(Max)
Mercury	0.2(DL)	0.2(DL)	0.2(DL)	0.2(DL)	0.2(DL)	0.2(DL)	0.2(DL)	0.2(DL)
Molybdenum	2.0(DL)	2.0(DL)	2.0(DL)	2.0(DL)	2.0(DL)	2.0(DL)	2.0(DL)	2.0(DL)
Nickel	3,100(80th)	4,500(95th)	83(UCL80)	110(UCL95)	48(UCL80)	70(UCL95)	27(UCL80)	71(UCL95)
Selenium	0.5(DL)	0.5(DL)	0.5(DL)	0.5(DL)	0.5(DL)	0.75(Max)	0.5(DL)	0.5(DL)
Silver	1.0(DL)	1.7(Max)	1.0(DL)	1.0(DL)	1.0(DL)	1.0(DL)	1.0(DL)	1.0(DL)
Thallium	1.0(DL)	1.0(DL)	1.0(DL)	1.0(DL)	1.0(DL)	1.0(DL)	1.0(DL)	1.0(DL)
Vanadium	51(80th)	74(95th)	62(UCL80)	90(UCL95)	59(UCL80)	92(UCL95)	23(UCL80)	61(UCL95)
Zinc	86(80th)	160(95th)	43(UCL80)	60(UCL95)	42(UCL80)	66(UCL95)	41(UCL80)	120(UCL95)

Notes:

DL - Detection Limit: A typical detection limit is included when there were insufficient data to calculate a 95% UCL of the 80th and/or the 95th percentiles (e.g., fewer than 50% detections).

Max: Maximum concentration detected in background samples of this lithology (threshold level when there are fewer than 50% detections).

95th: The concentration corresponding to the 95th percentile of the lognormal data distribution calculated for data sets with a frequency of detection greater than 50%. Applied to serpentinite only due to small number of data in background data set.

80th: The concentration corresponding to the 80th percentile of the lognormal data distribution calculated for data sets with a frequency of detection greater than 50%. Applied to serpentinite only due to small number of data in background data set.

UCL95: The concentration corresponding to the 95% UCL of the 95th percentile of the lognormal data distribution.

UCL80: The concentration corresponding to the 95% UCL of the 80th percentile of the lognormal data distribution.

TABLE 6-6
CONCENTRATIONS OF METALS IN REGIONAL BACKGROUND SOIL STUDIES

Presidio of San Francisco, California

Metal	Location and Range of Metal Concentrations Reported											
	N. Santa Clara County (a)		Lawrence Berkeley Lab (b)		California Soils (c)		SF Bay Wetlands (d)		Panoche Creek (e)		Hamilton Air Field (f)	
	150 samples		492 samples		50 samples		14 samples		721 samples		62 samples	
	Minimum Detected (mg/kg)	Maximum Detected (mg/kg)	Minimum Detected (mg/kg)	Maximum Detected (mg/kg)	Minimum Detected (mg/kg)	Maximum Detected (mg/kg)	Minimum Detected (mg/kg)	Maximum Detected (mg/kg)	Minimum Detected (mg/kg)	Maximum Detected (mg/kg)	Minimum Detected (mg/kg)	Maximum Detected (mg/kg)
Antimony	-	-	1	9	0.15	1.95	-	-	-	-	0.06	1.2
Arsenic	0.5	20	0.25	63	0.6	11	5.29	23.7	3.4	21	1.1	25.2
Barium	-	-	0.5	1,300	133	1,400	-	-	12	2,300	26	435
Beryllium	0.25	3.2	0.05	2.7	0.25	2.7	-	-	1	3	0.53	1.68
Cadmium	0.4	14	0.05	16	0.05	1.7	0.14	0.56	-	-	0.41	1.8
Chromium	9.5	170	4.1	478	23	1,579	110	224	11	410	9.6	149
Cobalt	-	-	1.7	39	2.7	46.9	-	-	5	34	5.5	32
Copper	4.6	67	0.3	250	9.1	96.4	24.2	90.6	2	86	5.7	88.7
Lead	3.4	54	0.5	31	12.4	97.1	13.7	85.6	2	96	3.3	85.6
Mercury	0.02	1.3	0.05	2.2	0.1	0.9	0.059	0.515	0.02	2.5	0.07	0.43
Molybdenum	-	-	0.25	63	1	9.6	-	-	2	9	0.28	0.97
Nickel	6	145	6	309	9	509	32.2	145.2	6	380	10	139
Selenium	0.12	4	0.5	28	0.015	0.43	0.14	0.91	0.1	4.5	0.34	0.37
Silver	0.3	4.8	0.2	6.5	0.1	8.3	-	-	-	-	0.1	0.21
Thallium	0.41	3.8	0.5	18 (g)	0.17	1.1	-	-	-	-	5.7	33.7 (i)
Vanadium	-	-	0.5	130	39	288	-	-	30	260	15	136
Zinc	7.8	120	3.8	174	88	236	88.5	166.1	11	230	16.6	232

TABLE 6-6
CONCENTRATIONS OF METALS IN REGIONAL BACKGROUND SOIL STUDIES

Presidio of San Francisco, California

Notes:

(a) Scott, C.M. 1995. *Background Metal Concentrations in Soils in Northern Santa Clara County, California* in Recent Geological Studies in the San Francisco Bay Area, Pacific Section of the Society of Economic Paleontologists and Mineralogists, Volume 76.

(b) Lawrence Berkeley National Laboratory. 1995. *Protocol for Determining Background Concentrations of Metals in Soil at Lawrence Berkeley National Laboratory*. U.S. Department of Energy Contract DE-AC03-76F00098.

(c) Bradford, G.R., et al. 1996. *Background Concentrations of Trace and Major Elements in California Soils*. Kearney Foundation of Soil Science, University of California, Riverside.

(d) Lee, C.R., et al. 1995. *Field Survey of Contaminant Concentrations in Existing Wetlands in the San Francisco Bay Area*. Miscellaneous Paper EL-95, U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.

(e) Ryder, J.L., et al. 1989. *Analysis of 721 Soil Samples from the Panoche Fan Area of the San Joaquin Valley, California*. USGS Open File Report 89-298.

(f) International Technology Corporation. 27 April 2000. *Draft Human Health and Ecological Risk Assessment, BRAC Property, Hamilton Army Airfield, Novato, California.*

(g) Apparent outliers removed by EKI.

TABLE 6-7
DISSOLVED CHROMIUM AND HEXAVALENT CHROMIUM CONCENTRATIONS IN SURFACE WATER, SEEPS, AND GROUNDWATER (a)

Presidio of San Francisco, California

Site	Surface Water, Seep, or Groundwater Sample Location	Is Monitoring Well Screened in Serpentinite?	Range of Dissolved Chromium (b); (c)		Range of Hexavalent Chromium (b); (c)	
			minimum	maximum	minimum	maximum
Main Post:						
• Building 215 Area	215GW01	no	**17**	**26.8**	**12**	**38**
	215GW02	no	**31.8**	**31.8**	**23.5**	**26**
	215GW03	no	**29.5**	**29.5**	**24.6**	**26**
Fort Scott:						
• Battery Howe/Wagner	HWGW01	yes	**82**	**146**	**120**	**220**
	HWGW04	yes	**7**	**18**	**7.4**	**36.6**
	HWGW05	yes	<1	<10	<0.5	**16.1**
	HWGW100	yes	- (d)	-	**40**	**40**
	HWGW101	yes	-	-	**40**	**40**
	HWSW100	seep	-	-	**10**	**10**
	BHWSP01	seep	**6**	**6**	-	-
	BHWSP02	seep	<3	<3	-	-
Letterman Complex:						
• Fill Site 6	LF6GW100	no	<10	<10	-	-
	LF6GW101	no	**12**	**12**	-	-
	LF6GW102	no	<10	<10	-	-
	LF6GW103	no	**27**	**28**	-	-
Public Health Service Hospital:						
• Landfill 8	LF8GW01	yes	**2.3**	**16 (50.7); (e)**	-	-
	LF8GW02B	yes	**20**	**58.4**	-	-
	LF8GW03	no	**22**	**32.3**	-	-
	LF8GW04	no	**1.9**	**25.4**	-	-
	LF8GW06	no	<10	<10	-	-
• Landfill 10	LF10GW01	yes	**71.5**	**110**	-	-
	LF10GW02	no	<1	<10	-	-
	LF10GW03	yes	**2.1**	**14**	-	-
East Housing:						
• Landfill E	DAEGW03	no	**15**	**30**	-	-
	DAEGW04	no	**10**	**23.4 (130); (e)**	-	-
	DAEGW05	no	<10	**22**	-	-
	DAEGW06	yes (f)	<1	<10	-	-
	DAEGW07	no	<1	<10	-	-
	DAEGW08	no	**1**	**19**	-	-
	DAESP01	seep	<3	**20.4**	-	-
	DAESP02	seep	<10	<50	-	-
	DAESP02A	seep	<3	<3	-	-
	DAESP03	seep	<10	**29.1**	-	-
	DAESP04	seep	<10	<10	-	-

TABLE 6-7
DISSOLVED CHROMIUM AND HEXAVALENT CHROMIUM CONCENTRATIONS IN SURFACE WATER, SEEPS, AND GROUNDWATER (a)

Presidio of San Francisco, California

Site	Surface Water, Seep, or Groundwater Sample Location	Is Monitoring Well Screened in Serpentinite?	Range of Dissolved Chromium (b); (c)		Range of Hexavalent Chromium (b); (c)	
			minimum	maximum	minimum	maximum
East Housing (contd):						
• Fill Site 1	LF1GW01	no	<1	<10	**1.3**	**15.1**
	LF1GW02	no	**11**	**40.4**	**32.1**	**34.5**
	LF1GW03	no	**34**	**49**	**38.3**	**137**
	LF1GW04	yes (f)	**16**	**24**	**18.9**	**82.4**
	LF1GW05	no	**9**	**12**	**2.1**	**102**
	LF1GW06	no	**5**	**22.4**	**10.7**	**31.1**
	LF1GW07	yes (f)	**14**	**29**	<10	**24.7**
	LF1SP01	seep	<3	<10	-	-
	LF1SP02	seep	<3	<10	-	-
• Tennessee Hollow	TH-1	yes (g)	**17.1**	**17.4**	**12**	**14**
	TH-2	no	**20.4**	**23.1**	<10	**19**
	TH-3	no	<10	**16.7**	<10	<10
	TH-4	no	**20.9**	**22.2**	**19**	**26**
• El Polin Spring	EPSP01 (h)	seep	**19**	**29**	**22.4**	**29.7**
Presidio Hill:						
• Nike Facility and Nike Swale	NKGW01	yes	**2.5**	**4.1**	-	-
	NKGW02	yes (f)	**5.9**	**20**	<10	<10
	NKGW03	no	<10	<10	<10	<10
	NKGW04	yes	**4.2**	<10	<10	<10
	NKGW05	yes	**4.8**	**23**	<10	<10
	NSSW100	surface water	-	-	ND (i)	ND
Presidio Forest:						
• Landfill 2	LF2GW01	yes	**6**	**14**	**5**	**29.9**
	LF2GW02	yes	<1	<10	<0.5	**13.7**
	LF2GW04	yes (f)	<1	<10	**0.72**	<10
	LF2SP01	seep	<3	<10	-	-
• Landfill 4	LF4GW03	no	**2**	<10	<10	<10
• Building 1349 Area	1349MW01	yes (j)	-	-	<10	<10
	1349MW02	yes	-	-	**43**	**43**
Coastal Bluffs:						
• Fill Site 5	1349MW03	yes	-	-	**69**	**69**
	LF5GW100	yes	**31**	**31**	**30**	**30**
	LF5GW101	yes	**36**	**38**	**40**	**40**

TABLE 6-7
DISSOLVED CHROMIUM AND HEXAVALENT CHROMIUM CONCENTRATIONS IN SURFACE WATER, SEEPS, AND GROUNDWATER (a)

Presidio of San Francisco, California

Site	Surface Water, Seep, or Groundwater Sample Location	Is Monitoring Well Screened in Serpentinite?	Range of Dissolved Chromium (b); (c)		Range of Hexavalent Chromium (b); (c)	
			minimum	maximum	minimum	maximum
Upland Areas of Presidio:						
Background Locations	UBR01GW01	yes	**25**	**66**	**26.6**	**65.4**
	UBR02GW01	yes	**48**	**49**	**45**	**52.1**
	UBR02GW02	yes	**98**	**100**	**89.2**	**98.3**
	UBR03GW01	no	<10	<10	<0.5	<0.5
	UBR03GW02	no	<10	<10	**0.64**	**0.64**

Notes:

(a) Surface water, seep, and groundwater sample analytical results were obtained from an electronic database assembled by Montgomery Watson, and the following additional sources:

- Montgomery Watson. 1998 and 1999. *Groundwater Monitoring Program. Building 1349 Area.*
- Montgomery Watson. 16 July 1999. *Hexavalent Chromium in Serpentinite Bedrock and Groundwater in Upland Areas.*
- Erler & Kalinowski, Inc. October 2000. *Draft Sampling Results for Selected Main Installation Sites.*

(b) Analytical results of dissolved chromium and hexavalent chromium in groundwater consist of filtered samples and unfiltered samples collected through use of low flow sampling techniques.

(c) Analytical results of unfiltered samples are included for dissolved chromium and hexavalent chromium in surface water and freshwater seeps.

(d) Hyphen indicates sample not analyzed or analytical results are not available.

(e) Concentration in parenthesis is not likely representative of dissolved chromium because high concentrations of other metals in sample indicate filter breakthrough likely occurred.

(f) Screened in serpentinite or Franciscan Formation at the bottom of monitoring well only.

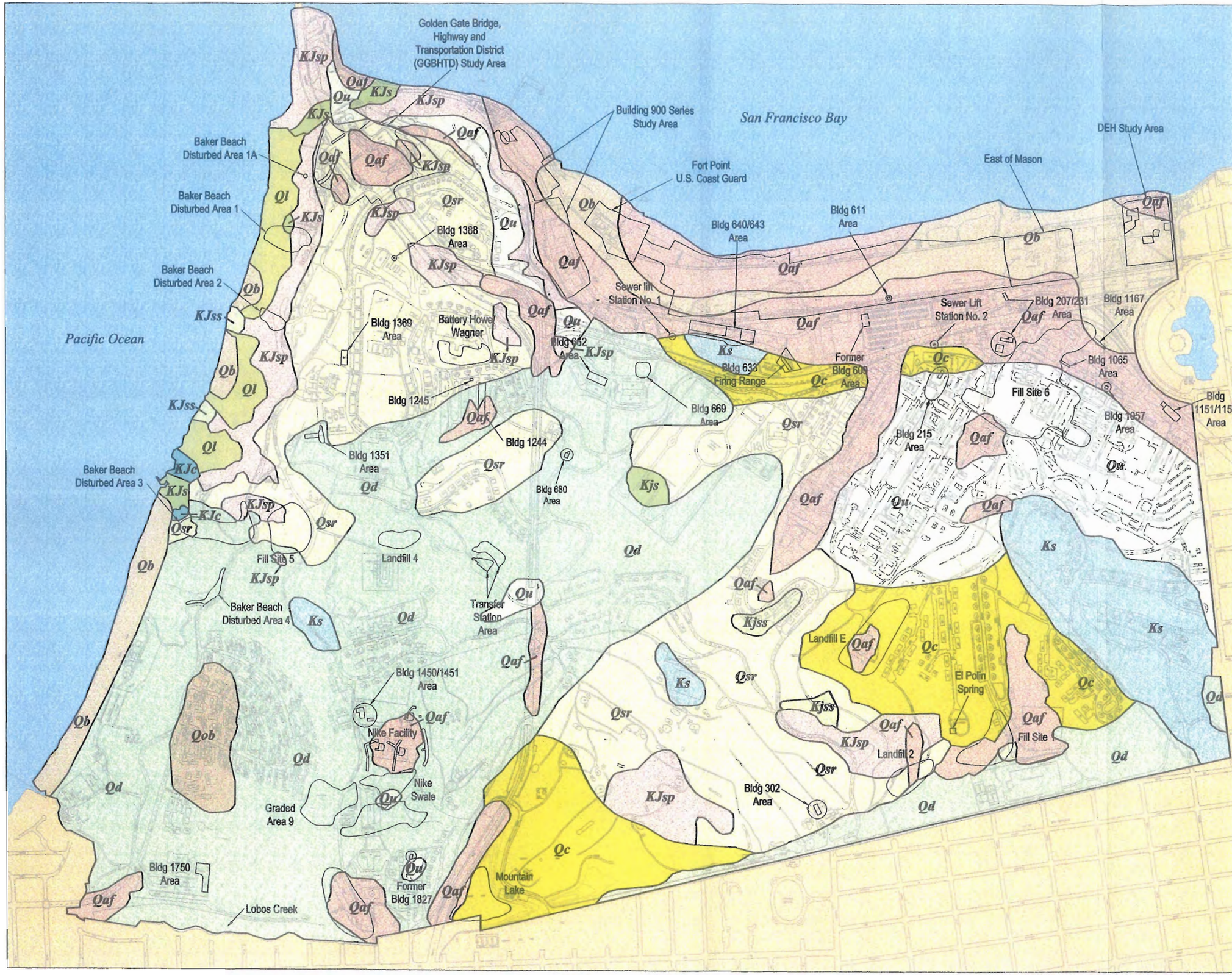
(g) Lithologic log of boring in which monitoring well was constructed indicates greenish clay that is possibly weathered serpentinite.

(h) Seep samples consist of samples identified as EPSP01, EPSPRING, EPSPRING2, and EPSSWO1.

(i) Not detected ("ND"). Chromium was not measured above analytical laboratory reporting limit. Reporting limit value was not provided in reference reviewed.

(j) Monitoring well is screened in melange, which typically contains serpentinite fragments. Lithologic log of boring in which monitoring well was constructed indicates weathered serpentinite at bottom of boring.

FIGURES



N

0 800 1600

(Approximate Scale in Feet)

LEGEND

Quarternary Surficial Deposits

- Qaf — Artificial Fill
- Qb — Modern Beach Deposits
- Qsr — Slope Debris & Ravine Fill
- Qd — Dune Sand
- Ql — Landslide Deposits
- Qu — Undivided Surficial Deposits
- Qob — Older Beach Deposits
- Qc — Colma Formation

Mesozoic Franciscan Formation Bedrock

- Ks — Undifferentiated Sheared Rocks
- KJsp — Serpentinite
- KJc — Radiolarian Chert & Shale
- KJss — Sandstone
- KJs — Undifferentiated Sandstone & Shale

Notes:

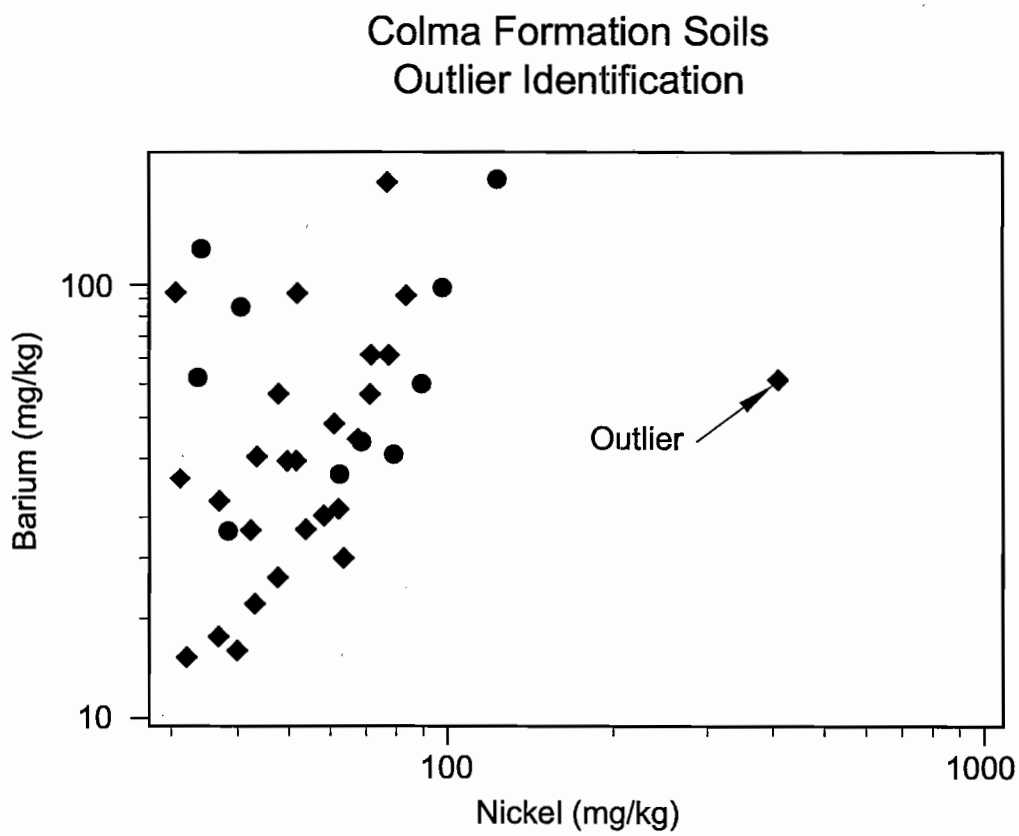
1. All locations are approximate.
2. Figure modified from Montgomery Watson, Draft Basewide Groundwater Monitoring Plan, July 1996.

Erler & Kalinowski, Inc.

Surface Deposits at the Presidio

Presidio Trust
San Francisco, CA
October 2002
EKI A000003.04

Figure 6-1



LEGEND:

- ● Background
- ◆ Site

Erler & Kalinowski, Inc.

Screening of Individual Outlier from Proposed Colma Background Data Set

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September 2002
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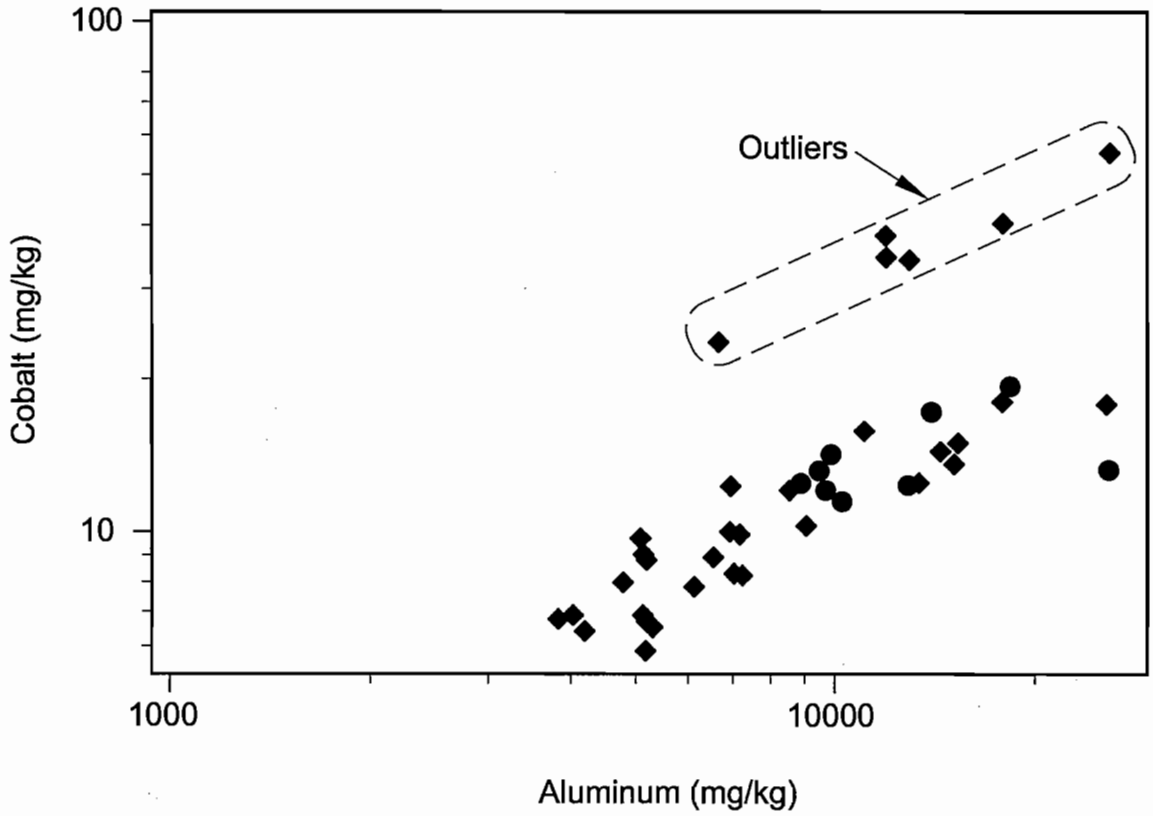
Figure 6-2



LEGEND:

- ● Background
- ◆ Site

Erler & Kalinowski, Inc.

Screening of Outlier Trend from Proposed Colma Background Data Set

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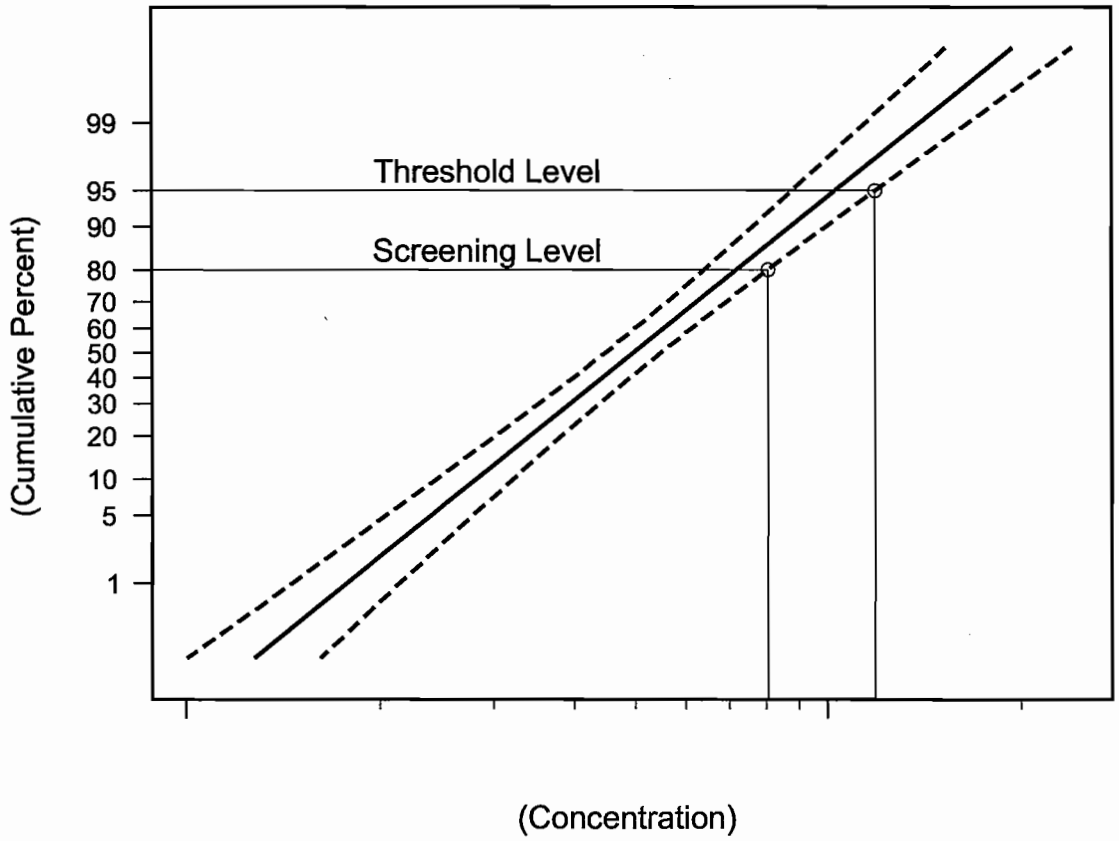
Figure 6-3



LEGEND:

——— Lognormal Metal Population

----- 95% Confidence Interval Around Metals Population

Erler & Kalinowski, Inc.

Schematic Data Plot Showing Terminology Used to Define Screening and Threshold Metals Levels

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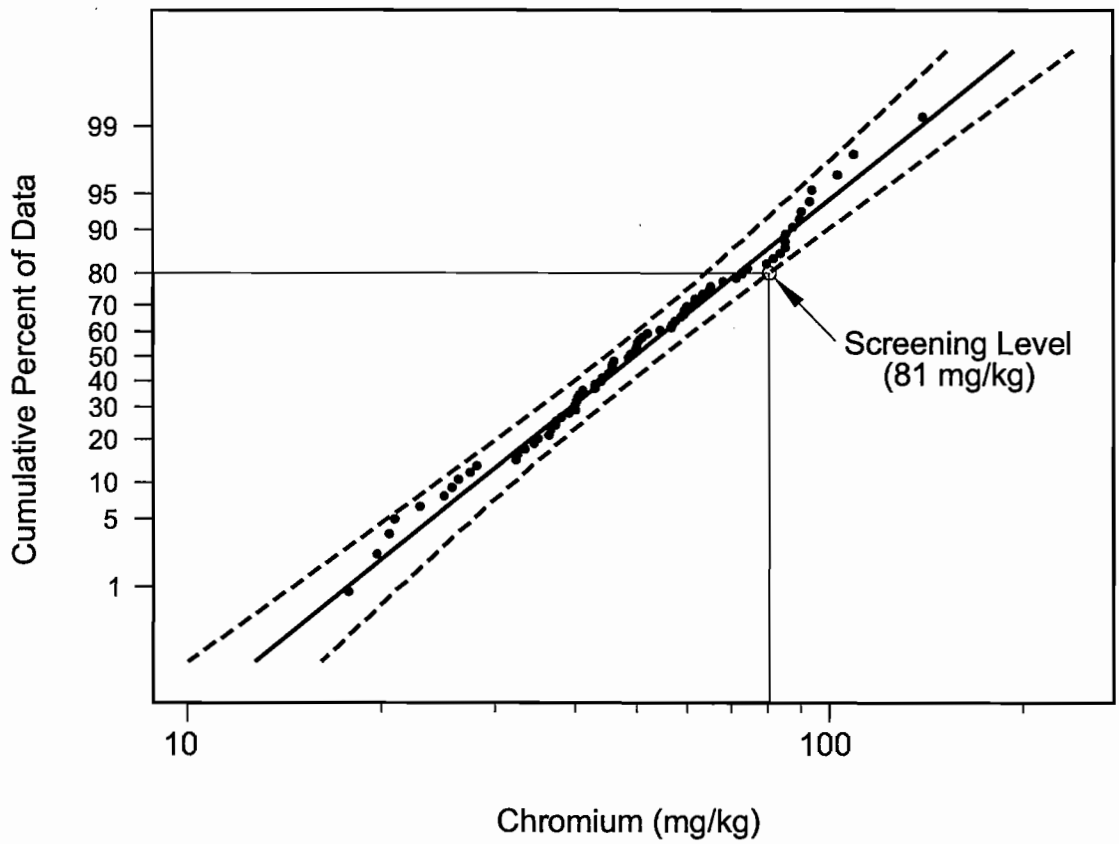
Figure 6–4



LEGEND:

- 80th Percentile
- 95% Confidence Interval Around Metals Population
- Lognormal Metal Population

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Derivation of Screening Level Concentration for Chromium in Background Beach/Dune Soil

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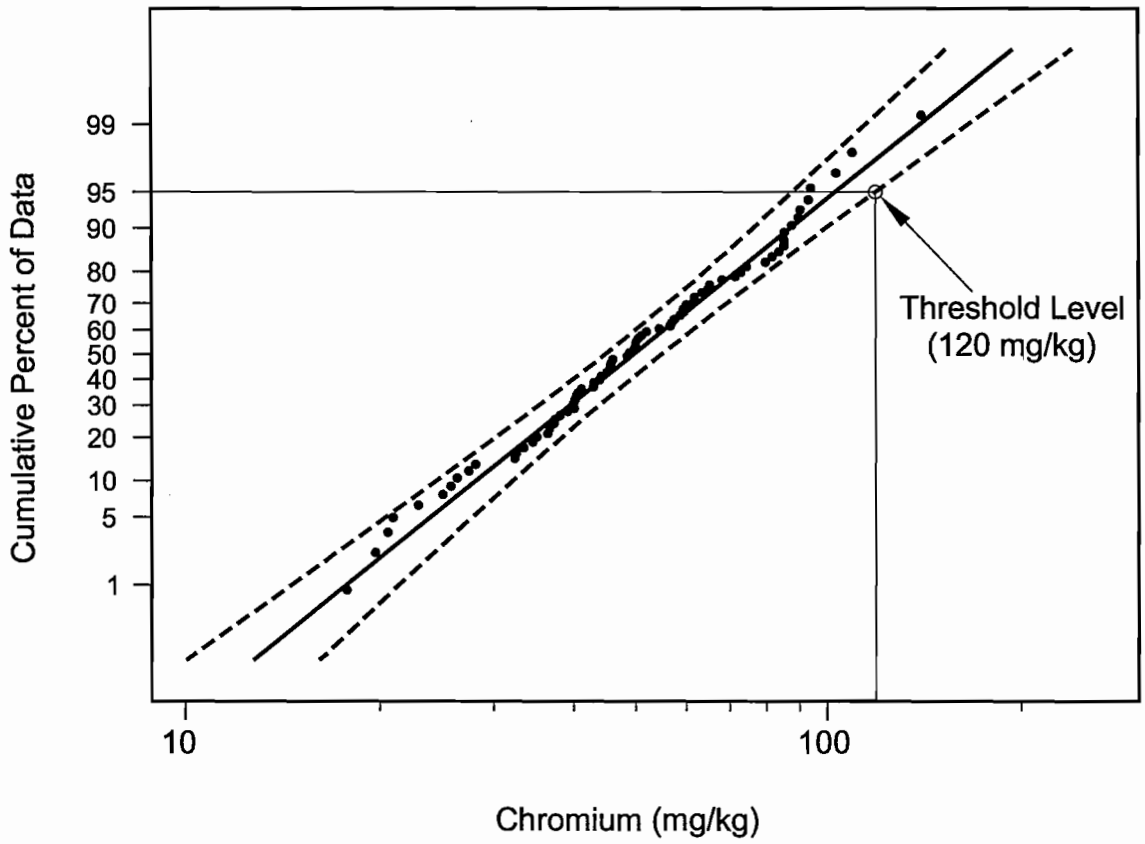
Figure 6-5



LEGEND:

——— 95th Percentile

- - - - - 95% Confidence Interval Around Metals Population

——— Lognormal Metal Population

Erler & Kalinowski, Inc.

Derivation of Threshold Level Concentration for Chromium in Background Beach/Dune Soil

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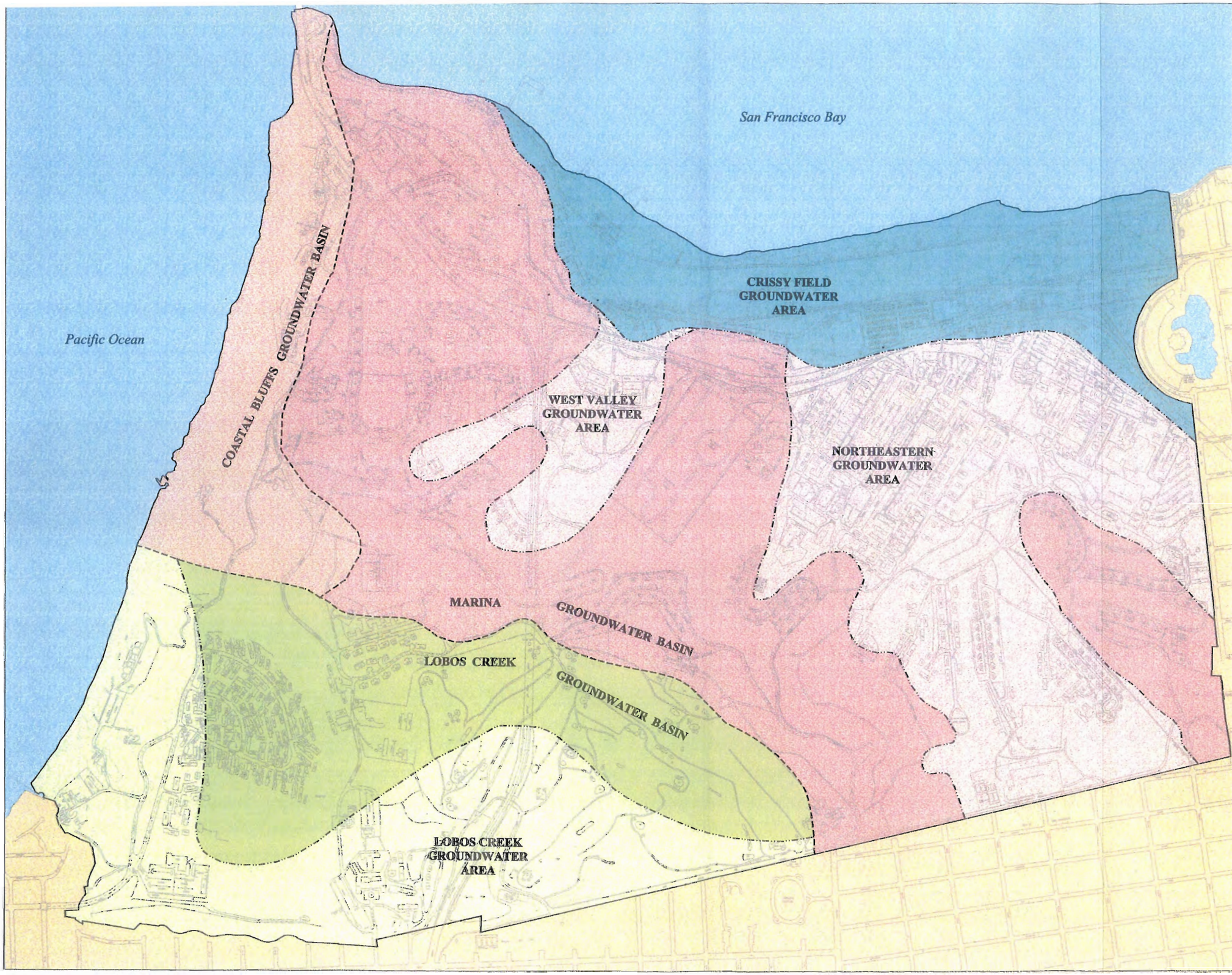
Figure 6-6



N

0 800 1600

(Approximate Scale in Feet)

LEGEND

- Groundwater Basin Boundaries
- Groundwater Area Boundaries
- Coastal Bluffs Groundwater Basin
- Lobos Creek Groundwater Basin
- Lobos Creek Groundwater Area
- Marina Groundwater Basin
- West Valley and Northwestern Groundwater Area
- Crissy Field Groundwater Area

Notes:

1. All locations are approximate.
2. Figure modified from Montgomery Watson, Draft Basewide Groundwater Monitoring Plan, July 1996.

Erler & Kalinowski, Inc.

Groundwater Basins and Areas at the Presidio

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October 2002
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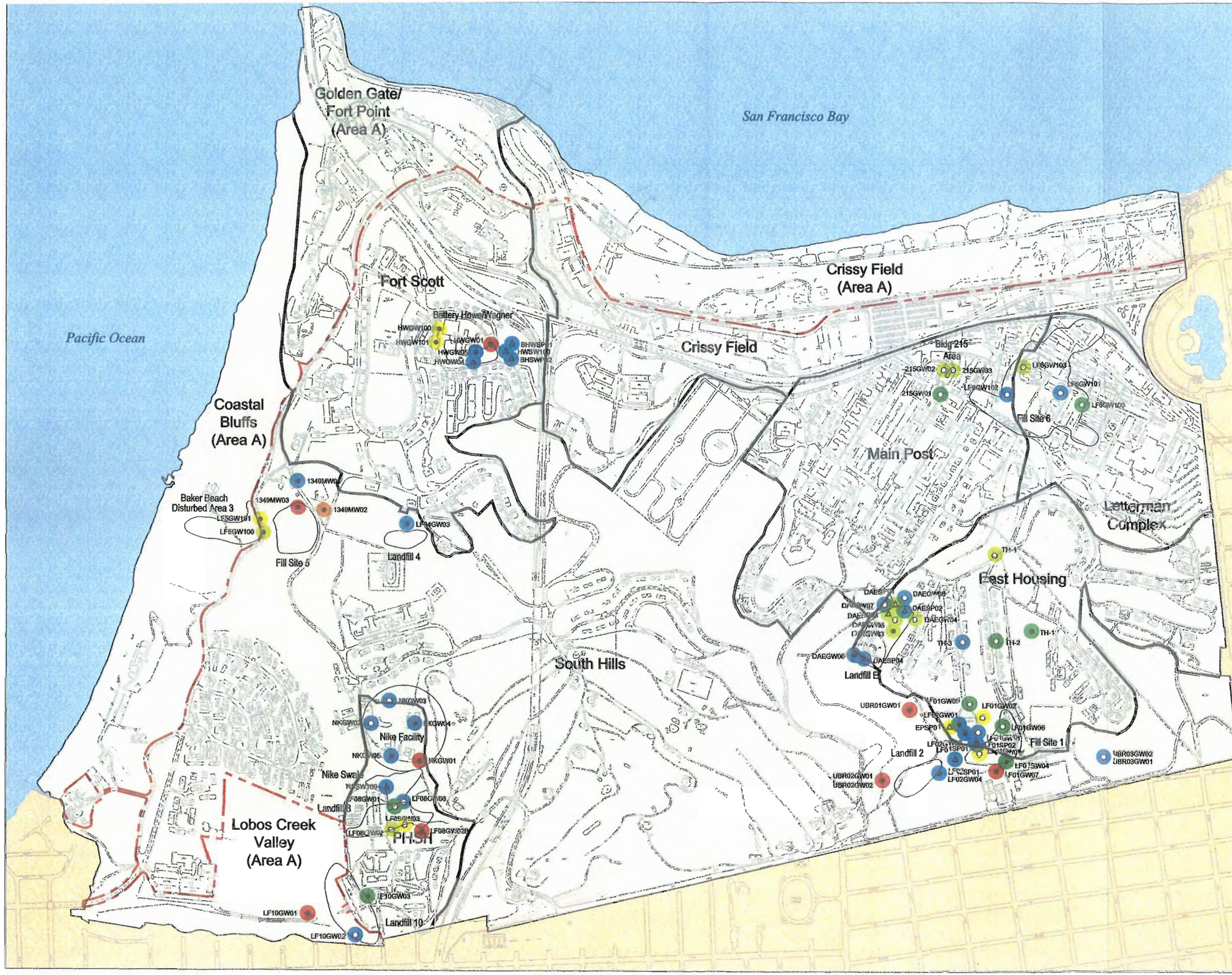
Figure 6–7



N

0 800 1600

(Approximate Scale in Feet)

LEGEND

- Area A/B Boundary
- Presidio Planning Area or District Boundary
- Groundwater Monitoring Well Screened in Serpentinite
- Groundwater Monitoring Well Screened in Other Formations
- Seep or Surface Water Sample

Dissolved Chromium and Hexavalent Chromium Concentrations in µg/L

- 0–10
- 10–20
- 20–30
- 30–40
- 40–50
- >50

Note:

1. All locations are approximate.

References for Groundwater Data:

Analytical Results Obtained from: Draft Sampling Results for Selected Main Installation Sites, Presidio of San Francisco, California, Erler & Kalinowski, Inc., October 2000.

Montgomery Watson, Hexavalent Chromium in Serpentinite Bedrock and Groundwater in Upland Areas, Technical Memorandum, Presidio of San Francisco, 16 July 1999.

Montgomery Watson, Groundwater Monitoring Program, Annual and Quarterly Summary Reports, 1998 and 1999.

U.S. EPA, Analytical Results, Elemental Constituent Results for Groundwater Samples, Presidio Army Base, San Francisco, California, 24 February 1999.

U.S. EPA, Analytical Reports, Inorganic Results for Samples from Presidio Army Base, San Francisco, California, 30 April 1997.

Dames & Moore, Final Remedial Investigation Report, Presidio Main Installation, January 1997.

Erler & Kalinowski, Inc.

Chromium Concentrations in Surface Water, Seeps, and Groundwater

Presidio Trust
San Francisco, CA
October 2002
EKI A000003.04

Figure 6–8

7. DERIVATION OF CLEANUP LEVELS

7. DERIVATION OF CLEANUP LEVELS

Remedial measures should assure protection of human health and the environment. U.S. EPA (1995c, 1991c, 1989a) requires remedies to take into account future land use that is reasonable and that is associated with the most significant risk posed by exposure to COCs. Accordingly, remedial action objectives ("RAOs") for Presidio sites consist of implementing remedies that are cost-effective, and prevent humans and ecological receptors from being exposed to unacceptable concentrations of COCs but still allow the reuse described in the GMPA and PTMP or other planned uses envisioned by the Trust. To determine the appropriate cleanup levels that should be applied to specific areas of the Presidio, future land use and planned water resource use at Presidio sites must be clearly defined. Sections 7.1 and 7.2 describe the planned land and water resource uses at the Presidio. Section 7.3 presents the procedures to determine which specific cleanup levels are applicable to a given site.

7.1 PLANNED LAND USES

Figures 7-1 and 7-2 depict planned human and ecological land use at the Presidio.

7.1.1 Human Land Use

Four broad categories of land use are defined in the GMPA for the Presidio (and are generally maintained in the PTMP). These categories consist of residential, recreational, institutional (education/conference), and industrial uses. The hatch type on Figure 7-1 signifies residential, recreational, institutional, and commercial/industrial areas on the Presidio and the color type depicts the corresponding cleanup levels that will protect people who reside, work, or visit these areas. Suitable cleanup levels are defined by the most sensitive population that is reasonably associated with the planned land use identified for different areas of the Presidio. These soil cleanup levels should be applied to a depth of 10 feet below ground surface, to account for soil disturbance during potential future construction.

7.1.1.1 Residential

Significant portions of the Presidio are designated as residential areas. Residential cleanup levels are applied to those Presidio sites situated in areas that have the following uses:

- **Residential:** Residential use is designated for single family housing and the grounds extending 150 feet from the structures in all directions, as well as playgrounds, and common areas near such housing. For example, it is reasonable to assume that children living in housing next to Fill Site 1 will use the open space at Fill Site 1 for a play area. Similarly, Julius Kahn playground is considered a

"residential" area because adults and children who live adjacent to the Presidio spend considerable time at this playground and use it like a "backyard."

- **Institutional (Educational/Conference):** As described in the GMPA and PTMP, several areas of the Presidio will be used as educational/conference centers. Housing in these areas will provide permanent and temporary lodging for tenant employees and their families, visiting scholars, students, and researchers. While the land use for such areas generally may be described as institutional, the distinction between residential and institutional housing is inconsequential for purposes of selecting appropriate cleanup levels. The potential exposure scenarios for people living in such housing are comparable to those living in single family residences. Accordingly, residential cleanup levels are applied to institutional housing. For example, the GMPA and PTMP indicate Fort Scott may be used for education, research, and training. The barracks would provide residential accommodations for people completing short- and long-term internships.

7.1.1.2 Recreational

Recreational cleanup levels are applied to those Presidio sites situated in areas that have the following land uses:

Commercial/Recreational: Areas and the surrounding open spaces surrounding such places as museums, visitor centers, and park partner buildings will be frequented by recreational users, including children who likely will be picnicking and playing in the areas surrounding the buildings (e.g., the Main Post and Crissy Field). At sites having such mixed or multiple uses, the population having the most significant risk (i.e., the most sensitive user) determines the applicable cleanup levels. For the Presidio, the most sensitive populations frequenting commercial/recreational areas will be recreational users.

Open Spaces: Areas of the Presidio not designated as residential, institutional, commercial/recreational, or industrial use areas are open spaces. Recreational users will frequent open spaces. Accordingly, recreational cleanup levels are applied in such areas.

7.1.1.3 Commercial/Industrial

As shown on Figure 7-1, only a small portion of the Presidio can be considered strictly commercial/industrial. These commercial/industrial areas consist of the water treatment plant area and the park maintenance facilities at Building 1750. Commercial/industrial cleanup levels are applied to these areas.

7.1.2 Ecological Land Use

The planned and existing ecological land use areas depicted on Figure 7-2 encompass most open spaces and recreational areas. Also included on Figure 7-2 are the saltwater and freshwater ecological protection zones defined in Order 96-070 issued by RWQCB in 1996 to the U.S. Army. In this order, the Tennessee Hollow riparian corridor, the Crissy Field wetlands, and Crissy Field shoreline are identified as sensitive habitats requiring more stringent petroleum hydrocarbon cleanup levels than elsewhere on the Presidio. The area where more stringent petroleum cleanup levels apply to the Tennessee Hollow riparian corridor is designated as the freshwater ecological protection zone. The area where more stringent petroleum cleanup levels apply to the Crissy Field wetlands is designated as the saltwater ecological protection zone.

Figure 7-3 indicates the vegetation types to be preserved and rehabilitated at the Presidio. This figure is taken from the VMP. Native plants, including threatened or endangered species, and historic plants are some of the vegetation types to be preserved and their growth enhanced in the future. Also to be preserved and enhanced under the VMP is the historic forest. The historic forest originates from the efforts of Army Major W.A. Jones. In 1883, Major Jones proposed a major tree-planting program to create windbreaks and to visually enhance the ridges, entrances, and perimeters of the Presidio. Planting of the historic forest began in 1886 and continued until the early 1900s.

Arguably, ecological cleanup levels should apply throughout the Presidio since activities at all locations may have some impact on the environment. However, review of the GMPA, VMP, and PTMP suggest that most ecologically sensitive areas and special status species[11] areas encompass land designated for open space and recreational use (e.g., forested areas of South Hills, , Coastal Bluffs, Lobos Creek), and areas designated as ecological protection zones (i.e., Crissy Field wetlands, Crissy Field shoreline, and concomitant drainage area that includes the Tennessee Hollow riparian corridor). Figure 7-2 identifies areas where special status species are assumed to be present and ecological special status cleanup levels are applicable. These areas were established from the VMP and correspond to native plant habitat areas and forested areas. The remaining areas of the Presidio designated as ecological land use areas where special status species are not likely to be present (e.g., the golf course in the South Hills) are established as "buffer zone" ecological areas subject to the less-stringent buffer zone ecological cleanup levels (see Figure 7-2). Areas on Figure 7-2 where ecological cleanup levels are not applicable generally correspond to developed areas of the Presidio.

As described above, in areas where special status species are likely to be present, more stringent cleanup levels are applicable than in buffer zone ecological areas. However, the NPS (in Area A) and the Trust (in Area B), will have the option to assess and modify the applicability of special status cleanup levels on a site-by-site basis. In such cases, the

[11] Special status species include those species that are listed or proposed for listing as threatened or endangered under federal or state Endangered Species Acts, the California Native Plant Protection Act, the Migratory Bird Treaty Act, California Species of Special Concern as defined by the California Department of Fish and Game, or protected by other laws.

Trust or NPS will coordinate with the State or Federal natural resource trustees, as appropriate, to determine if special status species are present at these sites. Such areas could include locations that are not currently identified as ecological land use on Figure 7-2. If an area demarcated as special status species on Figure 7-2 is modified to be a buffer zone ecological area or a non-ecological area (i.e., a less stringent cleanup level would become applicable), then the Trust must obtain approval from the DTSC to change the applicable cleanup level. Where ecological land uses overlap with human land uses, the more stringent cleanup level is the assigned cleanup level upon which remedial actions will be based. The identification of applicable cleanup levels at individual sites is described in more detail in Section 7.3.

7.2 PLANNED WATER RESOURCE USE

U.S. EPA has established in the NCP various expectations regarding the types of remedies that it has determined are consistent with (1) preferences and mandates set forth in Section 121 of CERCLA and (2) its practical experience in complying with such preferences and mandates (Federal Register, 1990). U.S. EPA expects, in part, to return usable groundwater to its beneficial use wherever practicable, within a reasonable time frame. When restoration of groundwater is not practicable, the NCP at 40 CFR §300.430(a)(1)(iii)(F) states that U.S. EPA expects that action will be taken to prevent continued migration of contamination, prevent exposure to the contaminated groundwater, and evaluate further risk reduction. Similar expectations are contained in California's laws, regulations, and policies (e.g., California Water Code §13304 and SWRCB Resolution No. 92-49).

Both the GMPA and RWQCB (1995) recognize that beneficial uses of groundwater at the Presidio include municipal or potable water supply and recharge to streams that enhance ecological and recreational uses. Surface water flow in Lobos Creek has provided most of the potable water at the Presidio. Planned future use of surface water and groundwater at the Presidio includes potable supply (NPS, 1994). As described in the GMPA, potable supply will continue to be provided by on-site sources but reliance on surface water will be reduced in favor of increased use of groundwater. The reasons for this change are that groundwater is less intensive to treat than surface water and that the Lobos Creek ecosystem might benefit if surface water is not diverted (NPS, 1994).

Besides potable supply, beneficial uses of surface water and groundwater that discharges to water bodies at the Presidio include ecological and recreational uses. Areas of the Presidio where ecological and recreational beneficial uses should be protected include, at a minimum, Lobos Creek drainage basin, Tennessee Hollow drainage basin, Nike Swale, Mountain Lake, Crissy Field wetlands, and coastal and shoreline areas.

7.3 PRESIDIO CLEANUP LEVELS APPLICABLE TO SPECIFIC SITES

According to U.S. EPA (1991a), under the NCP, chemical-specific ARARs and risk-based PRGs are the two sources that can be used to establish cleanup levels that remedial actions must achieve under a ROD or RAP. Chemical-specific ARARs identified in Section 3 have been adopted as proposed cleanup levels, if available and greater than naturally occurring or background concentrations of metals in soil and water. In the absence of chemical-specific ARARs, risk-based PRGs derived in Sections 4 and 5 are used as cleanup levels if the PRGs are greater than background concentrations of metals in soil and water.

Naturally occurring metal concentrations should be considered when adopting chemical-specific ARARs and PRGs as cleanup levels for a site because it is not the intent of U.S. EPA (1992b, 1989a) nor DTSC (1999) to have releases of COCs remediated to concentrations below inorganic background levels. To reduce the potential of this event occurring at Presidio sites, chemical-specific ARARs and PRGs were compared to threshold concentrations of metals in soil to determine if the chemical-specific ARARs and PRGs are attainable cleanup levels.

It should also be recognized that chemical-specific ARARs and PRGs derived from toxicological data may be below the range of typical analytical method reporting limits for some PCOCs, such as SVOCs, and PCBs, pesticides, and herbicides in water. The typical analytical method reporting limits range from 0.1 to 10 µg/L for SVOCs by U.S. EPA Methods 8310 and 8270, and from 0.05 to 0.5 µg/L for PCBs, pesticides, and herbicides by U.S. EPA Methods 8081 and 8082 (U.S. EPA, 1997c). For those PCOCs in water, the Trust has selected the chemical-specific ARAR or PRG as the desirable cleanup level, but attainment can only be determined at the standard analytical method reporting limit. For SVOCs, PCBs, pesticides, herbicides and other classes of compounds that may have very low chemical-specific ARARs or PRGs in soil or water, the cleanup levels are established at the typical analytical method reporting limit ranges for these PCOCs assuming no matrix interference. In the event of matrix interference in soil or water samples, actual method reporting limits determining compliance with cleanup levels may be raised.

To allow timely reuse contemplated under the GMPA, the Army addressed chemical release sites at DEH and Crissy Field under separate RAPs. These RAPs (Army and DTSC, 1997 and 1998,) contained cleanup levels specific to sites at DEH and Crissy Field. Cleanup levels in the DEH and Crissy Field RAPs should be used at sites considered under those RAPs to avoid confusion regarding which cleanup levels should be applied in the event that additional contamination is discovered at these areas. The cleanup levels presented in this Presidio-wide Cleanup Level Document are intended for use at all other chemical release sites at the Presidio (e.g., Main Installation sites, the Firing Ranges, and new sites that may be discovered).

Based on chemical-specific ARARs and risk-based PRGs, human health cleanup levels for soil, ecological cleanup levels for soil and sediment, and cleanup levels for surface

water, seeps, and groundwater were developed for the Presidio. Table 7-1 summarizes the process used to identify site-specific cleanup levels applicable to each Presidio site. The table presents the evaluation steps, potential parameters, and reference figures or tables from this document to identify which cleanup level applies to a given site. Fill Site 1 is included in Table 7-1 as an example. Sections 7.3.1 through 7.3.4 discuss the basis for the human health cleanup levels for soil, ecological cleanup levels for soil and sediment, and cleanup levels for surface water, seeps, and groundwater developed for the Presidio and referenced in Table 7-1. Section 7.3.5 revisits Table 7-1 and illustrates how site specific cleanup levels are determined for the Presidio.

7.3.1 Human Health Cleanup Levels for Non-Petroleum Compounds in Soil

Chemical-specific ARARs for soil are available for only a limited number of contaminants. Human health cleanup levels for lead, PCBs, VOCs, and petroleum hydrocarbons in soil and water at the Presidio are generally derived from ARARs (for some receptors, the cleanup levels for these compounds are risk-based). Cleanup levels for remaining PCOCs in soil are risk-based PRGs or, in the case of metals, background concentrations if naturally occurring levels of metals in soil are greater than PRGs. Background concentrations of metals in serpentinite, Colma Formation, beach/dune sand, and chert/shale are derived in Tables 6-1 through 6-4, respectively, and summarized in Table 6-5. These four soil types are the primary lithologies encountered at the Presidio. Chert/shale, believed to be imported from Marin County, has been used as fill and base rock at Crissy Field and other locations at the Presidio and is not necessarily considered chemically-impacted soil material.

The 5 January 2001 *Federal Register* stated that TSCA was amended to establish a hazard standard of 400 mg/kg lead in bare residential soil. A human health cleanup level of 400 mg/kg of lead in soil is being used as a not-to-exceed value for residential areas at the Presidio; the PRG of 370 mg/kg of lead in soil derived in Section 4.2.10 is being used as a maximum average lead concentration in soil at residential sites.

Requirements governing cleanup of PCB-containing soil and wastes were broadened by amendments to TSCA in 1998. As part of these amendments, U.S. EPA added 40 CFR §761.61 to Subpart D of TSCA, which provides cleanup and disposal provisions for PCB-containing soil and other types of remediation wastes. This section of Subpart D sets cleanup levels for high occupancy areas (e.g., residence) at 1 mg/kg of PCBs in soil. However, the human health PRGs for PCBs were calculated in Tables 4-3 through 4-5. For the residential and recreational land uses, the calculated site-specific PRGs for PCBs are less than 1 mg/kg. Therefore, the calculated value is proposed as the cleanup level for those populations. For the commercial/industrial land use, a human health cleanup level of 1 mg/kg of PCBs is proposed to comply with TSCA because the site-specific PRG is greater than the TSCA value. Cleanup levels for petroleum hydrocarbons and related constituents are presented in Section 7.3.3.

Soil cleanup levels for PCOCs other than lead in residential areas, PCBs in commercial/industrial locations, most VOCs, and petroleum hydrocarbons are risk-based

PRGs presented in Section 4. As presented in Sections 4.2.7 and 4.2.9, PRGs for most VOCs were established as the Groundwater Protection RBSL. Table 7-2 includes human health cleanup level values for PCOCs in soil, other than petroleum hydrocarbons and related constituents. Naturally occurring concentrations of metals in soil are also shown on this table, to ensure that the cleanup level used for a given PCOC and specific lithology is not less than background levels. The human health cleanup levels also need to be compared to the ecological cleanup levels in Table 7-2, as appropriate, to identify the lowest applicable cleanup level for the location (Figures 7-1 and 7-2).

7.3.2 Ecological Cleanup Levels for Non-Petroleum Compounds in Soil and Sediment

Figure 7-2 indicates areas of the Presidio where habitat suitable for ecological receptors exists or is planned. Buffer zone and special status ecological cleanup levels pertain to specific areas shown on Figure 7-2. Ecological cleanup levels do not apply to locations that are paved or dominated by designed landscapes (e.g., lawns or ornamental plantings). The NPS (in Area A) and the Trust (in Area B), will have the option to assess and modify the applicability of ecological cleanup levels on a site-by-site basis, with approval from DTSC if the applicable cleanup level is changed to a less stringent value (e.g., modifying a buffer zone ecological area to a non-ecological area).

Table 7-2 lists ecological PRGs that are used for the development of ecological cleanup levels of non-petroleum compounds. The table identifies buffer zone and special status species cleanup levels, which can be compared to background metal and human health cleanup levels to identify the lowest appropriate cleanup level for a location.

Tables 7-3 and 7-4 list ecological cleanup level values for non-petroleum compounds in freshwater and marine sediment at the Presidio, respectively. The tables include cleanup levels for special status species, if available. In the absence of values for special status species, the regular ecological cleanup levels should be used. To account for naturally occurring concentrations of metals in the primary lithologies encountered at the Presidio, ecological cleanup levels for sediments have been developed separately for serpentinite, Colma Formation, beach/dune sand, and chert/shale lithologies.

7.3.3 Human Health and Ecological Cleanup Levels for Petroleum Hydrocarbons and Constituents in Soil and Sediment

Cleanup levels for petroleum hydrocarbons and related constituents developed in connection with Order No. 96-070 are being adopted for areas of the Presidio where releases of petroleum hydrocarbons may have occurred with other types of chemicals. Cleanup levels for petroleum hydrocarbons and related constituents were included in Order No. 96-070 or were developed from subsequent studies required by the order. These studies consisted of performing bioassays and reviewing toxicological data published in scientific literature to develop cleanup levels for the saltwater ecological protection zone (IT Corporation, 1997) and freshwater protection zone (Montgomery Watson, 1999b).

Cleanup level values for petroleum hydrocarbons and related constituents in soil and sediment within the saltwater and freshwater ecological protection zones, and at other areas of the Presidio are summarized in Table 7-5. Figure 7-2 identifies the locations of the saltwater and freshwater ecological protection zones. For sites within these zones, cleanup levels for ecological protection must include not only the values for terrestrial receptors, but also the values for saltwater or freshwater aquatic organisms listed in Table 7-5.

7.3.4 Cleanup Levels for Surface Water, Seeps, and Groundwater

Chemical-specific ARARs were used to establish groundwater and surface cleanup levels for protection of human health and the environment. Promulgated MCLs or published action levels have been adopted as cleanup levels to protect human health due to groundwater ingestion (U.S. EPA, Region IX, 2000d).

Promulgated water quality criteria were applied to existing and planned freshwater surface bodies, and groundwater that recharges surface water or emerges as seeps. Existing surface water bodies at the Presidio include Mountain Lake, Crissy Field wetlands, and Lobos Creek. In addition, Tennessee Hollow and Dragonfly Creek are recognized surface water resources of the Presidio and will be treated as such in applying cleanup levels. Water quality criteria adopted as cleanup levels for surface water and groundwater that recharges surface water at the Presidio are intended to protect freshwater aquatic organisms, and humans who may drink the water and consume fish or other organisms inhabiting the water bodies from chronic exposure to PCOCs. Water quality criteria adopted as cleanup levels for freshwater seeps at the Presidio are intended to protect freshwater aquatic organisms from chronic exposure to PCOCs. Seeps observed at the Presidio are not considered potential habitat that would support fish or other organisms that could be consumed by humans. Water quality criteria used to establish surface water, groundwater recharge to surface water, and seep cleanup levels were obtained from the following references:

- RWQCB *Water Quality Control Plan, San Francisco Bay Basin* or Basin Plan, dated 21 June 1995.

- Title 40 CFR §131.38, *Establishment of Numerical Criteria for Priority Toxic Pollutants for the State of California* or CTR.

Table 7-6 presents cleanup level values for PCOCs in surface water, seeps, and groundwater. Groundwater cleanup level values for PCOCs in Table 7-6 are established as drinking water standards (i.e., MCLs or action levels) unless the site is located near a surface water body (e.g., Mountain Lake, Tennessee Hollow riparian corridor, Lobos Creek) or seep. For sites near surface water bodies, cleanup levels based on water quality criteria for protection of aquatic life or human health are applicable if they are more stringent than relevant MCL or action levels for the PCOC under consideration. For sites near seeps, cleanup levels are based on protection of aquatic life alone.

7.3.5 Site-Specific Cleanup Level Selection Process

Once a site is identified, site-specific cleanup levels for each media must be determined. The process for soil and sediment is presented first in Table 7-1, followed by the process for surface water, seeps and groundwater. The following discussion presents this process for soils and sediments followed by water. The cleanup level selection for Fill Site 1 is also provided as an example of the cleanup level selection process.

- For sites with soil, freshwater sediment, and/or marine sediment, the predominant lithology should be identified based on Figure 6-1 and lithologic logs for the site. For Fill Site 1, the soil lithology is Colma.

- Next, the planned human land use should be determined, as identified on Figure 7-1 and described in Section 7.1.1; for Fill Site 1 residential use is planned. The appropriate human land use and soil lithology columns should be used to select cleanup levels from Table 7-2.

- The site should be evaluated to determine if it is located in an area where buffer zone or special status ecological cleanup levels are applicable, based on Figure 7-2. In addition, NPS or Trust natural resource staff should be consulted to determine if special status species are present. For Fill Site 1, the site is located in an area with significant ecological habitat where special status species may be present. The combination of ecological land use, lithology, and media (soil, freshwater sediment, or marine sediment) is used to select the appropriate column of cleanup levels from Tables 7-2, 7-3, or 7-4. If no values are listed for special status species for the sediments, then the non-special status species values should be used.

- If petroleum hydrocarbons and related constituents are present, cleanup levels are presented on Table 7-5 that are specific to the various human land uses (which will correspond to the same land use from Table 7-2), ecological protection, and groundwater protection. The petroleum hydrocarbon standards are taken directly from Order No. 96-070, Site Cleanup Requirements (RWQCB, 1996). Where cleanup levels for petroleum related constituents, such as PAHs, are presented in both Tables 7-2 through 7-4 and in Table 7-5, the more stringent value should be used for the appropriate land use at a given site. At Fill Site 1, petroleum hydrocarbons and related constituents cleanup levels include the following columns on Table 7-5: protection of residential human health, protection of terrestrial ecological receptors, protection of freshwater aquatic organisms (since Fill Site 1 is with the Freshwater Ecological Protection Zone identified on Figure 7-2), and protection of groundwater resources to maintain drinking water standards in groundwater assuming soil is greater than five feet above groundwater.

- The cleanup level for each PCOC is the minimum cleanup level from the applicable columns of the applicable Tables 7-2 through 7-5. For example, cleanup levels at Fill Site 1 for arsenic, lead, benzo(a)pyrene, and total petroleum hydrocarbons as diesel

("TPHd") would be 6.2 mg/kg (based on Table 7-2), 160 mg/kg (based on Table 7-2), 0.027 mg/kg (based on Table 7-2), and 700 mg/kg (based on Table 7-5), respectively. Any chemical that has been detected at a site at a concentration greater than this minimum cleanup level is identified as a COC for soil or sediment.

The process of screening PCOCs in surface water, seeps and groundwater is similar to that described above for soil and sediment.

- Once the site and type of water resource are identified, the protection level for the water resource must be determined. The cleanup level for freshwater bodies should be used to protect freshwater aquatic organisms, and humans who may drink the water and consume fish or other organisms inhabiting the surface water body. The cleanup level for freshwater seeps should be used to protect only freshwater aquatic organisms within a freshwater seep. The cleanup level for drinking water should be used to protect use of surface water or groundwater as potable supply. The cleanup level for saltwater should protect saltwater aquatic organisms. In some cases, site-specific requirements will include the combination of more than one cleanup level to protection a variety of potential receptors. For Fill Site 1, cleanup levels should consider both protection of drinking water and freshwater aquatic organisms in the seeps.

- The PCOCs should be screened against the lowest water cleanup level. The cleanup level for each PCOC is the minimum cleanup level from the applicable columns of Table 7-6. Any chemical that has been detected at a site at a concentration greater than this minimum cleanup level is identified as a COC for water. Cleanup levels at Fill Site 1 for arsenic, lead, benzo(a)pyrene, and TPHd in groundwater would be 10 μg/L (based on MCLs), 3.2 μg/L (based on freshwater seep water quality criteria), 0.2 μg/L (based on MCLs, since there is no freshwater seep value), and 880 μg/L (based on FPALDR), respectively.

Once cleanup levels are identified, COCs can be determined, and appropriate remedial alternatives, if required, evaluated and selected. In addition, cleanup levels for any chemical, whether or not a PCOC, can be determined through the process described in this section.

7.3.6 Summary

In summary, this document can be used to identify PCOCs and COCs at Presidio sites, and to determine applicable cleanup levels for these chemicals. PCOCs include all organic chemicals detected at a site, assuming these are anthropogenic. In addition, inorganic chemicals detected in soil samples above screening levels identified in Table 6-5 are also included as PCOCs. The screening levels are based on the four main Presidio lithologies (serpentinite, Colma Formation, beach/dune, and chert/shale). The process outlined in Table 7-1 is used to identify the applicable cleanup levels. These cleanup levels are compared with site data to identify the chemicals that are considered COCs at a given site.

Cleanup levels derived from the process and tables presented in this document are intended to be applicable to all Presidio sites that do not have an existing regulatory agency-approved decision document. If new chemicals are identified at a site, the process used herein should be used to derive cleanup levels for those chemicals.

In addition, it is possible that the background metals concentrations developed in this document may not accurately reflect background conditions at all sites throughout the Presidio. If, for example, the Trust is having difficulty meeting cleanup levels during site remediation (when no other indicators for site contamination are present), the Trust may present supporting data to the DTSC and other stakeholders to determine if alternate background concentrations or lithologies may be appropriate for that site, or if other risk management measures should be considered. Similarly, the special status species PRGs developed in Section 5.10 were, in some cases, established as the method detection limit or other low concentration. As a practical matter, it may be difficult to achieve these cleanup levels during remediation. If such cases arise during remediation, the Trust may present the data to the DTSC and other stakeholders to determine alternate ecological cleanup levels at that time or other risk management measures.

TABLES

TABLE 7-1
STEPS TO IDENTIFY SITE-SPECIFIC CLEANUP LEVELS AT THE PRESIDIO

Presidio of San Francisco, California

	Evaluation Process Steps	Potential Parameters	References	Example
Soil and Sediment				
1	Identify Site	--	--	Fill Site 1
2	Identify Media	Soil, freshwater sediment, marine sediment	--	soil
3	Identify Predominant Lithology(ies)	Colma, Serpentinite, Beach/Dune, Chert/Shale	Site-specific lithologic logs, Figure 6-1	Colma
4	Identify Planned Human Land Use and Applicable Cleanup Levels	Residential, Recreational, Commercial/Industrial	Figure 7-1	Residential
5	Identify Applicable Ecological Cleanup Levels	None, buffer zone ecological ("ECO"), ecological special status	Figure 7-2 and NPS or Trust Natural Resource Staff (if ecological special status)	ECO special status
6	Identify Whether Petroleum Hydrocarbons and Related Constituents Present	Petroleum hydrocarbons, BTEX, and PAHs	List of chemicals detected at site	Petroleum hydrocarbons are present
7	If Petroleum Hydrocarbons and Related Constituents Present, Identify Resources to be Protected	Human health, terrestrial ecological receptors, freshwater or saltwater ecological protection zone, soil 5 feet above or below groundwater protected to drinking water standards, soil 5 feet above or below groundwater in Lobos Creek Basin, soil 5 feet above or below groundwater at Crissy Field	Figures 7-1 and 7-2, Table 7-5	Residential, ECO terrestrial, freshwater ECO protection zone, soil greater than 5 feet above groundwater (drinking water standard)
8	Screen Site Chemicals Based on Most Stringent Cleanup Levels from Applicable Tables	• Human Health and Ecological (Non-Petroleum, Soil)	Table 7-2	Colma, residential, ECO special status
		• Ecological (Non-Petroleum, Freshwater Sediment)	Table 7-3	--
		• Ecological (Non-Petroleum, Marine Sediment)	Table 7-4	--
		• Human Health and Ecological (Petroleum Hydrocarbons and Constituents, Soil and Sediment)	Table 7-5	Residential, ECO terrestrial and freshwater, soil >5 feet above groundwater (drinking water standard)

TABLE 7-1
STEPS TO IDENTIFY SITE-SPECIFIC CLEANUP LEVELS AT THE PRESIDIO

Presidio of San Francisco, California

Evaluation Process Steps	Potential Parameters	References	Example
Surface Water, Seeps, and Groundwater			
1 Identify Site	--	--	Fill Site 1
2 Determine Type of Water	Surface water, seep, groundwater; freshwater or marine	--	Groundwater and seeps
3 Determine Protection Level for Groundwater	Cleanup level to protect aquatic organisms and humans who potentially drink the water or consume fish or other species from surface water ("SW"); cleanup level to protect aquatic organisms in freshwater seep ("FW"); cleanup level to protect marine organisms ("M"); and cleanup level to protect use of water as potable supply ("DW").	Table 7-6	Potential drinking water and freshwater seeps immediately downstream of site
4 Screen Site Chemicals Based on Most Stringent Cleanup Levels from Applicable Table	SW, FW, M, DW	Table 7-6	DW and FW

TABLE 7-2
SUMMARY OF SELECTION OF PRELIMINARY REMEDIATION GOALS AND PROPOSED CLEANUP LEVELS FOR NON-PETROLEUM COMPOUNDS IN SOIL

Presidio of San Francisco, California

Potential Chemical of Concern	Ecological								Human Health			Lithology				Notes (f)
	Summary of Plant and Soil Fauna PRGs (mg/kg); (a)			Summary of Wildlife PRGs (mg/kg); (a)			Proposed Buffer Zone PRGs (mg/kg); (b)	Proposed Special Status PRGs (mg/kg); (c)	Proposed PRGs (mg/kg); (d)			Presidio Background Metals Concentrations by Lithology (mg/kg); (e)				
	PRG_{low}	PRG_{high}	Arithmetic Mean	PRG_{low}	PRG_{high}	Arithmetic Mean			Residential	Recreational	Comm/Ind.	Serpentinite	Colma	Beach/Dune	Chert/Shale	
Inorganic Chemicals																
Antimony	5	5	5	162	490	326	5	5	29	70	760	$3.0^{(DL)}$	$3.0^{(DL)}$	$3.0^{(DL)}$	$3.0^{(DL)}$	1
Arsenic	10	224	117	46	692	369	64 (g)	10	0.36	0.88	3.3	$5.4^{(95th)}$	$6.2^{(UCL95)}$	$5.9^{(UCL95)}$	$3.2^{(Max)}$	2
Barium	500	500	500	320	3,200	1,760	500	320	5,000	12,000	130,000	$230^{(95th)}$	$180^{(UCL95)}$	$120^{(UCL95)}$	$900^{(UCL95)}$	3
Beryllium	10	10	10	160	8,000	4,080	10	10	140	350	3,800	$1.1^{(Max)}$	$0.99^{(UCL95)}$	$0.89^{(UCL95)}$	$0.72^{(UCL95)}$	1
Cadmium	4	100	52	0.017	0.44	0.23	0.23	0.017	1.7	4.2	16	$1.9^{(Max)}$	$0.8^{(DL)}$	$1.7^{(Max)}$	$1.7^{(Max)}$	2
Chromium	5	200	103	4	42	23	23	4	1,200 (h)	2,800 (h)	11,000 (h)	$1,700^{(95th)}$	$140^{(UCL95)}$	$120^{(UCL95)}$	$41^{(UCL95)}$	2
Cobalt	20	75	48	220	3,300	1,760	48	20	4,000	10,000	110,000	$170^{(95th)}$	$21^{(UCL95)}$	$16^{(UCL95)}$	$37^{(UCL95)}$	3
Copper	50	400	225	30	200	115	120	30	- (i)	-	-	$85^{(95th)}$	$49^{(UCL95)}$	$43^{(UCL95)}$	$360^{(UCL95)}$	3
Cyanide	-	-	-	6,298	18,894	12,596	13,000	6,300	1,000	2,500	23,000	-	-	-	-	4
Lead (j)	-	-	-	-	-	-	300	160	400	500	3,500	$66^{(95th)}$	$7.5^{(UCL95)}$	$57^{(UCL95)}$	$45^{(Max)}$	1
Tetraethyl Lead	-	-	-	1.1	52	27	27	1.1	0.0052	0.013	0.11	-	-	-	-	4
Mercury	0.3	10	5.15	0.038	12	6	1.6 (g)	0.4 (k)	20	52	570	$0.2^{(DL)}$	$0.2^{(DL)}$	$0.2^{(DL)}$	$0.2^{(DL)}$	1
Molybdenum	-	-	-	11.5	582	297	300	12	360	870	9,400	$2.0^{(DL)}$	$2.0^{(DL)}$	$2.0^{(DL)}$	$2.0^{(DL)}$	1
Nickel	30	500	265	58	1,440	749	71 (g)	30	1,400	3,500	38,000	$4,500^{(95th)}$	$110^{(UCL95)}$	$70^{(UCL95)}$	$71^{(UCL95)}$	2
Selenium	1	70	35.5	0.20	2	1	1.1	0.2	360	870	9,400	$0.5^{(DL)}$	$0.5^{(DL)}$	$0.75^{(Max)}$	$0.5^{(DL)}$	1
Silver	2	2	2	6	144	75	2	2	360	870	9,400	$1.7^{(Max)}$	$1.0^{(DL)}$	$1.0^{(DL)}$	$1.0^{(DL)}$	1
Thallium	1	1	1	0.15	39	20	1	0.15	5.7	14	150	$1.0^{(DL)}$	$1.0^{(DL)}$	$1.0^{(DL)}$	$1.0^{(DL)}$	2
Vanadium	2	20	11	2	8	5	5	2	650	1,600	17,000	$74^{(95th)}$	$90^{(UCL95)}$	$92^{(UCL95)}$	$61^{(UCL95)}$	2
Zinc	50	864	457	4	97	51	50	4	22,000	52,000	570,000	$160^{(95th)}$	$60^{(UCL95)}$	$66^{(UCL95)}$	$120^{(UCL95)}$	2
Semivolatile Organic Compounds																
Acenaphthene	30	50	40	84	2,547	1,316	40	30	2,700	6,600	55,000	-	-	-	-	1
Acenaphthylene	30	50	40	84	2,547	1,316	40	30	-	-	-	-	-	-	-	1
Anthracene	30	50	40	84	2,547	1,316	40	30	14,000	33,000	280,000	-	-	-	-	1
Benzo(a)anthracene	30	50	40	84	2,547	1,316	40	30	0.27	0.65	2.3	-	-	-	-	4
Benzo(a)pyrene	30	50	40	84	2,547	1,316	40	30	0.027	0.065	0.23	-	-	-	-	4
Benzo(b)fluoranthene	30	50	40	84	2,547	1,316	40	30	0.27	0.65	2.3	-	-	-	-	4
Benzo(g,h,i)perylene	30	50	40	84	2,547	1,316	40	30	-	-	-	-	-	-	-	1
Benzo(k)fluoranthene	30	50	40	84	2,547	1,316	40	30	0.27	0.65	2.3	-	-	-	-	4
Benzyl Alcohol	-	-	-	1	164	83	40 (l)	1	14,000	38,000	280,000	-	-	-	-	1
Chrysene	30	50	40	84	2,547	1,316	40	30	2.7	6.5	23	-	-	-	-	4
Dibenzo(a,h)anthracene	30	50	40	84	2,547	1,316	40	30	0.078	0.19	0.67	-	-	-	-	4
Dibenzofuran	-	-	-	-	-	-	-	-	910	2,200	18,000	-	-	-	-	4
Fluoranthene	30	50	40	84	2,547	1,316	40	30	1,800	4,400	37,000	-	-	-	-	1
Fluorene	30	50	40	84	2,547	1,316	40	30	1,800	4,400	37,000	-	-	-	-	1

TABLE 7-2
SUMMARY OF SELECTION OF PRELIMINARY REMEDIATION GOALS AND PROPOSED CLEANUP LEVELS FOR NON-PETROLEUM COMPOUNDS IN SOIL

Presidio of San Francisco, California

Potential Chemical of Concern	Ecological								Human Health			Lithology				Notes (f)
	Summary of Plant and Soil Fauna PRGs (mg/kg); (a)			Summary of Wildlife PRGs (mg/kg); (a)			Proposed Buffer Zone PRGs (mg/kg); (b)	Proposed Special Status PRGs (mg/kg); (c)	Proposed PRGs (mg/kg); (d)			Presidio Background Metals Concentrations by Lithology (mg/kg); (e)				
	PRG_{low}	PRG_{high}	Arithmetic Mean	PRG_{low}	PRG_{high}	Arithmetic Mean			Residential	Recreational	Comm/Ind.	Serpentinite	Colma	Beach/Dune	Chert/Shale	
Semivolatile Organic Compounds																
Indeno(1,2,3-cd)pyrene	30	50	40	84	2,547	1,316	40	30	0.27	0.65	2.3	-	-	-	-	4
2-methylnaphthalene	30	50	40	84	2,547	1,316	40	30	-	-	-	-	-	-	-	1
4-methylphenol (p-Cresol)	50	50	50	11,167	55,782	33,474	50	50	260	640	5,600	-	-	-	-	1
Naphthalene	30	50	40	84	2,547	1,316	40	30	910	2,200	18,000	-	-	-	-	1
n-nitrosodiphenylamine	20	109	65	16,981	50,942	33,962	65	20	43	104	380	-	-	-	-	5
Pentachlorophenol	3	4	3.5	22	660	341	3.5	3	5	12	42	-	-	-	-	1
Phenanthrene	30	50	40	84	2,547	1,316	40	30	-	-	-	-	-	-	-	1
Phenol	30	188	109	2,547	7,641	5,094	109	30	27,000	76,000	550,000	-	-	-	-	1
Pyrene	30	50	40	84	2,547	1,316	40	30	1,400	3,300	28,000	-	-	-	-	1
Volatile Organic Compounds																
Acetone	-	-	-	8,490	127,356	67,923	68,000	8,500	0.24 (m)	0.24 (m)	0.24 (m)	-	-	-	-	4
2-butanone (MEK)	-	-	-	4,245	25,471	14,858	15,000	4,200	3.8 (m)	3.8 (m)	3.8 (m)	-	-	-	-	4
Carbon disulfide	-	-	-	934	28,018	14,476	14,000	934	200 (m)	200 (m)	200 (m)	-	-	-	-	4
1,4-dichlorobenzene	20	128	74	2,123	12,736	7,429	74	20	0.13 (m)	0.59 (m)	0.49 (m)	-	-	-	-	4
p-isopropyltoluene (p-cymene)	200 (n)	1,000 (n)	600 (n)	2,207 (n)	22,075 (n)	12,141 (n)	600 (n)	200 (n)	130 (m)	130 (m)	130 (m)	-	-	-	-	4
Methylene Chloride	-	-	-	459	34,377	17,418	17,000	459	0.076 (m)	0.076 (m)	0.076 (m)	-	-	-	-	4
1,2,3-trichlorobenzene (o)	20	115	67.5	-	-	-	68	20	15 (m)	15 (m)	15 (m)	-	-	-	-	4
1,2,4-trichlorobenzene	20	127	73.5	-	-	-	74	20	15 (m)	15 (m)	15 (m)	-	-	-	-	4
Trichlorofluoromethane	-	-	-	-	-	-	-	-	40 (m)	80 (m)	80 (m)	-	-	-	-	4
1,1,1-trichloroethane	-	-	-	9,679	1,451,858	730,768	730,000	9,700	8 (m)	8 (m)	8 (m)	-	-	-	-	4
PCBs, Pesticides, and Herbicides																
PCBs (Arochlor 1254)	40	240	140	0.010	0.45	0.23	0.23	*0.033*	0.16	0.39	1 (p)	-	-	-	-	1
Aldrin	-	-	-	0.0039	0.19	0.1	0.1	0.0039	0.029	0.07	0.26	-	-	-	-	5
alpha-BHC	-	-	-	0.062	9.8	4.9	2.4 (g)	0.062	0.18	0.44	1.6	-	-	-	-	5
beta-BHC	-	-	-	0.062	9.8	4.9	2.4 (g)	0.062	0.32	0.79	2.9	-	-	-	-	5
delta-BHC	-	-	-	0.062	9.8	4.9	2.4 (g)	0.062	0.18	0.44	1.6	-	-	-	-	5
Chlordane	-	-	-	0.0090	0.071	0.04	0.04	0.0090	0.37	0.91	3.4	-	-	-	-	1
2,4-D	-	-	-	-	-	-	5	*0.025*	620	1,500	15,000	-	-	-	-	1
Dicamba	-	-	-	-	-	-	5	*0.01*	1,800	4,500	44,000	-	-	-	-	1
4,4'-DDD	40	200	120	0.049	2.4	1.2	0.53 (g)	0.049	2.0	4.9	18	-	-	-	-	1
4,4'-DDE	40	200	120	0.098	2.4	1.3	0.61 (g)	0.098	1.4	3.5	13	-	-	-	-	1
4,4'-DDT	40	200	120	0.0082	2.4	1.2	0.53 (g)	0.0082	1.4	3.5	13	-	-	-	-	1
Dieldrin	50	100	75	0.039	0.48	0.26	0.26	0.039	0.030	0.074	0.27	-	-	-	-	5
Endosulfan	-	-	-	1.1	5.5	3.3	3.3	1.1	370	900	8,700	-	-	-	-	1
Endosulfan Sulfate (o)	-	-	-	1.1	5.5	3.3	3.3	1.1	370	900	8,700	-	-	-	-	1
Endrin	-	-	-	0.0035	0.50	0.25	0.11 (g)	*0.004*	18	45	440	-	-	-	-	1
Endrin Aldehyde (o)	-	-	-	0.0035	0.50	0.25	0.11 (g)	*0.004*	18	45	440	-	-	-	-	1
Endrin Ketone (o)	-	-	-	0.0035	0.50	0.25	0.11 (g)	*0.004*	18	45	440	-	-	-	-	1

TABLE 7-2
SUMMARY OF SELECTION OF PRELIMINARY REMEDIATION GOALS AND PROPOSED CLEANUP LEVELS FOR NON-PETROLEUM COMPOUNDS IN SOIL

Presidio of San Francisco, California

Potential Chemical of Concern	Ecological								Human Health			Lithology				Notes (f)
	Summary of Plant and Soil Fauna PRGs (mg/kg); (a)			Summary of Wildlife PRGs (mg/kg); (a)			Proposed Buffer Zone PRGs (mg/kg); (b)	Proposed Special Status PRGs (mg/kg); (c)	Proposed PRGs (mg/kg); (d)			Presidio Background Metals Concentrations by Lithology (mg/kg); (e)				
	PRG_{low}	PRG_{high}	Arithmetic Mean	PRG_{low}	PRG_{high}	Arithmetic Mean			Residential	Recreational	Comm/Ind.	Serpentinite	Colma	Beach/Dune	Chert/Shale	
PCBs, Pesticides, and Herbicides																
gamma-BHC (Lindane)	-	-	-	0.010	1.6	0.8	0.37 (g)	0.010	0.44	1.1	4.0	-	-	-	-	5
Heptachlor	-	-	-	0.017	7.4	3.7	3.7	0.017	0.12	0.29	1.1	-	-	-	-	5
Heptachlor Epoxide	-	-	-	0.017	7.4	3.7	3.7	0.017	0.088	0.21	0.79	-	-	-	-	5
Isodrin (o)	-	-	-	0.0039	0.19	0.1	0.1	0.0039	0.029	0.069	0.26	-	-	-	-	5
MCPP	-	-	-	-	-	-	-	*5.0*	-	-	-	-	-	-	-	1
Methoxychlor	-	-	-	0.44	35	18	18	0.44	310	750	7,300	-	-	-	-	1

Notes:

(a) Listed in these columns are the following: (1) the plant and soil fauna represent the low and high Preliminary Remediation Goals ("PRGs") from Tables 5-12 and 5-13; (2) the wildlife PRG_{low} represents the lowest of the wildlife PRG_{low} from Table 5-12; and (3) the wildlife PRG_{high} represents the lowest of the wildlife PRG_{high} from Table 5-13.

(b) The buffer zone PRG proposed for protection of non-special status species is the lowest of the arithmetic mean of plant and soil fauna PRGs, the arithmetic mean of wildlife PRGs, the special status PRGs identified in Table 5-21, or 5 mg/kg for pesticides or herbicides for which not enough toxicological data exist to calculate a PRG_{low} and PRG_{high} (e.g., 2,4-D, Dicamba, and MCPP).

(c) Values are proposed as soil PRGs for special status species. The special status PRG, as used in this document, is established as the PRG_{low}. *Italics* indicates that the laboratory detection limit exceeds the PRGlow, and thus is selected as the cleanup level. The laboratory detection limit is also used as the special status PRG for pesticides and herbicides for which not enough toxicological data exist to calculate ecological PRGs.

(d) The human health PRGs proposed for residential, recreational, and commercial/industrial land use are from Tables 4-3, 4-4, and 4-5, respectively. For VOCs, the human health PRGs are from Table 4-7.

(e) The following abbreviations are used in the Background Metals columns:
DL - Detection Limit: A typical detection limit is included when there were insufficient data to calculate a 95% upper confidence level ("UCL") of the 95th percentile (e.g., fewer than 50% detections).
Max: Maximum concentration detected in background samples of this lithology (threshold level when there are fewer than 50% detections).
95th: The concentration corresponding to the 95th percentile of the lognormal data distribution calculated for data sets with a frequency of detection greater than 50%. Applied to serpentinite only due to small number of data in background data set.
UCL95: The concentration corresponding to the 95% UCL of the 95th percentile of the lognormal data distribution.

(f) In general, the cleanup levels are the minimum of applicable buffer zone ecological, ecological special status, and human health values, above background concentrations. Unless otherwise noted, for a given site, only applicable columns would be used to select the appropriate cleanup level. For example, ecological cleanup levels would not be applied to a site that is classified as only recreational human land use.
1. Cleanup level governed by ecological values.
2. Cleanup level governed by background metals concentrations.
3. Cleanup level governed by ecological values or background metal concentration, depending on lithology.
4. Cleanup level governed by human health values.
5. Cleanup level governed by ecological values or human health values, depending on land use.

(g) For these chemicals, which have a large difference (greater than one order of magnitude) between PRG_{low} and PRG_{high}, alternate PRGs were developed for special status species ("Alternate PRGs"). As discussed in note (c), special status values were ultimately established as the PRG_{low}. For the chemicals indicated, the Alternate PRG was subsequently established as the Buffer Zone PRG, in lieu of the arithmetic mean PRG.

(h) The cleanup levels for chromium are based on the assumption that chromium (VI) comprises up to 0.28 percent of the total chromium in serpentinite at the Presidio (Montgomery Watson, 1999a).

(i) Hyphen indicates that PRG could not be calculated due to lack of applicable toxicity data in available literature, or no value is appropriate.

(j) Ecological PRGs for lead were calculated through use of the Monte Carlo method. The residential cleanup level for lead in soil has been established as a not-to-exceed value of 400 mg/kg, based on chemical-specific ARARs and a maximum average concentration of 370 mg/kg, based on the site-specific PRG. Refer to text for discussion of methodology used to derive the ecological and human health PRGs for lead.

(k) Mercury level for special status species is based on risk management concerns and is established at 2 times the typical method detection limit.

(l) For benzyl alcohol, the buffer zone PRG was decreased from the wildlife arithmetic mean PRG to be more in line with the other semivolatile organic compounds.

TABLE 7-2
SUMMARY OF SELECTION OF PRELIMINARY REMEDIATION GOALS AND PROPOSED CLEANUP LEVELS FOR NON-PETROLEUM COMPOUNDS IN SOIL

Presidio of San Francisco, California

Notes (continued):

(m) For VOCs, human health cleanup levels were calculated using the more stringent of Risk-based Screening Levels based on the protection of groundwater quality, direct contact with soil, or vapor intrusion of VOCs into indoor air. The calculations are described in Section 4.2.9 of this document.

(n) For ecological PRGs only, toluene was used as a surrogate for isopropyltoluene.

(o) For human health PRGs only, values for for 1,2,4-trichlorobenzene were used for 1,2,3-trichlorobenzene. For all PRGs, values for Endosulfan were used for Endosulfan Sulfate, values for Endrin were used for Endrin Aldehyde and Endrin Ketone. Isodrin is an isomer of Aldrin; for all PRGs values for Aldrin were used for Isodrin.

(p) Human health cleanup level of 1 mg/kg for polychlorinated biphenyls in soil obtained from Title 40 of the Code of Federal Regulations §761.61 to Subpart D of Toxic Substances Control Act ("TSCA"). Human health PRGs for PCBs in soil in commercial/industrial land use calculated with the same assumptions as the other chemicals is 1.4 mg/kg, as shown in Table 4-5. The TSCA value of 1 mg/kg is considered protective of human health and conservative, as it corresponds to an estimated lifetime incremental cancer risks of $7x10^{-7}$, which is below U.S. EPA's acceptable risk range of 10^{-4} to 10^{-6}.

TABLE 7-3
ECOLOGICAL CLEANUP LEVELS FOR NON-PETROLEUM COMPOUNDS IN SEDIMENT AT THE PRESIDIO OF SAN FRANCISCO (FRESHWATER)

Presidio of San Francisco, California

Potential Chemical of Concern	Buffer Zone Ecological Cleanup Level (mg/kg)				Special Status Species Cleanup Level (mg/kg); (a)			
	Serpentinite	Colma	Beach/Dune	Chert/Shale	Serpentinite	Colma	Beach/Dune	Chert/Shale
Inorganic Chemicals								
Antimony	3.0 (b)	3.0 (b)	3.0 (b)	3.0 (b)				
Arsenic	19	19	19	19				
Barium	3,100	3,100	3,100	3,100				
Beryllium	7,200	7,200	7,200	7,200				
Cadmium	1.9 (c)	1.1	1.7 (c)	1.7 (c)				
Chromium	1,700 (c)	140 (c)	120 (c)	42				
Cobalt	170 (c)	50	50	50				
Copper	114	114	114	360 (c)				
Cyanide	- (d)	-	-	-				
Lead	82	82	82	82				
Tetraethyl Lead	86	86	86	86				
Mercury	0.62	0.62	0.62	0.62				
Molybdenum	522	522	522	522				
Nickel	4,500 (c)	110 (c)	70 (c)	71 (c)				
Selenium	4.5	4.5	4.5	4.5	1.6	1.6	1.6	1.6
Silver	1.7 (c)	1.0 (c)	1.0 (c)	1.0 (c)				
Thallium	35	35	35	35	3.7	3.7	3.7	3.7
Vanadium	74 (c)	90 (c)	92 (c)	61 (c)				
Zinc	230	230	230	230				

TABLE 7-3
ECOLOGICAL CLEANUP LEVELS FOR NON-PETROLEUM COMPOUNDS IN SEDIMENT AT THE PRESIDIO OF SAN FRANCISCO (FRESHWATER)

Presidio of San Francisco, California

Potential Chemical of Concern	Buffer Zone Ecological Cleanup Level (mg/kg)				Special Status Species Cleanup Level (mg/kg); (a)			
	Serpentinite	Colma	Beach/Dune	Chert/Shale	Serpentinite	Colma	Beach/Dune	Chert/Shale
Semivolatile Organic Compounds								
Acenaphthene	0.31	0.31	0.31	0.31				
Acenaphthylene	0.067	0.067	0.067	0.067				
Anthracene	0.45	0.45	0.45	0.45				
Benzo(a)anthracene	0.54	0.54	0.54	0.54				
Benzo(a)pyrene	0.74	0.74	0.74	0.74				
Benzo(b)fluoranthene	0.79	0.79	0.79	0.79				
Benzo(g,h,i)perylene	0.25	0.25	0.25	0.25				
Benzo(k)fluoranthene	0.79	0.79	0.79	0.79				
Benzyl Alcohol	140	140	140	140				
Chrysene	0.67	0.67	0.67	0.67				
Dibenzo(a,h)anthrancene	0.071	0.071	0.071	0.071				
Dibenzofuran	2	2	2	2				
Fluoranthene	1.5	1.5	1.5	1.5				
Fluorene	0.28	0.28	0.28	0.28				
Indeno(1,2,3-cd)pyrene	0.26	0.26	0.26	0.26				
2-methylnaphthalene	0.11	0.11	0.11	0.11				
4-methylphenol (p-Cresol)	-	-	-	-				
Naphthalene	0.3	0.3	0.3	0.3				
n-nitrosodiphenylamine	-	-	-	-				
Pentachlorophenol	-	-	-	-				
Phenanthrene	0.61	0.61	0.61	0.61				
Phenol	-	-	-	-				
Pyrene	0.79	0.79	0.79	0.79				

TABLE 7-3
ECOLOGICAL CLEANUP LEVELS FOR NON-PETROLEUM COMPOUNDS IN SEDIMENT AT THE PRESIDIO OF SAN FRANCISCO (FRESHWATER)

Presidio of San Francisco, California

Potential Chemical of Concern	Buffer Zone Ecological Cleanup Level (mg/kg)				Special Status Species Cleanup Level (mg/kg); (a)			
	Serpentinite	Colma	Beach/Dune	Chert/Shale	Serpentinite	Colma	Beach/Dune	Chert/Shale
Volatile Organic Compounds								
Acetone	-	-	-	-				
2-Butanone (MEK)	-	-	-	-				
Carbon disulfide	-	-	-	-				
1,4-dichlorobenzene	0.35	0.35	0.35	0.35				
p-Isopropyltoluene (p-cymene)	-	-	-	-				
Methylene Chloride	-	-	-	-				
1,2,3-trichlorobenzene	-	-	-	-				
1,2,4-trichlorobenzene	-	-	-	-				
Trichlorfluoromethane	-	-	-	-				
1,1,1-trichloroethane	0.17	0.17	0.17	0.17				
PCBs, Pesticides, and Herbicides								
PCBs (Arochlor 1254)	0.36	0.36	0.36	0.36	0.14	0.14	0.14	0.14
Aldrin	0.005	0.005	0.005	0.005				
alpha-BHC	0.008	0.008	0.008	0.008				
beta-BHC	0.013	0.013	0.013	0.013				
delta-BHC	0.0075	0.0075	0.0075	0.0075				
Chlordane	0.01	0.010	0.01	0.01				
2,4-D	-	-	-	-				
Dicamba	-	-	-	-				
4,4'-DDD	0.016	0.016	0.016	0.016				
4,4'-DDE	0.016	0.016	0.016	0.016				
4,4'-DDT	0.032	0.032	0.032	0.032				
Dieldrin	0.032	0.032	0.032	0.032				
Endosulfan	0.0054	0.0054	0.0054	0.0054				
Endosulfan Sulfate	0.0054	0.0054	0.0054	0.0054				

TABLE 7-3
ECOLOGICAL CLEANUP LEVELS FOR NON-PETROLEUM COMPOUNDS IN SEDIMENT AT THE PRESIDIO OF SAN FRANCISCO (FRESHWATER)

Presidio of San Francisco, California

Potential Chemical of Concern	Buffer Zone Ecological Cleanup Level (mg/kg)				Special Status Species Cleanup Level (mg/kg); (a)			
	Serpentinite	Colma	Beach/Dune	Chert/Shale	Serpentinite	Colma	Beach/Dune	Chert/Shale
PCBs, Pesticides, and Herbicides (cont.)								
Endrin	0.1	0.1	0.1	0.1				
Endrin Aldehyde	0.1	0.1	0.1	0.1				
Endrin Ketone	0.1	0.1	0.1	0.1				
gamma-BHC (Lindane)	0.003	0.003	0.003	0.003				
Heptachlor	0.0083	0.0083	0.0083	0.0083				
Heptachlor Epoxide	0.0083	0.0083	0.0083	0.0083				
Isodrin	0.005	0.005	0.005	0.005				
MCPP	-	-	-	-				
Methoxychlor	0.019	0.019	0.019	0.019				

Notes:

(a) Buffer zone ecological cleanup levels apply to special status species as well if no special status species cleanup level is listed for a potential chemical of concern ("PCOC").

(b) Cleanup level for this compound and this lithology is based on the background level in soil. Background level for this compound and this lithology is derived from the typical detection limit.

(c) Cleanup level for this compound and this lithology is based on the background level in soil.

(d) Hyphen indicates that a cleanup level cannot be calculated. No published toxicity values for PCOC were found.

TABLE 7-4
ECOLOGICAL CLEANUP LEVELS FOR NON-PETROLEUM COMPOUNDS IN SEDIMENT AT THE PRESIDIO OF SAN FRANCISCO (MARINE)

Presidio of San Francisco, California

Potential Chemical of Concern	Buffer Zone Ecological Cleanup Level (mg/kg)				Special Status Species Cleanup Level (mg/kg); (a)			
	Serpentinite	Colma	Beach/Dune	Chert/Shale	Serpentinite	Colma	Beach/Dune	Chert/Shale
Inorganic Chemicals								
Antimony	14	14	14	14				
Arsenic	39	39	39	39				
Barium	3,100	3,100	3,100	3,100				
Beryllium	7,200	7,200	7,200	7,200				
Cadmium	1.9 (c)	1.6	1.7 (c)	1.7 (c)				
Chromium	1,700 (c)	140 (c)	120 (c)	42				
Cobalt	38,088	38,088	38,088	38,088				
Copper	152	152	152	152				
Cyanide	- (b)	-	-	-				
Lead	132	132	132	132				
Tetraethyl Lead	86	86	86	86				
Mercury	0.43	0.43	0.43	0.43				
Molybdenum	522	522	522	522				
Nickel	4,500 (c)	110 (c)	70 (c)	71 (c)				
Selenium	4.5	4.5	4.5	4.5	1.6	1.6	1.6	1.6
Silver	2.4	2.4	2.4	2.4				
Thallium	35	35	35	35	3.7	3.7	3.7	3.7
Vanadium	74 (c)	90 (c)	92 (c)	61 (c)				
Zinc	214	214	214	214				

TABLE 7-4
ECOLOGICAL CLEANUP LEVELS FOR NON-PETROLEUM COMPOUNDS IN SEDIMENT AT THE PRESIDIO OF SAN FRANCISCO (MARINE)

Presidio of San Francisco, California

Potential Chemical of Concern	Buffer Zone Ecological Cleanup Level (mg/kg)				Special Status Species Cleanup Level (mg/kg); (a)			
	Serpentinite	Colma	Beach/Dune	Chert/Shale	Serpentinite	Colma	Beach/Dune	Chert/Shale
Semivolatile Organic Compounds								
Acenaphthene	0.32	0.32	0.32	0.32				
Acenaphthylene	0.34	0.34	0.34	0.34				
Anthracene	0.59	0.59	0.59	0.59				
Benzo(a)anthracene	0.93	0.93	0.93	0.93				
Benzo(a)pyrene	1.0	1.0	1.0	1.0				
Benzo(b)fluoranthene	-	-	-	-				
Benzo(g,h,i)perylene	-	-	-	-				
Benzo(k)fluoranthene	-	-	-	-				
Benzyl Alcohol	145	145	145	145				
Chrysene	1.6	1.6	1.6	1.6				
Dibenzo(a,h)anthrancene	0.16	0.16	0.16	0.16				
Dibenzofuran	2.00	2.00	2.00	2.00				
Fluoranthene	2.85	2.85	2.85	2.85				
Fluorene	0.28	0.28	0.28	0.28				
Indeno(1,2,3-cd)pyrene	-	-	-	-				
2-methylnaphthalene	0.37	0.37	0.37	0.37				
4-methylphenol (p-Cresol)	-	-	-	-				
Naphthalene	1.1	1.1	1.1	1.1				
n-nitrosodiphenylamine	-	-	-	-				
Pentachlorophenol	-	-	-	-				
Phenanthrene	0.87	0.87	0.87	0.87				
Phenol	-	-	-	-				
Pyrene	1.6	1.6	1.6	1.6				

TABLE 7-4
ECOLOGICAL CLEANUP LEVELS FOR NON-PETROLEUM COMPOUNDS IN SEDIMENT AT THE PRESIDIO OF SAN FRANCISCO (MARINE)

Presidio of San Francisco, California

Potential Chemical of Concern	Buffer Zone Ecological Cleanup Level (mg/kg)				Special Status Species Cleanup Level (mg/kg); (a)			
	Serpentinite	Colma	Beach/Dune	Chert/Shale	Serpentinite	Colma	Beach/Dune	Chert/Shale
Volatile Organic Compounds								
Acetone	-	-	-	-				
2-Butanone (MEK)	-	-	-	-				
Carbon disulfide	-	-	-	-				
1,4-dichlorobenzene	0.35	0.35	0.35	0.35				
p-Isopropyltoluene (p-cymene) (d)	0.67	0.67	0.67	0.67				
Methylene Chloride	-	-	-	-				
1,2,3-trichlorobenzene (e)	9.2	9.2	9.2	9.2				
1,2,4-trichlorobenzene	9.2	9.2	9.2	9.2				
Methylene Chloride	-	-	-	-				
Trichlorfluoromethane	-	-	-	-				
1,1,1-trichloroethane	0.17	0.17	0.17	0.17				
PCBs, Pesticides, and Herbicides								
PCBs (Arochlor 1254)	0.10	0.10	0.10	0.10				
Aldrin	0.46	0.46	0.46	0.46	0.10	0.10	0.10	0.10
alpha-BHC	0.0007	0.0007	0.0007	0.0007				
beta-BHC	0.0007	0.0007	0.0007	0.0007				
delta-BHC	0.0007	0.0007	0.0007	0.0007				
Chlordane	0.0033	0.0033	0.0033	0.0033				
2,4-D	-	-	-	-				
Dicamba	-	-	-	-				
4,4'-DDD	0.011	0.011	0.011	0.011				
4,4'-DDE	0.015	0.015	0.015	0.015				
4,4'-DDT	0.004	0.004	0.004	0.004				
Dieldrin	0.026	0.026	0.026	0.026				
Endosulfan	0.005	0.005	0.005	0.005				
Endosulfan Sulfate	0.005	0.005	0.005	0.005				

TABLE 7-4
ECOLOGICAL CLEANUP LEVELS FOR NON-PETROLEUM COMPOUNDS IN SEDIMENT AT THE PRESIDIO OF SAN FRANCISCO (MARINE)

Presidio of San Francisco, California

Potential Chemical of Concern	Buffer Zone Ecological Cleanup Level (mg/kg)				Special Status Species Cleanup Level (mg/kg); (a)			
	Serpentinite	Colma	Beach/Dune	Chert/Shale	Serpentinite	Colma	Beach/Dune	Chert/Shale
PCBs, Pesticides, and Herbicides (cont.)								
Endrin	0.023	0.023	0.023	0.023				
Endrin Aldehyde	0.023	0.023	0.023	0.023				
Endrin Ketone	0.023	0.023	0.023	0.023				
gamma-BHC (Lindane)	0.002	0.002	0.002	0.002				
Heptachlor	437	437	437	437	44	44	44	44
Heptachlor Epoxide	437	437	437	437	44	44	44	44
Isodrin	0.457	0.457	0.457	0.457	0.10	0.10	0.10	0.10
MCPP	-	-	-	-				
Methoxychlor	0.019	0.019	0.019	0.019				

Notes:

(a) Buffer zone ecological cleanup levels apply to special status species as well if no special status species cleanup level is listed for a potential chemical of concern ("PCOC").

(b) Hyphen indicates that a cleanup level cannot be calculated. No published toxicity values for PCOC were found.

(c) Cleanup level for this compound and this lithology is based on the background level in soil.

(d) Values for toluene were used for isopropyltoluene.

(e) Values for 1,2,4-trichlorobenzene were used for 1,2,3-trichlorobenzene.

TABLE 7-5
HUMAN HEALTH AND ECOLOGICAL CLEANUP LEVELS FOR PETROLEUM HYDROCARBONS AND CONSTITUENTS IN SOIL AND SEDIMENT AT THE PRESIDIO OF SAN FRANCISCO

Presidio of San Francisco, California

Potential Chemical of Concern	Protection of Human Health			Protection of Ecological Receptors			Protection of Groundwater Resources					
							Cleanup Level for Soil to Maintain Drinking Water Standard in Groundwater		Cleanup Level for Soil to Maintain Non-detectable Concentration in Groundwater in Lobos Creek Basin		Cleanup Level for Soil at Crissy Field	
	Residential (mg/kg); (a)	Recreational (mg/kg); (a)	Maintenance (mg/kg); (a)	Terrestrial Receptors (mg/kg); (a)	Freshwater Aquatic Organisms (mg/kg); (b)	Saltwater Aquatic Organisms (mg/kg); (c)	Less than 5 feet Above Groundwater (mg/kg); (a)	Greater than 5 feet Above Groundwater (mg/kg); (a)	Less than 5 feet Above Groundwater (mg/kg); (a)	Greater than 5 feet Above Groundwater (mg/kg); (a)	Less than 5 feet Above Groundwater (mg/kg); (a)	Greater than 5 feet Above Groundwater (mg/kg); (a)
Inorganic Chemicals												
Lead	-	-	-	50 (d)	-	-	-	-	-	-	-	-
Semivolatile Organic Compounds												
Anthracene	5,900	13,800	17,800	-	-	-	308	-	0.05	-	1,120	-
Benzo(a)anthracene	0.43	1	1.5	-	-	-	8	-	0.2	-	23	-
Benzo(a)pyrene	0.04	0.1	0.15	0.3	-	-	3	-	0.8	-	9	-
Benzo(b)fluoranthene	0.43	1	1.5	-	-	-	23	-	0.6	-	64	-
Benzo(g,h,i)perylene	620	1,400	1,700	-	-	-	5,040	-	2	-	19,500	-
Benzo(k)fluoranthene	0.43	1	1.5	-	-	-	23	-	0.6	-	64	-
Chrysene	4.3	10	15	-	-	-	54	-	0.3	-	151	-
Fluoranthene	820	1,900	2,300	-	-	-	316	-	0.05	-	1,160	-
Fluorene	770	1,800	2,300	-	-	-	60	-	0.05	-	220	-
Naphthalene	480	1,100	2,300	-	-	-	9	-	0.05	-	140	-
Phenanthrene	600	1,400	1,700	-	-	-	86	-	0.05	-	410	-
Total Carcinogenic PAHs	5.6	13	19.7	-	-	-	111	-	2.5	-	253	-
Pyrene	620	1,400	1,700	-	-	-	241	-	0.09	-	910	-
Petroleum Hydrocarbons and Constituents												
TPH (as diesel); (e)	1,380	3,200	6,700	700	144 (f); (g)	144 (f)	115	15,000	7	15,000	1,950	15,000
TPH (as gasoline)	1,030	2,400	5,900	610	140	11.6	100	5,000	7	5,000	1,690	5,000
TPH (as fuel oil) (h)	1,900	4,500	9,400	980	144 (g)	144	160	15,000	10	15,000	2,730	15,000
Benzene	0.6	1.5	5	40	0.79	50	0.005	140	0.005	140	1	140
Ethylbenzene	840	1,900	6,600	125	15	5	13	60	0.009	60	19	60
Toluene	530	1,200	12,800	270	3	260	1	420	0.005	420	14	420
Total Xylenes	1,080	2,500	109,000	55	5.7	22	33	180	0.009	180	4,340	180

TABLE 7-5
HUMAN HEALTH AND ECOLOGICAL CLEANUP LEVELS FOR PETROLEUM HYDROCARBONS AND CONSTITUENTS IN SOIL AND SEDIMENT AT THE PRESIDIO OF SAN FRANCISCO

Presidio of San Francisco, California

Notes:

(a) Cleanup level values listed are obtained from Tables 1 through 5 of California Environmental Protection Agency, Regional Water Quality Control Board, San Francisco Bay Region Order No. 96-070, *Site Cleanup Requirements for the Cleanup of Petroleum Impacted Soils, U.S. Army, Presidio of San Francisco, California*, dated 15 May 1996.

(b) Cleanup level values listed are point-of-compliance concentrations for freshwater sediment obtained from Tables 5 and 6 of Montgomery Watson *Development of Point of Compliance Concentrations (POCCs) for Gasoline in Surface Waters and Sediments of the Proposed Freshwater Stream,* dated May 1999. Locations apply to Freshwater Ecological Protection Zones shown on Figure 7-2.

(c) Cleanup level values listed are point-of-compliance concentrations for saltwater sediment obtained from Table 16 of International Technology Corporation *Report of Petroleum Hydrocarbon Bioassay and Point-of-Compliance Concentration Determinations Saltwater Ecological Protection Zone, Presidio of San Francisco,* dated December 1997. Locations apply to Saltwater Ecological Protection Zones shown on Figure 7-2.

(d) According to Order No. 96-070, the value for lead applies only to cleanup of leaded gasoline releases and not from releases from other sources. Order No. 96-070 states that an alternative cleanup level can be derived for protection of ecological receptors from releases of lead other than leaded gasoline. Refer to Tables 7-2 through 7-4 for ecological cleanup level values that apply to releases of lead not from leaded gasoline.

(e) Total petroleum hydrocarbons ("TPH").

(f) Although value is derived for fuel oil, adoption of this cleanup level for TPH (as diesel) has been tentatively approved by RWQCB.

(g) Although value is derived for saltwater aquatic organisms, this cleanup level is also being used for freshwater organisms.

(h) These values also apply to TPH quantified as motor oil.

›le 3.2 Recommended Point of Compliance Concentrat" (POCCs) for the Freshwater Ecological Protection Zo
Presidio of . .n Francisco
San Francisco, California

Site Designations	TPH-gasoline		TPH-diesel		TPH-fuel oil	
	Soil mg/kg	Water µg/L	Soil mg/kg	Water µg/L	Soil mg/kg	Water µg/L
Building 207/231 CAP Area	11.6	443	144 (115)[a]	443	144	443
Fill Site 6A	11.6	443	144 (115)[a]	443	144	443
Building 1065 CAP Area	TBD[b]	TBD[b]	TBD[b]	TBD[b]	TBD[b]	TBD[b]
Fill Site 6B	TBD[b]	TBD[b]	TBD[b]	TBD[b]	TBD[b]	TBD[b]
Inside FEPZ Zone and Other Areas Within FEPZ Zone of Application	140 (100)[a]	443	140 (115)	443	140	443
Other Areas Outside of FEPZ Zone of Application[c]	see SCRs	770	see SCRs	880	see SCRs	1,200

TPH	Total petroleum hydrcarbons.
µg/L	Micrograms per liter.
mg/kg	Milligrams per kilogram.
FEPZ	Freshwater ecological protection zone.
SCR	Site Cleanup Requirement.
TBD	To be determined.

Notes:

POCCs adopted from existing POCCs presented in the FPALDR (1995) and RWQCB Order R2-2003-0080 (2003).

[a] Cleanup level shown in parentheses applies if depth to groundwater from TPH contamination in soil is less than 5 feet.

[b] For the Building 1065 CAP Area and Fill Site 6B, the POCCs for the Building 207/231 CAP Area will be used as interim screening levels for the freshwater zone until site-specific POCCs are selected.

[c] POCCs will not apply to areas outside of the FEPZ zone of application. Soil cleanup levels for these areas are based on the SCRs from RWQCB Order R2-2003-0080 (which include SCRs for human health, ecological terrestrial, and groundwater protection). Water cleanup levels for these areas will be drinking water levels.

TABLE 7-6
CLEANUP LEVELS FOR SURFACE WATER, SEEPS, AND GROUNDWATER AT THE PRESIDIO OF SAN FRANCISCO

Presidio of San Francisco, California

Potential Chemical of Concern	Water Quality Criteria									
							Drinking Water Cleanup Level (d);(e) (µg/L)			
	Surface Water (a) (µg/L)	Reference	Freshwater Seep (b) (µg/L)	Reference	Salt Water (c) (µg/L)	Reference	Background Levels	Reference	MCLs or Risk-Based Drinking Water Standards	Reference
Inorganic Chemicals										
Antimony	14	CTR (f)	- (g)	-	-	-	-	-	6	Federal MCL
Arsenic	150 (h, i)	Basin Plan (j)	150 (h, i)	Basin Plan	36 (h, i)	Basin Plan	-	-	10	Federal MCL
Barium	-	-	-	-	-	-	-	-	1,000	California MCL
Beryllium	-	-	-	-	-	-	-	-	4	Federal MCL
Cadmium	1.1 (h, k)	Basin Plan	1.1 (h, k)	Basin Plan	9.3 (h, i)	Basin Plan	-	-	5	Federal MCL
Chloride	-	-	-	-	-	-	-	-	250,000 (l)	Secondary MCL
Chromium (III)	180 (i, k)	NTR (m)	180 (i, k)	NTR	-	-	-	-	50	California MCL
Hexavalent Chromium	11 (h, i)	Basin Plan	11 (h, i)	Basin Plan	50 (h, i)	Basin Plan	-	-	-	-
Chromium (Total)	180 (i, k)	CTR	180 (i, k)	CTR	50 (i)	Basin Plan	-	-	50	California MCL
Cobalt	-	-	-	-	-	-	-	-	-	-
Copper	9.0 (h, i, k)	Basin Plan	9.0 (h, i, k)	Basin Plan	3.1 (h, i)	CTR	-	-	1,000	Secondary MCL
Cyanide	5.2	NTR	5.2	NTR	1	NTR	-	-	150	California MCL
Lead	2.5 (h, i, k)	Basin Plan	2.5 (h, i, k)	Basin Plan	8.1 (h, i)	Basin Plan	-	-	15 (n)	Federal MCL
Mercury	0.012 (o)	Basin Plan	0.012 (o)	Basin Plan	0.025	Basin Plan	-	-	2	Federal MCL
Molybdenum	-	-	-	-	-	-	-	-	-	-
Nickel	52 (h, i, k)	Basin Plan	52 (h, i, k)	Basin Plan	8.2 (h, i)	Basin Plan	-	-	100	California MCL
Selenium	5	NTR	5	NTR	71 (i)	NTR	-	-	50	Federal MCL
Silver	3.4 (h, i, k)	Basin Plan	3.4 (h, i, k)	Basin Plan	1.9 (h, i)	Basin Plan	-	-	50	Basin Plan
Thallium	1.7	CTR	-	-	-	-	-	-	2	Federal MCL
Vanadium	-	-	-	-	-	-	-	-	-	-
Zinc	120 (h, i, k)	Basin Plan	120 (h, i, k)	Basin Plan	81 (h, i)	Basin Plan	-	-	5,000	Secondary MCL

TABLE 7-6
CLEANUP LEVELS FOR SURFACE WATER, SEEPS, AND GROUNDWATER AT THE PRESIDIO OF SAN FRANCISCO

Presidio of San Francisco, California

Potential Chemical of Concern	Water Quality Criteria									
							Drinking Water Cleanup Level (d);(e) (µg/L)			
	Surface Water (a) (µg/L)	Reference	Freshwater Seep (b) (µg/L)	Reference	Salt Water (c) (µg/L)	Reference	Background Levels	Reference	MCLs or Risk-Based Drinking Water Standards	Reference
Semivolatile Organic Compounds										
Acenaphthene	1,200	CTR	-	-	-	-	-	-	-	-
Acenaphthylene	-	-	-	-	-	-	-	-	-	-
Anthracene	9,600	CTR	-	-	-	-	0.05	FPALDR	770	FPALDR (p)
Benzo(a)anthracene	0.0044 (q)	CTR	-	-	-	-	0.05	FPALDR	0.1	Proposed MCL
Benzo(a)pyrene	0.0044 (q)	CTR	-	-	-	-	0.05	FPALDR	0.2	Federal MCL
Benzo(b)fluoranthene	0.0044 (q)	CTR	-	-	-	-	0.05	FPALDR	0.2	Proposed MCL
Benzo(g,h,i)perylene	-	-	-	-	-	-	0.06	FPALDR	150	FPALDR
Benzo(k)fluoranthene	0.0044 (q)	CTR	-	-	-	-	0.05	FPALDR	2	FPALDR
Benzyl Alcohol	-	-	-	-	-	-	-	-	-	-
Bis(2-ethylhexyl)phthalate	1.8	CTR	-	-	-	-	-	-	4	California MCL
Chrysene	0.0044 (q)	CTR	-	-	-	-	0.05	FPALDR	20	FPALDR
Dibenzo(a,h)anthracene	0.0044 (q)	CTR	-	-	-	-	-	-	-	-
Dibenzofuran	-	-	-	-	-	-	-	-	-	-
Fluoranthene	300	CTR	-	-	-	-	0.06	FPALDR	300	FPALDR
Fluorene	1,300	CTR	-	-	-	-	0.05	FPALDR	300	FPALDR
Indeno(1,2,3-c,d)-pyrene	0.0044 (q)	CTR	-	-	-	-	-	-	-	-
2-methylnaphthalene	-	-	-	-	-	-	-	-	-	-
2-methylphenol (o-Cresol)	-	-	-	-	-	-	-	-	-	-
Methylphenol (m- and p-Cresol)	-	-	-	-	-	-	-	-	-	-
Naphthalene	-	-	-	-	-	-	0.05	FPALDR	300	FPALDR

TABLE 7-6
CLEANUP LEVELS FOR SURFACE WATER, SEEPS, AND GROUNDWATER AT THE PRESIDIO OF SAN FRANCISCO

Presidio of San Francisco, California

Potential Chemical of Concern	Water Quality Criteria									
							Drinking Water Cleanup Level (d);(e) (µg/L)			
	Surface Water (a) (µg/L)	Reference	Freshwater Seep (b) (µg/L)	Reference	Salt Water (c) (µg/L)	Reference	Background Levels	Reference	MCLs or Risk-Based Drinking Water Standards	Reference
Semivolatile Organic Compounds (contd)										
n-dotriacontane	-	-	-	-	-	-	-	-	-	-
n-hentriacontane	-	-	-	-	-	-	-	-	-	-
n-nitrosodiphenylamine	5	CTR	-	-	-	-	-	-	-	-
n-triacontane	-	-	-	-	-	-	-	-	-	-
Pentachlorophenol	0.28	CTR	15	CTR	7.9	CTR	-	-	1	Federal MCL
Phenanthrene	-	-	-	-	-	-	0.05	FPALDR	230	FPALDR
Phenol	21,000	CTR	-	-	-	-	-	-	1	Basin Plan
Polycyclic Aromatic Hydrocarbons	0.031 (q)	Basin Plan	-	-	0.031 (q)	Basin Plan	-	-	26 (r)	FPALDR
Pyrene	960	CTR	-	-			0.09	FPALDR	230	FPALDR
Volatile Organic Compounds										
Acetone	-	-	-	-	-	-	-	-	-	-
Bromodichloromethane	0.56	CTR	-	-	-	-	-	-	80	Federal MCL
2-Butanone (MEK)	-	-	-	-	-	-	-	-	-	-
Carbon Disulfide	-	-	-	-	-	-	-	-	-	-
Carbon Tetrachloride	0.25	CTR	-	-	-	-	-	-	0.5	California MCL
Chlorodibromomethane	0.41	CTR	-	-	-	-	-	-	80	Federal MCL
Chlorobenzene	680	CTR	-	-	-	-	-	-	70	California MCL
Chloroform	-	-	-	-	-	-	-	-	80	Federal MCL
Chloromethane	-	-	-	-	-	-	-	-	-	-
1,4-dichlorobenzene	400	CTR	-	-	-	-	-	-	5	California MCL
1,2-dichloroethane	0.38	CTR	-	-	-	-	-	-	0.5	California MCL
1,1-dichloroethene	0.057	CTR	-	-	-	-	-	-	6	California MCL
cis-1,2-dichloroethene	-	-	-	-	-	-	-	-	6	California MCL

TABLE 7-6
CLEANUP LEVELS FOR SURFACE WATER, SEEPS, AND GROUNDWATER AT THE PRESIDIO OF SAN FRANCISCO

Presidio of San Francisco, California

Potential Chemical of Concern	Water Quality Criteria									
							Drinking Water Cleanup Level (d);(e) (µg/L)			
	Surface Water (a) (µg/L)	Reference	Freshwater Seep (b) (µg/L)	Reference	Salt Water (c) (µg/L)	Reference	Background Levels	Reference	MCLs or Risk-Based Drinking Water Standards	Reference
Volatile Organic Compounds (contd)										
p-Isopropyltoluene (p-cymene)	-	-	-	-	-	-	-	-	-	-
Methylene Chloride	4.7	CTR	-	-	-	-	-	-	5	Federal MCL
Tetrachloroethene	0.8	CTR	-	-	-	-	-	-	5	Federal MCL
1,2,3-trichlorobenzene (s)	-	-	-	-	-	-	-	-	5	California MCL
1,2,4-trichlorobenzene	-	-	-	-	-	-	-	-	5	California MCL
1,1,1-trichloroethane	-	-	-	-	-	-	-	-	200	Federal MCL
Trichloroethene	2.7	CTR	-	-	-	-	-	-	5	Federal MCL
Trichlorofluoromethane	-	-	-	-	-	-	-	-	150	California MCL
Petroleum Hydrocarbons and Constituents										
Gasoline Range Hydrocarbons	443	Order (t)	443	Order	1,200	Order	50	FPALDR	770	FPALDR
Diesel Range Hydrocarbons	443 (u)	BBL Study (t)	443 (u)	BBL Study	2,200	Order	50	FPALDR	880	FPALDR
Fuel Oil Range Hydrocarbons (v)	443 (u)	BBL Study	443 (u)	BBL Study	2,200	Order	50	FPALDR	1,200	FPALDR
Benzene	1.2	CTR	463	Order	510	Order	0.5	FPALDR	1	California MCL
Ethylbenzene	845	Order	845	Order	43	Order	0.5	FPALDR	300	California MCL
Toluene	490	Order	490	Order	1,000	Order	0.5	FPALDR	150	California MCL
Tetraethyl Lead	-	-	-	-	-	-	-	-	-	-
Total Xylenes	318	Order	318	Order	130	Order	0.5	FPALDR	1,750	California MCL
Methyl t-butyl ether (MTBE)	-	-	-	-	4,400	Order	-	-	13	California MCL
PCBs, Pesticides, and Herbicides										
Polychlorinated Biphenyls	0.00017 (w, x)	CTR	0.014 (w, x)	CTR	0.03	CTR	-	-	0.5	Federal MCL
Aldrin	0.00013 (x)	CTR	3	CTR	1.3	CTR	-	-	-	-
Chlordane	0.00057 (x)	CTR	0.0043 (x)	CTR	0.004	CTR	-	-	0.1	California MCL

TABLE 7-6
CLEANUP LEVELS FOR SURFACE WATER, SEEPS, AND GROUNDWATER AT THE PRESIDIO OF SAN FRANCISCO

Presidio of San Francisco, California

Potential Chemical of Concern	Water Quality Criteria									
							Drinking Water Cleanup Level (d);(e) (µg/L)			
	Surface Water (a) (µg/L)	Reference	Freshwater Seep (b) (µg/L)	Reference	Salt Water (c) (µg/L)	Reference	Background Levels	Reference	MCLs or Risk-Based Drinking Water Standards	Reference
PCBs, Pesticides, and Herbicides (contd)										
2,4-D	-	-	-	-	-	-	-	-	70	Federal MCL
4,4'-DDD (y)	0.00083 (x)	CTR	0.001 (x)	CTR	0.001 (x)	CTR	-	-	-	-
4,4'-DDE (y)	0.00059 (x)	CTR	0.001 (x)	CTR	0.001 (x)	CTR	-	-	-	-
4,4'-DDT	0.00059 (x)	CTR	0.001 (x)	CTR	0.001 (x)	CTR	-	-	-	-
Dicamba	-	-	-	-	-	-	-	-	-	-
Dieldrin	0.00014 (x)	CTR	0.056 (x)	CTR	0.0019 (x)	CTR	-	-	0.5	Action Level (z)
Endosulfan	0.056 (x)	CTR	0.056 (x)	CTR	0.0087 (x)	CTR	-	-	-	-
Endosulfan Sulfate (s)	0.056 (x)	CTR	0.056 (x)	CTR	0.0087 (x)	CTR	-	-	-	-
Endrin	0.036 (x)	CTR	0.036 (x)	CTR	0.0023 (x)	CTR	-	-	2	Federal MCL
Endrin Aldehyde (s)	0.036 (x)	CTR	0.036 (x)	CTR	0.0023 (x)	CTR	-	-	2	Federal MCL
Endrin Ketone (s)	0.036 (x)	CTR	0.036 (x)	CTR	0.0023 (x)	CTR	-	-	2	Federal MCL
beta-BHC	0.014 (x)	CTR	-	-	-	-	-	-	0.3	Action Level (z)
gamma-BHC (Lindane)	0.019 (x)	CTR	0.95	CTR	0.16	CTR	-	-	0.2	Federal MCL
Heptachlor	0.00021 (x)	CTR	0.0038 (x)	CTR	0.0036 (x)	CTR	-	-	0.01 (x)	California MCL
Heptachlor Epoxide	0.00010 (x)	CTR	0.0038 (x)	CTR	0.0036 (x)	CTR	-	-	0.01 (x)	California MCL
Isodrin (aa)	0.00013 (x)	CTR	3	CTR	1.3	CTR	-	-	-	-
MCPP	-	-	-	-	-	-	-	-	-	-
Methoxychlor	-	-	-	-	-	-	-	-	30	California MCL

TABLE 7-6
CLEANUP LEVELS FOR SURFACE WATER, SEEPS, AND GROUNDWATER AT THE PRESIDIO OF SAN FRANCISCO

Presidio of San Francisco, California

Notes:

(a) Cleanup levels are based upon concentrations of chemicals of concern ("COCs") that result in chronic toxicity to freshwater aquatic organisms, or to humans through consumption of water and fish, whichever is more stringent. Cleanup levels apply to freshwater surface water and groundwater that may exfiltrate directly to surface water, such as Lobos Creek, Mountain Lake, and the Tennessee Hollow Riparian Corridor upon enhancement.

(b) Cleanup levels are based upon concentrations of COCs that result in chronic toxicity to freshwater aquatic organisms. Cleanup levels apply to seeps and to groundwater that emerges as freshwater seeps.

(c) Cleanup levels are based upon concentrations of COCs that result in chronic toxicity to marine organisms. Cleanup levels apply to marine or salt water environments.

(d) Cleanup levels listed in the FPALDR are the Practical Quantitation Limits ("PQLs"). Background levels (i.e., the PQLs) will be used as water quality goals for the Lobos Creek Groundwater Basin.

(e) Cleanup level listed is a promulgated or proposed federal Maximum Contaminant Level ("MCL"), promulgated or proposed MCL or action level specific to the State of California, or a water quality objective for municipal supply as identified in the Basin Plan (California Environmental Protection Agency, Regional Water Quality Control Board, San Francisco Bay Region, Water Quality Control Plan, San Francisco Bay Basin, San Francisco Bay Region ("Basin Plan"), dated 21 June 1995), as updated by Resolution R2-2004-003 dated 21 January 2004. Federal MCLs obtained from U.S. EPA, 2002 Edition of Drinking Water Standards and Health Advisories, dated Summer 2002. California MCLs obtained from Title 22 of the California Code of Regulations, §64431 and §64444. Proposed MCLs and action levels obtained from U.S. EPA Region IX, *Drinking Water Standards and Health Advisories Table,* dated November 2000, revised February 2001. Drinking water cleanup levels apply to groundwater and surface water at the Presidio.

(f) Cleanup level obtained from Title 40 of the Code of Federal Regulations, Part §131.38, *Establishment of Numerical Criteria for Priority Toxic Pollutants for the State of California*, or California Toxics Rule ("CTR"), promulgated 18 May 2000.

(g) Hyphen indicates that a cleanup level is not available.

(h) Cleanup level is expressed as a function of the water-effects ratio, as defined in the CTR.

(i) These objectives for metals are expressed in terms of the dissolved fraction of the metal in the water column.

(j) Cleanup level obtained from the Basin Plan (as defined above).

(k) Cleanup level is a function of hardness. Value shown is based on a hardness of 100 mg/L as calcium carbonate.

TABLE 7-6
CLEANUP LEVELS FOR SURFACE WATER, SEEPS, AND GROUNDWATER AT THE PRESIDIO OF SAN FRANCISCO

Presidio of San Francisco, California

Notes (contd):

(l) Cleanup level listed is a secondary MCL. Secondary MCLs apply to chemicals in drinking water that adversely affect its odor, taste, or appearance and therefore cause people to discontinue using the water.

(m) Cleanup level obtained from Title 40 of the Code of Federal Regulations, Part §131.36, *Establishment of Numerical Criteria for Priority Toxic Pollutants,* or National Toxics Rule ("NTR"), promulgated 22 December 1992, as amended. The Basin Plan indicates values for these chemicals should be obtained from the NTR. The values in the NTR are consistent with those presented in the CTR.

(n) MCL based upon treatment technique. Treatment technique and public notification required at action level of 15 µg/L for lead.

(o) Cleanup level for mercury is 0.012 µg/L. However, this level is below the typical analytical method reporting limit of 0.025 µg/L. A cleanup objective of 0.012 µg/L is desirable, but attainment can only be determined at the analytical method reporting limit.

(p) Cleanup level obtained from Montgomery Watson, *Fuel Product Action Level Development Report, Presidio of San Francisco, California* ("FPALDR"), dated October 1995. Numerical values developed based upon residential exposure to COCs in groundwater through ingestion and inhalation pathways.

(q) This level is below the typical analytical method reporting limit range of 0.1 to 10 µg/L for semivolatile organic compounds. Cleanup level listed is desirable, but attainment can only be determined at the analytical method reporting limit. Cleanup level is established at the typical analytical method reporting limit range for semivolatile organic compounds assuming no matrix interference. In the event of matrix interference, actual method reporting limits determining compliance with cleanup levels may be raised.

(r) The drinking water standard in the FPALDR is for total carcinogenic polyclic aromatic hydrocarbons ("PAHs"). These carcinogenic PAHs include benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, and chrysene.

(s) Values for 1,2,4-trichlorobenzene were used for 1,2,3-trichlorobenzene. Values for Endosulfan were used for Endosulfan Sulfate. Values for Endrin were used for Endrin Aldehyde and Endrin Ketone.

TABLE 7-6
CLEANUP LEVELS FOR SURFACE WATER, SEEPS, AND GROUNDWATER AT THE PRESIDIO OF SAN FRANCISCO

Presidio of San Francisco, California

Notes (contd):

(t) Cleanup levels for TPH-diesel for the saltwater zone are from Order No. R2-2003-0080, *Revised Site Cleanup Requirements and Recision of Order No. 91-082 and Order No. 96-070 for the Property Located at The Presidio of San Francisco, City and County of San Francisco,* issued by the California Regional Water Quality Control Board, 20 August 2003 ("Order").
Cleanup levels for TPH-diesel and TPH-fuel oil for the freshwater ecological protection zone were obtained from Blasland, Bouck, & Lee ("BBL"), *Draft Development of Freshwater TPH-diesel and TPH-fuel oil Point of Compliance Concentration Determinations, Presidio of San Francisco, California,* dated 15 July 2004 ("BBL Study"). This report was approved by the RWQCB on 7 September 2004 in a letter from Bruce H. Wolfe.

(u) The BBL Study developed Point of Compliance Concentrations for areas within the Freshwater Ecological Protection Zone ("FEPZ"). Value is to be used within FEPZ Zone of Application, as discussed in the BBL Study, and in other areas of the Presidio where freshwater cleanup levels may be appropriate (e.g., Lobos Creek).

(v) Fuel oil range hydrocarbons includes motor oil.

(w) Cleanup level applies to total polychlorinated biphenyls ("PCBs").

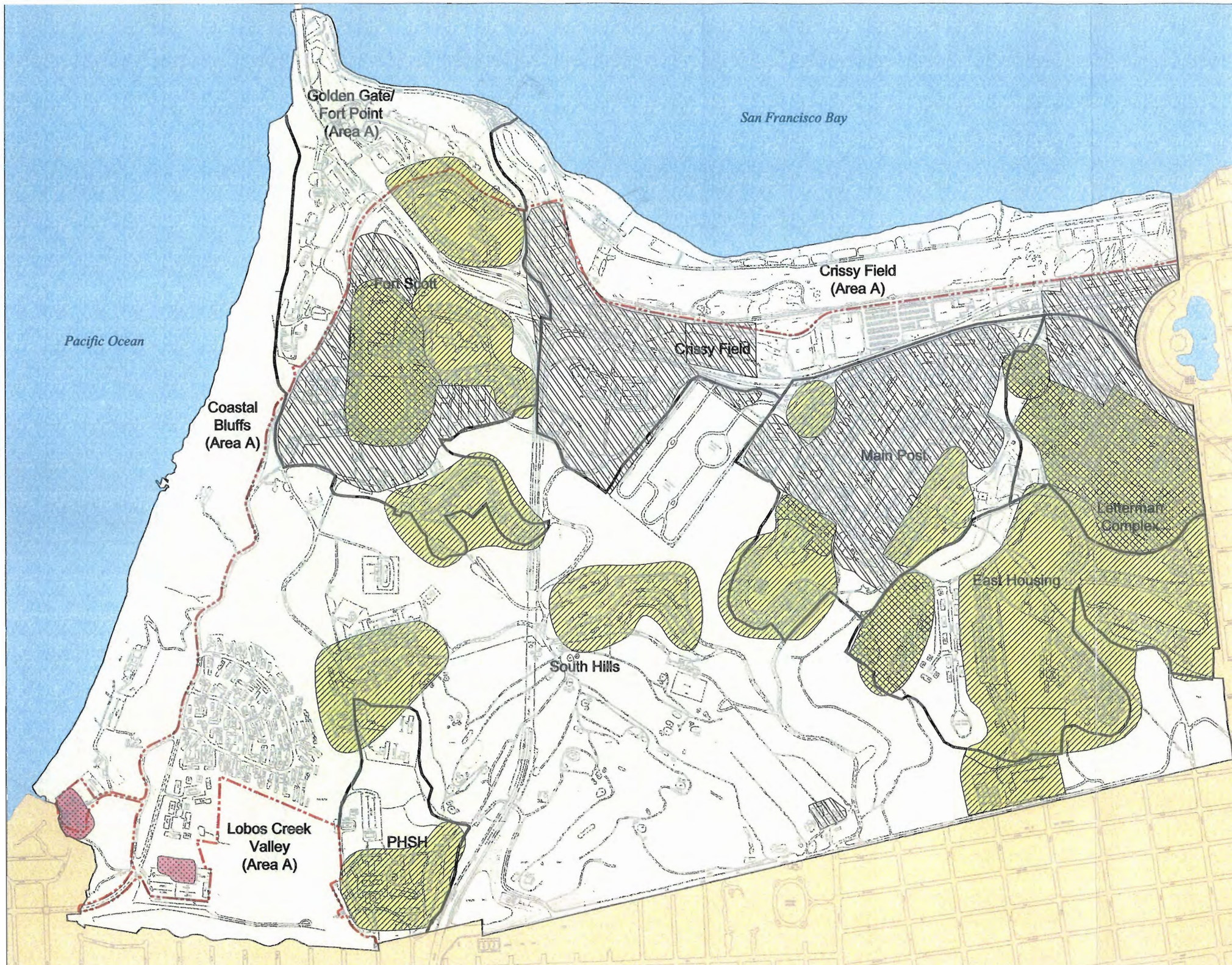
(x) This level is below the typical analytical method reporting limit range of 0.05 to 0.5 μg/L for PCBs and pesticides. Cleanup level listed is desirable, but attainment can only be determined at the analytical method reporting limit.

(y) In the absence of a published value for 4,4'-DDD or 4,4'-DDE, the value for 4,4'-DDT is used.

(z) Cleanup level is State of California action level for drinking water.

(aa) Isodrin is an isomer of Aldrin. Values for Aldrin were used for Isodrin.

FIGURES



N

0 800 1600

(Approximate Scale in Feet)

LEGEND

Area A/B Boundary

Presidio Planning Area or District Boundary

Planned Human Land Use (Note 4)

Planned Residential Use

Planned Commercial/ Recreational Use

Planned Institutional Use (Educational/Conference)

Planned Commercial/ Industrial Land Use

Appropriate Soil Cleanup Level

Residential Cleanup Level

Recreational Cleanup Level

Commercial/Industrial Cleanup Level

Notes:

1. All locations are approximate.
2. Basemap developed from site plan provided by the Presidio Trust.
3. Designated human land use is based on the National Park Service's Final General Management Plan Amendment ("GMPA"), dated July 1994, and Presidio Trust Management Plan ("PTMP") dated May 2002.
4. Planned human land use is recreational if none of the above patterns are shown.
5. Appropriate cleanup levels are based on the most restrictive human land use defined in the GMPA and PTMP.
6. PHSH is the Public Health Service Hospital Planning Area.

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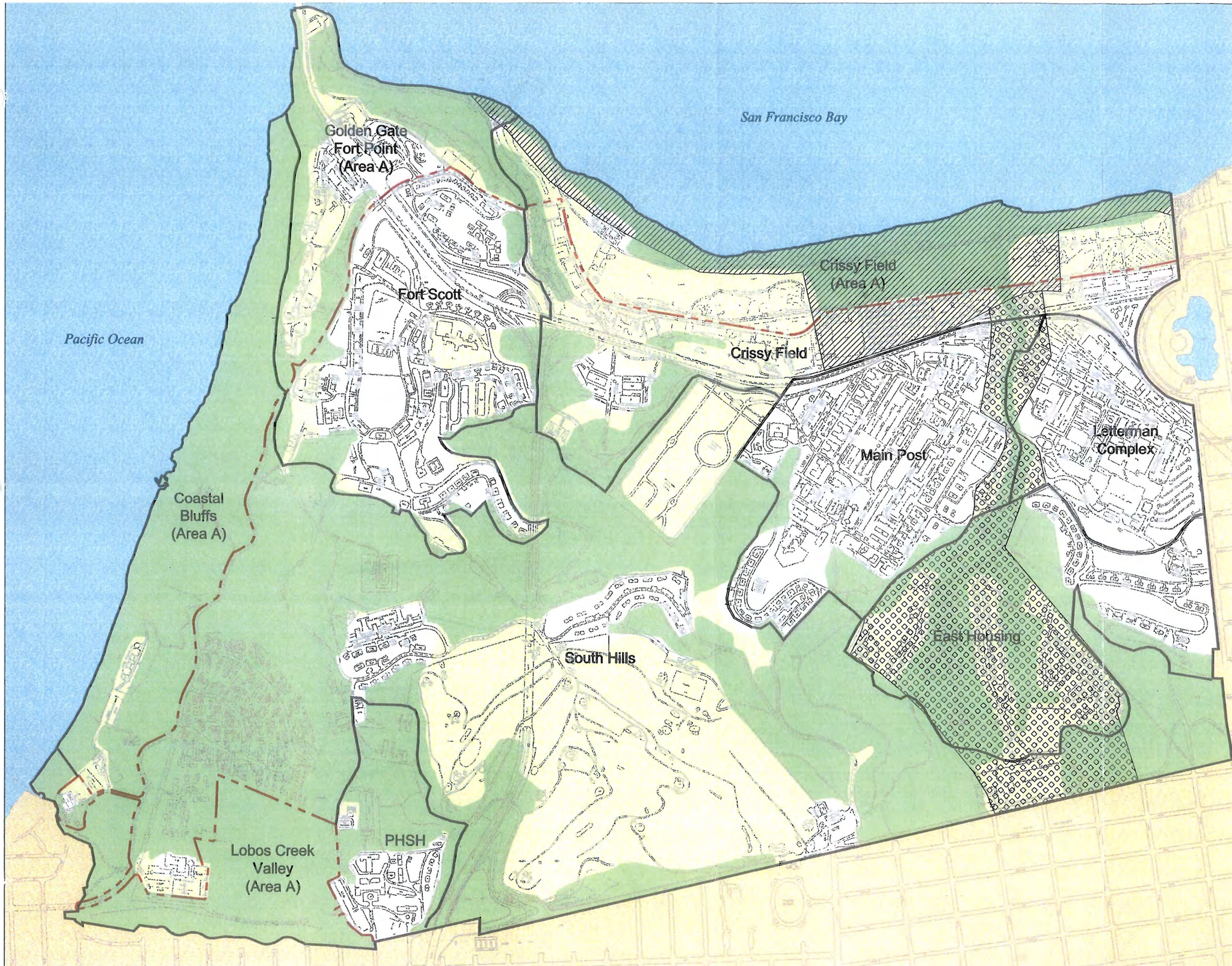
Planned Human Land Use at the Presidio

Presidio Trust
San Francisco, CA
October 2002
EKI A000003.04

Figure 7-1



N

0 800 1600

(Approximate Scale in Feet)

LEGEND

Area A/B Boundary

Presidio Planning Area or District Boundary

Ecological Potection Zones (Note 3)

Saltwater Ecological Protection Zone

Freshwater Ecological Protection Zone

Appropriate Soil Cleanup Level

Human Health Cleanup Level (Developed Areas Outside Ecological Protection Zones)

Buffer Zone Ecological Cleanup Level (Manicured Open Space Areas)

Special Status Ecological Cleanup Level (See Note 4)

Notes:

1. All locations are approximate.
2. Basemap developed from site plan provided by the Presidio Trust.
3. Ecological Protection Zones are defined in California Regional Water Quality Control Board, Order No. 96-070, dated 15 May 1996.
4. Special Status Ecological Areas include Native Plant Community Zones, Historic Forest Zones, and Special Management Zones identified in the Vegetation Management Plan and Environmental Assessment, NPS and Presidio Trust, December 2001.
5. PHSH is the Public Health Service Hospital Planning Area.

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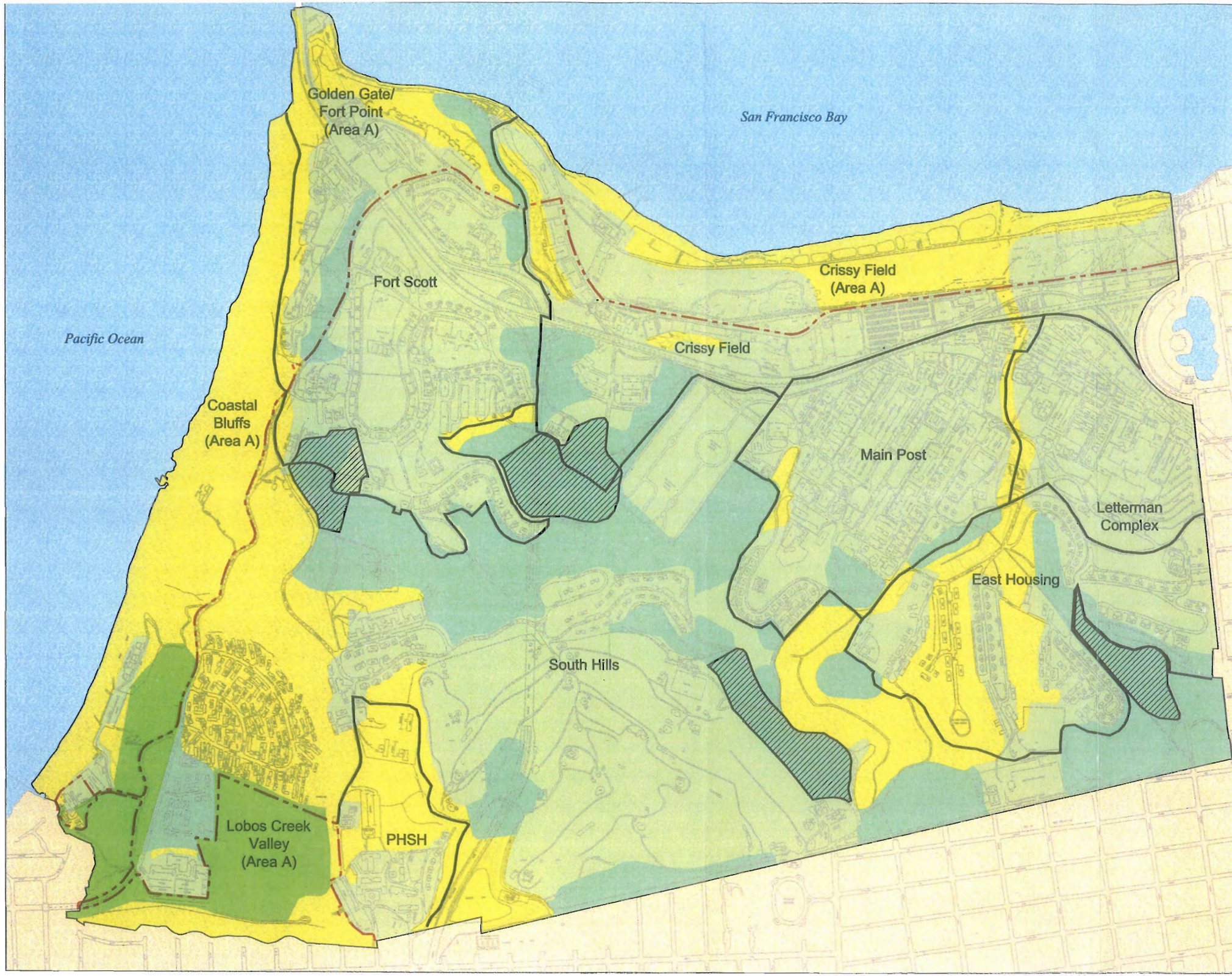
Planned Ecological Land Use at the Presidio

Presidio Trust
San Francisco, CA
October 2002
EKI A000003.04

Figure 7-2



N

0 800 1600

(Approximate Scale in Feet)

LEGEND

- Area A/B Boundary
- Presidio Planning Area or District Boundary
- Native Plant Communities Zone
- Historic Forest Zone
- Landscape Vegetation Zone
- Special Management Zone
- Key Historic Forest Stands

Notes:

1. All locations are approximate.
2. Basemap developed from site plan provided by the Presidio Trust.
3. PHSH is the Public Health Service Hospital Planning Area.
4. Figure taken from Vegetation Management Plan and Environmental Staff Report, NPS and Presidio Trust, October 2000, and Vegetation Management Plan and Environmental Assesment, December 2001.

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Planned Vegetation Types at the Presidio

Presidio Trust
San Francisco, CA
October 2002
EKI A000003.04

Figure 7–3

8. REFERENCES

8. REFERENCES

Argonne National Laboratory. November 1989. *Enhanced Preliminary Assessment Report: Presidio of San Francisco Military Reservation, San Francisco, California.* Prepared for U.S. Army Toxic and Hazardous Materials Agency.

Azar, A., H.J. Trochimowicz, and M.E. Maxfield. 1973. *Review of Lead Studies in Animals Carried Out at Haskell Laboratory - Two-Year Feeding Study and Response to Hemorrhage Study*. International Symposium. Environmental Health Aspects of Lead.

Bechtel Jacobs Company L.L.C. September 1998. *Empirical Models for Uptake of Inorganic Chemicals from Soil to Plants*. United States Department of Energy Oak Ridge National Laboratory. BJC/OR-133.

Beutel, Marc. November 1997. *Mountain Lake Water Quality Report 1996/1997.*

Bradford, G.R., et al. 1996. *Background Concentrations of Trace and Major Elements in California Soils*. Kearney Foundation of Soil Science, University of California, Riverside.

Brooks, R.R. 1987. *Serpentinite and Its Vegetation: A Multidisciplinary Approach.* Dioscorides Press.

California Department of Fish and Game. September 1995. *Endangered, Threatened, or Rare Plants of California*. Natural Heritage Division, Plant Conservation Program, Sacramento, California.

California Department of Health Services. September 1997. *Medical Guidelines, Occupational Lead Poisoning Prevention Program and Hazard Evaluation System and Information Service*. Occupational Health Branch.

Canadian Council of Ministers of the Environment. 1999. *Canadian Sediment Quality Guidelines for the Protection of Aquatic Life*. Summary Tables.

Canada Environmental Protection Agency. 1993. *1,2-Dichlorobenzene, Priority Substances List Assessment Report*. Health Canada, Ottawa, Canada: Canada Communications Group Publishing.

Dames & Moore. May 1997a. *Final Feasibility Study Report, Presidio Main Installation, Presidio of San Francisco.*

Dames & Moore. January 1997b. *Final Remedial Investigation Report, Presidio Main Installation, Presidio of San Francisco.*

Dames & Moore. 1996. *Draft Final Marine Ecological Sampling and Analysis Program Report.*

Department of the Army and Department of Toxic Substances Control. April 1998. *Final Remedial Action Plan Crissy Field Area, Presidio of San Francisco.*

Department of the Army and Department of Toxic Substances Control. January 1997. *Draft Document, Presidio of San Francisco, Directorate of Engineering and Housing (DEH) Study Area, Evaluation of Remedial Alternatives and Draft Remedial Action Plan (RAP).*

Department of the Army. February 1995. *Record of Decision, Former Public Health Services Hospital, Presidio of San Francisco.* Army Environmental Center, Aberdeen Proving Grounds, Maryland.

Department of the Interior, National Park Service and Presidio Trust. December 2001. *Vegetation Management Plan and Environmental Assessment for the Presidio of San Francisco.*

Department of the Interior, National Park Service and Presidio Trust. 23 May 2001. *Vegetation Management Plan and Environmental Assessment for the Presidio of San Francisco.*

Department of the Interior, National Park Service. 1995. *Restoration Project Action Plan, Lobos Creek Dunes Restoration Management Plan, Presidio of San Francisco.*

Department of the Interior, National Park Service. July 1994. *Creating a Park for the 21st Century, from Military Post to National Park - Final General Management Plan Amendment, Presidio of San Francisco, Golden Gate National Park Recreation Area, California.*

Department of Toxic Substances Control ("DTSC"). 9 November 2001. Letter from Robert Boggs to Sharron Reackhof of the Presidio Trust transmitting comments on the August 2001 *Draft Development of Presidio-Wide Cleanup Levels for Soil, Sediment, Groundwater, and Surface Water* from James M. Polisini, Ph.D. and A. Kimiko Klein, Ph.D., both of DTSC Human and Ecological Risk Division ("HERD"), to Robert Boggs, Office Military Facilities, Berkeley Office, Department of Toxic Substances Control.

DTSC. 2000a. CalEcotox Computerized Database. www.ewa.des.ucdavis.edu/calecotox.

DTSC. 9 August 2000b. *Presidio of San Francisco Ecological Soil Screening Values and Probabilistic Analysis of Lead Toxicity Reference Value.* Memorandum from James M. Polisini, Ph.D., Human and Ecological Risk Division, to Henry Chui, P.E., Office of Military Facilities, Berkeley Office, Department of Toxic Substances Control.

DTSC. 13 July 2000c. *Presidio of San Francisco, Hexavalent Chromium in Serpentinite Bedrock and Groundwater*. Letter from Daniel E. Murphy, P.E., Chief, Berkeley Unit, Office of Military Facilities, to Sharron L. Reackhof, The Presidio Trust.

DTSC. 5 June 2000d. Presidio of San Francisco, California. Memorandum from A. Kimiko Klein, Ph.D., Staff Toxicologist, Human Health and Ecological Risk Division, to Henry Chui, Office Military Facilities, Berkeley Office, Department of Toxic Substances Control.

DTSC. June 1999. *Preliminary Endangerment Assessment Guidance Manual*. Second Printing.

DTSC. August 1996. *Supplemental Guidance for Human Health Multimedia Risk Assessments of Hazardous Waste Sites and Permitted Facilities*.

Donker, M.H., H.E. van Capelleveen, and N.M. van Straalen. 1993 *Metal Contamination Affects Size-structure and Life-history Dynamics in Isopod Field Populations*. Ecotoxicology of Metals in Invertebrates. Lewis Publishers.

Efroymson, R.A., M.E. Will, G.W. Suter I.I., and A.C. Wooten, November 1997. *Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants, 1997 Revision*. United States Department of Energy .

Erler & Kalinowski, Inc. 13 July 2001. *Draft Technical Memorandum, Bivariate Scatter Plots for Soil Metals Data, Main Installation Sites, Presidio of San Francisco, California.*

Federal Register.5 January 2001. Vol.66, p.1240.

Federal Register. 8 March 1990. Vol. 55, pp. 8666, 8702, 8710.

Friberg, L., G.F. Nordberg, and V.B. Vouk. 1979. *Handbook of Toxicology of Metals*. Elsevier/North Holland Biomedical Press.

Groten, J.P., E.J. Sinkeldam, J. B. Luten, and P.J. Van Bladeren. 1991. *Comparison of the Toxicity of Inorganic and Liver-Incorporated Cadmium: A Four Week Feeding Study in Rats*. Food and Chemical Toxicology. Vol. 28, pp. 435-442.

Hudson, R., R.K. Tucker, and M.A. Haegele. 1984. *Handbook of Toxicity of Pesticides to Wildlife (2nd ed.)*. United States Fish and Wildlife Service. Res. Publ. 153.

International Technology Corporation. 27 April 2000. *Draft Human Health and Ecological Risk Assessment, BRAC Property, Hamilton Army Airfield, Novato, California.*

International Technology Corporation. 26 April 1999. *Ambient Concentrations of Metals in Chert and Shale at the Presidio of San Francisco.*

International Technology Corporation. December 1997. *Report of Petroleum Hydrocarbon Bioassay and Point-of-Compliance Concentration Determinations, Saltwater Ecological Protection Zone, Presidio of San Francisco, California.*

Jones & Stokes Associates, Inc. 1997. *Presidio of San Francisco Natural Resource Inventory and Vegetation Management Options.*

Jones & Stokes Associates, Inc. 1994. *Presidio of San Francisco Forest Management Plan, Draft.*

Kruckeberg, A. R. 1984. *California Serpentines: Flora, Vegetation, Geology, Soils, and Management Problems.*

Lawrence Berkeley National Laboratory. 1995. *Protocol for Determining Background Concentrations of Metals in Soil at Lawrence Berkeley National Laboratory.* U.S. Department of Energy Contract DE-AC03-76F00098.

Lee, C.R., et al. 1995. *Field Survey of Contaminant Concentrations in Existing Wetlands in the San Francisco Bay Area.* Miscellaneous Paper EL-95, U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.

Levinson, A.A. 1974. *Introduction to Exploration Geochemistry.* Applied Publishing Ltd.

Long, E.R., D.D. MacDonald, S.L. Smith, and F.D. Calder, 1995. *Incidence of Adverse Biological Effects Within Ranges of Chemical Concentrations in Marine and Estuarine Sediments.* Environmental Management. Vol. 19, No. 1, pp. 81-97.

MacDonald, D.M., C.G. Ingersoll, and T.A. Berger. 2000. *Development and Evaluation of Consensus-Based Sediment Quality Guidelines for Freshwater Ecosystems.* Archives of Environmental Contamination and Toxicology. Vol. 39, pp. 20-31.

Montgomery Watson. July 1999a. *Hexavalent Chromium in Serpentinite Bedrock and Groundwater in Upland Areas.*

Montgomery Watson. 4 May 1999b. *Development of Point of Compliance Concentrations (POCCs) for Gasoline in Surface Waters and Sediments of the Proposed Freshwater Stream, Presidio of San Francisco, California.* Final Technical Memorandum.

Montgomery Watson. October 1998a. *Transformation of the Presidio of San Francisco: Hydrogeology and Environmental Restoration.* California Groundwater Resources Association, San Francisco Branch, 1998 Field Trip Guidebook.

Montgomery Watson. April 1998b. *Technical Memorandum: Hexavalent Chromium in Groundwater, Presidio of San Francisco.*

Montgomery Watson. July 1996. *Draft Basewide Groundwater Monitoring Plan, Presidio of San Francisco, California.*

Montgomery Watson. October 1995. *Fuel Product Action Level Development Report, Presidio of San Francisco, California.*

National Oceanic and Atmospheric Administration. 1999. *Screening Quick Reference Tables.*

Office of Environmental Health Hazard Assessment. April 1999. *Technical Support Document for Describing Available Cancer Potency Factors.*

Office of Environmental Health Hazard Assessment. January 1994. *Status Report: No Significant Risk Levels for Carcinogens and Acceptable Intake Levels for Reproductive Toxicants.* Safe Drinking Water and Toxic Enforcement Act of 1986 (Proposition 65).

Persuad, D., R. Jaagumagi, and A. Hayton. August 1993. *Guidelines for the Protection and Management of Aquatic Sediment Quality in Ontario.* Ontario Ministry of Environment and Energy. ISBN 0-7729-9248-7.

PRC Environmental Management. June 1997. *Development of Toxicity Reference Values as Part of a Regional Approach for Conducting Ecological Risk Assessments at Naval Facilities in California.* Draft Technical Memorandum.

Puls, R.W and R.M. Powell. 1992. *Acquisition of Representative Ground Water Quality Samples for Metals.* Groundwater Monitoring Review. Vol. 12(3), pp. 167-176.

Regional Water Quality Control Board ("RWQCB"). December 2001a. *Application of Risk-Based Screening Levels and Decision Making to Sites with Impacted Soil and Groundwater, Volume 1: Summary Tier 1 Lookup Tables, Interim Final.* San Francisco Bay Region.

RWQCB. December 2001b. *Application of Risk-Based Screening Levels and Decision Making to Sites with Impacted Soil and Groundwater, Volume 2: Background Documentation for the Development of Tier 1 Soil and Groundwater Screening Levels, Interim Final.* San Francisco Bay Region.

RWQCB. 15 May 1996. *Order No. 96-070, Site Cleanup Requirements for the Cleanup of Petroleum Impacted Soils, U.S. Army, Presidio of San Francisco, California.* San Francisco Bay Region.

RWQCB. 21 June 1995. *Water Quality Control Plan, San Francisco Bay Basin.* San Francisco Bay Region.

RWQCB. 20 August 1991. *Tri-Regional Board Staff Recommendations for Preliminary Evaluation and Investigation of Underground Tank Sites.*

Roylance, K.J., C.D. Jorgensen, G.M. Booth, and M.W. Carter. 1985. *Effects of Dietary Endrin on Reproduction of Mallard Ducks.* Archives of Environmental Contamination and Toxicology. Vol. 14. pp. 705-711.

Ryder, J.L., et al. 1989. *Analysis of 721 Soil Samples from the Panoche Fan Area of the San Joaquin Valley, California.* USGS Open File Report 89-298.

Salomons, W. and Forstner, U. 1984. *Metals in the Hydrocycle.* Springer Verlag.

Sample, B.E., et al. February 1998a. *Development and Validation of Bioaccumulation Models for Earthworms.* United States Department of Energy. ES/ER/TM-220.

Sample, B.E., et al. February 1998b. *Development and Validation of Bioaccumulation Models for Small Mammals.* United States Department of Energy. ES/ER/TM-219.

Sample, B.E., D.M. Opresko, and G.W. Suter I.I. June 1996. *Toxicological Benchmarks for Wildlife: 1996 Revision.* Oak Ridge National Laboratory.

Sample, B.E. and G.W. Suter, I.I. 1994. *Estimating Exposure of Terrestrial Wildlife to Contaminants. Oak Ridge National Laboratory*, United States Department of Energy. ES/ER/TM-125.

San Francisco Bay Conservation and Development Commission June 1998. *San Francisco Bay Plan.*

Schlocker, J. 1974. *Geology of the San Francisco North Quadrangle, California.* United States Geological Survey Professional Paper 782.

Scott, C.M. 1995. *Background Metal Concentrations in Soils in Northern Santa Clara County, California* in Recent Geological Studies in the San Francisco Bay Area, Pacific Section of the Society of Economic Paleontologists and Mineralogists, Volume 76.

Sinclair, A.J. 1976. *Applications of Probability Graphs in Mineral Exploration.* Special Volume No. 4, Association of Exploration Geochemists, Richmond Printers Ltd.

Skinner, M.W. and B.M. Pavlik. 1994. *Inventory of Rare and Endangered Vascular Plants of California.* 5th Edition. California Native Plant Society.

Skorupa J.P., S.P. Morman, and J.S. Sefchick-Edwards. March 1996. *Guidelines for Interpreting Selenium Exposures of Biota Associated with Nonmarine Aquatic Habitats.* Sacramento Field Office.

State Water Resources Control Board ("SWRCB"). 2000. *Policy for Implementation of Toxic Standards for Inland Surface Waters, Enclosed Bays, and Estuaries of California, (Phase 1 of the Inland Surface Waters Plan and the Enclosed Bays and Estuaries Plan).*

SWRCB 11 April 1991a. *California Enclosed Bays and Estuaries Plan, Water Quality Control Plan for Enclosed Bays and Estuaries of California.*

SWRCB 11 April 1991b. *California Inland Surface Waters Plan, Water Quality Control Plan for Inland Surface Waters of California.*

Trust, 2002. *Presidio Trust Management Plan, Land Use Policies for Area B of the Presidio of San Francisco*, Presidio Trust, May 2002.

TTEMI, 2001. *Presidio-Wide Quality Assurance Project Plan, Sampling and Analysis Plan, Revision 1, Presidio of San Francisco, San Francisco, California*, TetraTech EM Inc. ("TTEMI"), April 2001.

United States Department of Energy. November 1997. *Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Sediment-Associated Biota: 1997 Revision.* ES/ER/TM-95/R4.

United States Department of Health and Human Services, Agency for Toxic Substances and Disease Registry ("ATSDR"). 1999. *Toxicological Profile for N-Nitrosodiphenylamine.*

United States Department of Health and Human Services, ATSDR. 1 September 1995. *Case Studies in Environmental Medicine: Lead Toxicity.*

United States Environmental Protection Agency ("U.S. EPA"). 2000a. Integrated Risk Information System Computerized Database. www.epa.gov/ngispgm3/iris/subst/.

U.S. EPA. 3 August 2000b. *Analytical Results, Elemental and Organic Constituent Results for Seep Samples, Presidio Army Base, San Francisco, California.* National Enforcement Investigations Center.

U.S. EPA. June 2000c. *Draft Ecological Soil Screening Level (Eco-SSL) Guidance.*

U.S. EPA. February 2000d. *Drinking Water Standards and Health Advisories Table.* Region IX, Drinking Water Office.

U.S. EPA. February 2000e. *Institutional Controls and Transfer of Real Property under CERCLA Section 120(h)(3)(A), (B) or (C).* Federal Facilities Restoration and Reuse Office.

U.S. EPA. 7 October 1999a. *Issuance of Final Guidance: Ecological Risk Assessment and Risk Management Principles for Superfund Sites*. Memorandum from Stephen D. Luftig, Director, Office of Emergency and Remedial Response, to Superfund National Policy Managers, Region 1-10. Office of Solid Waste and Emergency Response. OSWER Directive No. 9285.7-28 P.

U.S. EPA. 1 October 1999b. *Region 9 Preliminary Remediation Goals (PRGs) 1999*. Memorandum from Stanford J. Smucker, Ph.D., Regional Toxicologist (SFD-8-B), Technical Support Team to PRG Table Mailing List.

U.S. EPA. 24 February 1999c. *Analytical Results, Elemental Constituent Results for Groundwater Samples, Presidio Army Base, San Francisco, California*. National Enforcement Investigations Center.

U.S. EPA. May 1998a. *Risk Assessment Guidance for Superfund Volume 1: Human Health Evaluation Manual, Supplemental Guidance Dermal Risk Assessment*. Interim Guidance. Office of Emergency Response. NCEA-W-0364.

U.S. EPA. April 1998b. *Guidelines for Ecological Risk Assessment*. Office of Research and Development. EPA/630/R-95/002F.

U.S. EPA. January 1998c. *Guidance for Data Quality Assessment, Practical Methods for Data Analysis*. Office of Research and Development. EPA/600/R-96/084.

U.S. EPA. 1997a. *Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments, Interim Final*. EPA/540-R97-006.

U.S. EPA. December 1997b. *Analytical Results, Elemental Constituent Results for Soil Samples from Presidio Army Base, San Francisco, California*. National Enforcement Investigations Center.

U.S. EPA. May 1997c. *Test Methods for Evaluating Solid Waste, Volume 1B: Laboratory Manual, Physical/Chemical Methods*. Revision III. Office of Solid Waste and Emergency Response. SW 846.

U.S. EPA. August 1997d *Exposure Factors Handbook Volume I General Factors: Principles and Applications*. Office of Research and Development. EPA 600/P-95/002F.

U.S. EPA. July 1997e. *Health Effects Assessment Summary Tables*.

U.S. EPA. 30 April 1997f. *Analytical Results, Inorganic Results for Samples from Presidio Army Base, San Francisco, California*. National Enforcement Investigations Center.

U.S. EPA. 1996a. *Ecotox Thresholds*. ECO Update. Vol. 3(2), pp. 1-12. Office of Solid Waste and Emergency Response.

U.S. EPA. June 1996b. *Analytical Results – Hexavalent Chromium Results for Samples from the Presidio Army Base, San Francisco, California*. National Enforcement Investigations Center.

U.S. EPA. 1995a. *Ecological Screening Values*. Ecological Risk Assessment Bulletin No. 2. Region IV, Waste Management Division.

U.S. EPA. 1995b. *Great Lakes Water Quality Initiative Criteria Documents for the Protection of Wildlife: DDT, Mercury, 2,3,7,8 TCDD, and PCBs*. EPA-820-B-95-008.

U.S. EPA. 25 May 1995c. *Land Use in the CERCLA Remedy Selection Process*. Memorandum from Elliot P. Laws, Assistant Administrator. Office of Solid Waste and Emergency Response. OSWER Directive No. 9355.7-04.

U.S. EPA. 14 July 1994. *Revised Interim Soil Lead Guidance for CERCLA Sites and RCRA Corrective Action Facilities* Memorandum from Elliot P. Laws, Assistant Administrator to Regional Administrators I-X. Office of Solid Waste and Emergency Response. OSWER Directive No. 9335.4-12.

U.S. EPA. 1993. *Wildlife Exposure Factors Handbook, Volumes I and II*. Office of Research and Development. EPA/600/R-93/187 (a and b).

U.S. EPA. November 1992a. *RCRA Ground-Water Monitoring: Draft Technical Guidance*. Office of Solid Waste. EPA/530-R-93-001.

U.S. EPA. April 1992b. *Guidance for Data Useability in Risk Assessment (Part A), Final*. Office of Emergency and Remedial Response. Publication 9285.7-09A.

U.S. EPA. February 1992c. *Framework for Ecological Risk Assessment*. Risk Assessment Forum. EPA/630/R-92/001.

U.S. EPA. 1991a. *Risk Assessment Guidance for Superfund: Volume 1 – Human Health Evaluation Manual (Part B, Development of Risk-based Preliminary Remediation Goals), Interim*. Office of Solid Waste and Emergency Response. Publication: 9285.7-01B.

U.S. EPA. July 1991b. *ARARs Q's & A's: General Policy, RCRA, CWA, SDWA, Post-ROD Information, and Contingent Waivers*. Office of Solid Waste and Emergency Response. Publication 9234.2-01/FS-A.

U.S. EPA. 22 April 1991c. *Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions*. Memorandum from Don R. Clay, Assistant Administrator. Office of Solid Waste and Emergency Response. OSWER Directive No. 9355.0-30.

U.S. EPA. 25 March 1991d. *Risk Assessment Guidance for Superfund, Volume 1: Human Health Evaluation Manual, Supplemental Guidance, Standard Default Exposure Factors.* Interim Final. OSWER Directive 9285.6-03.

U.S. EPA. December 1989a. *Risk Assessment Guidance for Superfund: Volume 1 – Human Health Evaluation Manual (Part A), Interim.* Office of Solid Waste and Emergency Response. EPA/540/1-89/002.

U.S. EPA. December 1989b. *Risk Assessment Guidance for Superfund Human Health Risk Assessment.* U.S. EPA Region IX.

Wiseman, J. 1987. *Feeding of Non-Ruminant Livestock.* Butterworths.

World Health Organization. 1999. *Beryllium; Environmental Health Criteria 106.* Geneva, Switzerland.

APPENDICES

APPENDIX A

LEAD SPREAD VERSION 7.0

COMPUTER SPREADSHEETS

APPENDIX A

LEAD SPREAD VERSION 7.0
COMPUTER SPREADSHEETS

October 2002

TABLE A-1
LEAD INTAKE SUMMARY FOR RESIDENTIAL, RECREATIONAL, AND COMMERCIAL/INDUSTRIAL USERS (a)

Presidio of San Francisco, California

Potentially Exposed Population	Exposure Frequency (days/week)	Exposure Media/Lead Concentration					Blood Lead (f) (µg/dl)
		Air (b) (µg/m^3)	Water (b) (µg/L)	Food Intake (c) (kg/day)	Background Soil (d) (mg/kg)	Presidio Soil (e) (mg/kg)	
Residential (child)	7 (Presidio)	0.028	2.4	1.9	0	**370**	10
Recreational (child)	7 (Background)	0.028	15	1.1	0	0	4.6
	4 (Background)	0	0	0	66	0	0.8
	3 (Presidio)	0	0	0	0	**500**	4.6
							10
Commercial/Industrial (adult)	5 (Presidio)	0.028	15	1.9	0	**3,500**	10

Notes:

(a) Lead concentration in blood calculated using California Environmental Protection Agency, Department of Toxic Substances Control ("DTSC") Lead Spread Version 7.0 (beta test version) computer model.

(b) Air, water and food intake concentrations are based on DTSC default factors, except for lead in residential tap water. A value of 2.4 ug/L is based on the 95% upper confidence limit of the average lead concentration measured in residential tap water at the Presidio in 1998, 1999, and 2000 (see data in Appendix A).

(c) Food intake is based on DTSC default factor. The lead concentration in food is assumed to be 3.1 µg/kg, which is also a DTSC default factor.

(d) Background concentrations of lead in soil at the Presidio are used for background in Lead Spread. A value of 66 mg/kg of lead corresponds to the background concentration in serpentinite, which is the maximum background concentration calculated by EKI for the four lithologies at the Presidio.

TABLE A-1
LEAD INTAKE SUMMARY FOR RESIDENTIAL, RECREATIONAL, AND COMMERCIAL/INDUSTRIAL USERS (a)

Presidio of San Francisco, California

Notes (continued):

(e) The concentration of lead in Presidio soil corresponds to the value that results in a cumulative blood lead concentration of 10 µg/dl. This value is the proposed cleanup level for the scenario indicated.

(f) See Appendix A for the computer spreadsheets in which blood lead concentration is calculated.

BLOOD LEAD CONCENTRATION FOR EXPOSURE OF RESIDENTIAL POPULATIONS TO LEAD IN SOIL AT PROPOSED CLEANUP LEVEL

CALIFORNIA DEPARTMENT OF TOXIC SUBSTANCES CONTROL

USER'S GUIDE to version 7

INPUT	
MEDIUM	LEVEL
Lead in Air (ug/m^3)	0.028
Lead in Soil/Dust (ug/g)	**370.0**
Lead in Water (ug/l)	2.4
% Home-grown Produce	0%
Respirable Dust (ug/m^3)	1.5

OUTPUT							
	Percentile Estimate of Blood Pb (ug/dl)					PRG-99	PRG-95
	50th	90th	95th	98th	99th	(ug/g)	(ug/g)
BLOOD Pb, ADULT	0.8	1.4	1.6	2.0	2.3	3184	4575
BLOOD Pb, CHILD	3.4	6.1	7.3	8.8	**10.0**	368	549
BLOOD Pb, PICA CHILD	6.0	10.9	12.9	15.7	17.8	185	276
BLOOD Pb, OCCUPATIONA	0.4	0.7	0.8	1.0	1.1	#DIV/0!	#DIV/0!

EXPOSURE PARAMETERS			
	units	adults	children
Days per week	days/wk	7	
Days per week, occupational			
Geometric Standard Deviation		1.6	
Blood lead level of concern (ug/dl)		10	
Skin area, residential	cm^2	5700	2900
Skin area occupational	cm^2	2900	
Soil adherence	ug/cm^2	70	200
Dermal uptake constant	(ug/dl)/(ug/day)	0.0001	
Soil ingestion	mg/day	50	100
Soil ingestion, pica	mg/day		200
Ingestion constant	(ug/dl)/(ug/day)	0.04	0.16
Bioavailability	unitless	0.44	
Breathing rate	m^3/day	20	6.8
Inhalation constant	(ug/dl)/(ug/day)	0.082	0.192
Water ingestion	l/day	1.4	0.4
Food ingestion	kg/day	1.9	1.1
Lead in market basket	ug/kg	3.1	
Lead in home-grown produce	ug/kg	166.5	

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PATHWAYS						
ADULTS	Residential			Occupational		
	Pathway contribution			Pathway contribution		
Pathway	PEF	ug/dl	percent	PEF	ug/dl	percent
Soil Contact	3.8E-5	0.01	2%	0.0E+0	0.00	0%
Soil Ingestion	8.8E-4	0.33	43%	0.0E+0	0.00	0%
Inhalation, bkgrnd		0.05	6%		0.00	0%
Inhalation	2.5E-6	0.00	0%	0.0E+0	0.00	0%
Water Ingestion		0.13	18%		0.13	37%
Food Ingestion, bkgrnd		0.23	31%		0.23	63%
Food Ingestion	0.0E+0	0.00	0%			0%

CHILDREN	typical			with pica		
	Pathway contribution			Pathway contribution		
Pathway	PEF	ug/dl	percent	PEF	ug/dl	percent
Soil Contact	5.6E-5	0.02	1%		0.02	0%
Soil Ingestion	7.0E-3	2.60	78%	1.4E-2	5.21	87%
Inhalation	2.0E-6	0.00	0%		0.00	0%
Inhalation, bkgrnd		0.04	1%		0.04	1%
Water Ingestion		0.15	5%		0.15	3%
Food Ingestion, bkgrnd		0.54	16%		0.54	9%
Food Ingestion	0.0E+0	0.00	0%		0.00	0%

BLOOD LEAD CONCENTRATION FOR EXPOSURE OF CHILDREN TO BACKGROUND LEAD IN AIR, WATER, AND FOOD UNDER A RECREATIONAL SCENARIO

CALIFORNIA DEPARTMENT OF TOXIC SUBSTANCES CONTROL

USER'S GUIDE to version 7

INPUT	
MEDIUM	LEVEL
Lead in Air (ug/m^3)	**0.028**
Lead in Soil/Dust (ug/g)	0.0
Lead in Water (ug/l)	**15**
% Home-grown Produce	0%
Respirable Dust (ug/m^3)	1.5

OUTPUT							
	Percentile Estimate of Blood Pb (ug/dl)					PRG-99	PRG-95
	50th	90th	95th	98th	99th	(ug/g)	(ug/g)
BLOOD Pb, ADULT	1.1	2.0	2.4	2.9	3.3	2417	3809
BLOOD Pb, CHILD	1.5	2.8	3.3	4.0	**4.6**	255	435
BLOOD Pb, PICA CHILD	1.5	2.8	3.3	4.0	4.6	128	219
BLOOD Pb, OCCUPATIONAL	1.1	2.0	2.4	2.9	3.3	3475	5464

EXPOSURE PARAMETERS			
	units	adults	**children**
Days per week	days/wk	7	
Days per week, occupational		5	
Geometric Standard Deviation		1.6	
Blood lead level of concern (ug/dl)		10	
Skin area, residential	cm^2	5700	2900
Skin area occupational	cm^2	2900	
Soil adherence	ug/cm^2	70	200
Dermal uptake constant	(ug/dl)/(ug/day)	0.0001	
Soil ingestion	mg/day	50	100
Soil ingestion, pica	mg/day		200
Ingestion constant	(ug/dl)/(ug/day)	0.04	0.16
Bioavailability	unitless	0.44	
Breathing rate	m^3/day	20	6.8
Inhalation constant	(ug/dl)/(ug/day)	0.082	0.192
Water ingestion	l/day	1.4	0.4
Food ingestion	kg/day	1.9	1.1
Lead in market basket	ug/kg	3.1	
Lead in home-grown produce	ug/kg	0.0	

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PATHWAYS						
ADULTS	Residential			Occupational		
	Pathway contribution			Pathway contribution		
Pathway	PEF	ug/dl	percent	PEF	ug/dl	percent
Soil Contact	3.8E-5	0.00	0%	1.4E-5	0.00	0%
Soil Ingestion	8.8E-4	0.00	0%	6.3E-4	0.00	0%
Inhalation, bkgrnd		0.05	4%		0.03	3%
Inhalation	2.5E-6	0.00	0%	1.8E-6	0.00	0%
Water Ingestion		0.84	75%		0.84	76%
Food Ingestion, bkgrnd		0.23	21%		0.23	21%
Food Ingestion	0.0E+0	0.00	0%			0%

CHILDREN	typical			with pica		
	Pathway contribution			Pathway contribution		
Pathway	PEF	ug/dl	percent	PEF	ug/dl	percent
Soil Contact	5.6E-5	0.00	0%		0.00	0%
Soil Ingestion	7.0E-3	0.00	0%	1.4E-2	0.00	0%
Inhalation	2.0E-6	0.00	0%		0.00	0%
Inhalation, bkgrnd		0.04	2%		0.04	2%
Water Ingestion		0.96	62%		0.96	62%
Food Ingestion, bkgrnd		0.54	35%		0.54	35%
Food Ingestion	0.0E+0	0.00	0%		0.00	0%

BLOOD LEAD CONCENTRATION FOR EXPOSURE OF CHILDREN TO BACKGROUND LEAD IN SOIL UNDER A RECREATIONAL SCENARIO

CALIFORNIA DEPARTMENT OF TOXIC SUBSTANCES CONTROL

USER'S GUIDE to version 7

INPUT	
MEDIUM	LEVEL
Lead in Air (ug/m^3)	0.0
Lead in Soil/Dust (ug/g)	**66.0**
Lead in Water (ug/l)	0.0
% Home-grown Produce	0%
Respirable Dust (ug/m^3)	1.5

OUTPUT	Percentile Estimate of Blood Pb (ug/dl)					PRG-99	PRG-95
	50th	90th	95th	98th	99th	(ug/g)	(ug/g)
BLOOD Pb, ADULT	0.3	0.5	0.6	0.7	0.8	5914	8349
BLOOD Pb, CHILD	0.3	0.5	0.6	0.7	**0.8**	825	1141
BLOOD Pb, PICA CHILD	0.5	1.0	1.2	1.4	1.6	414	573
BLOOD Pb, OCCUPATIONAL	0.3	0.5	0.6	0.7	0.8	4830	6819

EXPOSURE PARAMETERS	units	adults	children
Days per week	days/wk	4	
Days per week, occupational		5	
Geometric Standard Deviation		1.6	
Blood lead level of concern (ug/dl)		10	
Skin area, residential	cm^2	5700	2900
Skin area occupational	cm^2	2900	
Soil adherence	ug/cm^2	70	200
Dermal uptake constant	(ug/dl)/(ug/day)	0.0001	
Soil ingestion	mg/day	50	100
Soil ingestion, pica	mg/day		200
Ingestion constant	(ug/dl)/(ug/day)	0.04	0.16
Bioavailability	unitless	0.44	
Breathing rate	m^3/day	20	6.8
Inhalation constant	(ug/dl)/(ug/day)	0.082	0.192
Water ingestion	l/day	1.4	0.4
Food ingestion	kg/day	1.9	0.0
Lead in market basket	ug/kg	3.1	
Lead in home-grown produce	ug/kg	29.7	

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PATHWAYS						
ADULTS	Residential			Occupational		
	Pathway contribution			Pathway contribution		
Pathway	PEF	ug/dl	percent	PEF	ug/dl	percent
Soil Contact	2.2E-5	0.00	1%	1.4E-5	0.00	0%
Soil Ingestion	5.0E-4	0.03	12%	6.3E-4	0.04	15%
Inhalation, bkgrnd		0.00	0%		0.00	0%
Inhalation	1.4E-6	0.00	0%	1.8E-6	0.00	0%
Water Ingestion		0.00	0%		0.00	0%
Food Ingestion, bkgrnd		0.23	87%		0.23	85%
Food Ingestion	0.0E+0	0.00	0%			0%

CHILDREN	typical			with pica		
	Pathway contribution			Pathway contribution		
Pathway	PEF	ug/dl	percent	PEF	ug/dl	percent
Soil Contact	3.2E-5	0.00	1%		0.00	0%
Soil Ingestion	4.0E-3	0.27	99%	8.0E-3	0.53	100%
Inhalation	1.1E-6	0.00	0%		0.00	0%
Inhalation, bkgrnd		0.00	0%		0.00	0%
Water Ingestion		0.00	0%		0.00	0%
Food Ingestion, bkgrnd		0.00	0%		0.00	0%
Food Ingestion	0.0E+0	0.00	0%		0.00	0%

BLOOD LEAD CONCENTRATION FOR EXPOSURE OF CHILDREN TO LEAD IN SOIL AT PROPOSED CLEANUP LEVEL UNDER A RECREATIONAL SCENARIO

CALIFORNIA DEPARTMENT OF TOXIC SUBSTANCES CONTROL

USER'S GUIDE to version 7

INPUT	
MEDIUM	LEVEL
Lead in Air (ug/m^3)	0.0
Lead in Soil/Dust (ug/g)	**510.0**
Lead in Water (ug/l)	0.0
% Home-grown Produce	0%
Respirable Dust (ug/m^3)	1.5

OUTPUT	Percentile Estimate of Blood Pb (ug/dl)					PRG-99	PRG-95
	50th	90th	95th	98th	99th	(ug/g)	(ug/g)
BLOOD Pb, ADULT	0.4	0.8	0.9	1.1	1.3	7885	11133
BLOOD Pb, CHILD	1.6	2.8	3.4	4.1	**4.6**	1100	1521
BLOOD Pb, PICA CHILD	3.1	5.6	6.7	8.1	9.2	552	764
BLOOD Pb, OCCUPATIONAL	0.6	1.0	1.2	1.5	1.7	4830	6819

EXPOSURE PARAMETERS	units	adults	children
Days per week	days/wk	3	
Days per week, occupational		5	
Geometric Standard Deviation		1.6	
Blood lead level of concern (ug/dl)		10	
Skin area, residential	cm^2	5700	2900
Skin area occupational	cm^2	2900	
Soil adherence	ug/cm^2	70	200
Dermal uptake constant	(ug/dl)/(ug/day)	0.0001	
Soil ingestion	mg/day	50	100
Soil ingestion, pica	mg/day		200
Ingestion constant	(ug/dl)/(ug/day)	0.04	0.16
Bioavailability	unitless	0.44	
Breathing rate	m^3/day	20	6.8
Inhalation constant	(ug/dl)/(ug/day)	0.082	0.192
Water ingestion	l/day	1.4	0.4
Food ingestion	kg/day	1.9	0.0
Lead in market basket	ug/kg	3.1	
Lead in home-grown produce	ug/kg	229.5	

Click here for REFERENCES

PATHWAYS

ADULTS	Residential			Occupational		
	Pathway contribution			Pathway contribution		
Pathway	PEF	ug/dl	percent	PEF	ug/dl	percent
Soil Contact	1.6E-5	0.01	2%	1.4E-5	0.01	1%
Soil Ingestion	3.8E-4	0.19	44%	6.3E-4	0.32	57%
Inhalation, bkgrnd		0.00	0%		0.00	0%
Inhalation	1.1E-6	0.00	0%	1.8E-6	0.00	0%
Water Ingestion		0.00	0%		0.00	0%
Food Ingestion, bkgrnd		0.23	54%		0.23	42%
Food Ingestion	0.0E+0	0.00	0%			0%

CHILDREN	typical			with pica		
	Pathway contribution			Pathway contribution		
Pathway	PEF	ug/dl	percent	PEF	ug/dl	percent
Soil Contact	2.4E-5	0.01	1%		0.01	0%
Soil Ingestion	3.0E-3	1.54	99%	6.0E-3	3.08	100%
Inhalation	8.4E-7	0.00	0%		0.00	0%
Inhalation, bkgrnd		0.00	0%		0.00	0%
Water Ingestion		0.00	0%		0.00	0%
Food Ingestion, bkgrnd		0.00	0%		0.00	0%
Food Ingestion	0.0E+0	0.00	0%		0.00	0%

BLOOD LEAD CONCENTRATION FOR EXPOSURE OF COMMERCIAL/INDUSTRIAL POPULATIONS TO LEAD IN SOIL AT PROPOSED CLEANUP LEVEL

CALIFORNIA DEPARTMENT OF TOXIC SUBSTANCES CONTROL

USER'S GUIDE to version 7

INPUT	
MEDIUM	LEVEL
Lead in Air (ug/m^3)	0.028
Lead in Soil/Dust (ug/g)	**3450.0**
Lead in Water (ug/l)	15.0
% Home-grown Produce	0%
Respirable Dust (ug/m^3)	1.5

OUTPUT							
	Percentile Estimate of Blood Pb (ug/dl)					PRG-99	PRG-95
	50th	90th	95th	98th	99th	(ug/g)	(ug/g)
BLOOD Pb, ADULT	3.4	6.2	7.3	8.9	10.1	3404	5353
BLOOD Pb, CHILD	19.0	34.7	41.1	50.0	**56.9**	359	611
BLOOD Pb, PICA CHILD	36.4	66.4	78.6	95.5	108.7	180	307
BLOOD Pb, OCCUPATIONA	3.3	6.1	7.2	8.7	10.0	3475	5464

EXPOSURE PARAMETERS			
	units	adults	children
Days per week	days/wk	**5**	
Days per week, occupational		5	
Geometric Standard Deviation		1.6	
Blood lead level of concern (ug/dl)		10	
Skin area, residential	cm^2	5700	2900
Skin area occupational	cm^2	2900	
Soil adherence	ug/cm^2	70	200
Dermal uptake constant	(ug/dl)/(ug/day)	0.0001	
Soil ingestion	mg/day	50	100
Soil ingestion, pica	mg/day		200
Ingestion constant	(ug/dl)/(ug/day)	0.04	0.16
Bioavailability	unitless	0.44	
Breathing rate	m^3/day	20	6.8
Inhalation constant	(ug/dl)/(ug/day)	0.082	0.192
Water ingestion	l/day	1.4	0.4
Food ingestion	kg/day	1.9	1.1
Lead in market basket	ug/kg	3.1	
Lead in home-grown produce	ug/kg	1552.5	

Click here for REFERENCES

PATHWAYS						
ADULTS	Residential			Occupational		
	Pathway contribution			Pathway contribution		
Pathway	PEF	ug/dl	percent	PEF	ug/dl	percent
Soil Contact	2.7E-5	0.09	3%	1.4E-5	0.05	1%
Soil Ingestion	6.3E-4	2.17	64%	6.3E-4	2.17	65%
Inhalation, bkgrnd		0.03	1%		0.03	1%
Inhalation	1.8E-6	0.01	0%	1.8E-6	0.01	0%
Water Ingestion		0.84	25%		0.84	25%
Food Ingestion, bkgrnd		0.23	7%		0.23	7%
Food Ingestion	0.0E+0	0.00	0%			0%

CHILDREN	typical			with pica		
	Pathway contribution			Pathway contribution		
Pathway	PEF	ug/dl	percent	PEF	ug/dl	percent
Soil Contact	4.0E-5	0.14	1%		0.14	0%
Soil Ingestion	5.0E-3	17.35	91%	1.0E-2	34.70	95%
Inhalation	1.4E-6	0.00	0%		0.00	0%
Inhalation, bkgrnd		0.03	0%		0.03	0%
Water Ingestion		0.96	5%		0.96	3%
Food Ingestion, bkgrnd		0.54	3%		0.54	1%
Food Ingestion	0.0E+0	0.00	0%		0.00	0%

TABLE A-2
SUMMARY OF LEAD RESULTS FROM SAMPLING IN RESIDENCES

Presidio of San Francisco, California

Street Address / Sample ID	Lead Concentration (µg/L) (a)		
	12/1/98	4/27/99	9/12/00
PR-1	2.8	4.7	NA (b)
PR-2	4.6	3.1	NA
PR-3	1.5	NA	NA
PR-4	-- (c)	1.2	NA
PR-5	10.2	5.9	NA
PR-6	1.1	3.8	NA
PR-7	<1.0	1.7	NA
PR-8	<1.0	<1.0	NA
PR-9	--	3.3	NA
PR-10	2.1	2.4	NA
PR-11	<1.0	<1.0	NA
PR-12	1.2	<1.0	NA
PR-13	--	<1.0	NA
PR-14	--	1.6	NA
PR-15	<1.0	<1.0	NA
PR-16	1.4	1.4	NA
PR-17	--	NA	NA
PR-18	1.1	<1.0	NA
PR-19	1.9	3.3	NA
PR-20	1.5	2.2	NA
PR-21	1.8	NA	NA
PR-22	1.1	NA	NA
PR-23	NA	1.1	NA
PR-28	NA	NA	2.3
PR-29	NA	NA	<1.0
PR-30	NA	NA	1.5
PR-31	NA	NA	<1.0
PR-32	NA	NA	3.6
PR-33	NA	NA	<1.0
PR-34	NA	NA	<1.0
PR-35	NA	NA	27 (d)
PR-36	NA	NA	<1.0
PR-37	NA	NA	<1.0
95% Upper Confidence Limit of the Mean	2.4 µg/L		

Notes:

(a) Samples were collected to comply with the monitoring requirements of the Lead and Copper Rule. Water samples collected by the Trust for lead analysis were from the first draw of the day. For the 12/1/98 and 4/27/99 monitoring events, the Presidio was using 100% Lobos Creek water. For the 9/12/00 monitoring event the Presidio was using 75-80% Lobos Creek water and 20-25% City water.

(b) NA = Not analyzed or no data available.

(c) "--" indicates sample data not valid due to faucet use before sample collection.

(d) It is EKI's understanding that the tap was significantly corroded; tap has been replaced. This data point is not included in statistical analysis of lead data, as it is not considered representative of the actual water.

APPENDIX B

CRYSTAL BALL INPUT PARAMETERS AND MONTE CARLO METHOD OUTPUT

APPENDIX B

CRYSTAL BALL™ INPUT PARAMETERS AND MONTE CARLO METHOD OUTPUT

October 2002

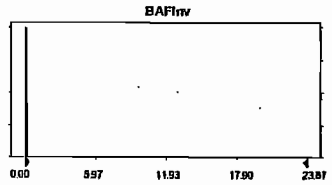
Uncertainty Analysis for Birds Based on Low and High BTAG TRVs
Presidio of San Francisco
San Francisco, California

Assumption: BAFinv **Cell: K2**

Lognormal distribution with parameters:

Mean	0.27
Standard Dev.	18.82

Selected range is from 0.00 to +Infinity
Mean value in simulation was 0.22

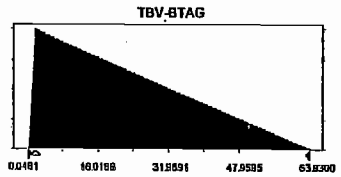


Assumption: TBV-BTAG **Cell: B3**

Triangular distribution with parameters:

Minimum	0.0481
Likeliest	1.7500
Maximum	63.9300

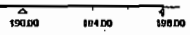
Selected range is from 0.0481 to 63.9300
Mean value in simulation was 21.8493



Uncertainty Analysis for Birds Based on Low and High BTAG TRVs

Presidio of San Francisco

San Francisco, California

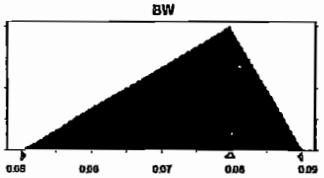


Selected range is from 182.00 to 198.00
Mean value in simulation was 190.02

Assumption: BW **Cell: J2**

Triangular distribution with parameters:

Minimum	0.06
Likeliest	0.08
Maximum	0.09



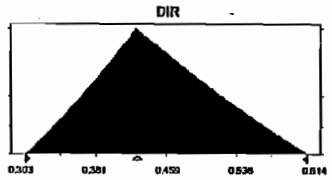
Selected range is from 0.06 to 0.09
Mean value in simulation was 0.07

Uncertainty Analysis for Birds Based on Low and High BTAG TRVs
Presidio of San Francisco
San Francisco, California

Assumption: DIR **Cell: D2**

Triangular distribution with parameters:

Minimum	0.303
Likeliest	0.426
Maximum	0.614

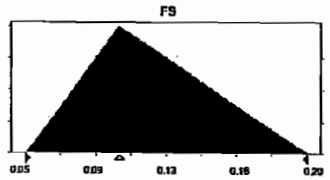


Selected range is from 0.303 to 0.614
Mean value in simulation was 0.447

Assumption: FS **Cell: E2**

Triangular distribution with parameters:

Minimum	0.05
Likeliest	0.10
Maximum	0.20

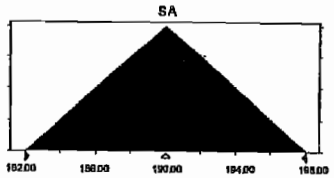


Selected range is from 0.05 to 0.20
Mean value in simulation was 0.12

Assumption: SA **Cell: G2**

Triangular distribution with parameters:

Minimum	182.00
Likeliest	190.00
Maximum	198.00



Uncertainty Analysis for Birds Based on Low and High BTAG TRVs
Presidio of San Francisco
San Francisco, California

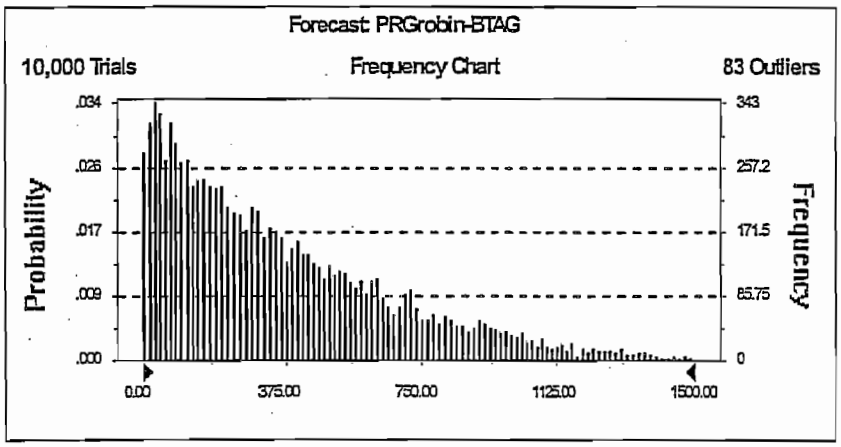
Forecast: PRGrobin-BTAG

Summary:

Display Range is from 0.00 to 1500.00
Entire Range is from 0.08 to 2386.91
After 10,000 Trials, the Std. Error of the Mean is 3.34

Statistics:

	Value
Trials	10,000
Mean	386
Median	297
Mode	---
Standard Deviation	334
Variance	111,420
Skewness	1.35
Kurtosis	5.18
Coeff. of Variability	0.87
Range Minimum	0.08
Range Maximum	2,387
Range Width	2,387
Mean Std. Error	3.34



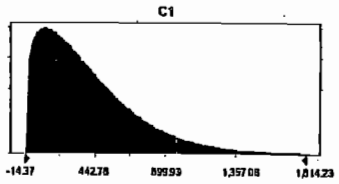
Percentile	Value	Percentile	Value
0%	0	55%	338
5%	25	60%	385
10%	48	65%	436
15%	73	70%	495
20%	98	75%	559
25%	126	80%	633
30%	156	85%	724
35%	189	90%	853
40%	220	95%	1033
45%	257	100%	2387
50%	297		

Assumptions for Uncertainty Analysis for Plants
Presidio of San Francisco
San Francisco, California

Assumption: Non-lethal NOECs

Weibull distribution with parameters:

Location	-14.37
Scale	442.21
Shape	1.26122401



Selected range is from -14.37 to +Infinity
Mean value in simulation was 396.27

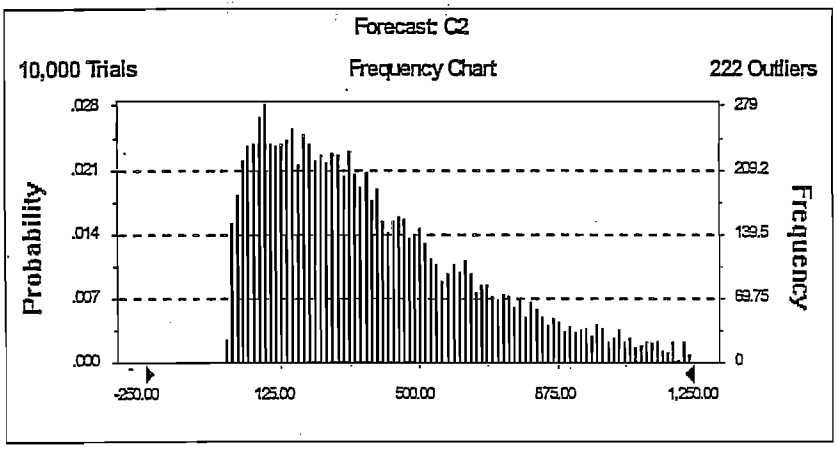
Uncertainty Analysis for Plants
Presidio of San Francisco
San Francisco, California

Forecast: Non-lethal effects on plants

Summary:

Display Range is from 0.00 to 1,250.00
Entire Range is from 0.03 to 2,503.82
After 10,000 Trials, the Std. Error of the Mean is 3.25

Statistics:	Value
Trials	10000
Mean	403.93
Median	324.17
Mode	---
Standard Deviation	325.43
Variance	105,902.02
Skewness	1.33
Kurtosis	5.24
Coeff. of Variability	0.81
Range Minimum	0.03
Range Maximum	2,735.80
Range Width	2,735.80
Mean Std. Error	3.25



Percentile	Value	Percentile	Value
0%	0.03	55%	360.65
5%	33.57	60%	403.57
10%	66.90	65%	452.63
15%	97.89	70%	509.64
20%	128.11	75%	568.32
25%	157.08	80%	644.91
30%	186.04	85%	730.93
35%	219.55	90%	856.43
40%	254.06	95%	1,047.45
45%	289.09	100%	2,735.80
50%	324.17		

APPENDIX C

BACKGROUD MEETALS DATA SETS FOR SERPENTINITE, COLMA FORMATION, BEACH/DUNE AND CHERT/SHALE SAMPLES

APPENDIX C

BACKGROUND METALS DATA SETS FOR SERPENTINITE, COLMA FORMATION, BEACH/DUNE, AND CHERT/SHALE SAMPLES

October 2002

TABLE C-1
BACKGROUND DATA SET - SERPENTINITE LITHOLOGY
Presidio of San Francisco, California

Sample ID	Depth (ft.) (a)	Sample Date	Laboratories (b)	Major Elements (mg/kg)			
				Iron	Aluminum	Magnesium	Manganese
1a	NA (c)	10/16/96	NEIC	78,900	18,100	95,900	1,260
1b	NA	10/16/96	NEIC	72,400	15,900	95,200	1,200
1c	NA	10/16/96	NEIC	73,500	15,600	88,200	1,200
1d	NA	10/16/96	NEIC	80,000	16,800	85,200	1,280
BKGDSB04	0	09/02/92	ED	36,000	5,260	160,000	505
BKGDSB10	18	12/07/94	QA	56,800	7,610	15,300	594
BKGDSB14	1.5	12/08/94	QA	80,700	8,660	89,200	590
BKGDSB15	14.5	12/08/94	QA	73,100	3,500	124,000	2,090
BKGDSB15	20.5	12/08/94	QA	58,300	2,530	179,000	825
BKGSO03A	0.3	11/27/90	UB	52,700	3,560	270,000	791
UBR01SB02	COMP (d)	02/24/99	CALLAB	47,100	7,380	193,000	595
UBR02SB02	COMP (d)	02/25/99	CALLAB	44,700	1,130	213,000	671
1261 WEST	10	06/21/93	UNKNOWN	56,600	NA	NA	3,450
1351SO01B	17	10/26/90	UB	63,000	7,720	140,000	988
1351SO02B	15	10/29/90	UB	94,000	33,100	120,000	1,020
GCEX01	3	10/19/98	QUANT	120,000	20,300	33,500	1,150
GCEX02	3	10/19/98	QUANT	102,000	10,000	72,500	1,330
GCEX03	3	10/19/98	QUANT	71,800	3,520	174,000	1,260
GGSB05	2	08/07/92	ED	54,000	21,000	12,000	811
TRENCH II	1	09/16/93	UNKNOWN	36,700	NA	NA	667
UST 1221.3 EAST	14	09/29/93	UNKNOWN	50,600	NA	NA	1,130
UST 1221.4 EAST	14	09/29/93	UNKNOWN	32,300	NA	NA	452

TABLE C-1
BACKGROUND DATA SET - SERPENTINITE LITHOLOGY
Presidio of San Francisco, California

Sample ID	Title 22 Metals (mg/kg)																
	Antimony	Arsenic	Barium	Beryllium	Cadmium	Chromium	Cobalt	Copper	Lead	Mercury	Molybdenum	Nickel	Selenium	Silver	Thallium	Vandium	Zinc
1a	<4	NA	63.8	0.15	<0.5	1,380	118	32.3	<1	NA	<0.9	2,590	<6	<1	0.077	29.3	80
1b	<4	NA	63.8	0.11	<0.5	1,310	115	29.9	16	NA	<0.9	2,290	<6	<1	0.064	34.7	85
1c	<4	NA	66.1	<0.09	<0.5	1,520	117	45.2	64	NA	<0.9	2,210	<6	<1	0.069	38.6	109
1d	<4	NA	67.6	0.1	<0.5	1,680	122	33	52	NA	<0.9	2,290	<6	<1	0.067	39.7	114
BKGDSB04	<41.3	1.290	NA	<0.50	<0.515	750	59.8	12.6	NA	<0.027	NA	1,120	<0.25	<0.521	<14.7	27.7	17.7
BKGDSB10	<0.1	<0.250	16.5	<0.10	<0.80	1,290	73.1	64.6	4.48	<0.059	NA	1,940	<0.416	<0.500	<0.162	36.2	42.6
BKGDSB14	<0.1	2.49	92.3	NA	NA	1,050	135	44.2	NA	<0.059	NA	3,670	<0.416	1.67	<0.162	27	20.8
BKGDSB15	<0.1	0.507	62.4	NA	NA	672	140	51.4	NA	<0.059	NA	3,950	<0.416	<0.644	<0.162	40.2	95
BKGDSB15	<0.1	0.320	18.7	<1.0	NA	910	111	17.3	4.01	<0.059	NA	2,530	<0.416	<5.00	<0.162	34.2	50.6
BKGSO03A	<19.6	<2.5	<3.29	<0.427	<1.2	812	85.3	5.08	3.72	<0.05	NA	2,190	<0.449	<0.803	<34.3	11.8	6.64
UBR01SB02	<13.6	NA	30.5	<1.1	0.94	1,160	101	11.1	NA	NA	NA	2,070	<56.7	<2.3	<454	35.2	17
UBR02SB02	<21.6	NA	NA	<1.8	<1.8		97.6	4.6	NA	NA	NA	1,950	<90.1	<3.6	<721	10.4	21.6
1261 WEST	NA	2.9	NA	0.35	1.5	493	NA	59.4	76.8	NA	NA	1,430	NA	NA	NA	50.2	139
1351SO01B	NA	<2.5	56.0	<0.427	NA	753	106	13.3	3.72	0.058	NA	2,600	NA	NA	NA	28.4	33.6
1351SO02B	NA	<2.5	149	0.774	NA	1,270	82.4	41	3.72	<0.05	NA	2,530	NA	NA	NA	56.0	60.5
GCEX01	NA	NA	81.4	NA	NA	1,350	146	29.9	2.6	NA	NA	3,510	NA	NA	NA	48.7	58.3
GCEX02	NA	NA	49.7	NA	NA	1,090	165	21.4	0.67	NA	NA	4,290	NA	NA	NA	28.8	52.5
GCEX03	NA	NA	20.2	NA	NA	586	153	18.5	NA	NA	NA	2,880	NA	NA	NA	25.3	28.4
GGSB05	<41.3	4.09	106	1.07	1.85	556	103	40.50	6.29	0.069	NA	1,020	<0.25	<0.521	NA	84.4	67.2
TRENCH II	NA	NA	NA	NA	0.86	914	NA	45.6	NA	NA	NA	1,430	NA	NA	NA	35.8	45.4
UST 1221.3 EAST	NA	1.2	NA	NA	NA	786	NA	49.4	3.5	NA	NA	882	NA	NA	NA	61	79.3
UST 1221.4 EAST	NA	2.4	NA	NA	NA	527	NA	30.9	11.3	NA	NA	686	NA	NA	NA	54.4	55.8

TABLE C-1
BACKGROUND DATA SET - SERPENTINITE LITHOLOGY
Presidio of San Francisco, California

Abbreviations:

NA	Not Analyzed or Rejected Data

Notes:

a) Depth in feet below ground surface.

b) Laboratory Abbreviations:

CALLAB	Caltest Analytical Laboratory, Napa, California
ED	Environmental Science and Engineering, Inc., Englewood, Colorado
NEIC	U.S. EPA National Enforcement Investigations Center
UB	DataChem, Inc., Salt Lake City, Utah
QA	Quality Assurance Laboratories, San Diego, California
QUANT	Quanterra, Sacramento, California

c) See text for discussion of data.

d) COMP = Composite Sample

TABLE C-2

BACKGROUND DATA SET - COLMA FORMATION LITHOLOGY

Presidio of San Francisco, California

Sample ID	Depth (ft.) (a)	Sample Date	Laboratories (b)	Major Elements (mg/kg) Iron	Aluminum	Magnesium	Manganese
BKGDSB01	2	08/21/92	ED	26,000	14,000	4,220	390
BKGDSB01	5	08/21/92	ED	20,000	9,900	4,230	NA (c)
BKGDSB11	5	12/07/94	QA	31,200	25,900	3,540	270
BKGDSB12	5	12/07/94	QA	14,700	10,300	3,470	227
BKGDSB12	9.5	12/07/94	QA	16,800	9,480	4,060	271
BKGDSB13	5	12/07/94	QA	17,400	13,000	3,910	231
BKGDSB13	9.5	12/07/94	QA	15,400	8,910	4,090	232
LF10BK01	21.5	09/06/94	UNKNOWN	18,800	9,690	2,870	374
LF10BK03	57.5	09/06/94	UNKNOWN	35,600	18,400	7,380	400
LF10BK1BDUP	0	09/06/94	UNKNOWN	NA	NA	NA	NA
CFLSSB01	4	11/18/94	QA	12,300	8,600	2,430	88.1
CFLSSB02	3	11/18/94	QA	12,100	7,010	3,020	227
DAEGW04	8	10/19/92	ED	19,000	9,100	3,310	261
DAESB03	28	08/26/92	ED	17,000	7,200	3,110	243
LF6SB01	20	11/20/94	SU	7,560	4,200	2,640	81.6
LF6SB01	9	11/20/94	SU	20,200	6,160	3,810	224
LF6SB02	20	11/20/94	SU	10,900	4,800	3,160	120
LF6SB02	3	11/20/94	SU	18,100	7,230	3,950	373
LF6SB02	8	11/20/94	SU	14,300	5,170	3,740	154
LF6SB03	20	11/20/94	SU	16,700	6,950	4,310	167
LF6SB03	3	11/20/94	SU	35,500	11,100	4,330	422
LF6SB03	8	11/20/94	SU	16,400	6,540	3,490	207
LF6SB04	20.5	11/20/94	SU	11,400	3,830	3,710	110
LF6SB04	8	11/20/94	SU	9,790	5,170	2,970	132
LF6SB05	20	11/20/94	SU	9,630	4,030	2,580	91.8
LF6SB05	3.5	11/20/94	SU	16,800	6,940	3,470	224
LF6SB05	8.5	11/20/94	SU	11,900	5,290	3,460	216
LF6SB06	20	11/20/94	SU	15,500	5,120	3,810	131
LF6SB06	3	11/20/94	SU	30,200	13,400	4,700	381
LF6SB06	8	11/20/94	SU	34,900	5,130	3,490	164
LF6SO03B	7.5	11/08/90	UB	30,000	15,100	5,250	368
LF8SO02B	19	10/01/90	UB	35,400	25,700	6,500	922

TABLE C-2
BACKGROUND DATA SET - COLMA FORMATION LITHOLOGY
Presidio of San Francisco, California

Sample ID	Depth (ft.) (a)	Sample Date	Table 22 Metals (mg/kg)																
			Antimony	Arsenic	Barium	Beryllium	Cadmium	Chromium	Cobalt	Copper	Lead	Mercury	Molybdenum	Nickel	Selenium	Silver	Thallium	Vandium	Zinc
BKGDSB01	2	08/21/92	<41.3	5	100	<0.50	<0.515	100	17	17.3	4.95	0.031	NA	97.5	0.456	<0.521	NA	63.3	36.9
BKGDSB01	5	08/21/92	<41.3	3.27	58.6	<0.50	<0.515	90.2	14	13.9	4.55	<0.027	NA	89.1	0.400	<0.521	<14.7	55.4	33.9
BKGDSB11	5	12/07/94	<0.40	<2.50	121	0.681	<0.80	78.3	13.0	20.9	5.61	<0.059	NA	34.6	<1.66	<0.500	<0.162	64.9	47.3
BKGDSB12	5	12/07/94	<0.50	<2.50	36.9	0.251	<0.80	51.8	11.3	13.0	3.04	<0.059	NA	63.0	<0.416	<0.500	<0.162	37.2	29.1
BKGDSB12	9.5	12/07/94	<0.40	<2.50	43.7	0.256	<0.80	64.6	12.9	80.8	3.84	<0.059	NA	69.3	<0.416	<0.500	<0.162	43.3	61.6
BKGDSB13	5	12/07/94	<0.40	<2.50	41.1	0.301	<0.80	78.4	12.2	10.4	3.99	<0.059	NA	78.5	<0.416	<0.500	<0.162	43.7	29.1
BKGDSB13	9.5	12/07/94	<0.40	<2.50	26.9	0.248	<0.80	67.8	12.3	20.3	3.34	<0.059	NA	38.5	<0.416	<0.500	<0.162	41.6	40.8
LF10BK01	21.5	09/06/94	NA	2.6	61.0	NA	NA	55.6	11.8	11.9	2.9	<0.11	NA	34.1	NA	NA	NA	43.4	27.7
LF10BK03	57.5	09/06/94	NA	2.1	175	NA	NA	103	19.0	28.2	3.4	<0.12	NA	123	NA	NA	NA	49.4	50.4
LF10BK1BDUP	0	09/06/94	NA	3.4	89.4	NA	NA	41.4	9.9	13.5	4.7	<0.12	NA	40.6	NA	NA	NA	42.6	31.9
CFLSSB01	4	11/18/94	<0.40	1.58	35.2	0.207	<0.80	58.0	12.0	9.03	3.94	<0.059	NA	31.2	<0.416	<0.500	<0.162	42.4	22.9
CFLSSB02	3	11/18/94	NA	3.86	55.7	0.178	NA	58.3	8.21	10.9	7.06	<0.059	NA	48.1	<0.416	NA	NA	35.0	25.2
DAEGW04	8	10/19/92	<41.3	3.78	43.8	<0.50	<0.515	96.9	10.2	24.4	3.24	<0.027	NA	67.8	<0.250	<0.521	NA	43.1	33.1
DAESB03	28	08/26/92	<41.3	3.14	29.4	<0.50	<0.515	58.9	9.77	19.5	8.18	<0.027	NA	59.1	<0.250	<0.521	<14.7	40.3	40.6
LF6SB01	20	11/20/94	NA	NA	15.6	0.348	<0.5	24	6.36	3.36	1.8	NA	NA	37.2	NA	<2.76	NA	12	16.8
LF6SB01	9	11/20/94	NA	NA	40.3	0.123	<0.1	43.7	7.73	4.93	2.58	NA	NA	43.7	NA	<7.73	NA	34.7	21.3
LF6SB02	20	11/20/94	NA	NA	18.5	<0.1	<0.1	30.5	7.85	4.03	2.18	NA	NA	43.6	NA	<4.36	NA	19.6	18.5
LF6SB02	3	11/20/94	NA	NA	47.5	0.124	<0.1	49.7	8.14	5.2	2.6	NA	NA	61	NA	<7.01	NA	31.6	22.6
LF6SB02	8	11/20/94	NA	NA	27.5	<0.1	0.22	41.8	8.8	4.62	2.42	NA	NA	53.9	NA	<6.05	NA	27.5	22
LF6SB03	20	11/20/94	<0.5	NA	23.6	<0.1	<0.1	51.5	12.1	5.84	3.06	NA	NA	64	NA	<7.09	NA	29.2	26.4
LF6SB03	3	11/20/94	<0.5	NA	68.8	0.222	0.444	81	15.5	9.54	3.44	NA	NA	72.1	NA	<11.1	NA	49.9	31.1
LF6SB03	8	11/20/94	NA	NA	39.3	0.24	<0.5	50.2	8.83	4.91	2.73	NA	NA	50.2	NA	<7.09	NA	32.7	21.8
LF6SB04	20.5	11/20/94	NA	NA	13.9	<0.1	0.371	41.8	6.73	3.02	1.97	NA	NA	32.5	NA	<6.38	NA	29	17.4
LF6SB04	8	11/20/94	NA	NA	31.9	<0.1	<0.1	26.4	5.83	3.74	2.42	NA	NA	37.4	NA	<3.96	NA	16.5	18.7
LF6SB05	20	11/20/94	NA	NA	14.6	<0.1	0.235	28	6.83	3.47	2.35	NA	NA	40.3	NA	<4.03	NA	19	16.8
LF6SB05	3.5	11/20/94	NA	NA	39.2	0.123	0.493	41.4	9.85	5.82	1.68	NA	NA	51.5	NA	<6.94	NA	29.1	22.4
LF6SB05	8.5	11/20/94	NA	NA	27	<0.1	<0.1	42.1	6.48	4.32	2.48	NA	NA	42.1	NA	<5.08	NA	23.8	20.5
LF6SB06	20	11/20/94	NA	NA	21.4	<0.1	<0.5	36.9	9.64	4.52	2.26	NA	NA	47.6	NA	<6.79	NA	31	20.2
LF6SB06	3	11/20/94	NA	NA	56	0.504	<0.5	91.8	12.3	9.74	3.02	NA	NA	71.7	NA	<12.3	NA	54.9	31.4
LF6SB06	8	11/20/94	NA	3.16	30.5	<0.1	<0.5	52.3	8.94	5.67	1.2	NA	NA	62.2	NA	<9.81	NA	48	20.7
LF6SO03B	7.5	11/08/90	NA	NA	68.8	NA	NA	149	13.5	7.97	3.72	<0.05	NA	77.4	NA	NA	NA	NA	37.2
LF8SO02B	19	10/01/90	<19.6	<2.5	172	<0.427	<1.2	79.2	17.6	22	3.72	<0.05	NA	77	<0.449	<0.803	<34.3	73.1	49.2

TABLE C-2

BACKGROUND DATA SET - COLMA FORMATION LITHOLOGY

Presidio of San Francisco, California

Sample ID	Depth (ft.) (a)	Sample Date	Laboratories (b)	Major Elements (mg/kg)			
				Iron	Aluminum	Magnesium	Manganese
LF8SO03B	19	10/02/90	UB	37,800	17,900	4,870	423
NKSB13	10	12/05/94	QA	10,800	5,130	NA	NA
NKSB14	9.5	12/07/94	QA	16,600	14,500	2,910	589
NKSB15	5	12/07/94	QA	19,000	15,300	4,630	382

TABLE C-2
BACKGROUND DATA SET - COLMA FORMATION LITHOLOGY
Presidio of San Francisco, California

Sample ID	Depth (ft.) (a)	Sample Date	Table 22 Metals (mg/kg)																
			Antimony	Arsenic	Barium	Beryllium	Cadmium	Chromium	Cobalt	Copper	Lead	Mercury	Molybdenum	Nickel	Selenium	Silver	Thallium	Vandium	Zinc
LF8SO03B	19	10/02/90	<19.6	<2.5	95.4	<0.427	<1.2	120	17.7	15.7	3.72	0.118	NA	84.2	<0.449	<0.803	<34.3	85	35.9
NKSB13	10	12/05/94	NA	2.20	14.6	0.429	NA	40.2	6.78	3.92	NA	NA	NA	NA	NA	NA	NA	34.1	15.5
NKSB14	9.5	12/07/94	NA	1.49	95.8	0.481	NA	53.6	14.2	24.4	3.97	<0.059	NA	31.2	NA	NA	NA	45.8	39.7
NKSB15	5	12/07/94	NA	2.38	95.8	0.460	NA	53.8	14.7	20.8	5.02	0.104	NA	51.8	NA	NA	NA	44.8	39.5

TABLE C-2

BACKGROUND DATA SET - COLMA FORMATION LITHOLOGY

Presidio of San Francisco, California

Abbreviations:

NA Not Analyzed or Rejected Data

Notes:

a) Depth in feet below ground surface.

b) Laboratory Abbreviations:

ED	Environmental Science and Engineering, Inc., Englewood, Colorado
QA	Quality Assurance Laboratories, San Diego, California
SU	Superior Precision Analytical, Inc., Maritime, California
UB	DataChem, Inc., Salt Lake City, Utah

c) See text for discussion of data.

Table C-3
CHERT/SHALE LITHOLOGY
Presidio of San Francisco, California

Sample ID	Depth (ft.) (a)	Sample Date	Laboratories (b)	Major Elements (mg/kg)			
				Iron	Aluminum	Magnesium	Manganese
950CR	NA (c)	9/24/98	CHROMALA	2,200	460	NA	130
950CT002	NA	10/6/98	CHROMALA	4,500	1,200	NA	4,100
950CT004	NA	10/6/98	CHROMALA	420	160	NA	24
950CT005	NA	10/6/98	CHROMALA	2,400	460	NA	570
950CT006	NA	10/6/98	CHROMALA	1,300	340	NA	100
950CT007	NA	10/6/98	CHROMALA	1,900	360	NA	260
950CT009	NA	10/6/98	CHROMALA	2,900	720	NA	2,200
950CT010	NA	10/6/98	CHROMALA	770	220	NA	700
950CT011	NA	10/15/98	CHROMALA	4,200	1,500	NA	150
950CT012	NA	10/15/98	CHROMALA	18,000	4,600	NA	390
950CT014	NA	10/15/98	CHROMALA	1,300	280	NA	110
950CT015	NA	10/15/98	CHROMALA	3,000	810	NA	180
950CT016	NA	10/15/98	CHROMALA	2,900	390	NA	150
950CT017	NA	10/15/98	CHROMALA	3,700	670	NA	51
950CT018	NA	10/15/98	CHROMALA	7,800	700	NA	150
950CT019	NA	10/15/98	CHROMALA	2,800	650	NA	40
950CT020	NA	10/15/98	CHROMALA	6,600	1,300	NA	1,400
950CT021	NA	10/15/98	CHROMALA	6,400	1,500	NA	600
950CT022	NA	10/15/98	CHROMALA	1,700	240	NA	230
950CT023	NA	10/15/98	CHROMALA	510	220	NA	120
950CT024	NA	10/15/98	CHROMALA	1,100	190	NA	<1.0
950CT025	NA	10/15/98	CHROMALA	1,300	340	NA	1,300
950CT026	NA	10/15/98	CHROMALA	840	240	NA	550
950CT027	NA	10/15/98	CHROMALA	4,400	350	NA	<1.0
950CT028	NA	10/15/98	CHROMALA	880	170	NA	1,000
950CT029	NA	10/15/98	CHROMALA	3,200	530	NA	480
950CT030	NA	10/15/98	CHROMALA	9,700	2400	NA	1,100
950CT031	NA	10/15/98	CHROMALA	2,000	450	NA	630
950CT032	NA	10/15/98	CHROMALA	3,800	500	NA	300

Table C-3

CHERT/SHALE LITHOLOGY

Presidio of San Francisco, California

Sample ID	Depth (ft.) (a)	Sample Date	Title 22 Metals (mg/kg)																
			Antimony	Arsenic	Barium	Beryllium	Cadmium	Chromium	Cobalt	Copper	Lead	Mercury	Molybdenum	Nickel	Selenium	Silver	Thallium	Vandium	Zinc
950CR	NA (c)	9/24/98	<3.0	<2.5	36	<0.20	<0.50	2.6	2.0	9.4	<10	<0.21	<2.0	5.4	<25	<1.0	<5.0	2.4	5.4
950CT002	NA	10/6/98	<3.0	<2.5	280	<0.20	<0.50	52	6.3	86	<10	<0.20	<2.0	110	<25	<1.0	<5.0	6.8	16
950CT004	NA	10/6/98	<3.0	<2.5	23	<0.20	<0.50	<1.0	<2.0	3.1	<10	<0.20	<2.0	<4.0	<25	<1.0	<5.0	<1.0	<2.0
950CT005	NA	10/6/98	<3.0	<2.5	96	<0.20	<0.50	1.5	13	20	<10	<0.20	<2.0	<4.0	<25	<1.0	<5.0	2.8	5.5
950CT006	NA	10/6/98	<3.0	<2.5	12	<0.20	<0.50	1.4	<2.0	9.2	<10	<0.20	<2.0	<4.0	<25	<1.0	<5.0	1.2	<2.0
950CT007	NA	10/6/98	<3.0	<2.5	13	<0.20	<0.50	6.9	2.2	24	<10	<0.20	<2.0	4.0	<25	<1.0	<5.0	2.9	2.6
950CT009	NA	10/6/98	<3.0	<2.5	160	<0.20	<0.50	<1.0	2.7	35	<10	<0.20	<2.0	7.0	<25	<1.0	<5.0	3.4	5.3
950CT010	NA	10/6/98	<3.0	<2.5	42	<0.20	<0.50	1.2	<2.0	13	<10	<0.20	<2.0	<4.0	<25	<1.0	<5.0	6.3	2.4
950CT011	NA	10/15/98	<3.0	<2.5	17	<0.20	<0.50	2.4	2.8	12	<10	<0.20	<2.0	<4.0	<25	<1.0	<5.0	11	8.1
950CT012	NA	10/15/98	<3.0	<2.5	96	<0.20	0.61	15	7.8	50	<10	<0.20	<2.0	25	<25	<1.0	<5.0	38	56
950CT014	NA	10/15/98	<3.0	<2.5	13	<0.20	<0.50	<1.0	<2.0	6.1	<10	<0.20	<2.0	<4.0	<25	<1.0	<5.0	2.2	<2.0
950CT015	NA	10/15/98	<3.0	<2.5	31	<0.20	<0.50	1.6	<2.0	26	<10	<0.20	<2.0	4.3	<25	<1.0	<5.0	2.9	7.1
950CT016	NA	10/15/98	<3.0	<2.5	18	<0.20	<0.50	6.3	<2.0	16	<10	<0.20	<2.0	4.2	<25	<1.0	<5.0	3.0	7.9
950CT017	NA	10/15/98	<3.0	<2.5	12	<0.20	<0.50	2.4	<2.0	15	<10	<0.20	<2.0	<4.0	<25	<1.0	<5.0	4.4	3.0
950CT018	NA	10/15/98	<3.0	<2.5	36	<0.20	<0.50	6.2	<2.0	18	<10	<0.20	<2.0	4.4	<25	<1.0	<5.0	7.7	10
950CT019	NA	10/15/98	<3.0	<2.5	12	<0.20	<0.50	2.5	<2.0	11	<10	<0.20	<2.0	<4.0	<25	<1.0	<5.0	3.3	2.7
950CT020	NA	10/15/98	<3.0	<2.5	160	<0.20	<0.51	2.2	9.8	36	<10	<0.20	<2.0	22	<25	<1.0	<5.1	12	8.2
950CT021	NA	10/15/98	<3.0	<2.5	92	<0.20	<0.50	4.3	3.9	26	<10	<0.20	<2.0	5.1	<25	<1.0	<5.0	9.6	4.4
950CT022	NA	10/15/98	<3.0	<2.5	25	<0.20	<0.50	<1.0	<2.0	14	<10	<0.20	<2.0	<4.0	<25	<1.0	<5.0	2.9	<2.0
950CT023	NA	10/15/98	<3.0	<2.5	10	<0.20	<0.50	<1.0	<2.0	3.2	<10	<0.20	<2.0	<4.0	<25	<1.0	<5.0	<1.0	2.0
950CT024	NA	10/15/98	<3.0	<2.5	190	<0.20	<0.50	<1.0	<2.0	4.6	<10	<0.20	<2.0	<4.0	<25	<1.0	<5.0	4.9	4.8
950CT025	NA	10/15/98	<3.0	<2.5	110	<0.20	<0.50	<1.0	2.5	22	<10	<0.20	<2.0	6.2	<25	<1.0	<5.0	2.7	6
950CT026	NA	10/15/98	<3.0	<2.5	46	<0.20	<0.50	<1.0	3.7	13	<10	<0.20	<2.0	4.0	<25	<1.0	<5.0	1.3	3.8
950CT027	NA	10/15/98	<3.0	3.2	250	<0.20	0.64	<1.0	16	140	<10	<0.20	<2.0	33	<25	<1.0	<5.0	7.9	30
950CT028	NA	10/15/98	<3.0	<2.5	31	<0.20	<0.50	<1.0	2.3	15	<10	<0.20	<2.0	6.2	<25	<1.0	<5.0	1.6	14
950CT029	NA	10/15/98	<3.0	<2.5	52	<0.20	<0.50	1.8	2	22	<10	<0.20	<2.0	4.8	<25	<1.0	<5.0	3.6	4.2
950CT030	NA	10/15/98	<3.0	<2.5	120	<0.20	<0.50	4.1	10	52	<10	<0.20	<2.0	9.0	<25	<1.0	<5.0	9.4	16
950CT031	NA	10/15/98	<3.0	<2.5	120	<0.20	<0.50	1.1	5.4	58	<10	<0.20	<2.0	11	<25	<1.0	<5.0	3.7	9
950CT032	NA	10/15/98	<3.0	<2.5	50	<0.20	<0.50	1.9	2.2	25	<10	<0.20	<2.0	5.5	<25	<1.0	<5.0	4.5	4.6

Table C-3
CHERT/SHALE LITHOLOGY
Presidio of San Francisco, California

Sample ID	Depth (ft.) (a)	Sample Date	Laboratories (b)	Major Elements (mg/kg)			
				Iron	Aluminum	Magnesium	Manganese
950CT033	NA	10/15/98	CHROMALA	3,900	970	NA	77
950CT034	NA	10/15/98	CHROMALA	5,800	1,500	NA	400
950SH001	NA	12/21/98	CHROMALA	27,000	7,600	NA	2,000
950SH002	NA	12/21/98	CHROMALA	46,000	7,800	NA	10,000
950SH003	NA	10/15/98	CHROMALA	30,000	6,100	NA	4,600
950SH004	NA	10/15/98	CHROMALA	14,000	5,000	NA	2,600
950SH005	NA	10/15/98	CHROMALA	13,000	3,800	NA	2,900
950SH006	NA	10/15/98	CHROMALA	26,000	4,000	NA	3,300
950SH007	NA	10/15/98	CHROMALA	34,000	3,700	NA	2,300
950SH008	NA	10/15/98	CHROMALA	29,000	3,300	NA	3,000
950SH009	NA	10/15/98	CHROMALA	43,000	3,700	NA	11,000
950SH010	NA	10/15/98	CHROMALA	7,200	2,300	NA	56
950SH011	NA	10/15/98	CHROMALA	34,000	5,200	NA	420
950SH012	NA	10/15/98	CHROMALA	17,000	3,700	NA	1,300
950SH013	NA	10/15/98	CHROMALA	14,000	3,000	NA	340
950SH014	NA	10/15/98	CHROMALA	18,000	4,000	NA	800
950SH015	NA	10/15/98	CHROMALA	14,000	4,400	NA	260
BKGDSB03	0.1	9/2/92	ED	31,000	9,500	4270	853

Table C-5

CHERT/SHALE LITHOLOGY

Presidio of San Francisco, California

Sample ID	Depth (ft.) (a)	Sample Date	Title 22 Metals (mg/kg)																
			Antimony	Arsenic	Barium	Beryllium	Cadmium	Chromium	Cobalt	Copper	Lead	Mercury	Molybdenum	Nickel	Selenium	Silver	Thallium	Vandium	Zinc
950CT033	NA	10/15/98	<3.0	<2.5	32	<0.20	<0.50	4.0	<2.0	28	<10	<0.20	<2.0	<4.0	<25	<1.0	<5.0	3.2	5.9
950CT034	NA	10/15/98	<3.0	<2.5	79	0.25	<0.50	3.5	3.1	88	<10	<0.20	<2.0	15	<25	<1.0	<5.0	7.2	20
950SH001	NA	12/21/98	<3.1	<2.6	60	0.31	0.67	12	25	51	<10	<0.21	<2.1	9.2	<26	<1.0	<5.2	25	7.9
950SH002	NA	12/21/98	<3.1	<2.6	210	0.44	1.0	13	87	210	<10	<0.21	<2.0	58	<26	<1.0	<5.1	47	17
950SH003	NA	10/15/98	<3.0	<2.5	190	0.55	0.76	12	22	150	12	<0.21	<2.0	15	<25	<1.0	<5.0	34	10
950SH004	NA	10/15/98	<3.0	<2.5	320	0.27	<0.50	5.9	16	310	<10	<0.21	<2.0	22	<25	<1.0	<5.0	7.6	47
950SH005	NA	10/15/98	<3.0	<2.5	280	<0.20	<0.50	6.9	6.5	110	<10	<0.20	<2.0	18	<25	<1.0	<5.0	14	36
950SH006	NA	10/15/98	<3.0	<2.5	270	0.39	0.96	11	8.2	110	20	<0.21	<2.0	19	<25	<1.0	<5.0	17	51
950SH007	NA	10/15/98	<3.0	<2.5	220	0.53	1.3	7.0	14	110	17	<0.21	<2.0	16	<25	<1.0	<5.0	12	32
950SH008	NA	10/15/98	<3.0	<2.5	250	0.34	1.1	6.7	6.1	110	13	<0.21	<2.0	16	<25	<1.0	<5.0	12	34
950SH009	NA	10/15/98	<3.0	<2.5	1,100	0.72	1.7	6.8	8.7	120	37	<0.20	<2.0	38	<25	<1.0	<5.0	17	140
950SH010	NA	10/15/98	<3.0	NA	50	<0.20	<0.50	4.5	<2.0	39	<10	<0.20	<2.0	<4.0	<25	<1.0	<5.0	15	7.9
950SH011	NA	10/15/98	<3.0	<2.5	170	0.40	0.98	7.2	2.4	76	<10	<0.21	<2.0	4.5	<25	<1.0	<5.1	34	12
950SH012	NA	10/15/98	<3.0	<2.5	400	0.37	<0.51	6.4	8.5	100	<10	<0.21	<2.0	24	<25	<1.0	<5.1	12	39
950SH013	NA	10/15/98	<3.0	<2.5	220	0.32	<0.51	6.4	3.9	140	<10	<0.21	<2.0	16	<25	<1.0	<5.1	7.4	46
950SH014	NA	10/15/98	<3.1	<2.6	280	0.43	0.52	8.8	4.5	160	<10	<0.20	<2.0	18	<26	<1.0	<5.1	12	44
950SH015	NA	10/15/98	<3.1	<2.6	280	0.40	<0.51	9.1	4.5	100	<10	<0.21	<2.0	23	<26	<1.0	<5.1	11	51
BKGDSB03	0.1	9/2/92	<41.3	2.460	229	<0.50	<0.515	48.4	15.3	49.4	45	0.036	NA	32.5	<0.250	<0.521	<14.7	71.3	64.5

Table C-3
CHERT/SHALE LITHOLOGY
Presidio of San Francisco, California

Abbreviations:

NA	Not Analyzed or Rejected Data

Notes:

a) Depth in feet below ground surface.

b) Laboratory Abbreviations:

CHROMALA	ChromaLab, Pleasanton, California
ED	Environmental Science and Engineering, Inc., Englewood, Colorado

c) See text for discussion of data.

TABLE C-4

BACKGROUND DATA SET - BEACH/DUNE LITHOLOGY

Presidio of San Francisco, California

Sample ID	Depth (ft.) (a)	Sample Date	Laboratories (b)	Major Elements (mg/kg)			
				Iron	Aluminum	Magnesium	Manganese
BKGDSB05	5	12/07/94	QA	7,210	3,030	2,040	226
BKGDSB05	9.5	12/07/94	QA	13,100	3,990	1,740	248
BKGDSB06	2	12/07/94	QA	11,400	4,690	3,860	185
BKGDSB06	9.5	12/07/94	QA	10,200	4,640	4,040	171
BKGDSB07	5	12/08/94	QA	18,600	5,480	2,270	180
BKGDSB07	9.5	12/08/94	QA	12,500	5,600	2,480	148
BKGDSB08	5.5	12/08/94	QA	7,580	4,640	1,860	109
BKGDSB08	9.5	12/08/94	QA	14,700	4,670	2,150	151
BKGDSB10	3.5	12/07/94	QA	8,580	5,080	2,140	123
BKGDSB10	7.5	12/07/94	QA	6,030	3,260	1,520	91.5
BKGSO01B	4.5	11/26/90	UB	12,800	5,580	3,680	104
BKGSO02A	0.8	11/27/90	UB	21,800	6,580	2,810	178
BKGSO02B	3.5	11/27/90	UB	19,900	7,660	3,070	176
1065SB02	10	12/14/94	SU	NA	NA	NA	NA
1065SB04	5	01/12/95	SU	NA	NA	NA	NA
1167SB02	6.5	11/19/94	QA	15,800	16,500	5,880	162
1167SB03	10	11/19/94	QA	14,300	11,200	6,320	127
1351SO03B	5	11/29/90	UB	28,000	11,900	2,960	237
1351SO04B	4.5	11/29/90	UB	26,500	16,200	3,280	302
1351SO05B	4.5	11/29/90	UB	31,600	17,400	3,310	588
1351SO06B	4.5	11/29/90	UB	30,800	19,300	3,480	709
231GW04B	6	10/22/90	UB	34,900	25,700	6,740	588
231GW05B	5.5	10/23/90	UB	19,800	10,600	4,305	357
231GW06B	12	10/24/90	UB	29,300	20,000	3,860	440
231GW07B	7	10/25/90	UB	29,800	18,700	7,360	515
231SB16	4	12/06/94	SU	NA	NA	NA	NA
231SB28	4	04/06/95	SU	NA	NA	NA	NA
268SO02	3	12/11/90	UB	32,200	17,800	8,750	432
268SO05	3.5	12/12/90	UB	21,100	10,300	7,030	346
269SB01	2.5	11/19/94	QA	17,700	NA	10,500	174
283SO01B	5	12/10/90	UB	14,900	7,220	4,550	201

TABLE C-4
BACKGROUND DATA SET - BEACH/DUNE LITHOLOGY
Presidio of San Francisco, California

Sample ID	Depth (ft.) (a)	Sample Date	Title 22 Metals (mg/kg)																
			Antimony	Arsenic	Barium	Beryllium	Cadmium	Chromium	Cobalt	Copper	Lead	Mercury	Molybdenum	Nickel	Selenium	Silver	Thallium	Vandium	Zinc
BKGDSB05	5	12/07/94	<0.10	<2.50	11.3	0.170	<0.800	19.9	4.75	21.2	1.59	<0.059	NA	19.7	<0.416	<0.500	<0.162	16.4	19.2
BKGDSB05	9.5	12/07/94	<0.10	<2.50	8.12	0.198	<0.800	72.8	6.07	24.1	2.54	<0.059	NA	20.5	<0.416	<0.500	<0.162	42.0	27.5
BKGDSB06	2	12/07/94	<0.10	3.80	22.8	0.201	<0.800	39.5	7.14	16.7	4.87	<0.059	NA	25.3	<0.416	<0.500	<0.162	29.1	25.4
BKGDSB06	9.5	12/07/94	<0.10	5.43	13.2	0.180	<0.800	32.8	7.12	21.2	2.73	<0.059	NA	26.3	<0.416	<0.500	<0.162	23.5	22.9
BKGDSB07	5	12/08/94	<0.10	1.66	13.1	0.202	<0.800	60.3	8.43	12.9	3.96	<0.059	NA	22.9	<0.416	<0.500	<0.162	64.1	26.5
BKGDSB07	9.5	12/08/94	<0.10	2.29	10.5	0.201	<0.800	50.4	7.23	57.2	3.28	<0.059	NA	24.0	<0.416	<0.500	<0.162	39.1	35.6
BKGDSB08	5.5	12/08/94	<0.10	1.78	11.9	0.134	<0.800	27.7	4.95	34.3	1.93	<0.059	NA	21.1	<0.416	<0.500	<0.162	20.6	32.0
BKGDSB08	9.5	12/08/94	<0.10	1.68	11.8	0.208	<0.800	49.5	7.16	46.5	2.83	<0.059	NA	20.6	<0.416	<0.500	<0.162	48.6	40.3
BKGDSB10	3.5	12/07/94	<0.10	<2.50	13.2	0.172	<0.800	28.3	5.73	8.61	2.65	<0.059	NA	15.1	<0.416	<0.500	<0.162	23.2	19.6
BKGDSB10	7.5	12/07/94	<0.10	<2.50	10.8	0.172	<0.800	17.9	3.99	18.4	1.80	<0.059	NA	15.0	<0.416	<0.500	<0.162	15.7	16.2
BKGSO01B	4.5	11/26/90	<19.6	4.18	21.8	<0.427	<1.2	40.8	5.6	4.84	3.72	<0.05	NA	30.1	<0.449	<0.803	<34.3	21.4	17.2
BKGSO02A	0.8	11/27/90	<19.6	2.76	15.5	0.7	<1.2	69.3	7.07	5	11.8	<0.05	NA	24.4	<0.449	<0.803	<34.3	58.9	25.4
BKGSO02B	3.5	11/27/90	<19.6	2.85	14.6	0.646	<1.2	57.4	7.4	4.6	3.72	<0.05	NA	25.3	<0.449	<0.803	<34.3	53.8	19.7
1065SB02	10	12/14/94	NA	NA	NA	NA	NA	NA	NA	NA	4.93	NA	NA	NA	NA	NA	NA	NA	NA
1065SB04	5	01/12/95	NA	NA	NA	NA	NA	NA	NA	NA	4.12	NA	NA	NA	NA	NA	NA	NA	NA
1167SB02	6.5	11/19/94	NA	3.67	31.8	0.389	<0.800	66.2	9.76	NA	17.6	<0.059	NA	64.7	NA	NA	NA	37.4	47.5
1167SB03	10	11/19/94	NA	5.96	17.7	0.297	<0.800	46.2	9.05	14.0	4.18	<0.059	NA	39.7	NA	NA	NA	30.1	38.0
1351SO03B	5	11/29/90	NA	<2.50	54.9	0.720	NA	92.1	11.8	12.5	13.9	<0.050	NA	31.6	NA	NA	NA	68.8	51.7
1351SO04B	4.5	11/29/90	NA	<2.50	81.5	0.914	NA	85.4	9.35	13.7	3.72	<0.050	NA	36.1	NA	NA	NA	61.8	38.1
1351SO05B	4.5	11/29/90	NA	<2.50	103	1.05	NA	89.1	15.8	14.1	3.72	0.059	NA	45.2	NA	NA	NA	77.4	36.0
1351SO06B	4.5	11/29/90	NA	<2.50	132	1.27	NA	91.2	24.2	16.6	3.72	0.063	NA	50.6	NA	NA	NA	68.1	39.2
231GW04B	6	10/22/90	NA	<2.50	251	0.695	NA	95.5	19.5	35.2	52.6	0.646	NA	68.6	NA	<0.803	NA	74.6	62.3
231GW05B	5.5	10/23/90	NA	<2.50	64.6	<0.427	NA	NA	8.84	9.71	20.9	0.070	NA	40.9	NA	<0.803	NA	40.2	49.6
231GW06B	12	10/24/90	NA	<2.50	118	0.738	NA	NA	15	15.6	13.8	0.053	NA	47.7	NA	<0.803	NA	64.0	38.6
231GW07B	7	10/25/90	NA	2.96	111	0.752	NA	NA	15.6	21.9	75.1	0.083	NA	82.9	NA	<0.803	NA	57.2	74.3
231SB16	4	12/06/94	NA	NA	NA	NA	NA	NA	NA	NA	13	NA	NA	NA	NA	NA	NA	NA	NA
231SB28	4	04/06/95	NA	NA	NA	NA	NA	NA	NA	NA	81	NA	NA	NA	NA	NA	NA	NA	NA
268SO02	3	12/11/90	NA	4.57	161	<0.427	<1.20	49.2	14.9	40.6	44.6	0.107	NA	50.6	NA	<0.803	NA	39.8	92.6
268SO05	3.5	12/12/90	NA	2.51	59.7	<0.427	<1.20	142	9.97	24.1	37.4	NA	NA	51.6	NA	<0.803	NA	36.4	36.8
269SB01	2.5	11/19/94	NA	3.01	15.4	0.194	NA	105	15.8	14.2	17.3	NA	NA	80.8	0.532	NA	NA	44.7	32.2
283SO01B	5	12/10/90	NA	2.83	25.3	<0.427	<1.20	64.2	6.76	5.47	3.72	NA	NA	31.1	NA	<0.803	NA	25.7	18.5

TABLE C-4

BACKGROUND DATA SET - BEACH/DUNE LITHOLOGY

Presidio of San Francisco, California

Sample ID	Depth (ft.) (a)	Sample Date	Laboratories (b)	Major Elements (mg/kg)			
				Iron	Aluminum	Magnesium	Manganese
283SO02B	5	12/11/90	UB	15,100	6,920	4,790	178
286SB06	5	12/01/94	QA	64,20	3,200	2,440	86.6
286SB07	5	12/01/94	QA	8,240	3,850	4,570	116
293SB01	2.5	11/15/94	SU	NA	NA	NA	NA
293SB01	4.5	11/15/94	SU	NA	NA	NA	NA
293SB02	4	11/15/94	SU	NA	NA	NA	NA
293SB03	4	11/15/94	SU	NA	NA	NA	NA
30S3R	1	10/11/94	PA	NA	NA	NA	NA
30S3R	1.5	10/11/94	PA	NA	NA	NA	NA
30S3R	2	10/11/94	PA	NA	NA	NA	NA
30S3R	3	10/11/94	PA	NA	NA	NA	NA
60S1R	1.5	10/11/94	PA	NA	NA	NA	NA
60S1R	2	10/11/94	PA	NA	NA	NA	NA
60S1R	3	10/11/94	PA	NA	NA	NA	NA
BBSB11	2	08/05/92	ED	9,500	4,110	3,670	<128
BBSB20	2	08/05/92	ED	12,000	4,900	2,270	<160
BBSB21	2	08/30/92	ED	26,000	13,000	3,210	323
BBSB22	2	08/30/92	ED	24,000	6,900	2,600	<173
CGGW02	2	08/12/92	ED	9,200	3,490	3,680	<131
CGGW02	3.5	08/12/92	ED	11,000	4,030	4,570	<178
CGSO01A	2	11/08/90	UB	14,100	6,230	7,080	171
CGSO02A	1	11/08/90	UB	13,700	5,580	4,650	168
CGSO02B	2	11/08/90	UB	12,800	5,890	5,090	170
CGSO03A	2	11/09/90	UB	12,400	5,080	4,420	151
CGSO03B	3	11/09/90	UB	12,000	5,640	4,700	145
CGSO04A	1	11/14/90	UB	13,600	5,270	4,290	180
CGSO04B	5	11/14/90	UB	13,500	5,480	4,070	152
DEHGW02	5	08/24/92	ED	17,000	6,310	8,310	<214
DEHSB01	3	08/07/92	ED	11,000	4,020	4,510	<139
DEHSB01	5	08/07/92	ED	16,000	4,120	3,740	99.6
EOMSB01	4.5	11/15/94	QA	6,950	3,290	2,330	102
EOMSB02	4.5	11/15/94	QA	9,050	3,690	3,380	118

TABLE C-4
BACKGROUND DATA SET - BEACH/DUNE LITHOLOGY
Presidio of San Francisco, California

Sample ID	Depth (ft.) (a)	Sample Date	Title 22 Metals (mg/kg)																
			Antimony	Arsenic	Barium	Beryllium	Cadmium	Chromium	Cobalt	Copper	Lead	Mercury	Molybdenum	Nickel	Selenium	Silver	Thallium	Vandium	Zinc
283SO02B	5	12/11/90	NA	<2.50	18.9	<0.427	1.68	59.5	6.81	4.81	3.72	<0.050	NA	34.4	NA	<0.803	NA	26.1	18.9
286SB06	5	12/01/94	NA	3.16	7.87	0.135	NA	26.6	4.43	11.3	1.60	NA	NA	21.1	NA	<0.500	NA	14.2	18.6
286SB07	5	12/01/94	NA	3.94	9.13	0.149	NA	35.3	5.88	13.0	2.25	NA	NA	36.5	NA	<0.500	NA	16.2	27.5
293SB01	2.5	11/15/94	NA	1.41	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
293SB01	4.5	11/15/94	NA	1.72	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
293SB02	4	11/15/94	NA	1.11	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
293SB03	4	11/15/94	NA	1.72	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
30S3R	1	10/11/94	NA	NA	NA	NA	NA	41	NA	NA	42	NA	NA	NA	NA	NA	NA	NA	NA
30S3R	1.5	10/11/94	NA	NA	NA	NA	NA	40.6	NA	NA	25.1	NA	NA	NA	NA	NA	NA	NA	NA
30S3R	2	10/11/94	NA	NA	NA	NA	NA	45.7	NA	NA	24.4	NA	NA	NA	NA	NA	NA	NA	NA
30S3R	3	10/11/94	NA	NA	NA	NA	NA	50.7	NA	NA	88.7	NA	NA	NA	NA	NA	NA	NA	NA
60S1R	1.5	10/11/94	NA	NA	NA	NA	NA	65.9	NA	NA	44.8	NA	NA	NA	NA	NA	NA	NA	NA
60S1R	2	10/11/94	NA	NA	NA	NA	NA	55	NA	NA	65.9	NA	NA	NA	NA	NA	NA	NA	NA
60S1R	3	10/11/94	NA	NA	NA	NA	NA	37.6	NA	NA	27.4	NA	NA	NA	NA	NA	NA	NA	NA
BBSB11	2	08/05/92	<41.3	2.81	8.1	0.558	<0.515	38.4	8.2	3.605	9.95	<0.027	NA	29.2	<0.25	0.682	NA	30.1	45.4
BBSB20	2	08/05/92	<41.3	2.55	9.0	<0.500	<0.515	44.4	9.75	3.64	21	<0.027	NA	24.2	<0.25	0.805	NA	40.3	31.8
BBSB21	2	08/30/92	<41.3	3.51	94.9	<0.500	<0.515	86.8	11	20.9	16	0.031	NA	56.3	<0.25	<0.521	<14.7	58.4	44.4
BBSB22	2	08/30/92	<41.3	2.73	19.1	<0.500	<0.515	111	9.88	8.64	2.08	<0.027	NA	51.2	<0.25	<0.521	<14.7	62.8	10.4
CGGW02	2	08/12/92	NA	4.48	5.5	<0.500	<0.515	36.8	7.25	3.11	3.95	0.028	NA	35.5	<0.25	<0.521	NA	21	9.75
CGGW02	3.5	08/12/92	NA	5.33	5.4	<0.500	0.690	50.5	8.55	4.68	4.11	<0.027	NA	42.3	<0.25	<0.521	NA	24.3	11.05
CGSO01A	2	11/08/90	NA	NA	22.8	NA	NA	60.2	7.06	6.29	8.26	0.054	NA	50.8	NA	NA	NA	28.1	21.1
CGSO02A	1	11/08/90	NA	NA	15.3	NA	NA	75.4	6.00	5.23	3.72	<0.05	NA	32.5	NA	NA	NA	27.6	18.0
CGSO02B	2	11/08/90	NA	NA	23.3	NA	NA	82.8	6.09	5.04	3.72	<0.050	NA	32.6	NA	<0.803	NA	26.3	19.8
CGSO03A	2	11/09/90	NA	NA	14.7	NA	NA	52.7	5.58	4.53	3.72	<0.050	NA	30.7	NA	NA	NA	23.3	16.9
CGSO03B	3	11/09/90	NA	NA	14.8	NA	NA	51.6	5.31	4.41	3.72	0.098	NA	30.3	NA	NA	NA	22.3	17.2
CGSO04A	1	11/14/90	NA	2.82	20.4	NA	NA	46.3	6.32	5.52	3.72	<0.050	NA	29.0	NA	NA	NA	25.2	20.4
CGSO04B	5	11/14/90	NA	2.72	14.4	NA	NA	34.8	5.97	4.95	3.72	<0.050	NA	27.0	NA	NA	NA	25.2	22.4
DEHGW02	5	08/24/92	<41.3	4.2	28.7	<0.500	<0.515	86.9	10.1	24	23	<0.027	NA	77.8	0.751	<0.521	NA	37.1	42
DEHSB01	3	08/07/92	<41.3	3.52	7.35	<0.500	<0.515	62.5	8.05	5.2	6.33	<0.027	NA	49.8	<0.25	<0.521	NA	24.2	11.4
DEHSB01	5	08/07/92	<41.3	3.52	5.45	<0.500	<0.515	44.7	7.5	5.55	7.01	<0.027	NA	40.2	<0.25	<0.521	NA	23.2	12.25
EOMSB01	4.5	11/15/94	NA	2.64	7.28	0.126	NA	20.7	4.35	4.55	20.9	<0.059	NA	19.3	NA	NA	NA	14.6	12.7
EOMSB02	4.5	11/15/94	NA	3.80	7.18	0.134	NA	23.1	5.77	3.93	2.47	<0.059	NA	25.5	NA	NA	NA	16.2	15.0

TABLE C-4
BACKGROUND DATA SET - BEACH/DUNE LITHOLOGY
Presidio of San Francisco, California

Sample ID	Depth (ft.) (a)	Sample Date	Laboratories (b)	Major Elements (mg/kg)			
				Iron	Aluminum	Magnesium	Manganese
EOMSB03	4.9	11/15/94	QA	9,500	4,140	3,770	205
EOMSB05	4.5	11/16/94	QA	9,400	4,630	3,070	114
HWSB04	22	08/05/92	ED	8,200	3,600	1,820	97.4
LF10BK04	3	07/19/94	UNKNOWN	16,600	6,840	2,480	208
LF10BK05	3.5	07/19/94	UNKNOWN	29,000	7,790	2,750	231
LF10SB02	35	09/02/94	UNKNOWN	15,900	8,390	3,450	244
LF10SB03	29.5	08/27/96	CALLAB	13,000	4,880	3,420	258
LF10SB04	20	08/27/96	CALLAB	18,000	8,960	3,090	243
LF10SB04	25	08/27/96	CALLAB	9,370	4,060	1,620	103
LF3SB03	5	08/25/92	ED	12,000	4,480	2,060	<140
LF3SB04	5	08/25/92	ED	29,000	6,100	2,280	<220
LF4SB03	13	08/19/92	ED	14,000	5,120	1,860	133
LF4SB06	5	12/01/94	SU	NA	NA	NA	NA
LF4SB20	10	04/06/95	SU	NA	NA	NA	NA
LF4SO01	10	10/08/90	UB	14,400	9,780	3,180	172
LF4SO02	10	10/08/90	UB	17,200	10,800	2,990	246
LF8SO01B	19	10/01/90	UB	18,100	7,150	2,850	172
LF9SB01	4	08/19/92	ED	11,000	5,800	2,060	<156
LF9TP102	6	06/20/00	C&T	NA	NA	NA	NA
NKSB11	4.5	11/20/94	QA	7,010	4,090	1,820	106
NKSB12	4.5	11/20/94	QA	9,780	5,230	1,760	156
NKSB12	9	11/20/94	QA	6,110	3,920	1,530	85.9
NKSB13	5	12/05/94	QA	9,960	5,240	NA	NA
NKSB14	5	12/07/94	QA	11,600	5,940	2,270	138

TABLE C-4
BACKGROUND DATA SET - BEACH/DUNE LITHOLOGY
Presidio of San Francisco, California

Sample ID	Depth (ft.) (a)	Sample Date	Title 22 Metals (mg/kg)																
			Antimony	Arsenic	Barium	Beryllium	Cadmium	Chromium	Cobalt	Copper	Lead	Mercury	Molybdenum	Nickel	Selenium	Silver	Thallium	Vandium	Zinc
EOMSB03	4.9	11/15/94	NA	3.85	14.5	0.171	NA	50.9	8.94	5.21	3.65	<0.059	NA	32.8	NA	NA	NA	19.7	20.3
EOMSB05	4.5	11/16/94	NA	2.73	29.7	0.166	NA	32.6	5.72	6.98	7.08	<0.059	NA	24.7	NA	NA	NA	19.4	26.3
HWSB04	22	08/05/92	<41.3	2.6	16	<0.500	<0.515	40.6	12.6	6.39	1.53	<0.027	NA	21.8	<0.25	0.864	NA	25	7.45
LF10BK04	3	07/19/94	NA	2.3	23.1	NA	NA	62.4	6.6	4.7	13.9	<0.10	NA	21.1	NA	NA	NA	52.0	26.5
LF10BK05	3.5	07/19/94	NA	2.4	18.7	NA	NA	94.9	9.2	5.2	9.0	<0.10	NA	26.9	NA	NA	NA	98.9	28.7
LF10SB02	35	09/02/94	NA	3.2	33.4	NA	NA	43.4	7.7	6.6	2.8	<0.11	NA	30.4	NA	NA	NA	45.6	23.4
LF10SB03	29.5	08/27/96	NA	3.0	20.2	NA	NA	43.4	5.4	7.3	3.8	<0.11	NA	34.2	NA	NA	NA	31.6	20.2
LF10SB04	20	08/27/96	NA	3.4	57.1	NA	NA	74.4	7.0	10.2	43.0	<0.11	NA	45.4	NA	NA	NA	46.8	30.7
LF10SB04	25	08/27/96	NA	1.8	8.6	NA	NA	33.7	4.1	4.2	1.3	<0.10	NA	17.6	NA	NA	NA	25.6	11.9
LF3SB03	5	08/25/92	NA	2.86	7.0	NA	NA	46.3	2.885	14.1	<1.72	<0.027	NA	21.1	NA	NA	<14.7	37.9	11.65
LF3SB04	5	08/25/92	NA	2.24	36.3	NA	NA	86.7	4.19	6.35	2.15	<0.027	NA	25.1	NA	NA	NA	100	29.8
LF4SB03	13	08/19/92	<41.3	4.61	16.1	0.598	NA	58.2	9	13.3	2.12	<0.027	NA	23.2	0.552	0.814	NA	53.5	25.5
LF4SB06	5	12/01/94	NA	NA	NA	NA	NA	NA	NA	NA	1.17	NA	NA	NA	NA	NA	NA	NA	NA
LF4SB20	10	04/06/95	NA	NA	NA	NA	NA	NA	NA	NA	3.4	NA	NA	NA	NA	NA	NA	NA	NA
LF4SO01	10	10/08/90	NA	NA	29.0	<0.427	NA	46.5	7.08	<2.84	3.72	<0.050	NA	23.3	NA	NA	NA	40.5	NA
LF4SO02	10	10/08/90	NA	<2.50	45.6	<0.427	NA	60.6	6.99	<2.84	3.72	<0.050	NA	18.3	NA	NA	NA	48.8	NA
LF8SO01B	19	10/01/90	<19.6	<2.5	15.4	<0.427	<1.2	57.7	6.75	3.652	3.72	<0.05	NA	22.5	<0.449	<0.803	<34.3	48.7	16.984
LF9SB01	4	08/19/92	NA	2.52	30.9	0.564	NA	40.4	3.785	11.3	2.57	<0.027	NA	22.3	<0.25	0.688	NA	41.3	12.5
LF9TP102	6	06/20/00	<2.9	1.7	52	0.13	0.84	26	4.4	5.3	4	<0.02	<0.98	19	<0.25	<0.25	0.37	20	21
NKSB11	4.5	11/20/94	NA	2.38	9.56	0.165	NA	25.2	4.91	3.12	1.89	<0.059	NA	17.8	NA	NA	NA	19.5	13.5
NKSB12	4.5	11/20/94	NA	1.79	20.8	0.191	NA	37.7	6.08	13.7	3.22	<0.059	NA	16.6	NA	NA	NA	31.4	21.2
NKSB12	9	11/20/94	NA	2.23	10.4	0.129	NA	21.1	4.34	33.5	2.29	<0.059	NA	15.7	NA	NA	NA	15.7	38.6
NKSB13	5	12/05/94	NA	1.25	12.9	0.209	NA	36.9	5.77	3.80	NA	NA	NA	NA	NA	NA	NA	32.0	17.1
NKSB14	5	12/07/94	NA	1.51	16.2	0.275	NA	41.5	6.74	8.45	7.25	<0.059	NA	21.5	NA	NA	NA	37.8	25.8

TABLE C-4
BACKGROUND DATA SET - BEACH/DUNE LITHOLOGY
Presidio of San Francisco, California

Abbreviations:

NA	Not Analyzed or Rejected Data

Notes:

a) Depth in feet below ground surface.

b) Laboratory Abbreviations:

C&T	Curtis & Tompkins, Berkeley, California
CALLAB	Caltest Analytical Laboratory, Napa, California
ED	Environmental Science and Engineering, Inc., Englewood, Colorado
PA	Precision Analytical Labs, Milwaukee, Wisconsin
SU	Superior Precision Analytical, Inc., Martinez, California
QA	Quality Assurance Laboratories, San Diego, California
UB	DataChem, Inc., Salt Lake City, Utah

c) See text for discussion of data.

APPENDIX D

RESULTS OF ARMY'S HEXAVALENT CHROMIUM STUDIES: MONTGOMERY WATSON, HEXAVALENT CHROMIUM IN SERPENTINITE BEDROCK AND GROUNDWATER IN UPLAND AREAS, JULY 1999

APPENDIX D

RESULTS OF ARMY'S HEXAVALENT CHROMIUM STUDIES: MONTGOMERY WATSON, HEXAVALENT CHROMIUM IN SERPENTINITE BEDROCK AND GROUNDWATER IN UPLAND AREAS, JULY 1999

October 2002

TECHNICAL MEMORANDUM

HEXAVALENT CHROMIUM IN SERPENTINITE BEDROCK AND GROUNDWATER IN UPLAND AREAS

PRESIDIO OF SAN FRANCISCO, CALIFORNIA

Contract No. DACW05-98-D-0033

Montgomery Watson Job No. 1212067.011804

Prepared for:

U.S. Army Corps of Engineers
Sacramento District
Sacramento, California

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July 1999

APPENDIX G

ANALYTICAL RESULTS

Analytical data for the Cr(VI) investigation are presented in the following tables:

- **Table G-1:** Summary of Analytes in Bedrock Samples
- **Table G-2:** Summary of Analytes in Groundwater Samples
- **Table G-3:** Summary of Analytes in Leachate
- **Table G-4:** Summary of Analytes in Leached Bedrock

Table G-5 describes the nomenclature used for the sample identification scheme. The analytical results tables present both the sample and the associated duplicate results (i.e., "A" and "B" fractions). Data referenced throughout this technical memorandum are the average value of the "A" and "B" fractions. Table G-6 lists data validation qualifiers reported on the analytical results tables. A more detailed description of the data validation qualifiers is found in Appendix H.

TABLE G-1

SUMMARY OF ANALYTES IN BEDROCK SAMPLES
HEXAVALENT CHROMIUM IN SERPENTINITE BEDROCK AND GROUNDWATER IN UPLAND AREAS
PRESIDIO OF SAN FRANCISCO
(Page 1 of 2)

Sample Location ID:	UBR01SB01	UBR02SB01	UBR03SB01	UBR01SB01
Sample Date:	2/24/99	2/25/99	2/23/99	2/24/99
Depth (feet):	Composite	Composite	Composite	24.0
Metals (mg/kg)				
Aluminum	**7,380**	**1,130**	**13,200**	NA
Antimony	<13.6 (U9)	<21.6 (U9)	<7.1	NA
Arsenic	<68.1	<108	<35.3	NA
Barium	**30.5**	<72.1	**130**	NA
Beryllium	<1.1	<1.8	**0.59**	NA
Cadmium	**0.94**	<1.8	**0.54 (J28)**	NA
Calcium	**1,110**	**1,410 (J28)**	**2,440**	NA
Chromium	**1,160**	**371**	**83.5**	NA
Cobalt	**101**	**97.6**	**19.9**	NA
Copper	**11.1**	**4.6 (J28)**	**23.4**	NA
Iron	**47,100**	**44,700**	**35,900**	NA
Lead	<22.7	<36.1	**8.8 (J28)**	NA
Magnesium	**193,000**	**213,000**	**5,400**	NA
Manganese	**595**	**671**	**216**	NA
Nickel	**2,070**	**1,950**	**69.1**	NA
Potassium	<1130	<1800	**1,520**	NA
Selenium	<56.7	<90.1	<29.4	NA
Silicon	**178 (J9, J12)**	**161 (J9, J12)**	**201**	NA
Silver	<2.3	<3.6	<1.2	NA
Sodium	<1130	<1800	<588	NA
Thallium	<454	<721	<235	NA
Titanium	**61.6 (J9)**	<18.0	**551**	NA
Vanadium	**35.2**	**10.4 (J28)**	**64.6**	NA
Zinc	**17.0**	**21.6**	**44.0**	NA
Soil Chemistry Parameters (mg/kg)				
Cr(VI) by Alkaline Digestion	**0.064**	**0.463**	**0.231**	**0.54**
Cr(VI) by DI Leach	**0.0102 (J28)**	**0.0103 (J28)**	**0.0137**	NA
Easily Reducible Manganese	**136**	**102**	**15**	**601**
Quick Oxidation Test	**1.6**	**1.01**	<0.08	**3.9**
Total Organic Carbon by Walkley-Black	**268**	**253**	**572**	NA
Total Organic Carbon by Method 9060	**329**	**452**	**897**	NA
Miscellaneous Parameters (mV)				
Eh (mV)[a]	**454**	**421**	**441**	NA
pH	**8.85**	**8.0**	**8.44**	NA
Percent Moisture (%)	**11.9**	**16.8**	**14.9**	**45.7**

TABLE G-1

SUMMARY OF ANALYTES IN BEDROCK SAMPLES
HEXAVALENT CHROMIUM IN SERPENTINITE BEDROCK AND GROUNDWATER IN UPLAND AREAS
PRESIDIO OF SAN FRANCISCO
(Page 2 of 2)

Sample Location ID:	**UBR01SB01**	**UBR02SB01**	**UBR02SB01**	**UBR03SB01**
Sample Date:	**2/24/99**	**2/25/99**	**2/25/99**	**2/23/99**
Depth (feet):	**34.0**	**47.0**	**48.0**	**33.0**
Metals (mg/kg)				
Aluminum	NA	**230**	**96.1**	**6,730**
Antimony	NA	<13.5	<19.8	<7.1 (U9)
Arsenic	NA	<67.3	<99.0	<35.6
Barium	NA	<44.9	<66.0	**105**
Beryllium	NA	<1.1	<1.6	<0.59
Cadmium	NA	<1.1	<1.6	<0.59
Calcium	NA	**14,100**	<1650	**1,890**
Chromium	NA	**89.5**	**71.0**	**55.6 (J10)**
Cobalt	NA	**108**	**114**	**24.1**
Copper	NA	<5.6	<8.2	**8.1**
Iron	NA	**49,000**	**49,900**	**20,100**
Lead	NA	<22.4	<33.0	<11.9
Magnesium	NA	**203,000**	**235,000**	**2,640**
Manganese	NA	**764**	**751**	**1,040**
Nickel	NA	**2,210**	**2,420**	**59.8**
Potassium	NA	<1120	<1650	**423 (J28)**
Selenium	NA	<56.1	<82.5	<29.7
Silicon	NA	**196**	**251**	**199 (J9)**
Silver	NA	<2.2	<3.3	<1.2
Sodium	NA	<1120	<1650	<593
Thallium	NA	<449	<660	<237
Titanium	NA	<11.2	<16.5	**520**
Vanadium	NA	<11.2	<16.5	**46.4**
Zinc	NA	**25.8**	**29.1**	**23.5**
Soil Chemistry Parameters (mg/kg)				
Cr(VI) by Alkaline Digestion	**0.602**	NA	NA	NA
Cr(VI) by DI Leach	NA	**0.0104 (J28)**	NA	**0.0264**
Easily Reducible Manganese	**1,235**	NA	NA	**891**
Quick Oxidation Test	**13.21**	NA	NA	NA
Total Organic Carbon by Walkley-Black	NA	NA	NA	NA
Total Organic Carbon by Method 9060	NA	NA	NA	**602**
Miscellaneous Parameters (mV)				
Eh (mV)[a]	NA	NA	NA	NA
pH	NA	NA	NA	NA
Percent Moisture (%)	**38.7**	**10.9**	**9.1**	**15.7**

[a] Eh values corrected for reference electrode and temperature
mV - millivolts
% - percent

TABLE G-2

SUMMARY OF ANALYTES IN GROUNDWATER SAMPLES
HEXAVALENT CHROMIUM IN SERPENTINITE BEDROCK AND GROUNDWATER IN UPLAND AREAS
PRESIDIO OF SAN FRANCISCO
(Page 1 of 3)

Sample Location ID:	UBR01GW01	UBR02GW01	UBR02GW02	UBR03GW01
Sample Date:	3/22/99	3/22/99	3/22/99	3/23/99
Dissolved Metals (µg/l)				
Aluminum	<200	<200	<200	<200
Antimony	<60	<60	<60	<60
Arsenic	<300	<300	<300	<300
Barium	**260**	<200	<200	<200
Beryllium	<5.0	<5.0	<5.0	<5.0
Cadmium	<5.0	<5.0	<5.0	<5.0
Calcium	**35,700**	**12,500**	**27,100**	**40,300**
Chromium	**66**	**49**	**100**	<10
Cobalt	<50	<50	<50	<50
Copper	<25	<25	<25	<25
Iron	<100	<100	<100	<100
Lead	<100	<100	<100	<100
Magnesium	**119,000**	**133,000**	**139,000**	**46,400**
Manganese	**13 (J28)**	<15	**10 (J28)**	**280**
Nickel	<40	<40	<40	<40
Potassium	<5000	<5000	<5000	**5,900**
Selenium	<250	<250	<250	<250
Silicon	**24,300**	**9,100**	**23,600**	**16,800**
Silver	<10	<10	<10	<10
Sodium	**51,200**	**247,000**	**257,000**	**81,300**
Thallium	<2000	<2000	<2000	<2000
Titanium	<50	<50	<50	<50
Vanadium	<50	<50	<50	<50
Zinc	**24**	<20	<20	**11 (J28)**
Hexavalent Chromium	**65.4 (J29)**	**52.1 (J29)**	**98.3 (J29)**	<0.50 (U29)
General Water Chemistry Parameters (µg/l)				
Alkalinity, Total	**491,000**	**323,000**	**347,000**	**260,000**
Bicarbonate	**491,000**	**292,000**	**347,000**	**260,000**
Carbonate	<5000	**31,000**	<5000	<5000
Chloride	**93,600**	**526,000**	**568,000**	**81,900**
Fluoride	<2500	<2500	<2500	<2500
Nitrate	**330 (J29)**	**2,700 (J29)**	**2,700 (J29)**	**11,000**
Nitrite	<250 (U29)	<2500 (U29)	<2500 (U29)	<250
pH	**7.7**	**8.3**	**7.7**	**7.3**
Sulfate	**46,800**	**20,100**	**29,700**	**60,400**
Total Dissolved Solids	**673,000**	**1,180,000**	**1,310,000**	**953,000**
Field Parameters				
Salinity (%)	**0.70**	**1.37**	**1.48**	**0.56**
pH	**8.31**	**9.18**	**8.36**	**7.53**
Temperature (°C)	**15.12**	**14.86**	**14.17**	**16.91**
Specific Conductivity (mS/cm)	**1.384**	**2.625**	**2.839**	**1.132**
Eh (mV)[a]	**423**	**348**	**308**	**464**
Turbidity (NTU)	**12.8**	**0.8**	**2.0**	**945.7**
Dissolved Oxygen (mg/l)	**3.17**	**2.81**	**3.77**	**4.28**

TABLE G-2

SUMMARY OF ANALYTES IN GROUNDWATER SAMPLES
HEXAVALENT CHROMIUM IN SERPENTINITE BEDROCK AND GROUNDWATER IN UPLAND AREAS
PRESIDIO OF SAN FRANCISCO
(Page 2 of 3)

Sample Location ID:	UBR03GW02	UBR01GW01	UBR01GW01	UBR01GW01
Sample Date:	3/23/99	2/24/99	3/4/99	3/4/99
Dissolved Metals (µg/l)				
Aluminum	<200	**120 (J28)**	<200	<200
Antimony	<60	<60	<60	<60
Arsenic	<300	<300	<300	<300
Barium	<200	**270**	**260**	**260**
Beryllium	<5.0	<5.0	<5.0	<5.0
Cadmium	<5.0	<5.0	<5.0	<5.0
Calcium	**30,000**	**38,700**	**34,200**	**33,600**
Chromium	<10	**25**	**66**	**65**
Cobalt	<50	<50	<50	<50
Copper	<25	<25	<25	<25
Iron	<100	**140**	<100	<100
Lead	<100	<100	<100	<100
Magnesium	**42,900**	**129,000**	**115,000**	**112,000**
Manganese	**59**	**71**	<15	<15
Nickel	<40	**27 (J28)**	<40	<40
Potassium	<5000	<5000	<5000	<5000
Selenium	<250	<250	<250	<250
Silicon	**16,600**	**25,700**	**23,900**	**23,400**
Silver	<10	<10	<10	<10
Sodium	**50,400**	**49,500**	**51,400**	**50,300**
Thallium	<2000	<2000	<2000	<2000
Titanium	<50	<50	<50	<50
Vanadium	<50	<50	<50	<50
Zinc	<20	<20	<20	<20
Hexavalent Chromium	**0.64 (J29)**	**26.6 (J29)**	**57.9**	**58.4**
General Water Chemistry Parameters (µg/l)				
Alkalinity, Total	**172,000**	NA	**468,000**	**459,000**
Bicarbonate	**172,000**	NA	**468,000**	**459,000**
Carbonate	<5000	NA	<5000	<5000
Chloride	**57,500**	NA	**98,800**	**98,400**
Fluoride	<500	NA	<1000	<1000
Nitrate	**6,800**	NA	**290**	**290**
Nitrite	<250	NA	<250	<250
pH	**6.4**	NA	**8.1**	**8.2**
Sulfate	**65,300**	NA	**48,800**	**48,000**
Total Dissolved Solids	**556,000**	NA	**689,000**	**699,000**
Field Parameters				
Salinity (%)	**0.40**	NA	**0.63**	NA
pH	**6.62**	NA	**8.32**	NA
Temperature (°C)	**15.89**	NA	**15.10**	NA
Specific Conductivity (mS/cm)	**0.807**	NA	**1.252**	NA
Eh (mV)[a]	**422**	NA	**-24**	NA
Turbidity (NTU)	**979.7**	NA	**1.5**	NA
Dissolved Oxygen (mg/l)	**0.68**	NA	**3.46**	NA

TABLE G-2

SUMMARY OF ANALYTES IN GROUNDWATER SAMPLES
HEXAVALENT CHROMIUM IN SERPENTINITE BEDROCK AND GROUNDWATER IN UPLAND AREAS
PRESIDIO OF SAN FRANCISCO
(Page 3 of 3)

Sample Location ID:	UBR02GW01	UBR02GW02
Sample Date:	3/4/99	3/4/99
Dissolved Metals (µg/l)		
Aluminum	<200	<200
Antimony	<60	<60
Arsenic	<300	<300
Barium	<200	<200
Beryllium	<5.0	<5.0
Cadmium	<5.0	<5.0
Calcium	**13,500**	**27,900**
Chromium	**48**	**98**
Cobalt	<50	<50
Copper	<25	<25
Iron	<100	<100
Lead	<100	<100
Magnesium	**130,000**	**143,000**
Manganese	<15	**16**
Nickel	<40	<40
Potassium	<5000	<5000
Selenium	<250	<250
Silicon	**10,300**	**24,100**
Silver	<10	<10
Sodium	**239,000**	**271,000**
Thallium	<2000	<2000
Titanium	<50	<50
Vanadium	<50	<50
Zinc	<20	<20
Hexavalent Chromium	**45.0**	**89.2**
General Water Chemistry Parameters (µg/l)		
Alkalinity, Total	**316,000**	**340,000**
Bicarbonate	**290,000**	**340,000**
Carbonate	**26,600**	<5000
Chloride	**552,000**	**601,000**
Fluoride	<10000	<10000
Nitrate	**2,800**	**2,700**
Nitrite	<1000	<1000
pH	**8.6**	**8.2**
Sulfate	**21,200**	**36,800**
Total Dissolved Solids	**1,140,000**	**1,270,000**
Field Parameters		
Salinity (%)	**1.25**	**1.37**
pH	**9.14**	**8.33**
Temperature (°C)	**14.83**	**14.09**
Specific Conductivity (mS/cm)	**2.420**	**2.638**
Eh (mV)[a]	**-15**	**-33**
Turbidity (NTU)	**1.4**	**0.1**
Dissolved Oxygen (mg/l)	**2.81**	**3.56**

[a] Eh values are corrected for reference electrode and temperature
mg/l - milligrams per liter
mS/cm - millisiemens per centimeter
mV - millivolts
NTU - nephelometric turbidity units
% - percent

TABLE G-3

SUMMARY OF ANALYTES IN LEACHATE
HEXAVALENT CHROMIUM IN SERPENTINITE BEDROCK AND GROUNDWATER IN UPLAND AREAS
PRESIDIO OF SAN FRANCISCO

Sample Location ID:	UBR01T01S01A	UBR01T01S01B	UBR01T01S02A	UBR01T01S02B	UBR01T01S03A	UBR01T01S03B	UBR01T01S04A
Sample Date:	3/16/99	3/16/99	3/16/99	3/16/99	3/17/99	3/17/99	3/23/99
Sampling Interval:	1 hour	1 hour	4 hours	4 hours	24 hours	24 hours	7 days
Dissolved Metals (µg/l)							
Aluminum	<200	<200	NA	NA	NA	NA	NA
Antimony	<60	<60	NA	NA	NA	NA	NA
Arsenic	<300	<300	NA	NA	NA	NA	NA
Barium	<200	<200	NA	NA	NA	NA	NA
Beryllium	<5.0	<5.0	NA	NA	NA	NA	NA
Cadmium	<5.0	<5.0	NA	NA	NA	NA	NA
Calcium	<5000	<5000	NA	NA	NA	NA	NA
Chromium	<10	<10	<10	<10	<10	<10	<10
Cobalt	<50	<50	NA	NA	NA	NA	NA
Copper	<25	<25	NA	NA	NA	NA	NA
Iron	<100	<100	<100	<100	<100	<100	<100
Lead	<100	<100	NA	NA	NA	NA	NA
Magnesium	<5000	<5000	<5000	<5000	<5000	<5000	<5000
Manganese	<15	<15	<15	<15	<15	<15	<15
Nickel	<40	<40	<40	<40	<40	<40	<40
Potassium	<5000	<5000	NA	NA	NA	NA	NA
Selenium	<250	<250	NA	NA	NA	NA	NA
Silicon	<200	<200	NA	NA	NA	NA	NA
Silver	<10	<10	NA	NA	NA	NA	NA
Sodium	<5000	<5000	NA	NA	NA	NA	NA
Thallium	<2000	<2000	NA	NA	NA	NA	NA
Titanium	<50	<50	NA	NA	NA	NA	NA
Vanadium	<50	<50	NA	NA	NA	NA	NA
Zinc	<20	<20	NA	NA	NA	NA	NA
Hexavalent Chromium	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
General Water Chemistry Parameters							
pH	**6.93**	**6.85**	**6.39**	**7.38**	**6.52**	**6.72**	**6.84**
Eh (mV)[a]	**434**	**447**	**464**	**447**	**443**	**421**	**451**

TABLE G-3

SUMMARY OF ANALYTES IN LEACHATE
HEXAVALENT CHROMIUM IN SERPENTINITE BEDROCK AND GROUNDWATER IN UPLAND AREAS
PRESIDIO OF SAN FRANCISCO

Sample Location ID:	**UBR01T01S04B**	**UBR01T01S05A**	**UBR01T01S05B**	**UBR01T01S06A**	**UBR01T01S06B**	**UBR01T01S07A**	**UBR01T01S07B**
Sample Date:	**3/23/99**	**3/30/99**	**3/30/99**	**4/6/99**	**4/6/99**	**4/13/99**	**4/13/99**
Sampling Interval:	**7 days**	**14 days**	**14 days**	**21 days**	**21 days**	**28 days**	**28 days**
Dissolved Metals (µg/l)							
Aluminum	NA	NA	NA	NA	NA	<200	<200
Antimony	NA	NA	NA	NA	NA	<60	<60
Arsenic	NA	NA	NA	NA	NA	<300	<300
Barium	NA	NA	NA	NA	NA	<200	<200
Beryllium	NA	NA	NA	NA	NA	<5.0	<5.0
Cadmium	NA	NA	NA	NA	NA	<5.0	<5.0
Calcium	NA	NA	NA	NA	NA	<5000	<5000
Chromium	<10	<10	<10	<10	<10	<10	<10
Cobalt	NA	NA	NA	NA	NA	<50	<50
Copper	NA	NA	NA	NA	NA	<25	<25
Iron	<100	<100	<100	<100	<100	<100	<100
Lead	NA	NA	NA	NA	NA	<100	<100
Magnesium	<5000	<5000	<5000	<5000	<5000	<5000	<5000
Manganese	<15	<15	<15	<15	**8.8 (J28)**	<15	<15
Nickel	<40	<40	<40	<40	<40	<40	<40
Potassium	NA	NA	NA	NA	NA	<5000	<5000
Selenium	NA	NA	NA	NA	NA	<250	<250
Silicon	NA	NA	NA	NA	NA	**1,600**	**1,100**
Silver	NA	NA	NA	NA	NA	<10	<10
Sodium	NA	NA	NA	NA	NA	<5000	<5000
Thallium	NA	NA	NA	NA	NA	<2000	<2000
Titanium	NA	NA	NA	NA	NA	<50	<50
Vanadium	NA	NA	NA	NA	NA	<50	<50
Zinc	NA	NA	NA	NA	NA	<20	<20
Hexavalent Chromium	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
General Water Chemistry Parameters							
pH	**6.89**	**7.26**	**7.10**	**7.54**	**7.36**	**7.36**	**6.34**
Eh (mV)[a]	**447**	**403**	**442**	**469**	**485**	**454**	**442**

TABLE G-3

SUMMARY OF ANALYTES IN LEACHATE
HEXAVALENT CHROMIUM IN SERPENTINITE BEDROCK AND GROUNDWATER IN UPLAND AREAS
PRESIDIO OF SAN FRANCISCO

Sample Location ID:	**UBR01T02S01A**	**UBR01T02S01B**	**UBR01T02S02A**	**UBR01T02S02B**	**UBR01T02S03A**	**UBR01T02S03B**	**UBR01T02S04A**
Sample Date:	**3/16/99**	**3/16/99**	**3/16/99**	**3/16/99**	**3/17/99**	**3/17/99**	**3/23/99**
Sampling Interval:	**1 hour**	**1 hour**	**4 hours**	**4 hours**	**24 hours**	**24 hours**	**7 days**
Dissolved Metals (µg/l)							
Aluminum	<200	<200	NA	NA	NA	NA	NA
Antimony	<60	<60	NA	NA	NA	NA	NA
Arsenic	<300	<300	NA	NA	NA	NA	NA
Barium	**220**	**210**	NA	NA	NA	NA	NA
Beryllium	<5.0	<5.0	NA	NA	NA	NA	NA
Cadmium	<5.0	<5.0	NA	NA	NA	NA	NA
Calcium	**40,500**	**40,500**	NA	NA	NA	NA	NA
Chromium	**63**	**63**	**62**	**58**	**64**	**56**	**64**
Cobalt	<50	<50	NA	NA	NA	NA	NA
Copper	<25	<25	NA	NA	NA	NA	NA
Iron	<100	<100	<100	<100	<100	<100	<100
Lead	<100	<100	NA	NA	NA	NA	NA
Magnesium	**101,000**	**101,000**	**101,000**	**92,200**	**99,000**	**89,400**	**97,900**
Manganese	<15	<15	<15	<15	<15	<15	<15
Nickel	<40	<40	<40	<40	<40	<40	<40
Potassium	<5000	<5000	NA	NA	NA	NA	NA
Selenium	<250	<250	NA	NA	NA	NA	NA
Silicon	**23,600**	**23,600**	NA	NA	NA	NA	NA
Silver	<10	<10	NA	NA	NA	NA	NA
Sodium	**50,800**	**49,600**	NA	NA	NA	NA	NA
Thallium	<2000	<2000	NA	NA	NA	NA	NA
Titanium	<50	<50	NA	NA	NA	NA	NA
Vanadium	<50	<50	NA	NA	NA	NA	NA
Zinc	<20	<20	NA	NA	NA	NA	NA
Hexavalent Chromium	**69.5**	**67.7**	**63.9**	**62.6**	**69.9**	**70.7**	**66.6**
General Water Chemistry Parameters							
pH	**7.88**	**7.92**	**7.83**	**7.79**	**8.00**	**7.97**	**7.85**
Eh (mV)[a]	**432**	**429**	**458**	**438**	**404**	**407**	**394**

TABLE G-3

SUMMARY OF ANALYTES IN LEACHATE
HEXAVALENT CHROMIUM IN SERPENTINITE BEDROCK AND GROUNDWATER IN UPLAND AREAS
PRESIDIO OF SAN FRANCISCO

Sample Location ID:	UBR01T02S04B	UBR01T02S05A	UBR01T02S05B	UBR01T02S06A	UBR01T02S06B	UBR01T02S07A	UBR01T02S07B
Sample Date:	3/23/99	3/30/99	3/30/99	4/6/99	4/6/99	4/13/99	4/13/99
Sampling Interval:	7 days	14 days	14 days	21 days	21 days	28 days	28 days
Dissolved Metals (µg/l)							
Aluminum	NA	NA	NA	NA	NA	<200	<200
Antimony	NA	NA	NA	NA	NA	<60	<60
Arsenic	NA	NA	NA	NA	NA	<300	<300
Barium	NA	NA	NA	NA	NA	**160 (J28)**	**150 (J28)**
Beryllium	NA	NA	NA	NA	NA	<5.0	<5.0
Cadmium	NA	NA	NA	NA	NA	<5.0	<5.0
Calcium	NA	NA	NA	NA	NA	**28,000**	**27,200**
Chromium	**65**	**64**	**63**	**56 (J33)**	**33 (J33)**	**8.6 (J28)**	**8.4 (J28)**
Cobalt	NA	NA	NA	NA	NA	<50	<50
Copper	NA	NA	NA	NA	NA	<25	<25
Iron	<100	<100	<100	<100	<100	<100	<100
Lead	NA	NA	NA	NA	NA	<100	<100
Magnesium	**97,400**	**94,700**	**96,600**	**80,800**	**90,500**	**83,300**	**82,000**
Manganese	<15	<15	<15	<15	<15	<15	<15
Nickel	<40	<40	<40	<40	<40	<40	<40
Potassium	NA	NA	NA	NA	NA	<5000	<5000
Selenium	NA	NA	NA	NA	NA	<250	<250
Silicon	NA	NA	NA	NA	NA	**24,200**	**23,900**
Silver	NA	NA	NA	NA	NA	<10	<10
Sodium	NA	NA	NA	NA	NA	**47,200**	**47,300**
Thallium	NA	NA	NA	NA	NA	<2000	<2000
Titanium	NA	NA	NA	NA	NA	<50	<50
Vanadium	NA	NA	NA	NA	NA	<50	<50
Zinc	NA	NA	NA	NA	NA	<20	<20
Hexavalent Chromium	**68.8**	**54.7**	**57.1**	**34.9 (J33)**	**19.0 (J33)**	**5.3**	**5.2**
General Water Chemistry Parameters							
pH	**7.83**	**7.86**	**7.87**	**8.09**	**7.93**	**7.86**	**7.96**
Eh (mV)[a]	**393**	**429**	**428**	**464**	**442**	**418**	**424**

TABLE G-3

SUMMARY OF ANALYTES IN LEACHATE
HEXAVALENT CHROMIUM IN SERPENTINITE BEDROCK AND GROUNDWATER IN UPLAND AREAS
PRESIDIO OF SAN FRANCISCO

Sample Location ID:	**UBR01T03S01A**	**UBR01T03S01B**	**UBR01T03S02A**	**UBR01T03S02B**	**UBR01T03S03A**	**UBR01T03S03B**	**UBR01T03S04A**
Sample Date:	**3/16/99**	**3/16/99**	**3/16/99**	**3/16/99**	**3/17/99**	**3/17/99**	**3/23/99**
Sampling Interval:	**1 hour**	**1 hour**	**4 hours**	**4 hours**	**24 hours**	**24 hours**	**7 days**
Dissolved Metals (μg/l)							
Aluminum	<200	<200	NA	NA	NA	NA	NA
Antimony	<60	<60	NA	NA	NA	NA	NA
Arsenic	<300	<300	NA	NA	NA	NA	NA
Barium	<200	<200	NA	NA	NA	NA	NA
Beryllium	<5.0	<5.0	NA	NA	NA	NA	NA
Cadmium	<5.0	<5.0	NA	NA	NA	NA	NA
Calcium	**2,800 (J28)**	**3,300 (J28)**	NA	NA	NA	NA	NA
Chromium	<10	<10	<10	<10	<10	**7.7 (J28)**	<10
Cobalt	<50	<50	NA	NA	NA	NA	NA
Copper	<25	<25	NA	NA	NA	NA	NA
Iron	<100	<100	<100	<100	**110**	<100	<100
Lead	<100	<100	NA	NA	NA	NA	NA
Magnesium	**4,200 (J28)**	**4,800 (J28)**	**6,900**	**6,100**	**6,800**	**6,400**	**8,900**
Manganese	<15	<15	<15	<15	<15	<15	<15
Nickel	<40	<40	<40	<40	<40	<40	<40
Potassium	<5000	<5000	NA	NA	NA	NA	NA
Selenium	<250	<250	NA	NA	NA	NA	NA
Silicon	**9,200**	**9,200**	NA	NA	NA	NA	NA
Silver	<10	<10	NA	NA	NA	NA	NA
Sodium	**7,200**	**6,700**	NA	NA	NA	NA	NA
Thallium	<2000	<2000	NA	NA	NA	NA	NA
Titanium	<50	<50	NA	NA	NA	NA	NA
Vanadium	<50	<50	NA	NA	NA	NA	NA
Zinc	<20	<20	NA	NA	NA	NA	NA
Hexavalent Chromium	**3.5**	**3.3**	**3.7**	**3.3**	**4.1**	**4.2**	**5.2**
General Water Chemistry Parameters							
pH	**8.78**	**8.84**	**8.38**	**8.38**	**8.75**	**8.74**	**8.29**
Eh (mV)[a]	**396**	**389**	**455**	**449**	**416**	**429**	**391**

TABLE G-3

SUMMARY OF ANALYTES IN LEACHATE
HEXAVALENT CHROMIUM IN SERPENTINITE BEDROCK AND GROUNDWATER IN UPLAND AREAS
PRESIDIO OF SAN FRANCISCO

Sample Location ID:	**UBR01T03S04B**	**UBR01T03S05A**	**UBR01T03S05B**	**UBR01T03S06A**	**UBR01T03S06B**	**UBR01T03S07A**	**UBR01T03S07B**
Sample Date:	**3/23/99**	**3/30/99**	**3/30/99**	**4/6/99**	**4/6/99**	**4/13/99**	**4/13/99**
Sampling Interval:	**7 days**	**14 days**	**14 days**	**21 days**	**21 days**	**28 days**	**28 days**
Dissolved Metals (µg/l)							
Aluminum	NA	NA	NA	NA	NA	<200	<200
Antimony	NA	NA	NA	NA	NA	<60	<60
Arsenic	NA	NA	NA	NA	NA	<300	<300
Barium	NA	NA	NA	NA	NA	<200	<200
Beryllium	NA	NA	NA	NA	NA	<5.0	<5.0
Cadmium	NA	NA	NA	NA	NA	<5.0	<5.0
Calcium	NA	NA	NA	NA	NA	**9,000**	**8,600**
Chromium	**6.7 (J28)**	**9.3 (J28)**	**6.0 (J28)**	**6.7 (J28)**	<10	<10	**5.0 (J28)**
Cobalt	NA	NA	NA	NA	NA	<50	<50
Copper	NA	NA	NA	NA	NA	<25	<25
Iron	**260**	<100	<100	<100	<100	<100	**83 (J28)**
Lead	NA	NA	NA	NA	NA	<100	<100
Magnesium	**8,900**	**11,000**	**8,700**	**10,300**	**10,100**	**11,000**	**10,100**
Manganese	<15	<15	<15	<15	<15	<15	<15
Nickel	<40	<40	<40	<40	<40	<40	<40
Potassium	NA	NA	NA	NA	NA	<5000	<5000
Selenium	NA	NA	NA	NA	NA	<250	<250
Silicon	NA	NA	NA	NA	NA	**18,300**	**17,400**
Silver	NA	NA	NA	NA	NA	<10	<10
Sodium	NA	NA	NA	NA	NA	**7,100**	**7,100**
Thallium	NA	NA	NA	NA	NA	<2000	<2000
Titanium	NA	NA	NA	NA	NA	<50	<50
Vanadium	NA	NA	NA	NA	NA	<50	<50
Zinc	NA	NA	NA	NA	NA	<20	<20
Hexavalent Chromium	**5.2**	**4.4**	**6.4**	**3.4**	**2.3**	**0.36 (J28)**	**2.0**
General Water Chemistry Parameters							
pH	**8.29**	**8.06**	**7.95**	**8.06**	**8.01**	**8.26**	**8.21**
Eh (mV)[a]	**396**	**416**	**425**	**442**	**450**	**403**	**403**

TABLE G-3

SUMMARY OF ANALYTES IN LEACHATE
HEXAVALENT CHROMIUM IN SERPENTINITE BEDROCK AND GROUNDWATER IN UPLAND AREAS
PRESIDIO OF SAN FRANCISCO

Sample Location ID:	UBR01T04S01A	UBR01T04S01B	UBR01T04S02A	UBR01T04S02B	UBR01T04S03A	UBR01T04S03B	UBR01T04S04A
Sample Date:	3/24/99	3/24/99	3/24/99	3/24/99	3/25/99	3/25/99	3/31/99
Sampling Interval:	1 hour	1 hour	4 hours	4 hours	24 hours	24 hours	7 days
Dissolved Metals (µg/l)							
Aluminum	<200	<200	NA	NA	NA	NA	NA
Antimony	<60	<60	NA	NA	NA	NA	NA
Arsenic	<300	<300	NA	NA	NA	NA	NA
Barium	<200	<200	NA	NA	NA	NA	NA
Beryllium	<5.0	<5.0	NA	NA	NA	NA	NA
Cadmium	<5.0	<5.0	NA	NA	NA	NA	NA
Calcium	**4,400 (J28)**	**4,600 (J28)**	NA	NA	NA	NA	NA
Chromium	**79**	**82**	**110**	**110**	**140**	**130**	**180**
Cobalt	<50	<50	NA	NA	NA	NA	NA
Copper	<25	<25	NA	NA	NA	NA	NA
Iron	<100	<100	<100	<100	<100	**96 (J28)**	<100
Lead	<100	<100	NA	NA	NA	NA	NA
Magnesium	**6,300**	**6,700**	**5,400**	**6,000**	**6,600**	**6,100**	**8,900**
Manganese	**59**	**24**	<15	**8.3 (J28)**	**16**	<15	**10 (J28)**
Nickel	<40	<40	<40	<40	<40	<40	<40
Potassium	<5000	<5000	NA	NA	NA	NA	NA
Selenium	<250	<250	NA	NA	NA	NA	NA
Silicon	**8,400**	**8,700**	NA	NA	NA	NA	NA
Silver	<10	<10	NA	NA	NA	NA	NA
Sodium	**4,500 (J28)**	**4,600 (J28)**	NA	NA	NA	NA	NA
Thallium	<2000	<2000	NA	NA	NA	NA	NA
Titanium	<50	<50	NA	NA	NA	NA	NA
Vanadium	**88**	**92**	NA	NA	NA	NA	NA
Zinc	<20	<20	NA	NA	NA	NA	NA
Hexavalent Chromium	**554**	**556**	**108**	**105**	**144**	**132**	**125**
General Water Chemistry Parameters							
pH	**8.59**	**8.57**	**8.68**	**8.61**	**7.98**	**8.39**	**8.30**
Eh (mV)[a]	**333**	**332**	**334**	**336**	**395**	**397**	**431**

TABLE G-3

SUMMARY OF ANALYTES IN LEACHATE
HEXAVALENT CHROMIUM IN SERPENTINITE BEDROCK AND GROUNDWATER IN UPLAND AREAS
PRESIDIO OF SAN FRANCISCO

Sample Location ID:	UBR01T04S04B	UBR01T04S05A	UBR01T04S05B	UBR01T04S06A	UBR01T04S06B	UBR01T04S07A	UBR01T04S07B
Sample Date:	3/31/99	4/7/99	4/7/99	4/14/99	4/14/99	4/21/99	4/21/99
Sampling Interval:	7 days	14 days	14 days	21 days	21 days	28 days	28 days
Dissolved Metals (µg/l)							
Aluminum	NA	NA	NA	NA	NA	<200	<200
Antimony	NA	NA	NA	NA	NA	<60	<60
Arsenic	NA	NA	NA	NA	NA	<300	<300
Barium	NA	NA	NA	NA	NA	<200	<200
Beryllium	NA	NA	NA	NA	NA	<5.0	<5.0
Cadmium	NA	NA	NA	NA	NA	<5.0	<5.0
Calcium	NA	NA	NA	NA	NA	**8,700**	**10,600**
Chromium	**200**	**190 (J33)**	**91 (J33)**	**180**	**190**	**190**	**170**
Cobalt	NA	NA	NA	NA	NA	<50	<50
Copper	NA	NA	NA	NA	NA	<25	<25
Iron	<100	<100	<100	<100	<100	<100	<100
Lead	NA	NA	NA	NA	NA	<100	<100
Magnesium	**9,100**	**9,300**	**10,800**	**10,200**	**10,000**	**11,000**	**12,900**
Manganese	<15	**12 (J28)**	<15	<15	<15	**28**	<15
Nickel	<40	<40	<40	<40	<40	<40	<40
Potassium	NA	NA	NA	NA	NA	<5000	<5000
Selenium	NA	NA	NA	NA	NA	<250	<250
Silicon	NA	NA	NA	NA	NA	**19,400**	**20,400**
Silver	NA	NA	NA	NA	NA	<10	<10
Sodium	NA	NA	NA	NA	NA	**6,700**	**6,800**
Thallium	NA	NA	NA	NA	NA	<2000	<2000
Titanium	NA	NA	NA	NA	NA	<50	<50
Vanadium	NA	NA	NA	NA	NA	<50	<50
Zinc	NA	NA	NA	NA	NA	<20	<20
Hexavalent Chromium	**133**	**139 (J33)**	**67.7 (J33)**	**151**	**152**	**182**	**156**
General Water Chemistry Parameters							
pH	**8.19**	**8.20**	**8.07**	**8.31**	**8.25**	**7.91**	**7.87**
Eh (mV)[a]	**425**	**460**	**450**	**437**	**438**	**399**	**411**

TABLE G-3

SUMMARY OF ANALYTES IN LEACHATE
HEXAVALENT CHROMIUM IN SERPENTINITE BEDROCK AND GROUNDWATER IN UPLAND AREAS
PRESIDIO OF SAN FRANCISCO

Sample Location ID:	**UBR01T05S01A**	**UBR01T05S01B**	**UBR01T05S02A**	**UBR01T05S02B**	**UBR01T05S03A**	**UBR01T05S03B**	**UBR01T05S04A**
Sample Date:	**3/24/99**	**3/24/99**	**3/24/99**	**3/24/99**	**3/25/99**	**3/25/99**	**3/31/99**
Sampling Interval:	**1 hour**	**1 hour**	**4 hours**	**4 hours**	**24 hours**	**24 hours**	**7 days**
Dissolved Metals (μg/l)							
Aluminum	<200	<200	NA	NA	NA	NA	NA
Antimony	<60	<60	NA	NA	NA	NA	NA
Arsenic	<300	<300	NA	NA	NA	NA	NA
Barium	<200	<200	NA	NA	NA	NA	NA
Beryllium	<5.0	<5.0	NA	NA	NA	NA	NA
Cadmium	<5.0	<5.0	NA	NA	NA	NA	NA
Calcium	**3,000 (J28)**	**2,900 (J28)**	NA	NA	NA	NA	NA
Chromium	**22 (J33)**	**14 (J33)**	**7.2 (J28)**	**6.6 (J28)**	**5.0 (J28)**	**5.5 (J28)**	**8.3 (J28)**
Cobalt	<50	<50	NA	NA	NA	NA	NA
Copper	<25	<25	NA	NA	NA	NA	NA
Iron	<100	<100	<100	<100	<100	<100	<100
Lead	<100	<100	NA	NA	NA	NA	NA
Magnesium	**4,200 (J28)**	**4,200 (J28)**	**5,200**	**4,100 (J28)**	**6,300**	**6,200**	**8,500**
Manganese	<15	<15	<15	<15	<15	<15	<15
Nickel	<40	<40	<40	<40	<40	<40	<40
Potassium	<5000	<5000	NA	NA	NA	NA	NA
Selenium	<250	<250	NA	NA	NA	NA	NA
Silicon	**6,200**	**6,200**	NA	NA	NA	NA	NA
Silver	<10	<10	NA	NA	NA	NA	NA
Sodium	**4,300 (J28)**	**4,400 (J28)**	NA	NA	NA	NA	NA
Thallium	<2000	<2000	NA	NA	NA	NA	NA
Titanium	<50	<50	NA	NA	NA	NA	NA
Vanadium	<50	<50	NA	NA	NA	NA	NA
Zinc	<20	<20	NA	NA	NA	NA	NA
Hexavalent Chromium	**4.9**	**4.9**	**4.7**	**4.5**	**5.1**	**5.1**	**4.6**
General Water Chemistry Parameters							
pH	**8.73**	**8.77**	**8.52**	**8.44**	**8.43**	**8.37**	**8.20**
Eh (mV)[a]	**432**	**441**	**373**	**378**	**397**	**407**	**422**

TABLE G-3

SUMMARY OF ANALYTES IN LEACHATE
HEXAVALENT CHROMIUM IN SERPENTINITE BEDROCK AND GROUNDWATER IN UPLAND AREAS
PRESIDIO OF SAN FRANCISCO

Sample Location ID:	**UBR01T05S04B**	**UBR01T05S05A**	**UBR01T05S05B**	**UBR01T05S06A**	**UBR01T05S06B**	**UBR01T05S07A**	**UBR01T05S07B**
Sample Date:	**3/31/99**	**4/7/99**	**4/7/99**	**4/14/99**	**4/14/99**	**4/21/99**	**4/21/99**
Sampling Interval:	**7 days**	**14 days**	**14 days**	**21 days**	**21 days**	**28 days**	**28 days**
Dissolved Metals (µg/l)							
Aluminum	NA	NA	NA	NA	NA	<200	<200
Antimony	NA	NA	NA	NA	NA	<60	<60
Arsenic	NA	NA	NA	NA	NA	<300	<300
Barium	NA	NA	NA	NA	NA	<200	<200
Beryllium	NA	NA	NA	NA	NA	<5.0	<5.0
Cadmium	NA	NA	NA	NA	NA	<5.0	<5.0
Calcium	NA	NA	NA	NA	NA	**11,100**	**10,800**
Chromium	**8.1 (J28)**	**7.5 (J28)**	**7.3 (J28)**	**9.8 (J28, J33)**	**31 (J33)**	**6.2 (J28)**	**7.2 (J28)**
Cobalt	NA	NA	NA	NA	NA	<50	<50
Copper	NA	NA	NA	NA	NA	<25	<25
Iron	<100	<100	<100	<100	<100	<100	<100
Lead	NA	NA	NA	NA	NA	<100	<100
Magnesium	**8,600**	**9,500**	**9,400**	**10,600**	**11,700**	**12,400**	**12,800**
Manganese	<15	<15	<15	<15	<15	<15	<15
Nickel	<40	<40	<40	<40	<40	<40	<40
Potassium	NA	NA	NA	NA	NA	<5000	<5000
Selenium	NA	NA	NA	NA	NA	<250	<250
Silicon	NA	NA	NA	NA	NA	**20,600**	**20,800**
Silver	NA	NA	NA	NA	NA	<10	<10
Sodium	NA	NA	NA	NA	NA	**7,100**	**7,800**
Thallium	NA	NA	NA	NA	NA	<2000	<2000
Titanium	NA	NA	NA	NA	NA	<50	<50
Vanadium	NA	NA	NA	NA	NA	<50	<50
Zinc	NA	NA	NA	NA	NA	<20	<20
Hexavalent Chromium	**4.7**	**5.2**	**5.1**	**5.1**	**6.3**	**4.3**	**6.1**
General Water Chemistry Parameters							
pH	**8.39**	**8.05**	**7.96**	**8.25**	**8.16**	**7.93**	**7.94**
Eh (mV)[a]	**419**	**446**	**449**	**436**	**440**	**418**	**420**

TABLE G-3

SUMMARY OF ANALYTES IN LEACHATE
HEXAVALENT CHROMIUM IN SERPENTINITE BEDROCK AND GROUNDWATER IN UPLAND AREAS
PRESIDIO OF SAN FRANCISCO

Sample Location ID:	UBR01T06S01A	UBR01T06S01B	UBR01T06S02A	UBR01T06S02B	UBR01T06S03A	UBR01T06S03B	UBR01T06S04A
Sample Date:	3/24/99	3/24/99	3/24/99	3/24/99	3/25/99	3/25/99	3/31/99
Sampling Interval:	1 hour	1 hour	4 hours	4 hours	24 hours	24 hours	7 days
Dissolved Metals (µg/l)							
Aluminum	<200	<200	NA	NA	NA	NA	NA
Antimony	<60	<60	NA	NA	NA	NA	NA
Arsenic	<300	<300	NA	NA	NA	NA	NA
Barium	**260**	**210**	NA	NA	NA	NA	NA
Beryllium	<5.0	<5.0	NA	NA	NA	NA	NA
Cadmium	<5.0	<5.0	NA	NA	NA	NA	NA
Calcium	**29,000**	**27,000**	NA	NA	NA	NA	NA
Chromium	**8,600**	**8,700**	**1,800**	**2,100**	**300**	**290**	**210**
Cobalt	**29 (J28)**	<50	NA	NA	NA	NA	NA
Copper	<25	<25	NA	NA	NA	NA	NA
Iron	<100	<100	<100	<100	<100	<100	<100
Lead	<100	<100	NA	NA	NA	NA	NA
Magnesium	**43,100**	**39,000**	**42,600**	**43,300**	**43,600**	**42,000**	**47,600**
Manganese	**780**	**190**	**240**	**130**	**88**	**60**	**29**
Nickel	**97**	**37 (J28)**	**38 (J28)**	**20 (J28)**	**24 (J28)**	<40	<40
Potassium	<5000	<5000	NA	NA	NA	NA	NA
Selenium	<250	<250	NA	NA	NA	NA	NA
Silicon	**5,100**	**4,800**	NA	NA	NA	NA	NA
Silver	<10	<10	NA	NA	NA	NA	NA
Sodium	**7,200**	**6,400**	NA	NA	NA	NA	NA
Thallium	<2000	<2000	NA	NA	NA	NA	NA
Titanium	<50	<50	NA	NA	NA	NA	NA
Vanadium	**33 (J28)**	<50	NA	NA	NA	NA	NA
Zinc	<20	<20	NA	NA	NA	NA	NA
Hexavalent Chromium	**3,590 (J33)**	**210 (J33)**	**117**	**156**	**73.7**	**108**	**147**
General Water Chemistry Parameters							
pH	**5.33**	**5.27**	**5.52**	**5.63**	**6.18**	**6.02**	**7.16**
Eh (mV)[a]	**541**	**459**	**493**	**491**	**443**	**407**	**439**

TABLE G-3

SUMMARY OF ANALYTES IN LEACHATE
HEXAVALENT CHROMIUM IN SERPENTINITE BEDROCK AND GROUNDWATER IN UPLAND AREAS
PRESIDIO OF SAN FRANCISCO

Sample Location ID:	**UBR01T06S04B**	**UBR01T06S05A**	**UBR01T06S05B**	**UBR01T06S06A**	**UBR01T06S06B**	**UBR01T06S07A**	**UBR01T06S07B**
Sample Date:	**3/31/99**	**4/7/99**	**4/7/99**	**4/14/99**	**4/14/99**	**4/21/99**	**4/21/99**
Sampling Interval:	**7 days**	**14 days**	**14 days**	**21 days**	**21 day**	**28 days**	**28 days**
Dissolved Metals (µg/l)							
Aluminum	NA	NA	NA	NA	NA	<200	<200
Antimony	NA	NA	NA	NA	NA	<60	<60
Arsenic	NA	NA	NA	NA	NA	<300	<300
Barium	NA	NA	NA	NA	NA	**150 (J28)**	**130 (J28)**
Beryllium	NA	NA	NA	NA	NA	<5.0	<5.0
Cadmium	NA	NA	NA	NA	NA	<5.0	<5.0
Calcium	NA	NA	NA	NA	NA	**37,900**	**37,300**
Chromium	**240**	**470 (J33)**	**230 (J33)**	**220**	**220**	**190 (J33)**	**120 (J33)**
Cobalt	NA	NA	NA	NA	NA	<50	<50
Copper	NA	NA	NA	NA	NA	<25	<25
Iron	<100	<100	<100	<100	<100	<100	<100
Lead	NA	NA	NA	NA	NA	<100	<100
Magnesium	**48,800**	**48,500**	**47,100**	**47,700**	**48,000**	**47,800**	**48,900**
Manganese	**30**	**51**	**27**	**67**	**22**	**47**	**17**
Nickel	<40	<40	<40	<40	<40	<40	<40
Potassium	NA	NA	NA	NA	NA	<5000	<5000
Selenium	NA	NA	NA	NA	NA	<250	<250
Silicon	NA	NA	NA	NA	NA	**22,600**	**23,500**
Silver	NA	NA	NA	NA	NA	<10	<10
Sodium	NA	NA	NA	NA	NA	**8,700**	**8,600**
Thallium	NA	NA	NA	NA	NA	<2000	<2000
Titanium	NA	NA	NA	NA	NA	<50	<50
Vanadium	NA	NA	NA	NA	NA	<50	<50
Zinc	NA	NA	NA	NA	NA	<20	<20
Hexavalent Chromium	**160**	**344 (J33)**	**169 (J33)**	**184**	**176**	**171 (J33)**	**104 (J33)**
General Water Chemistry Parameters							
pH	**7.04**	**7.25**	**7.08**	**7.31**	**7.24**	**6.93**	**7.07**
Eh (mV)[a]	**421**	**472**	**472**	**463**	**467**	**463**	**453**

[a] Eh values corrected for reference electrode and temperature by adding 244 mV
µg/l - micrograms per liter
mV - millivolts

TABLE G-4

SUMMARY OF ANALYTES IN LEACHED BEDROCK
HEXAVALENT CHROMIUM IN SERPENTINITE BEDROCK AND GROUNDWATER IN UPLAND AREAS
PRESIDIO OF SAN FRANCISCO

Sample ID:	UBR01T02S01A	UBR01T02S01B	UBR01T02S07A	UBR01T02S07B	UBR01T03S01A	UBR01T03S01B
Sample Date:	3/16/99	3/16/99	4/13/99	4/13/99	3/16/99	3/16/99
Sampling Interval:	1 hour	1 hour	28 days	28 days	1 hour	1 hour
Metals (mg/kg)						
Chromium	NA	NA	592	619	NA	NA
Iron	NA	NA	29,300	30,600	NA	NA
Magnesium	NA	NA	128,000	133,000	NA	NA
Manganese	NA	NA	335	364	NA	NA
Nickel	NA	NA	1,360	1,370	NA	NA
Soil Chemistry Parameters						
Cr(VI) by Alkaline Digestion (mg/kg)	0.088	0.092	0.255	0.220	0.100	0.086
Easily Reducible Manganese (mg/kg)	109	101	94	109	96	94
Quick Oxidation Test (mg/kg)	1.34	1.31	0.24	0.24	1.60	1.73
Percent Moisture (%)	23.1	21.4	26.2	24.2	18.6	21.0

TABLE G-4

SUMMARY OF ANALYTES IN LEACHED BEDROCK
HEXAVALENT CHROMIUM IN SERPENTINITE BEDROCK AND GROUNDWATER IN UPLAND AREAS
PRESIDIO OF SAN FRANCISCO
(Page 2 of 4)

Sample ID:	**UBR01T03S07A**	**UBR01T03S07B**	**UBR01T04S01A**	**UBR01T04S01B**	**UBR01T04S07A**	**UBR01T04S07B**
Sample Date:	**4/13/99**	**4/13/99**	**3/24/99**	**3/24/99**	**4/21/99**	**4/21/99**
Sampling Interval:	**28 days**	**28 days**	**1 hour**	**1 hour**	**28 days**	**28 days**
Metals (mg/kg)						
Chromium	**827**	**691**	NA	NA	**931**	**686**
Iron	**32,700**	**32,100**	NA	NA	**33,000**	**32,900**
Magnesium	**145,000**	**137,000**	NA	NA	**139,000**	**139,000**
Manganese	**377**	**359**	NA	NA	**402**	**383**
Nickel	**1,500**	**1,420**	NA	NA	**1,420**	**1,440**
Soil Chemistry Parameters						
Cr(VI) by Alkaline Digestion (mg/kg)	**0.162**	**0.148**	**0.788**	**1.032**	**0.315**	**0.312**
Easily Reducible Manganese (mg/kg)	**90**	**111**	**115**	**95**	**88**	**99**
Quick Oxidation Test (mg/kg)	**0.72**	**1.06**	**0.53**	**0.56**	**0.44**	**0.46**
Percent Moisture (%)	**24.6**	**28.6**	**20.2**	**20.8**	**21.9**	**21.2**

TABLE G-4

SUMMARY OF ANALYTES IN LEACHED BEDROCK
HEXAVALENT CHROMIUM IN SERPENTINITE BEDROCK AND GROUNDWATER IN UPLAND AREAS
PRESIDIO OF SAN FRANCISCO
(Page 3 of 4)

Sample Location ID:	UBR01T05S01A	UBR01T05S01B	UBR01T05S07A	UBR01T05S07B	UBR01T06S01A	UBR01T06S01B
Sample Date:	3/24/99	3/24/99	4/21/99	4/21/99	3/24/99	3/24/99
Sampling Interval:	1 hour	1 hour	28 days	28 days	1 hour	1 hour
Metals (mg/kg)						
Chromium	NA	NA	908	837	NA	NA
Iron	NA	NA	31,900	33,200	NA	NA
Magnesium	NA	NA	132,000	148,000	NA	NA
Manganese	NA	NA	23,700	8,420	NA	NA
Nickel	NA	NA	1,430	1,420	NA	NA
Soil Chemistry Parameters						
Cr(VI) by Alkaline Digestion (mg/kg)	0.163	0.151	0.173	0.114	18.15	9.615
Easily Reducible Manganese (mg/kg)	7,883	11,073	12,981	11,331	89	106
Quick Oxidation Test (mg/kg)	1.88	1.97	1.27	1.65	1.92	0.35
Percent Moisture (%)	18.6	23.0	21.2	21.2	21.3	19.7

TABLE G-4

SUMMARY OF ANALYTES IN LEACHED BEDROCK
HEXAVALENT CHROMIUM IN SERPENTINITE BEDROCK AND GROUNDWATER IN UPLAND AREAS
PRESIDIO OF SAN FRANCISCO
(Page 4 of 4)

Sample Location ID:	**UBR01T06S07A**	**UBR01T06S07B**
Sample Date:	**4/21/99**	**4/21/99**
Sampling Interval:	**28 days**	**28 days**
Metals (mg/kg)		
Chromium	**965**	**909**
Iron	**28,600**	**32,600**
Magnesium	**131,000**	**144,000**
Manganese	**316**	**359**
Nickel	**1,370**	**1,480**
Soil Chemistry Parameters		
Cr(VI) by Alkaline Digestion (mg/kg)	**3.714**	**3.075**
Easily Reducible Manganese (mg/kg)	**66**	**72**
Quick Oxidation Test (mg/kg)	**0.12**	**0.09**
Percent Moisture (%)	**17.9**	**22.3**

mg/kg - milligrams per kilogram

% - percent

TABLE G-5

SAMPLE IDENTIFICATION NOMENCLATURE
HEXAVALENT CHROMIUM IN SERPENTINITE BEDROCK AND GROUNDWATER IN UPLAND AREAS
PRESIDIO OF SAN FRANCISCO

BEDROCK SAMPLE IDs

UBR01SB01	Composite of bedrock samples taken from bedrock core at location UBR01 at 36.5, 40, 44, and 47 feet below ground surface (bgs)
UBR02SB01	Composite of bedrock samples taken from bedrock core at location UBR02 at 22, 27.5, and 32 feet bgs
UBR03SB02	Composite of bedrock samples taken from bedrock core at location UBR03 at 68 and 71 feet bgs

GROUNDWATER SAMPLE IDs

UBR01GW01	groundwater monitoring well at site UBR01
UBR02GW01	deep groundwater monitoring well at site UBR02
UBR02GW02	shallow groundwater monitoring well at site UBR02
UBR03GW01	deep groundwater monitoring well at site UBR03
UBR03GW02	shallow groundwater monitoring well at site UBR03

LEACHATE SAMPLE IDs

Note: Sampling Intervals:		Test Conditions:	
	S01 = 1 hour		T01 = DI water only
	S02 = 24 hrs		T02 = Bedrock + Groundwater
	S03 = 7 days		T03 = Bedrock + DI water
	S04 = 14 days		T04 = Bedrock + DI water + H_2O_2
	S05 = 21 days		T05 = Bedrock + DI water + MnO_2
	S06 = 28 days		T06 = Bedrock + DI water + $CrCl_3$

Example of leachate sample IDs

UBR01T01S01A	UBR01 = Bedrock composite used , T01 = First test condition, S01 = First sampling interval
UBR01T01S01B	Duplicate of UBR01T01S01
UBR01T01S02A	UBR01 = Bedrock composite used, T01 = First test condition, S02 = Second sampling interval, etc.

TABLE G-6

DATA VALIDATION QUALIFIER SUMMARY
HEXAVALENT CHROMIUM IN SERPENTINITE BEDROCK AND GROUNDWATER IN UPLAND AREAS
PRESIDIO OF SAN FRANCISCO

Data Validation Qualifiers:

J - Qualified as estimated U - Qualified as not detected R - Qualified as rejected

Data Validation Comments:

1 Qualified due to detected concentration in associated method blank sample.
2 Qualified due to detected concentration in associated trip blank sample.
3 Qualified due to detected concentration in associated filter blank sample.
4 Qualified due to detected concentration in associated equipment rinsate blank sample.
5 Qualified as positively biased due to surrogate recoveries above the established acceptance limits.
6 Qualified as negatively biased due to surrogate recoveries below the established acceptance limits.
7 Qualified due to surrogate recoveries outside the established acceptance limits; bias cannot be determined.
8 Qualified as positively biased due to MS/MSD recoveries above the established acceptance limits.
9 Qualified as negatively biased due to MS/MSD recoveries below the established acceptance limits.
10 Qualified due to MS/MSD recoveries outside the established acceptance limits; bias cannot be determined.
11 Qualified as positively biased due to LCS recoveries above the established acceptance limits.
12 Qualified as negatively biased due to LCS recoveries below the established acceptance limits.
13 Qualified due to LCS recoveries outside the established acceptance limits; bias cannot be determined.
14 Qualified as positively biased due to calibration nonconformances.
15 Qualified as negatively biased due to calibration nonconformances.
16 Qualified due to calibration nonconformances; bias cannot be determined.
17 Qualified as negatively biased due to holding time nonconformances.
18 Qualified as negatively biased due to sample receipt nonconformances.
19 Qualified as positively biased due to sample receipt nonconformances.
20 Qualified due to sample receipt nonconformances; bias can not be determined.
21 Qualified as positively biased due to other criteria.
22 Qualified as negatively biased due to other criteria.
23 Qualified due to other criteria; bias cannot be determined.
24 Qualified due to detected concentration in associated source water sample.
25 Qualified due to chromatographic pattern of the sample does not match the calibration pattern.
26 Reported value determined by method of standard addition; bias cannot be determined.
27 Qualified as negatively biased due to post-digest spike recovery between 40% to 85%.
28 Estimated value; result is detected between the method detection limit (MDL) and the reporting limit.
29 Qualified due to holding times exceeded.
30 Qualified as estimated; compound is a common laboratory contaminant.
31 Reported value determined by GC/MS library search; compound is tentatively identified and quantitation is estimated.
32 Qualified data explained further in the report associated with the sampling event.
33 Qualified due to field duplicate RPD outside of established limits; bias cannot be determined.
34 Final purge readings are not representative of site conditions. The reported readings are taken from earlier purge log entries.
35 Questionable field parameter results; readings do not appear to be representative of site conditions.

APPENDIX E

COPIES OF JOHNSON AND ETTINGER MODEL FUNS FOR VOLATILE ORGANIC CHEMICALS

APPENDIX E

COPIES OF JOHNSON AND ETTINGER MODEL RUNS FOR VOLATILE ORGANIC CHEMICALS

DATA ENTRY SHEET

SL-ADV
Version 2.3; 03/01

CALCULATE RISK-BASED SOIL CONCENTRATION (enter "X" in "YES" box)

YES [X]

OR

CALCULATE INCREMENTAL RISKS FROM ACTUAL SOIL CONCENTRATION (enter "X" in "YES" box and initial soil conc. below)

YES [ ]

ENTER Chemical CAS No. (numbers only, no dashes)	ENTER Initial soil conc., C_R (µg/kg)	Chemical
78933		Methyl ethyl ketone

MORE ↓

ENTER Average soil temperature, T_S (°C)	ENTER Depth below grade to bottom of enclosed space floor, L_F (cm)	ENTER Depth below grade to top of contamination, L_t (cm)	ENTER Depth below grade to bottom of contamination, (enter value of 0 if value is unknown) L_b (cm)	ENTER Totals must add up to value of L_t (cell D28) Thickness of soil stratum A, h_A (cm)	ENTER Thickness of soil stratum B, (Enter value or 0) h_B (cm)	ENTER Thickness of soil stratum C, (Enter value or 0) h_C (cm)	ENTER Soil stratum A SCS soil type (used to estimate soil vapor permeability)	OR	ENTER User-defined stratum A soil vapor permeability, k_v (cm^2)
20	15	15	485	15	0	0	S		

MORE ↓

ENTER Stratum A soil dry bulk density, ρ_b^A (g/cm^3)	ENTER Stratum A soil total porosity, n^A (unitless)	ENTER Stratum A soil water-filled porosity, θ_w^A (cm^3/cm^3)	ENTER Stratum A soil organic carbon fraction, f_{oc}^A (unitless)	ENTER Stratum B soil dry bulk density, ρ_b^B (g/cm^3)	ENTER Stratum B soil total porosity, n^B (unitless)	ENTER Stratum B soil water-filled porosity, θ_w^B (cm^3/cm^3)	ENTER Stratum B soil organic carbon fraction, f_{oc}^B (unitless)	ENTER Stratum C soil dry bulk density, ρ_b^C (g/cm^3)	ENTER Stratum C soil total porosity, n^C (unitless)	ENTER Stratum C soil water-filled porosity, θ_w^C (cm^3/cm^3)	ENTER Stratum C soil organic carbon fraction, f_{oc}^C (unitless)
1.5	0.43	0.15	0.006								

MORE ↓

ENTER Enclosed space floor thickness, L_{crack} (cm)	ENTER Soil-bldg. pressure differential, ΔP ($g/cm\cdot s^2$)	ENTER Enclosed space floor length, L_B (cm)	ENTER Enclosed space floor width, W_B (cm)	ENTER Enclosed space height, H_B (cm)	ENTER Floor-wall seam crack width, w (cm)	ENTER Indoor air exchange rate, ER (1/h)
15	40	961	961	488	0.1	2

ENTER Averaging time for carcinogens, AT_C (yrs)	ENTER Averaging time for noncarcinogens, AT_{NC} (yrs)	ENTER Exposure duration, ED (yrs)	ENTER Exposure frequency, EF (days/yr)	ENTER Target risk for carcinogens, TR (unitless)	ENTER Target hazard quotient for noncarcinogens, THQ (unitless)
70	30	30	350	1.0E-06	1

Used to calculate risk-based soil concentration.

END

Diffusivity in air, D_a (cm^2/s)	Diffusivity in water, D_w (cm^2/s)	Henry's law constant at reference temperature, H ($atm \cdot m^3/mol$)	Henry's law constant reference temperature, T_R (°C)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Normal boiling point, T_B (°K)	Critical temperature, T_C (°K)	Organic carbon partition coefficient, K_{oc} (cm^3/g)	Pure component water solubility, S (mg/L)	Unit risk factor, URF ($\mu g/m^3)^{-1}$	Reference conc., RfC (mg/m^3)	Physical state at soil temperature, (S,L,G)
9.18E-02	9.40E-06	5.16E-05	25	7,862	352.75	529.13	3.16E+01	2.85E+05	0.0E+00	5.0E-01	L

END

INTERMEDIATE CALCULATIONS SHEET

Exposure duration, τ (sec)	Source-building separation, L_T (cm)	Stratum A soil air-filled porosity, θ_a^A (cm^3/cm^3)	Stratum B soil air-filled porosity, θ_a^B (cm^3/cm^3)	Stratum C soil air-filled porosity, θ_a^C (cm^3/cm^3)	Stratum A effective total fluid saturation, S_{te} (cm^3/cm^3)	Stratum A soil intrinsic permeability, k_i (cm^2)	Stratum A soil relative air permeability, k_{rg} (cm^2)	Stratum A soil effective vapor permeability, k_v (cm^2)	Floor-wall seam perimeter, X_{crack} (cm)	Initial soil concentration used, C_R (µg/kg)	Bldg. ventilation rate, $Q_{building}$ (cm^3/s)
9.46E+08	1	0.280	ERROR	ERROR	0.257	1.01E-07	0.703	7.10E-08	3,844	1.00E+00	2.50E+05

Area of enclosed space below grade, A_B (cm^2)	Crack-to-total area ratio, η (unitless)	Crack depth below grade, Z_{crack} (cm)	Enthalpy of vaporization at ave. soil temperature, $\Delta H_{v,TS}$ (cal/mol)	Henry's law constant at ave. soil temperature, H_{TS} (atm-m^3/mol)	Henry's law constant at ave. soil temperature, H'_{TS} (unitless)	Vapor viscosity at ave. soil temperature, μ_{TS} (g/cm-s)	Stratum A effective diffusion coefficient, D^{eff}_A (cm^2/s)	Stratum B effective diffusion coefficient, D^{eff}_B (cm^2/s)	Stratum C effective diffusion coefficient, D^{eff}_C (cm^2/s)	Total overall effective diffusion coefficient, D^{eff}_T (cm^2/s)	Diffusion path length, L_d (cm)	Convection path length, L_p (cm)
9.24E+05	4.16E-04	15	8,775	4.00E-05	1.66E-03	1.78E-04	7.22E-03	0.00E+00	0.00E+00	7.22E-03	1	15

Soil-water partition coefficient, K_d (cm^3/g)	Source vapor conc., C_{source} (µg/m^3)	Crack radius, r_{crack} (cm)	Average vapor flow rate into bldg., Q_{soil} (cm^3/s)	Crack effective diffusion coefficient, D^{crack} (cm^2/s)	Area of crack, A_{crack} (cm^2)	Exponent of equivalent foundation Peclet number, exp(Pe^f) (unitless)	Infinite source indoor attenuation coefficient, α (unitless)	Infinite source bldg. conc., $C_{building}$ (µg/m^3)	Finite source β term (unitless)	Finite source ψ term $(sec)^{-1}$	Time for source depletion, τ_D (sec)	Exposure duration > time for source depletion (YES/NO)
1.90E-01	5.74E+00	0.10	6.74E+01	7.22E-03	3.84E+02	1.65E+158	NA	NA	9.99E+01	2.76E-05	5.70E+09	NO

Finite source indoor attenuation coefficient, <α> (unitless)	Mass limit bldg. conc., $C_{building}$ (µg/m^3)	Finite source bldg. conc., $C_{building}$ (µg/m^3)	Final finite source bldg. conc., $C_{building}$ (µg/m^3)	Unit risk factor, URF $(\mu g/m^3)^{-1}$	Reference conc., RfC (mg/m^3)
1.52E-04	NA	8.75E-04	8.75E-04	NA	5.0E-01

END

RISK-BASED SOIL CONCENTRATION CALCULATIONS:

Indoor exposure soil conc., carcinogen (µg/kg)	Indoor exposure soil conc., noncarcinogen (µg/kg)	Risk-based indoor exposure soil conc., (µg/kg)	Soil saturation conc., C_{sat} (µg/kg)	Final indoor exposure soil conc., (µg/kg)
NA	5.96E+05	5.96E+05	8.26E+07	5.96E+05

INCREMENTAL RISK CALCULATIONS:

Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
NA	NA

MESSAGE AND ERROR SUMMARY BELOW: (DO NOT USE RESULTS IF ERRORS ARE PRESENT)
MESSAGE: The values of Csource and Cbuilding on the INTERCALCS worksheet are based on unity and do not represent actual values.

SCROLL DOWN TO "END"

END

DATA ENTRY SHEET

SL-ADV
Version 2.3; 03/01

CALCULATE RISK-BASED SOIL CONCENTRATION (enter "X" in "YES" box)

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MORE ↓

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20	15	15	485	15	0	0	S		

MORE ↓

ENTER Stratum A soil dry bulk density, ρ_b^A (g/cm^3)	ENTER Stratum A soil total porosity, n^A (unitless)	ENTER Stratum A soil water-filled porosity, θ_w^A (cm^3/cm^3)	ENTER Stratum A soil organic carbon fraction, f_{oc}^A (unitless)	ENTER Stratum B soil dry bulk density, ρ_b^B (g/cm^3)	ENTER Stratum B soil total porosity, n^B (unitless)	ENTER Stratum B soil water-filled porosity, θ_w^B (cm^3/cm^3)	ENTER Stratum B soil organic carbon fraction, f_{oc}^B (unitless)	ENTER Stratum C soil dry bulk density, ρ_b^C (g/cm^3)	ENTER Stratum C soil total porosity, n^C (unitless)	ENTER Stratum C soil water-filled porosity, θ_w^C (cm^3/cm^3)	ENTER Stratum C soil organic carbon fraction, f_{oc}^C (unitless)
1.5	0.43	0.15	0.006								

MORE ↓

ENTER Enclosed space floor thickness, L_{crack} (cm)	ENTER Soil-bldg. pressure differential, ΔP ($g/cm\text{-}s^2$)	ENTER Enclosed space floor length, L_B (cm)	ENTER Enclosed space floor width, W_B (cm)	ENTER Enclosed space height, H_B (cm)	ENTER Floor-wall seam crack width, w (cm)	ENTER Indoor air exchange rate, ER (1/h)
15	40	961	961	488	0.1	5

ENTER Averaging time for carcinogens, AT_C (yrs)	ENTER Averaging time for noncarcinogens, AT_{NC} (yrs)	ENTER Exposure duration, ED (yrs)	ENTER Exposure frequency, EF (days/yr)	ENTER Target risk for carcinogens, TR (unitless)	ENTER Target hazard quotient for noncarcinogens, THQ (unitless)
70	25	25	250	1.0E-06	1

Used to calculate risk-based soil concentration.

END

Diffusivity in air, D_a (cm^2/s)	Diffusivity in water, D_w (cm^2/s)	Henry's law constant at reference temperature, H ($atm\text{-}m^3/mol$)	Henry's law constant reference temperature, T_R (°C)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Normal boiling point, T_B (°K)	Critical temperature, T_C (°K)	Organic carbon partition coefficient, K_{oc} (cm^3/g)	Pure component water solubility, S (mg/L)	Unit risk factor, URF $(\mu g/m^3)^{-1}$	Reference conc., RfC (mg/m^3)	Physical state at soil temperature, (S,L,G)
9.18E-02	9.40E-06	5.16E-05	25	7,862	352.75	529.13	3.16E+01	2.85E+05	0.0E+00	5.0E-01	L

END

INTERMEDIATE CALCULATIONS SHEET

Exposure duration, τ (sec)	Source-building separation, L_T (cm)	Stratum A soil air-filled porosity, θ_a^A (cm^3/cm^3)	Stratum B soil air-filled porosity, θ_a^B (cm^3/cm^3)	Stratum C soil air-filled porosity, θ_a^C (cm^3/cm^3)	Stratum A effective total fluid saturation, S_{te} (cm^3/cm^3)	Stratum A soil intrinsic permeability, k_i (cm^2)	Stratum A soil relative air permeability, k_{rg} (cm^2)	Stratum A soil effective vapor permeability, k_v (cm^2)	Floor-wall seam perimeter, X_{crack} (cm)	Initial soil concentration used, C_R (µg/kg)	Bldg. ventilation rate, $Q_{building}$ (cm^3/s)
7.88E+08	1	0.280	ERROR	ERROR	0.257	1.01E-07	0.703	7.10E-08	3,844	1.00E+00	6.26E+05

Area of enclosed space below grade, A_B (cm^2)	Crack-to-total area ratio, η (unitless)	Crack depth below grade, Z_{crack} (cm)	Enthalpy of vaporization at ave. soil temperature, $\Delta H_{v,TS}$ (cal/mol)	Henry's law constant at ave. soil temperature, H_{TS} (atm·m^3/mol)	Henry's law constant at ave. soil temperature, H'_{TS} (unitless)	Vapor viscosity at ave. soil temperature, μ_{TS} (g/cm·s)	Stratum A effective diffusion coefficient, D^{eff}_A (cm^2/s)	Stratum B effective diffusion coefficient, D^{eff}_B (cm^2/s)	Stratum C effective diffusion coefficient, D^{eff}_C (cm^2/s)	Total overall effective diffusion coefficient, D^{eff}_T (cm^2/s)	Diffusion path length, L_d (cm)	Convection path length, L_p (cm)
9.24E+05	4.16E-04	15	8,775	4.00E-05	1.66E-03	1.78E-04	7.22E-03	0.00E+00	0.00E+00	7.22E-03	1	15

Soil-water partition coefficient, K_d (cm^3/g)	Source vapor conc., C_{source} (µg/m^3)	Crack radius, r_{crack} (cm)	Average vapor flow rate into bldg., Q_{soil} (cm^3/s)	Crack effective diffusion coefficient, D^{crack} (cm^2/s)	Area of crack, A_{crack} (cm^2)	Exponent of equivalent foundation Peclet number, exp(Pe^f) (unitless)	Infinite source indoor attenuation coefficient, α (unitless)	Infinite source bldg. conc., $C_{building}$ (µg/m^3)	Finite source β term (unitless)	Finite source ψ term $(sec)^{-1}$	Time for source depletion, τ_D (sec)	Exposure duration > time for source depletion (YES/NO)
1.90E-01	5.74E+00	0.10	6.74E+01	7.22E-03	3.84E+02	1.65E+158	NA	NA	9.99E+01	2.76E-05	5.70E+09	NO

Finite source indoor attenuation coefficient, <α> (unitless)	Mass limit bldg. conc., $C_{building}$ (µg/m^3)	Finite source bldg. conc., $C_{building}$ (µg/m^3)	Final finite source bldg. conc., $C_{building}$ (µg/m^3)	Unit risk factor, URF $(\mu g/m^3)^{-1}$	Reference conc., RfC (mg/m^3)
6.43E-05	NA	3.69E-04	3.69E-04	NA	5.0E-01

END

RISK-BASED SOIL CONCENTRATION CALCULATIONS:

Indoor exposure soil conc., carcinogen (µg/kg)	Indoor exposure soil conc., noncarcinogen (µg/kg)	Risk-based indoor exposure soil conc., (µg/kg)	Soil saturation conc., C_{sat} (µg/kg)	Final indoor exposure soil conc., (µg/kg)
NA	1.98E+06	1.98E+06	8.26E+07	1.98E+06

INCREMENTAL RISK CALCULATIONS:

Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
NA	NA

MESSAGE AND ERROR SUMMARY BELOW: (DO NOT USE RESULTS IF ERRORS ARE PRESENT)
MESSAGE: The values of Csource and Cbuilding on the INTERCALCS worksheet are based on unity and do not represent actual values.

SCROLL DOWN TO "END"

END

DATA ENTRY SHEET

SL-ADV
Version 2.3; 03/01

CALCULATE RISK-BASED SOIL CONCENTRATION (enter "X" in "YES" box)

YES: X

OR

CALCULATE INCREMENTAL RISKS FROM ACTUAL SOIL CONCENTRATION (enter "X" in "YES" box and initial soil conc. below)

YES:

ENTER Chemical CAS No. (numbers only, no dashes)	ENTER Initial soil conc., C_R (µg/kg)	Chemical
75150		Carbon disulfide

MORE ↓

ENTER Average soil temperature, T_S (°C)	ENTER Depth below grade to bottom of enclosed space floor, L_F (cm)	ENTER Depth below grade to top of contamination, L_t (cm)	ENTER Depth below grade to bottom of contamination, (enter value of 0 if value is unknown) L_b (cm)	ENTER Totals must add up to value of L_t (cell D28) Thickness of soil stratum A, h_A (cm)	ENTER Thickness of soil stratum B, (Enter value or 0) h_B (cm)	ENTER Thickness of soil stratum C, (Enter value or 0) h_C (cm)	ENTER Soil stratum A SCS soil type (used to estimate soil vapor permeability)	OR	ENTER User-defined stratum A soil vapor permeability, k_v (cm^2)
20	15	15	485	15	0	0	S		

MORE ↓

ENTER Stratum A soil dry bulk density, ρ_b^A (g/cm^3)	ENTER Stratum A soil total porosity, n^A (unitless)	ENTER Stratum A soil water-filled porosity, θ_w^A (cm^3/cm^3)	ENTER Stratum A soil organic carbon fraction, f_{oc}^A (unitless)	ENTER Stratum B soil dry bulk density, ρ_b^B (g/cm^3)	ENTER Stratum B soil total porosity, n^B (unitless)	ENTER Stratum B soil water-filled porosity, θ_w^B (cm^3/cm^3)	ENTER Stratum B soil organic carbon fraction, f_{oc}^B (unitless)	ENTER Stratum C soil dry bulk density, ρ_b^C (g/cm^3)	ENTER Stratum C soil total porosity, n^C (unitless)	ENTER Stratum C soil water-filled porosity, θ_w^C (cm^3/cm^3)	ENTER Stratum C soil organic carbon fraction, f_{oc}^C (unitless)
1.5	0.43	0.15	0.006								

MORE ↓

ENTER Enclosed space floor thickness, L_{crack} (cm)	ENTER Soil-bldg. pressure differential, ΔP ($g/cm\text{-}s^2$)	ENTER Enclosed space floor length, L_B (cm)	ENTER Enclosed space floor width, W_B (cm)	ENTER Enclosed space height, H_B (cm)	ENTER Floor-wall seam crack width, w (cm)	ENTER Indoor air exchange rate, ER (1/h)
15	40	961	961	488	0.1	2

ENTER Averaging time for carcinogens, AT_C (yrs)	ENTER Averaging time for noncarcinogens, AT_{NC} (yrs)	ENTER Exposure duration, ED (yrs)	ENTER Exposure frequency, EF (days/yr)	ENTER Target risk for carcinogens, TR (unitless)	ENTER Target hazard quotient for noncarcinogens, THQ (unitless)
70	30	30	350	1.0E-06	1

Used to calculate risk-based soil concentration.

END

Diffusivity in air, D_a (cm^2/s)	Diffusivity in water, D_w (cm^2/s)	Henry's law constant at reference temperature, H ($atm \cdot m^3/mol$)	Henry's law constant reference temperature, T_R (°C)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Normal boiling point, T_B (°K)	Critical temperature, T_C (°K)	Organic carbon partition coefficient, K_{oc} (cm^3/g)	Pure component water solubility, S (mg/L)	Unit risk factor, URF ($\mu g/m^3)^{-1}$	Reference conc., RfC (mg/m^3)	Physical state at soil temperature, (S,L,G)
1.04E-01	1.00E-05	3.02E-02	25	6,391	319.00	552.00	4.57E+01	1.19E+03	0.0E+00	7.0E-01	L

END

INTERMEDIATE CALCULATIONS SHEET

Exposure duration, τ (sec)	Source-building separation, L_T (cm)	Stratum A soil air-filled porosity, θ_a^A (cm^3/cm^3)	Stratum B soil air-filled porosity, θ_a^B (cm^3/cm^3)	Stratum C soil air-filled porosity, θ_a^C (cm^3/cm^3)	Stratum A effective total fluid saturation, S_{te} (cm^3/cm^3)	Stratum A soil intrinsic permeability, k_i (cm^2)	Stratum A soil relative air permeability, k_{rg} (cm^2)	Stratum A soil effective vapor permeability, k_v (cm^2)	Floor-wall seam perimeter, X_{crack} (cm)	Initial soil concentration used, C_R (µg/kg)	Bldg. ventilation rate, $Q_{building}$ (cm^3/s)
9.46E+08	1	0.280	ERROR	ERROR	0.257	1.01E-07	0.703	7.10E-08	3,844	1.00E+00	2.50E+05

Area of enclosed space below grade, A_B (cm^2)	Crack-to-total area ratio, η (unitless)	Crack depth below grade, Z_{crack} (cm)	Enthalpy of vaporization at ave. soil temperature, $\Delta H_{v,TS}$ (cal/mol)	Henry's law constant at ave. soil temperature, H_{TS} (atm-m^3/mol)	Henry's law constant at ave. soil temperature, H'_{TS} (unitless)	Vapor viscosity at ave. soil temperature, μ_{TS} (g/cm-s)	Stratum A effective diffusion coefficient, D^{eff}_A (cm^2/s)	Stratum B effective diffusion coefficient, D^{eff}_B (cm^2/s)	Stratum C effective diffusion coefficient, D^{eff}_C (cm^2/s)	Total overall effective diffusion coefficient, D^{eff}_T (cm^2/s)	Diffusion path length, L_d (cm)	Convection path length, L_p (cm)
9.24E+05	4.16E-04	15	6,604	2.50E-02	1.04E+00	1.78E-04	8.11E-03	0.00E+00	0.00E+00	8.11E-03	1	15

Soil-water partition coefficient, K_d (cm^3/g)	Source vapor conc., C_{source} (µg/m^3)	Crack radius, r_{crack} (cm)	Average vapor flow rate into bldg., Q_{soil} (cm^3/s)	Crack effective diffusion coefficient, D^{crack} (cm^2/s)	Area of crack, A_{crack} (cm^2)	Exponent of equivalent foundation Peclet number, exp(Pe^f) (unitless)	Infinite source indoor attenuation coefficient, $\dot{\alpha}$ (unitless)	Infinite source bldg. conc., $C_{building}$ (µg/m^3)	Finite source β term (unitless)	Finite source ψ term $(sec)^{-1}$	Time for source depletion, τ_D (sec)	Exposure duration > time for source depletion (YES/NO)
2.74E-01	1.83E+03	0.10	6.74E+01	8.11E-03	3.84E+02	6.04E+140	NA	NA	1.12E+02	9.88E-03	1.65E+07	YES

Finite source indoor attenuation coefficient, <α> (unitless)	Mass limit bldg. conc., $C_{building}$ (µg/m^3)	Finite source bldg. conc., $C_{building}$ (µg/m^3)	Final finite source bldg. conc., $C_{building}$ (µg/m^3)	Unit risk factor, URF $(\mu g/m^3)^{-1}$	Reference conc., RfC (mg/m^3)
NA	2.75E-03	NA	2.75E-03	NA	7.0E-01

END

RISK-BASED SOIL CONCENTRATION CALCULATIONS:

Indoor exposure soil conc., carcinogen (µg/kg)	Indoor exposure soil conc., noncarcinogen (µg/kg)	Risk-based indoor exposure soil conc., (µg/kg)	Soil saturation conc., C_{sat} (µg/kg)	Final indoor exposure soil conc., (µg/kg)
NA	2.66E+05	2.66E+05	6.76E+05	2.66E+05

INCREMENTAL RISK CALCULATIONS:

Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
NA	NA

MESSAGE AND ERROR SUMMARY BELOW: (DO NOT USE RESULTS IF ERRORS ARE PRESENT)
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SCROLL DOWN TO "END"

END

DATA ENTRY SHEET

SL-ADV
Version 2.3; 03/01

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YES [X]

OR

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ENTER Enclosed space floor thickness, L_{crack} (cm)	ENTER Soil-bldg. pressure differential, ΔP ($g/cm\text{-}s^2$)	ENTER Enclosed space floor length, L_B (cm)	ENTER Enclosed space floor width, W_B (cm)	ENTER Enclosed space height, H_B (cm)	ENTER Floor-wall seam crack width, w (cm)	ENTER Indoor air exchange rate, ER (1/h)
15	40	961	961	488	0.1	5

ENTER Averaging time for carcinogens, AT_C (yrs)	ENTER Averaging time for noncarcinogens, AT_{NC} (yrs)	ENTER Exposure duration, ED (yrs)	ENTER Exposure frequency, EF (days/yr)	ENTER Target risk for carcinogens, TR (unitless)	ENTER Target hazard quotient for noncarcinogens, THQ (unitless)
70	25	25	250	1.0E-06	1

Used to calculate risk-based soil concentration.

END

Diffusivity in air, D_a (cm^2/s)	Diffusivity in water, D_w (cm^2/s)	Henry's law constant at reference temperature, H ($atm \cdot m^3/mol$)	Henry's law constant reference temperature, T_R (°C)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Normal boiling point, T_B (°K)	Critical temperature, T_C (°K)	Organic carbon partition coefficient, K_{oc} (cm^3/g)	Pure component water solubility, S (mg/L)	Unit risk factor, URF ($(\mu g/m^3)^{-1}$)	Reference conc., RfC (mg/m^3)	Physical state at soil temperature, (S,L,G)
1.04E-01	1.00E-05	3.02E-02	25	6,391	319.00	552.00	4.57E+01	1.19E+03	0.0E+00	7.0E-01	L

END

INTERMEDIATE CALCULATIONS SHEET

Exposure duration, τ (sec)	Source-building separation, L_T (cm)	Stratum A soil air-filled porosity, θ_a^A (cm^3/cm^3)	Stratum B soil air-filled porosity, θ_a^B (cm^3/cm^3)	Stratum C soil air-filled porosity, θ_a^C (cm^3/cm^3)	Stratum A effective total fluid saturation, S_{te} (cm^3/cm^3)	Stratum A soil intrinsic permeability, k_i (cm^2)	Stratum A soil relative air permeability, k_{rg} (cm^2)	Stratum A soil effective vapor permeability, k_v (cm^2)	Floor-wall seam perimeter, X_{crack} (cm)	Initial soil concentration used, C_R (µg/kg)	Bldg. ventilation rate, $Q_{building}$ (cm^3/s)
7.88E+08	1	0.280	ERROR	ERROR	0.257	1.01E-07	0.703	7.10E-08	3,844	1.00E+00	6.26E+05

Area of enclosed space below grade, A_B (cm^2)	Crack-to-total area ratio, η (unitless)	Crack depth below grade, Z_{crack} (cm)	Enthalpy of vaporization at ave. soil temperature, $\Delta H_{v,TS}$ (cal/mol)	Henry's law constant at ave. soil temperature, H_{TS} (atm·m^3/mol)	Henry's law constant at ave. soil temperature, H'_{TS} (unitless)	Vapor viscosity at ave. soil temperature, μ_{TS} (g/cm-s)	Stratum A effective diffusion coefficient, D^{eff}_A (cm^2/s)	Stratum B effective diffusion coefficient, D^{eff}_B (cm^2/s)	Stratum C effective diffusion coefficient, D^{eff}_C (cm^2/s)	Total overall effective diffusion coefficient, D^{eff}_T (cm^2/s)	Diffusion path length, L_d (cm)	Convection path length, L_p (cm)
9.24E+05	4.16E-04	15	6,604	2.50E-02	1.04E+00	1.78E-04	8.11E-03	0.00E+00	0.00E+00	8.11E-03	1	15

Soil-water partition coefficient, K_d (cm^3/g)	Source vapor conc., C_{source} (µg/m^3)	Crack radius, r_{crack} (cm)	Average vapor flow rate into bldg., Q_{soil} (cm^3/s)	Crack effective diffusion coefficient, D^{crack} (cm^2/s)	Area of crack, A_{crack} (cm^2)	Exponent of equivalent foundation Peclet number, exp(Pe^f) (unitless)	Infinite source indoor attenuation coefficient, α (unitless)	Infinite source bldg. conc., $C_{building}$ (µg/m^3)	Finite source β term (unitless)	Finite source ψ term $(sec)^{-1}$	Time for source depletion, τ_D (sec)	Exposure duration > time for source depletion (YES/NO)
2.74E-01	1.83E+03	0.10	6.74E+01	8.11E-03	3.84E+02	6.04E+140	NA	NA	1.12E+02	9.88E-03	1.65E+07	YES

Finite source indoor attenuation coefficient, <α> (unitless)	Mass limit bldg. conc., $C_{building}$ (µg/m^3)	Finite source bldg. conc., $C_{building}$ (µg/m^3)	Final finite source bldg. conc., $C_{building}$ (µg/m^3)	Unit risk factor, URF $(\mu g/m^3)^{-1}$	Reference conc., RfC (mg/m^3)
NA	1.32E-03	NA	1.32E-03	NA	7.0E-01

END

RISK-BASED SOIL CONCENTRATION CALCULATIONS:

Indoor exposure soil conc., carcinogen (µg/kg)	Indoor exposure soil conc., noncarcinogen (µg/kg)	Risk-based indoor exposure soil conc., (µg/kg)	Soil saturation conc., C_{sat} (µg/kg)	Final indoor exposure soil conc., (µg/kg)
NA	7.75E+05	7.75E+05	6.76E+05	6.76E+05

INCREMENTAL RISK CALCULATIONS:

Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
NA	NA

MESSAGE AND ERROR SUMMARY BELOW: (DO NOT USE RESULTS IF ERRORS ARE PRESENT)
MESSAGE: The values of Csource and Cbuilding on the INTERCALCS worksheet are based on unity and do not represent actual values.

SCROLL DOWN TO "END"

END

DATA ENTRY SHEET

SL-ADV
Version 2.3; 03/01

CALCULATE RISK-BASED SOIL CONCENTRATION (enter "X" in "YES" box)

YES [X]

OR

CALCULATE INCREMENTAL RISKS FROM ACTUAL SOIL CONCENTRATION (enter "X" in "YES" box and initial soil conc. below)

YES [ ]

ENTER Chemical CAS No. (numbers only, no dashes)	ENTER Initial soil conc., C_R (µg/kg)	Chemical
106467		1,4-Dichlorobenzene

MORE ↓

ENTER Average soil temperature, T_S (°C)	ENTER Depth below grade to bottom of enclosed space floor, L_F (cm)	ENTER Depth below grade to top of contamination, L_t (cm)	ENTER Depth below grade to bottom of contamination, (enter value of 0 if value is unknown) L_b (cm)	ENTER Totals must add up to value of L_t (cell D28) Thickness of soil stratum A, h_A (cm)	ENTER Thickness of soil stratum B, (Enter value or 0) h_B (cm)	ENTER Thickness of soil stratum C, (Enter value or 0) h_C (cm)	ENTER Soil stratum A SCS soil type (used to estimate soil vapor permeability)	OR	ENTER User-defined stratum A soil vapor permeability, k_v (cm^2)
20	15	15	485	15	0	0	S		

MORE ↓

ENTER Stratum A soil dry bulk density, ρ_b^A (g/cm^3)	ENTER Stratum A soil total porosity, n^A (unitless)	ENTER Stratum A soil water-filled porosity, θ_w^A (cm^3/cm^3)	ENTER Stratum A soil organic carbon fraction, f_{oc}^A (unitless)	ENTER Stratum B soil dry bulk density, ρ_b^B (g/cm^3)	ENTER Stratum B soil total porosity, n^B (unitless)	ENTER Stratum B soil water-filled porosity, θ_w^B (cm^3/cm^3)	ENTER Stratum B soil organic carbon fraction, f_{oc}^B (unitless)	ENTER Stratum C soil dry bulk density, ρ_b^C (g/cm^3)	ENTER Stratum C soil total porosity, n^C (unitless)	ENTER Stratum C soil water-filled porosity, θ_w^C (cm^3/cm^3)	ENTER Stratum C soil organic carbon fraction, f_{oc}^C (unitless)
1.5	0.43	0.15	0.006								

MORE ↓

ENTER Enclosed space floor thickness, L_{crack} (cm)	ENTER Soil-bldg. pressure differential, ΔP ($g/cm \cdot s^2$)	ENTER Enclosed space floor length, L_B (cm)	ENTER Enclosed space floor width, W_B (cm)	ENTER Enclosed space height, H_B (cm)	ENTER Floor-wall seam crack width, w (cm)	ENTER Indoor air exchange rate, ER (1/h)
15	40	961	961	488	0.1	2

ENTER Averaging time for carcinogens, AT_C (yrs)	ENTER Averaging time for noncarcinogens, AT_{NC} (yrs)	ENTER Exposure duration, ED (yrs)	ENTER Exposure frequency, EF (days/yr)	ENTER Target risk for carcinogens, TR (unitless)	ENTER Target hazard quotient for noncarcinogens, THQ (unitless)
70	30	30	350	1.0E-06	1

Used to calculate risk-based soil concentration.

END

Diffusivity in air, D_a (cm^2/s)	Diffusivity in water, D_w (cm^2/s)	Henry's law constant at reference temperature, H ($atm\text{-}m^3/mol$)	Henry's law constant reference temperature, T_R (°C)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Normal boiling point, T_B (°K)	Critical temperature, T_C (°K)	Organic carbon partition coefficient, K_{oc} (cm^3/g)	Pure component water solubility, S (mg/L)	Unit risk factor, URF ($(\mu g/m^3)^{-1}$)	Reference conc., RfC (mg/m^3)	Physical state at soil temperature, (S,L,G)
6.90E-02	7.90E-06	2.43E-03	25	9,271	447.21	684.75	6.17E+02	7.38E+01	1.1E-05	8.0E-01	S

END

INTERMEDIATE CALCULATIONS SHEET

Exposure duration, τ (sec)	Source-building separation, L_T (cm)	Stratum A soil air-filled porosity, θ_a^A (cm^3/cm^3)	Stratum B soil air-filled porosity, θ_a^B (cm^3/cm^3)	Stratum C soil air-filled porosity, θ_a^C (cm^3/cm^3)	Stratum A effective total fluid saturation, S_{te} (cm^3/cm^3)	Stratum A soil intrinsic permeability, k_i (cm^2)	Stratum A soil relative air permeability, k_{rg} (cm^2)	Stratum A soil effective vapor permeability, k_v (cm^2)	Floor-wall seam perimeter, X_{crack} (cm)	Initial soil concentration used, C_R (µg/kg)	Bldg. ventilation rate, $Q_{building}$ (cm^3/s)
9.46E+08	1	0.280	ERROR	ERROR	0.257	1.01E-07	0.703	7.10E-08	3,844	1.00E+00	2.50E+05

Area of enclosed space below grade, A_B (cm^2)	Crack-to-total area ratio, η (unitless)	Crack depth below grade, Z_{crack} (cm)	Enthalpy of vaporization at ave. soil temperature, $\Delta H_{v,TS}$ (cal/mol)	Henry's law constant at ave. soil temperature, H_{TS} (atm·m^3/mol)	Henry's law constant at ave. soil temperature, H'_{TS} (unitless)	Vapor viscosity at ave. soil temperature, μ_{TS} (g/cm·s)	Stratum A effective diffusion coefficient, D^{eff}_A (cm^2/s)	Stratum B effective diffusion coefficient, D^{eff}_B (cm^2/s)	Stratum C effective diffusion coefficient, D^{eff}_C (cm^2/s)	Total overall effective diffusion coefficient, D^{eff}_T (cm^2/s)	Diffusion path length, L_d (cm)	Convection path length, L_p (cm)
9.24E+05	4.16E-04	15	11,140	1.76E-03	7.33E-02	1.78E-04	5.38E-03	0.00E+00	0.00E+00	5.38E-03	1	15

Soil-water partition coefficient, K_d (cm^3/g)	Source vapor conc., C_{source} (µg/m^3)	Crack radius, r_{crack} (cm)	Average vapor flow rate into bldg., Q_{soil} (cm^3/s)	Crack effective diffusion coefficient, D^{crack} (cm^2/s)	Area of crack, A_{crack} (cm^2)	Exponent of equivalent foundation Peclet number, exp(Pe^f) (unitless)	Infinite source indoor attenuation coefficient, α (unitless)	Infinite source bldg. conc., $C_{building}$ (µg/m^3)	Finite source β term (unitless)	Finite source ψ term $(sec)^{-1}$	Time for source depletion, τ_D (sec)	Exposure duration > time for source depletion (YES/NO)
3.70E+00	1.92E+01	0.10	6.74E+01	5.38E-03	3.84E+02	1.42E+212	NA	NA	7.48E+01	6.89E-05	2.11E+09	NO

Finite source indoor attenuation coefficient, <α> (unitless)	Mass limit bldg. conc., $C_{building}$ (µg/m^3)	Finite source bldg. conc., $C_{building}$ (µg/m^3)	Final finite source bldg. conc., $C_{building}$ (µg/m^3)	Unit risk factor, URF $(\mu g/m^3)^{-1}$	Reference conc., RfC (mg/m^3)
8.95E-05	NA	1.72E-03	1.72E-03	1.1E-05	8.0E-01

END

RISK-BASED SOIL CONCENTRATION CALCULATIONS:

Indoor exposure soil conc., carcinogen (µg/kg)	Indoor exposure soil conc., noncarcinogen (µg/kg)	Risk-based indoor exposure soil conc., (µg/kg)	Soil saturation conc., C_{sat} (µg/kg)	Final indoor exposure soil conc., (µg/kg)
1.29E+02	4.85E+05	1.29E+02	2.82E+05	1.29E+02

INCREMENTAL RISK CALCULATIONS:

Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
NA	NA

MESSAGE AND ERROR SUMMARY BELOW: (DO NOT USE RESULTS IF ERRORS ARE PRESENT)

MESSAGE: The values of Csource and Cbuilding on the INTERCALCS worksheet are based on unity and do not represent actual values.

SCROLL DOWN TO "END"

END

DATA ENTRY SHEET

SL-ADV
Version 2.3; 03/01

CALCULATE RISK-BASED SOIL CONCENTRATION (enter "X" in "YES" box)

YES: X

OR

CALCULATE INCREMENTAL RISKS FROM ACTUAL SOIL CONCENTRATION (enter "X" in "YES" box and initial soil conc. below)

YES:

ENTER Chemical CAS No. (numbers only, no dashes)	ENTER Initial soil conc., C_R (µg/kg)	Chemical
106467		1,4-Dichlorobenzene

MORE ↓

ENTER Average soil temperature, T_S (°C)	ENTER Depth below grade to bottom of enclosed space floor, L_F (cm)	ENTER Depth below grade to top of contamination, L_t (cm)	ENTER Depth below grade to bottom of contamination, (enter value of 0 if value is unknown) L_b (cm)	ENTER Totals must add up to value of L_t (cell D28) Thickness of soil stratum A, h_A (cm)	ENTER Thickness of soil stratum B, (Enter value or 0) h_B (cm)	ENTER Thickness of soil stratum C, (Enter value or 0) h_C (cm)	ENTER Soil stratum A SCS soil type (used to estimate soil vapor permeability)	OR	ENTER User-defined stratum A soil vapor permeability, k_v (cm^2)
20	15	15	485	15	0	0	S		

MORE ↓

ENTER Stratum A soil dry bulk density, ρ_b^A (g/cm^3)	ENTER Stratum A soil total porosity, n^A (unitless)	ENTER Stratum A soil water-filled porosity, θ_w^A (cm^3/cm^3)	ENTER Stratum A soil organic carbon fraction, f_{oc}^A (unitless)	ENTER Stratum B soil dry bulk density, ρ_b^B (g/cm^3)	ENTER Stratum B soil total porosity, n^B (unitless)	ENTER Stratum B soil water-filled porosity, θ_w^B (cm^3/cm^3)	ENTER Stratum B soil organic carbon fraction, f_{oc}^B (unitless)	ENTER Stratum C soil dry bulk density, ρ_b^C (g/cm^3)	ENTER Stratum C soil total porosity, n^C (unitless)	ENTER Stratum C soil water-filled porosity, θ_w^C (cm^3/cm^3)	ENTER Stratum C soil organic carbon fraction, f_{oc}^C (unitless)
1.5	0.43	0.15	0.006								

MORE ↓

ENTER Enclosed space floor thickness, L_{crack} (cm)	ENTER Soil-bldg. pressure differential, ΔP ($g/cm\text{-}s^2$)	ENTER Enclosed space floor length, L_B (cm)	ENTER Enclosed space floor width, W_B (cm)	ENTER Enclosed space height, H_B (cm)	ENTER Floor-wall seam crack width, w (cm)	ENTER Indoor air exchange rate, ER (1/h)
15	40	961	961	488	0.1	5

ENTER Averaging time for carcinogens, AT_C (yrs)	ENTER Averaging time for noncarcinogens, AT_{NC} (yrs)	ENTER Exposure duration, ED (yrs)	ENTER Exposure frequency, EF (days/yr)	ENTER Target risk for carcinogens, TR (unitless)	ENTER Target hazard quotient for noncarcinogens, THQ (unitless)
70	25	25	250	1.0E-06	1

Used to calculate risk-based soil concentration.

END

Diffusivity in air, D_a (cm^2/s)	Diffusivity in water, D_w (cm^2/s)	Henry's law constant at reference temperature, H ($atm \cdot m^3/mol$)	Henry's law constant reference temperature, T_R (°C)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Normal boiling point, T_B (°K)	Critical temperature, T_C (°K)	Organic carbon partition coefficient, K_{oc} (cm^3/g)	Pure component water solubility, S (mg/L)	Unit risk factor, URF ($\mu g/m^3)^{-1}$	Reference conc., RfC (mg/m^3)	Physical state at soil temperature, (S,L,G)
6.90E-02	7.90E-06	2.43E-03	25	9,271	447.21	684.75	6.17E+02	7.38E+01	1.1E-05	8.0E-01	S

END

INTERMEDIATE CALCULATIONS SHEET

Exposure duration, τ (sec)	Source-building separation, L_T (cm)	Stratum A soil air-filled porosity, θ_a^A (cm^3/cm^3)	Stratum B soil air-filled porosity, θ_a^B (cm^3/cm^3)	Stratum C soil air-filled porosity, θ_a^C (cm^3/cm^3)	Stratum A effective total fluid saturation, S_{te} (cm^3/cm^3)	Stratum A soil intrinsic permeability, k_i (cm^2)	Stratum A soil relative air permeability, k_{rg} (cm^2)	Stratum A soil effective vapor permeability, k_v (cm^2)	Floor-wall seam perimeter, X_{crack} (cm)	**Initial soil concentration used, C_R (µg/kg)**	Bldg. ventilation rate, $Q_{building}$ (cm^3/s)
7.88E+08	1	0.280	ERROR	ERROR	0.257	1.01E-07	0.703	7.10E-08	3,844	**1.00E+00**	6.26E+05

Area of enclosed space below grade, A_B (cm^2)	Crack-to-total area ratio, η (unitless)	Crack depth below grade, Z_{crack} (cm)	Enthalpy of vaporization at ave. soil temperature, $\Delta H_{v,TS}$ (cal/mol)	Henry's law constant at ave. soil temperature, H_{TS} (atm·m^3/mol)	Henry's law constant at ave. soil temperature, H'_{TS} (unitless)	Vapor viscosity at ave. soil temperature, μ_{TS} (g/cm·s)	Stratum A effective diffusion coefficient, D^{eff}_A (cm^2/s)	Stratum B effective diffusion coefficient, D^{eff}_B (cm^2/s)	Stratum C effective diffusion coefficient, D^{eff}_C (cm^2/s)	Total overall effective diffusion coefficient, D^{eff}_T (cm^2/s)	Diffusion path length, L_d (cm)	Convection path length, L_p (cm)
9.24E+05	4.16E-04	15	11,140	1.76E-03	7.33E-02	1.78E-04	5.38E-03	0.00E+00	0.00E+00	5.38E-03	1	15

Soil-water partition coefficient, K_d (cm^3/g)	Source vapor conc., C_{source} (µg/m^3)	Crack radius, r_{crack} (cm)	Average vapor flow rate into bldg., Q_{soil} (cm^3/s)	Crack effective diffusion coefficient, D^{crack} (cm^2/s)	Area of crack, A_{crack} (cm^2)	Exponent of equivalent foundation Peclet number, exp(Pe^f) (unitless)	Infinite source indoor attenuation coefficient, α (unitless)	Infinite source bldg. conc., $C_{building}$ (µg/m^3)	**Finite source β term (unitless)**	**Finite source ψ term ($sec)^{-1}$**	Time for source depletion, τ_D (sec)	Exposure duration > time for source depletion (YES/NO)
3.70E+00	1.92E+01	0.10	6.74E+01	5.38E-03	3.84E+02	1.42E+212	NA	NA	7.48E+01	**6.89E-05**	2.11E+09	NO

Finite source indoor attenuation coefficient, <α> (unitless)	**Mass limit bldg. conc., $C_{building}$ (µg/m^3)**	Finite source bldg. conc., $C_{building}$ (µg/m^3)	Final finite source bldg. conc., $C_{building}$ (µg/m^3)	Unit risk factor, URF (µg/m^3)$^{-1}$	Reference conc., RfC (mg/m^3)
3.85E-05	NA	7.39E-04	7.39E-04	1.1E-05	8.0E-01

END

RISK-BASED SOIL CONCENTRATION CALCULATIONS:

Indoor exposure soil conc., carcinogen (µg/kg)	Indoor exposure soil conc., noncarcinogen (µg/kg)	Risk-based indoor exposure soil conc., (µg/kg)	Soil saturation conc., C_{sat} (µg/kg)	Final indoor exposure soil conc., (µg/kg)
5.03E+02	1.58E+06	5.03E+02	2.82E+05	5.03E+02

INCREMENTAL RISK CALCULATIONS:

Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
NA	NA

MESSAGE AND ERROR SUMMARY BELOW: (DO NOT USE RESULTS IF ERRORS ARE PRESENT)
MESSAGE: The values of Csource and Cbuilding on the INTERCALCS worksheet are based on unity and do not represent actual values.

SCROLL DOWN TO "END"

END

DATA ENTRY SHEET

SL-ADV
Version 2.3; 03/01

CALCULATE RISK-BASED SOIL CONCENTRATION (enter "X" in "YES" box)

YES [X]

OR

CALCULATE INCREMENTAL RISKS FROM ACTUAL SOIL CONCENTRATION (enter "X" in "YES" box and initial soil conc. below)

YES [ ]

ENTER Chemical CAS No. (numbers only, no dashes)	ENTER Initial soil conc., C_R (µg/kg)	Chemical
99876		Isopropyltoluene (p-Cymene)

MORE ↓

ENTER Average soil temperature, T_S (°C)	ENTER Depth below grade to bottom of enclosed space floor, L_F (cm)	ENTER Depth below grade to top of contamination, L_t (cm)	ENTER Depth below grade to bottom of contamination, (enter value of 0 if value is unknown) L_b (cm)	ENTER Totals must add up to value of L_t (cell D28) Thickness of soil stratum A, h_A (cm)	ENTER Thickness of soil stratum B, (Enter value or 0) h_B (cm)	ENTER Thickness of soil stratum C, (Enter value or 0) h_C (cm)	ENTER Soil stratum A SCS soil type (used to estimate soil vapor permeability)	OR	ENTER User-defined stratum A soil vapor permeability, k_v (cm^2)
20	15	15	485	15	0	0	S		

MORE ↓

ENTER Stratum A soil dry bulk density, ρ_b^A (g/cm^3)	ENTER Stratum A soil total porosity, n^A (unitless)	ENTER Stratum A soil water-filled porosity, θ_w^A (cm^3/cm^3)	ENTER Stratum A soil organic carbon fraction, f_{oc}^A (unitless)	ENTER Stratum B soil dry bulk density, ρ_b^B (g/cm^3)	ENTER Stratum B soil total porosity, n^B (unitless)	ENTER Stratum B soil water-filled porosity, θ_w^B (cm^3/cm^3)	ENTER Stratum B soil organic carbon fraction, f_{oc}^B (unitless)	ENTER Stratum C soil dry bulk density, ρ_b^C (g/cm^3)	ENTER Stratum C soil total porosity, n^C (unitless)	ENTER Stratum C soil water-filled porosity, θ_w^C (cm^3/cm^3)	ENTER Stratum C soil organic carbon fraction, f_{oc}^C (unitless)
1.5	0.43	0.15	0.006								

MORE ↓

ENTER Enclosed space floor thickness, L_{crack} (cm)	ENTER Soil-bldg. pressure differential, ΔP ($g/cm \cdot s^2$)	ENTER Enclosed space floor length, L_B (cm)	ENTER Enclosed space floor width, W_B (cm)	ENTER Enclosed space height, H_B (cm)	ENTER Floor-wall seam crack width, w (cm)	ENTER Indoor air exchange rate, ER (1/h)
15	40	961	961	488	0.1	2

ENTER Averaging time for carcinogens, AT_C (yrs)	ENTER Averaging time for noncarcinogens, AT_{NC} (yrs)	ENTER Exposure duration, ED (yrs)	ENTER Exposure frequency, EF (days/yr)	ENTER Target risk for carcinogens, TR (unitless)	ENTER Target hazard quotient for noncarcinogens, THQ (unitless)
70	30	30	350	1.0E-06	1

Used to calculate risk-based soil concentration.

END

Diffusivity in air, D_a (cm^2/s)	Diffusivity in water, D_w (cm^2/s)	Henry's law constant at reference temperature, H ($atm\text{-}m^3/mol$)	Henry's law constant reference temperature, T_R (°C)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Normal boiling point, T_B (°K)	Critical temperature, T_C (°K)	Organic carbon partition coefficient, K_{oc} (cm^3/g)	Pure component water solubility, S (mg/L)	Unit risk factor, URF ($\mu g/m^3)^{-1}$	Reference conc., RfC (mg/m^3)	Physical state at soil temperature, (S,L,G)
6.01E-02	5.28E-06	9.30E-03	15	9,365	450.00	675.00	5.01E+03	2.80E+01	0.0E+00	8.0E-01	L

END

INTERMEDIATE CALCULATIONS SHEET

Exposure duration, τ (sec)	Source-building separation, L_T (cm)	Stratum A soil air-filled porosity, θ_a^A (cm^3/cm^3)	Stratum B soil air-filled porosity, θ_a^B (cm^3/cm^3)	Stratum C soil air-filled porosity, θ_a^C (cm^3/cm^3)	Stratum A effective total fluid saturation, S_{te} (cm^3/cm^3)	Stratum A soil intrinsic permeability, k_i (cm^2)	Stratum A soil relative air permeability, k_{rg} (cm^2)	Stratum A soil effective vapor permeability, k_v (cm^2)	Floor-wall seam perimeter, X_{crack} (cm)	Initial soil concentration used, C_R (µg/kg)	Bldg. ventilation rate, $Q_{building}$ (cm^3/s)
9.46E+08	1	0.280	ERROR	ERROR	0.257	1.01E-07	0.703	7.10E-08	3,844	1.00E+00	2.50E+05

Area of enclosed space below grade, A_B (cm^2)	Crack-to-total area ratio, η (unitless)	Crack depth below grade, Z_{crack} (cm)	Enthalpy of vaporization at ave. soil temperature, $\Delta H_{v,TS}$ (cal/mol)	Henry's law constant at ave. soil temperature, H_{TS} (atm·m^3/mol)	Henry's law constant at ave. soil temperature, H'_{TS} (unitless)	Vapor viscosity at ave. soil temperature, μ_{TS} (g/cm-s)	Stratum A effective diffusion coefficient, D^{eff}_A (cm^2/s)	Stratum B effective diffusion coefficient, D^{eff}_B (cm^2/s)	Stratum C effective diffusion coefficient, D^{eff}_C (cm^2/s)	Total overall effective diffusion coefficient, D^{eff}_T (cm^2/s)	Diffusion path length, L_d (cm)	Convection path length, L_p (cm)
9.24E+05	4.16E-04	15	11,434	1.31E-02	5.43E-01	1.78E-04	4.69E-03	0.00E+00	0.00E+00	4.69E-03	1	15

Soil-water partition coefficient, K_d (cm^3/g)	Source vapor conc., C_{source} (µg/m^3)	Crack radius, r_{crack} (cm)	Average vapor flow rate into bldg., Q_{soil} (cm^3/s)	Crack effective diffusion coefficient, D^{crack} (cm^2/s)	Area of crack, A_{crack} (cm^2)	Exponent of equivalent foundation Peclet number, exp(Pe^f) (unitless)	Infinite source indoor attenuation coefficient, α (unitless)	Infinite source bldg. conc., $C_{building}$ (µg/m^3)	Finite source β term (unitless)	Finite source ψ term $(sec)^{-1}$	Time for source depletion, τ_D (sec)	Exposure duration > time for source depletion (YES/NO)
3.01E+01	1.80E+01	0.10	6.74E+01	4.69E-03	3.84E+02	4.16E+243	NA	NA	6.52E+01	5.61E-05	2.52E+09	NO

Finite source indoor attenuation coefficient, <α> (unitless)	Mass limit bldg. conc., $C_{building}$ (µg/m^3)	Finite source bldg. conc., $C_{building}$ (µg/m^3)	Final finite source bldg. conc., $C_{building}$ (µg/m^3)	Unit risk factor, URF $(\mu g/m^3)^{-1}$	Reference conc., RfC (mg/m^3)
8.70E-05	NA	1.56E-03	1.56E-03	NA	8.0E-01

END

RISK-BASED SOIL CONCENTRATION CALCULATIONS:

Indoor exposure soil conc., carcinogen (µg/kg)	Indoor exposure soil conc., noncarcinogen (µg/kg)	Risk-based indoor exposure soil conc., (µg/kg)	Soil saturation conc., C_{sat} (µg/kg)	Final indoor exposure soil conc., (µg/kg)
NA	5.33E+05	5.33E+05	8.48E+05	5.33E+05

INCREMENTAL RISK CALCULATIONS:

Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
NA	NA

MESSAGE AND ERROR SUMMARY BELOW: (DO NOT USE RESULTS IF ERRORS ARE PRESENT)
MESSAGE: The values of Csource and Cbuilding on the INTERCALCS worksheet are based on unity and do not represent actual values.

SCROLL DOWN TO "END"

END

DATA ENTRY SHEET

SL-ADV
Version 2.3; 03/01

CALCULATE RISK-BASED SOIL CONCENTRATION (enter "X" in "YES" box)

YES [X]

OR

CALCULATE INCREMENTAL RISKS FROM ACTUAL SOIL CONCENTRATION (enter "X" in "YES" box and initial soil conc. below)

YES [ ]

ENTER Chemical CAS No. (numbers only, no dashes)	ENTER Initial soil conc., C_R (µg/kg)	Chemical
99876		Isopropyltoluene (p-Cymene)

MORE ↓

ENTER Average soil temperature, T_S (°C)	ENTER Depth below grade to bottom of enclosed space floor, L_F (cm)	ENTER Depth below grade to top of contamination, L_t (cm)	ENTER Depth below grade to bottom of contamination, (enter value of 0 if value is unknown) L_b (cm)	ENTER Totals must add up to value of L_t (cell D28) Thickness of soil stratum A, h_A (cm)	ENTER Thickness of soil stratum B, (Enter value or 0) h_B (cm)	ENTER Thickness of soil stratum C, (Enter value or 0) h_C (cm)	ENTER Soil stratum A SCS soil type (used to estimate soil vapor permeability)	OR	ENTER User-defined stratum A soil vapor permeability, k_v (cm²)
20	15	15	485	15	0	0	S		

MORE ↓

ENTER Stratum A soil dry bulk density, ρ_b^A (g/cm³)	ENTER Stratum A soil total porosity, n^A (unitless)	ENTER Stratum A soil water-filled porosity, θ_w^A (cm³/cm³)	ENTER Stratum A soil organic carbon fraction, f_{oc}^A (unitless)	ENTER Stratum B soil dry bulk density, ρ_b^B (g/cm³)	ENTER Stratum B soil total porosity, n^B (unitless)	ENTER Stratum B soil water-filled porosity, θ_w^B (cm³/cm³)	ENTER Stratum B soil organic carbon fraction, f_{oc}^B (unitless)	ENTER Stratum C soil dry bulk density, ρ_b^C (g/cm³)	ENTER Stratum C soil total porosity, n^C (unitless)	ENTER Stratum C soil water-filled porosity, θ_w^C (cm³/cm³)	ENTER Stratum C soil organic carbon fraction, f_{oc}^C (unitless)
1.5	0.43	0.15	0.006								

MORE ↓

ENTER Enclosed space floor thickness, L_{crack} (cm)	ENTER Soil-bldg. pressure differential, ΔP (g/cm-s²)	ENTER Enclosed space floor length, L_B (cm)	ENTER Enclosed space floor width, W_B (cm)	ENTER Enclosed space height, H_B (cm)	ENTER Floor-wall seam crack width, w (cm)	ENTER Indoor air exchange rate, ER (1/h)
15	40	961	961	488	0.1	5

ENTER Averaging time for carcinogens, AT_C (yrs)	ENTER Averaging time for noncarcinogens, AT_{NC} (yrs)	ENTER Exposure duration, ED (yrs)	ENTER Exposure frequency, EF (days/yr)	ENTER Target risk for carcinogens, TR (unitless)	ENTER Target hazard quotient for noncarcinogens, THQ (unitless)
70	25	25	250	1.0E-06	1

Used to calculate risk-based soil concentration.

END

Diffusivity in air, D_a (cm^2/s)	Diffusivity in water, D_w (cm^2/s)	Henry's law constant at reference temperature, H ($atm \cdot m^3/mol$)	Henry's law constant reference temperature, T_R (°C)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Normal boiling point, T_B (°K)	Critical temperature, T_C (°K)	Organic carbon partition coefficient, K_{oc} (cm^3/g)	Pure component water solubility, S (mg/L)	Unit risk factor, URF $(\mu g/m^3)^{-1}$	Reference conc., RfC (mg/m^3)	Physical state at soil temperature, (S,L,G)
6.01E-02	5.28E-06	9.30E-03	15	9,365	450.00	675.00	5.01E+03	2.80E+01	0.0E+00	8.0E-01	L

END

INTERMEDIATE CALCULATIONS SHEET

Exposure duration, τ (sec)	Source-building separation, L_T (cm)	Stratum A soil air-filled porosity, θ_a^A (cm^3/cm^3)	Stratum B soil air-filled porosity, θ_a^B (cm^3/cm^3)	Stratum C soil air-filled porosity, θ_a^C (cm^3/cm^3)	Stratum A effective total fluid saturation, S_{te} (cm^3/cm^3)	Stratum A soil intrinsic permeability, k_i (cm^2)	Stratum A soil relative air permeability, k_{rg} (cm^2)	Stratum A soil effective vapor permeability, k_v (cm^2)	Floor-wall seam perimeter, X_{crack} (cm)	Initial soil concentration used, C_R (µg/kg)	Bldg. ventilation rate, $Q_{building}$ (cm^3/s)
7.88E+08	1	0.280	ERROR	ERROR	0.257	1.01E-07	0.703	7.10E-08	3,844	1.00E+00	6.26E+05

Area of enclosed space below grade, A_B (cm^2)	Crack-to-total area ratio, η (unitless)	Crack depth below grade, Z_{crack} (cm)	Enthalpy of vaporization at ave. soil temperature, $\Delta H_{v,TS}$ (cal/mol)	Henry's law constant at ave. soil temperature, H_{TS} (atm·m^3/mol)	Henry's law constant at ave. soil temperature, H'_{TS} (unitless)	Vapor viscosity at ave. soil temperature, μ_{TS} (g/cm·s)	Stratum A effective diffusion coefficient, D^{eff}_A (cm^2/s)	Stratum B effective diffusion coefficient, D^{eff}_B (cm^2/s)	Stratum C effective diffusion coefficient, D^{eff}_C (cm^2/s)	Total overall effective diffusion coefficient, D^{eff}_T (cm^2/s)	Diffusion path length, L_d (cm)	Convection path length, L_p (cm)
9.24E+05	4.16E-04	15	11,434	1.31E-02	5.43E-01	1.78E-04	4.69E-03	0.00E+00	0.00E+00	4.69E-03	1	15

Soil-water partition coefficient, K_d (cm^3/g)	Source vapor conc., C_{source} (µg/m^3)	Crack radius, r_{crack} (cm)	Average vapor flow rate into bldg., Q_{soil} (cm^3/s)	Crack effective diffusion coefficient, D^{crack} (cm^2/s)	Area of crack, A_{crack} (cm^2)	Exponent of equivalent foundation Peclet number, exp(Pe^f) (unitless)	Infinite source indoor attenuation coefficient, α (unitless)	Infinite source bldg. conc., $C_{building}$ (µg/m^3)	Finite source β term (unitless)	Finite source ψ term (sec)$^{-1}$	Time for source depletion, τ_D (sec)	Exposure duration > time for source depletion (YES/NO)
3.01E+01	1.80E+01	0.10	6.74E+01	4.69E-03	3.84E+02	4.16E+243	NA	NA	6.52E+01	5.61E-05	2.52E+09	NO

Finite source indoor attenuation coefficient, <α> (unitless)	Mass limit bldg. conc., $C_{building}$ (µg/m^3)	Finite source bldg. conc., $C_{building}$ (µg/m^3)	Final finite source bldg. conc., $C_{building}$ (µg/m^3)	Unit risk factor, URF (µg/m^3)$^{-1}$	Reference conc., RfC (mg/m^3)
3.74E-05	NA	6.72E-04	6.72E-04	NA	8.0E-01

END

RISK-BASED SOIL CONCENTRATION CALCULATIONS:

Indoor exposure soil conc., carcinogen (µg/kg)	Indoor exposure soil conc., noncarcinogen (µg/kg)	Risk-based indoor exposure soil conc., (µg/kg)	Soil saturation conc., C_{sat} (µg/kg)	Final indoor exposure soil conc., (µg/kg)
NA	1.73E+06	1.73E+06	8.48E+05	8.48E+05

INCREMENTAL RISK CALCULATIONS:

Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
NA	NA

MESSAGE AND ERROR SUMMARY BELOW: (DO NOT USE RESULTS IF ERRORS ARE PRESENT)
MESSAGE: The values of Csource and Cbuilding on the INTERCALCS worksheet are based on unity and do not represent actual values.

SCROLL DOWN TO "END"

END

DATA ENTRY SHEET

SL-ADV
Version 2.3; 03/01

CALCULATE RISK-BASED SOIL CONCENTRATION (enter "X" in "YES" box)

YES [X]

OR

CALCULATE INCREMENTAL RISKS FROM ACTUAL SOIL CONCENTRATION (enter "X" in "YES" box and initial soil conc. below)

YES [ ]

ENTER Chemical CAS No. (numbers only, no dashes)	ENTER Initial soil conc., C_R (µg/kg)	Chemical
75092		Methylene chloride

MORE ↓

ENTER Average soil temperature, T_S (°C)	ENTER Depth below grade to bottom of enclosed space floor, L_F (cm)	ENTER Depth below grade to top of contamination, L_t (cm)	ENTER Depth below grade to bottom of contamination, (enter value of 0 if value is unknown) L_b (cm)	ENTER Totals must add up to value of L_t (cell D28) Thickness of soil stratum A, h_A (cm)	ENTER Thickness of soil stratum B, (Enter value or 0) h_B (cm)	ENTER Thickness of soil stratum C, (Enter value or 0) h_C (cm)	ENTER Soil stratum A SCS soil type (used to estimate soil vapor permeability)	OR	ENTER User-defined stratum A soil vapor permeability, k_v (cm^2)
20	15	15	485	15	0	0	S		

MORE ↓

ENTER Stratum A soil dry bulk density, ρ_b^A (g/cm^3)	ENTER Stratum A soil total porosity, n^A (unitless)	ENTER Stratum A soil water-filled porosity, θ_w^A (cm^3/cm^3)	ENTER Stratum A soil organic carbon fraction, f_{oc}^A (unitless)	ENTER Stratum B soil dry bulk density, ρ_b^B (g/cm^3)	ENTER Stratum B soil total porosity, n^B (unitless)	ENTER Stratum B soil water-filled porosity, θ_w^B (cm^3/cm^3)	ENTER Stratum B soil organic carbon fraction, f_{oc}^B (unitless)	ENTER Stratum C soil dry bulk density, ρ_b^C (g/cm^3)	ENTER Stratum C soil total porosity, n^C (unitless)	ENTER Stratum C soil water-filled porosity, θ_w^C (cm^3/cm^3)	ENTER Stratum C soil organic carbon fraction, f_{oc}^C (unitless)
1.5	0.43	0.15	0.006								

MORE ↓

ENTER Enclosed space floor thickness, L_{crack} (cm)	ENTER Soil-bldg. pressure differential, ΔP ($g/cm\cdot s^2$)	ENTER Enclosed space floor length, L_B (cm)	ENTER Enclosed space floor width, W_B (cm)	ENTER Enclosed space height, H_B (cm)	ENTER Floor-wall seam crack width, w (cm)	ENTER Indoor air exchange rate, ER (1/h)
15	40	961	961	488	0.1	2

ENTER Averaging time for carcinogens, AT_C (yrs)	ENTER Averaging time for noncarcinogens, AT_{NC} (yrs)	ENTER Exposure duration, ED (yrs)	ENTER Exposure frequency, EF (days/yr)	ENTER Target risk for carcinogens, TR (unitless)	ENTER Target hazard quotient for noncarcinogens, THQ (unitless)
70	30	30	350	1.0E-06	1

Used to calculate risk-based soil concentration.

END

Diffusivity in air, D_a (cm^2/s)	Diffusivity in water, D_w (cm^2/s)	Henry's law constant at reference temperature, H ($atm \cdot m^3/mol$)	Henry's law constant reference temperature, T_R (°C)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Normal boiling point, T_B (°K)	Critical temperature, T_C (°K)	Organic carbon partition coefficient, K_{oc} (cm^3/g)	Pure component water solubility, S (mg/L)	Unit risk factor, URF ($(\mu g/m^3)^{-1}$)	Reference conc., RfC (mg/m^3)	Physical state at soil temperature, (S,L,G)
1.01E-01	1.17E-05	2.19E-03	25	6,706	313.00	510.00	1.17E+01	1.30E+04	4.7E-07	3.0E+00	L

END

INTERMEDIATE CALCULATIONS SHEET

Exposure duration, τ (sec)	Source-building separation, L_T (cm)	Stratum A soil air-filled porosity, θ_a^A (cm^3/cm^3)	Stratum B soil air-filled porosity, θ_a^B (cm^3/cm^3)	Stratum C soil air-filled porosity, θ_a^C (cm^3/cm^3)	Stratum A effective total fluid saturation, S_{te} (cm^3/cm^3)	Stratum A soil intrinsic permeability, k_i (cm^2)	Stratum A soil relative air permeability, k_{rg} (cm^2)	Stratum A soil effective vapor permeability, k_v (cm^2)	Floor-wall seam perimeter, X_{crack} (cm)	Initial soil concentration used, C_R (µg/kg)	Bldg. ventilation rate, $Q_{building}$ (cm^3/s)
9.46E+08	1	0.280	ERROR	ERROR	0.257	1.01E-07	0.703	7.10E-08	3,844	1.00E+00	2.50E+05

Area of enclosed space below grade, A_B (cm^2)	Crack-to-total area ratio, η (unitless)	Crack depth below grade, Z_{crack} (cm)	Enthalpy of vaporization at ave. soil temperature, $\Delta H_{v,TS}$ (cal/mol)	Henry's law constant at ave. soil temperature, H_{TS} (atm·m^3/mol)	Henry's law constant at ave. soil temperature, H'_{TS} (unitless)	Vapor viscosity at ave. soil temperature, μ_{TS} (g/cm·s)	Stratum A effective diffusion coefficient, D^{eff}_A (cm^2/s)	Stratum B effective diffusion coefficient, D^{eff}_B (cm^2/s)	Stratum C effective diffusion coefficient, D^{eff}_C (cm^2/s)	Total overall effective diffusion coefficient, D^{eff}_T (cm^2/s)	Diffusion path length, L_d (cm)	Convection path length, L_p (cm)
9.24E+05	4.16E-04	15	6,927	1.79E-03	7.46E-02	1.78E-04	7.88E-03	0.00E+00	0.00E+00	7.88E-03	1	15

Soil-water partition coefficient, K_d (cm^3/g)	Source vapor conc., C_{source} (µg/m^3)	Crack radius, r_{crack} (cm)	Average vapor flow rate into bldg., Q_{soil} (cm^3/s)	Crack effective diffusion coefficient, D^{crack} (cm^2/s)	Area of crack, A_{crack} (cm^2)	Exponent of equivalent foundation Peclet number, exp(Pe^f) (unitless)	Infinite source indoor attenuation coefficient, α (unitless)	Infinite source bldg. conc., $C_{building}$ (µg/m^3)	Finite source β term (unitless)	Finite source ψ term $(sec)^{-1}$	Time for source depletion, τ_D (sec)	Exposure duration > time for source depletion (YES/NO)
7.02E-02	4.05E+02	0.10	6.74E+01	7.88E-03	3.84E+02	8.64E+144	NA	NA	1.09E+02	2.13E-03	7.60E+07	YES

Finite source indoor attenuation coefficient, <α> (unitless)	Mass limit bldg. conc., $C_{building}$ (µg/m^3)	Finite source bldg. conc., $C_{building}$ (µg/m^3)	Final finite source bldg. conc., $C_{building}$ (µg/m^3)	Unit risk factor, URF $(\mu g/m^3)^{-1}$	Reference conc., RfC (mg/m^3)
NA	2.75E-03	NA	2.75E-03	4.7E-07	3.0E+00

END

RISK-BASED SOIL CONCENTRATION CALCULATIONS:

Indoor exposure soil conc., carcinogen (µg/kg)	Indoor exposure soil conc., noncarcinogen (µg/kg)	Risk-based indoor exposure soil conc., (µg/kg)	Soil saturation conc., C_{sat} (µg/kg)	Final indoor exposure soil conc., (µg/kg)
1.88E+03	1.14E+06	1.88E+03	2.39E+06	1.88E+03

INCREMENTAL RISK CALCULATIONS:

Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
NA	NA

MESSAGE AND ERROR SUMMARY BELOW: (DO NOT USE RESULTS IF ERRORS ARE PRESENT)
MESSAGE: The values of Csource and Cbuilding on the INTERCALCS worksheet are based on unity and do not represent actual values.

SCROLL DOWN TO "END"

END

DATA ENTRY SHEET

SL-ADV
Version 2.3; 03/01

CALCULATE RISK-BASED SOIL CONCENTRATION (enter "X" in "YES" box)

YES: X

OR

CALCULATE INCREMENTAL RISKS FROM ACTUAL SOIL CONCENTRATION (enter "X" in "YES" box and initial soil conc. below)

YES:

ENTER Chemical CAS No. (numbers only, no dashes)	ENTER Initial soil conc., C_R (µg/kg)	Chemical
75092		Methylene chloride

MORE ↓

ENTER Average soil temperature, T_S (°C)	ENTER Depth below grade to bottom of enclosed space floor, L_F (cm)	ENTER Depth below grade to top of contamination, L_t (cm)	ENTER Depth below grade to bottom of contamination, (enter value of 0 if value is unknown) L_b (cm)	ENTER Totals must add up to value of L_t (cell D28) Thickness of soil stratum A, h_A (cm)	ENTER Thickness of soil stratum B, (Enter value or 0) h_B (cm)	ENTER Thickness of soil stratum C, (Enter value or 0) h_C (cm)	ENTER Soil stratum A SCS soil type (used to estimate soil vapor permeability)	OR	ENTER User-defined stratum A soil vapor permeability, k_v (cm^2)
20	15	15	485	15	0	0	S		

MORE ↓

ENTER Stratum A soil dry bulk density, ρ_b^A (g/cm^3)	ENTER Stratum A soil total porosity, n^A (unitless)	ENTER Stratum A soil water-filled porosity, θ_w^A (cm^3/cm^3)	ENTER Stratum A soil organic carbon fraction, f_{oc}^A (unitless)	ENTER Stratum B soil dry bulk density, ρ_b^B (g/cm^3)	ENTER Stratum B soil total porosity, n^B (unitless)	ENTER Stratum B soil water-filled porosity, θ_w^B (cm^3/cm^3)	ENTER Stratum B soil organic carbon fraction, f_{oc}^B (unitless)	ENTER Stratum C soil dry bulk density, ρ_b^C (g/cm^3)	ENTER Stratum C soil total porosity, n^C (unitless)	ENTER Stratum C soil water-filled porosity, θ_w^C (cm^3/cm^3)	ENTER Stratum C soil organic carbon fraction, f_{oc}^C (unitless)
1.5	0.43	0.15	0.006								

MORE ↓

ENTER Enclosed space floor thickness, L_{crack} (cm)	ENTER Soil-bldg. pressure differential, ΔP ($g/cm \cdot s^2$)	ENTER Enclosed space floor length, L_B (cm)	ENTER Enclosed space floor width, W_B (cm)	ENTER Enclosed space height, H_B (cm)	ENTER Floor-wall seam crack width, w (cm)	ENTER Indoor air exchange rate, ER (1/h)
15	40	961	961	488	0.1	5

ENTER Averaging time for carcinogens, AT_C (yrs)	ENTER Averaging time for noncarcinogens, AT_{NC} (yrs)	ENTER Exposure duration, ED (yrs)	ENTER Exposure frequency, EF (days/yr)	ENTER Target risk for carcinogens, TR (unitless)	ENTER Target hazard quotient for noncarcinogens, THQ (unitless)
70	25	25	250	1.0E-06	1

Used to calculate risk-based soil concentration.

END

Diffusivity in air, D_a (cm^2/s)	Diffusivity in water, D_w (cm^2/s)	Henry's law constant at reference temperature, H ($atm \cdot m^3/mol$)	Henry's law constant reference temperature, T_R (°C)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Normal boiling point, T_B (°K)	Critical temperature, T_C (°K)	Organic carbon partition coefficient, K_{oc} (cm^3/g)	Pure component water solubility, S (mg/L)	Unit risk factor, URF ($\mu g/m^3)^{-1}$	Reference conc., RfC (mg/m^3)	Physical state at soil temperature, (S,L,G)
1.01E-01	1.17E-05	2.19E-03	25	6,706	313.00	510.00	1.17E+01	1.30E+04	4.7E-07	3.0E+00	L

END

INTERMEDIATE CALCULATIONS SHEET

Exposure duration, τ (sec)	Source-building separation, L_T (cm)	Stratum A soil air-filled porosity, θ_a^A (cm^3/cm^3)	Stratum B soil air-filled porosity, θ_a^B (cm^3/cm^3)	Stratum C soil air-filled porosity, θ_a^C (cm^3/cm^3)	Stratum A effective total fluid saturation, S_{te} (cm^3/cm^3)	Stratum A soil intrinsic permeability, k_i (cm^2)	Stratum A soil relative air permeability, k_{rg} (cm^2)	Stratum A soil effective vapor permeability, k_v (cm^2)	Floor-wall seam perimeter, X_{crack} (cm)	Initial soil concentration used, C_R (µg/kg)	Bldg. ventilation rate, $Q_{building}$ (cm^3/s)
7.88E+08	1	0.280	ERROR	ERROR	0.257	1.01E-07	0.703	7.10E-08	3,844	1.00E+00	6.26E+05

Area of enclosed space below grade, A_B (cm^2)	Crack-to-total area ratio, η (unitless)	Crack depth below grade, Z_{crack} (cm)	Enthalpy of vaporization at ave. soil temperature, $\Delta H_{v,TS}$ (cal/mol)	Henry's law constant at ave. soil temperature, H_{TS} (atm·m^3/mol)	Henry's law constant at ave. soil temperature, H'_{TS} (unitless)	Vapor viscosity at ave. soil temperature, μ_{TS} (g/cm·s)	Stratum A effective diffusion coefficient, D^{eff}_A (cm^2/s)	Stratum B effective diffusion coefficient, D^{eff}_B (cm^2/s)	Stratum C effective diffusion coefficient, D^{eff}_C (cm^2/s)	Total overall effective diffusion coefficient, D^{eff}_T (cm^2/s)	Diffusion path length, L_d (cm)	Convection path length, L_p (cm)
9.24E+05	4.16E-04	15	6,927	1.79E-03	7.46E-02	1.78E-04	7.88E-03	0.00E+00	0.00E+00	7.88E-03	1	15

Soil-water partition coefficient, K_d (cm^3/g)	Source vapor conc., C_{source} (µg/m^3)	Crack radius, r_{crack} (cm)	Average vapor flow rate into bldg., Q_{soil} (cm^3/s)	Crack effective diffusion coefficient, D^{crack} (cm^2/s)	Area of crack, A_{crack} (cm^2)	Exponent of equivalent foundation Peclet number, exp(Pe^f) (unitless)	Infinite source indoor attenuation coefficient, α (unitless)	Infinite source bldg. conc., $C_{building}$ (µg/m^3)	Finite source β term (unitless)	Finite source ψ term $(sec)^{-1}$	Time for source depletion, τ_D (sec)	Exposure duration > time for source depletion (YES/NO)
7.02E-02	4.05E+02	0.10	6.74E+01	7.88E-03	3.84E+02	8.64E+144	NA	NA	1.09E+02	2.13E-03	7.60E+07	YES

Finite source indoor attenuation coefficient, <α> (unitless)	Mass limit bldg. conc., $C_{building}$ (µg/m^3)	Finite source bldg. conc., $C_{building}$ (µg/m^3)	Final finite source bldg. conc., $C_{building}$ (µg/m^3)	Unit risk factor, URF $(\mu g/m^3)^{-1}$	Reference conc., RfC (mg/m^3)
NA	1.32E-03	NA	1.32E-03	4.7E-07	3.0E+00

END

RISK-BASED SOIL CONCENTRATION CALCULATIONS:

Indoor exposure soil conc., carcinogen (µg/kg)	Indoor exposure soil conc., noncarcinogen (µg/kg)	Risk-based indoor exposure soil conc., (µg/kg)	Soil saturation conc., C_{sat} (µg/kg)	Final indoor exposure soil conc., (µg/kg)
6.59E+03	3.32E+06	6.59E+03	2.39E+06	6.59E+03

INCREMENTAL RISK CALCULATIONS:

Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
NA	NA

MESSAGE AND ERROR SUMMARY BELOW: (DO NOT USE RESULTS IF ERRORS ARE PRESENT)
MESSAGE: The values of Csource and Cbuilding on the INTERCALCS worksheet are based on unity and do not represent actual values.

SCROLL DOWN TO "END"

END

DATA ENTRY SHEET

SL-ADV
Version 2.3; 03/01

CALCULATE RISK-BASED SOIL CONCENTRATION (enter "X" in "YES" box)

YES: X

OR

CALCULATE INCREMENTAL RISKS FROM ACTUAL SOIL CONCENTRATION (enter "X" in "YES" box and initial soil conc. below)

YES:

ENTER Chemical CAS No. (numbers only, no dashes)	ENTER Initial soil conc., C_R (µg/kg)	Chemical
120821		1,2,4-Trichlorobenzene

MORE ↓

ENTER Average soil temperature, T_S (°C)	ENTER Depth below grade to bottom of enclosed space floor, L_F (cm)	ENTER Depth below grade to top of contamination, L_t (cm)	ENTER Depth below grade to bottom of contamination, (enter value of 0 if value is unknown) L_b (cm)	ENTER Totals must add up to value of L_t (cell D28) Thickness of soil stratum A, h_A (cm)	ENTER Thickness of soil stratum B, (Enter value or 0) h_B (cm)	ENTER Thickness of soil stratum C, (Enter value or 0) h_C (cm)	ENTER Soil stratum A SCS soil type (used to estimate soil vapor permeability)	OR	ENTER User-defined stratum A soil vapor permeability, k_v (cm^2)
20	15	15	485	15	0	0	S		

MORE ↓

ENTER Stratum A soil dry bulk density, ρ_b^A (g/cm^3)	ENTER Stratum A soil total porosity, n^A (unitless)	ENTER Stratum A soil water-filled porosity, θ_w^A (cm^3/cm^3)	ENTER Stratum A soil organic carbon fraction, f_{oc}^A (unitless)	ENTER Stratum B soil dry bulk density, ρ_b^B (g/cm^3)	ENTER Stratum B soil total porosity, n^B (unitless)	ENTER Stratum B soil water-filled porosity, θ_w^B (cm^3/cm^3)	ENTER Stratum B soil organic carbon fraction, f_{oc}^B (unitless)	ENTER Stratum C soil dry bulk density, ρ_b^C (g/cm^3)	ENTER Stratum C soil total porosity, n^C (unitless)	ENTER Stratum C soil water-filled porosity, θ_w^C (cm^3/cm^3)	ENTER Stratum C soil organic carbon fraction, f_{oc}^C (unitless)
1.5	0.43	0.15	0.006								

MORE ↓

ENTER Enclosed space floor thickness, L_{crack} (cm)	ENTER Soil-bldg. pressure differential, ΔP ($g/cm \cdot s^2$)	ENTER Enclosed space floor length, L_B (cm)	ENTER Enclosed space floor width, W_B (cm)	ENTER Enclosed space height, H_B (cm)	ENTER Floor-wall seam crack width, w (cm)	ENTER Indoor air exchange rate, ER (1/h)
15	40	961	961	488	0.1	2

ENTER Averaging time for carcinogens, AT_C (yrs)	ENTER Averaging time for noncarcinogens, AT_{NC} (yrs)	ENTER Exposure duration, ED (yrs)	ENTER Exposure frequency, EF (days/yr)	ENTER Target risk for carcinogens, TR (unitless)	ENTER Target hazard quotient for noncarcinogens, THQ (unitless)
70	30	30	350	1.0E-06	1

Used to calculate risk-based soil concentration.

END

Diffusivity in air, D_a (cm^2/s)	Diffusivity in water, D_w (cm^2/s)	Henry's law constant at reference temperature, H ($atm \cdot m^3/mol$)	Henry's law constant reference temperature, T_R (°C)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Normal boiling point, T_B (°K)	Critical temperature, T_C (°K)	Organic carbon partition coefficient, K_{oc} (cm^3/g)	Pure component water solubility, S (mg/L)	Unit risk factor, URF ($(\mu g/m^3)^{-1}$)	Reference conc., RfC (mg/m^3)	Physical state at soil temperature, (S,L,G)
3.00E-02	8.23E-06	1.42E-03	25	10,471	486.15	725.00	1.78E+03	3.00E+02	0.0E+00	2.0E-01	L

END

INTERMEDIATE CALCULATIONS SHEET

Exposure duration, τ (sec)	Source-building separation, L_T (cm)	Stratum A soil air-filled porosity, θ_a^A (cm^3/cm^3)	Stratum B soil air-filled porosity, θ_a^B (cm^3/cm^3)	Stratum C soil air-filled porosity, θ_a^C (cm^3/cm^3)	Stratum A effective total fluid saturation, S_{te} (cm^3/cm^3)	Stratum A soil intrinsic permeability, k_i (cm^2)	Stratum A soil relative air permeability, k_{rg} (cm^2)	Stratum A soil effective vapor permeability, k_v (cm^2)	Floor-wall seam perimeter, X_{crack} (cm)	Initial soil concentration used, C_R (µg/kg)	Bldg. ventilation rate, $Q_{building}$ (cm^3/s)
9.46E+08	1	0.280	ERROR	ERROR	0.257	1.01E-07	0.703	7.10E-08	3,844	1.00E+00	2.50E+05

Area of enclosed space below grade, A_B (cm^2)	Crack-to-total area ratio, η (unitless)	Crack depth below grade, Z_{crack} (cm)	Enthalpy of vaporization at ave. soil temperature, $\Delta H_{v,TS}$ (cal/mol)	Henry's law constant at ave. soil temperature, H_{TS} (atm·m^3/mol)	Henry's law constant at ave. soil temperature, H'_{TS} (unitless)	Vapor viscosity at ave. soil temperature, μ_{TS} (g/cm·s)	Stratum A effective diffusion coefficient, D^{eff}_A (cm^2/s)	Stratum B effective diffusion coefficient, D^{eff}_B (cm^2/s)	Stratum C effective diffusion coefficient, D^{eff}_C (cm^2/s)	Total overall effective diffusion coefficient, D^{eff}_T (cm^2/s)	Diffusion path length, L_d (cm)	Convection path length, L_p (cm)
9.24E+05	4.16E-04	15	13,115	9.73E-04	4.05E-02	1.78E-04	2.34E-03	0.00E+00	0.00E+00	2.34E-03	1	15

Soil-water partition coefficient, K_d (cm^3/g)	Source vapor conc., C_{source} (µg/m^3)	Crack radius, r_{crack} (cm)	Average vapor flow rate into bldg., Q_{soil} (cm^3/s)	Crack effective diffusion coefficient, D^{crack} (cm^2/s)	Area of crack, A_{crack} (cm^2)	Exponent of equivalent foundation Peclet number, exp(Pe^f) (unitless)	Infinite source indoor attenuation coefficient, α (unitless)	Infinite source bldg. conc., $C_{building}$ (µg/m^3)	Finite source β term (unitless)	Finite source ψ term $(sec)^{-1}$	Time for source depletion, τ_D (sec)	Exposure duration > time for source depletion (YES/NO)
1.07E+01	3.75E+00	0.10	6.74E+01	2.34E-03	3.84E+02	#NUM!	NA	NA	3.31E+01	5.86E-06	2.15E+10	NO

Finite source indoor attenuation coefficient, <α> (unitless)	Mass limit bldg. conc., $C_{building}$ (µg/m^3)	Finite source bldg. conc., $C_{building}$ (µg/m^3)	Final finite source bldg. conc., $C_{building}$ (µg/m^3)	Unit risk factor, URF (µg/m^3)$^{-1}$	Reference conc., RfC (mg/m^3)
1.20E-04	NA	4.52E-04	4.52E-04	NA	2.0E-01

END

RISK-BASED SOIL CONCENTRATION CALCULATIONS:

Indoor exposure soil conc., carcinogen (µg/kg)	Indoor exposure soil conc., noncarcinogen (µg/kg)	Risk-based indoor exposure soil conc., (µg/kg)	Soil saturation conc., C_{sat} (µg/kg)	Final indoor exposure soil conc., (µg/kg)
NA	4.62E+05	4.62E+05	3.24E+06	4.62E+05

INCREMENTAL RISK CALCULATIONS:

Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
NA	NA

MESSAGE AND ERROR SUMMARY BELOW: (DO NOT USE RESULTS IF ERRORS ARE PRESENT)

MESSAGE: The values of Csource and Cbuilding on the INTERCALCS worksheet are based on unity and do not represent actual values.

SCROLL DOWN TO "END"

END

DATA ENTRY SHEET

SL-ADV
Version 2.3; 03/01

CALCULATE RISK-BASED SOIL CONCENTRATION (enter "X" in "YES" box)

YES [X]

OR

CALCULATE INCREMENTAL RISKS FROM ACTUAL SOIL CONCENTRATION (enter "X" in "YES" box and initial soil conc. below)

YES [ ]

ENTER Chemical CAS No. (numbers only, no dashes)	ENTER Initial soil conc., C_R (µg/kg)	Chemical
120821		1,2,4-Trichlorobenzene

MORE ↓

ENTER Average soil temperature, T_S (°C)	ENTER Depth below grade to bottom of enclosed space floor, L_F (cm)	ENTER Depth below grade to top of contamination, L_t (cm)	ENTER Depth below grade to bottom of contamination, (enter value of 0 if value is unknown) L_b (cm)	ENTER Totals must add up to value of L_t (cell D28) Thickness of soil stratum A, h_A (cm)	ENTER Thickness of soil stratum B, (Enter value or 0) h_B (cm)	ENTER Thickness of soil stratum C, (Enter value or 0) h_C (cm)	ENTER Soil stratum A SCS soil type (used to estimate soil vapor permeability)	OR	ENTER User-defined stratum A soil vapor permeability, k_v (cm^2)
20	15	15	485	15	0	0	S		

MORE ↓

ENTER Stratum A soil dry bulk density, ρ_b^A (g/cm^3)	ENTER Stratum A soil total porosity, n^A (unitless)	ENTER Stratum A soil water-filled porosity, θ_w^A (cm^3/cm^3)	ENTER Stratum A soil organic carbon fraction, f_{oc}^A (unitless)	ENTER Stratum B soil dry bulk density, ρ_b^B (g/cm^3)	ENTER Stratum B soil total porosity, n^B (unitless)	ENTER Stratum B soil water-filled porosity, θ_w^B (cm^3/cm^3)	ENTER Stratum B soil organic carbon fraction, f_{oc}^B (unitless)	ENTER Stratum C soil dry bulk density, ρ_b^C (g/cm^3)	ENTER Stratum C soil total porosity, n^C (unitless)	ENTER Stratum C soil water-filled porosity, θ_w^C (cm^3/cm^3)	ENTER Stratum C soil organic carbon fraction, f_{oc}^C (unitless)
1.5	0.43	0.15	0.006								

MORE ↓

ENTER Enclosed space floor thickness, L_{crack} (cm)	ENTER Soil-bldg. pressure differential, ΔP ($g/cm \cdot s^2$)	ENTER Enclosed space floor length, L_B (cm)	ENTER Enclosed space floor width, W_B (cm)	ENTER Enclosed space height, H_B (cm)	ENTER Floor-wall seam crack width, w (cm)	ENTER Indoor air exchange rate, ER (1/h)
15	40	961	961	488	0.1	5

ENTER Averaging time for carcinogens, AT_C (yrs)	ENTER Averaging time for noncarcinogens, AT_{NC} (yrs)	ENTER Exposure duration, ED (yrs)	ENTER Exposure frequency, EF (days/yr)	ENTER Target risk for carcinogens, TR (unitless)	ENTER Target hazard quotient for noncarcinogens, THQ (unitless)
70	25	25	250	1.0E-06	1

Used to calculate risk-based soil concentration.

END

Diffusivity in air, D_a (cm^2/s)	Diffusivity in water, D_w (cm^2/s)	Henry's law constant at reference temperature, H ($atm \cdot m^3/mol$)	Henry's law constant reference temperature, T_R (°C)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Normal boiling point, T_B (°K)	Critical temperature, T_C (°K)	Organic carbon partition coefficient, K_{oc} (cm^3/g)	Pure component water solubility, S (mg/L)	Unit risk factor, URF ($\mu g/m^3)^{-1}$	Reference conc., RfC (mg/m^3)	Physical state at soil temperature, (S,L,G)
3.00E-02	8.23E-06	1.42E-03	25	10,471	486.15	725.00	1.78E+03	3.00E+02	0.0E+00	2.0E-01	L

END

INTERMEDIATE CALCULATIONS SHEET

Exposure duration, τ (sec)	Source-building separation, L_T (cm)	Stratum A soil air-filled porosity, θ_a^A (cm^3/cm^3)	Stratum B soil air-filled porosity, θ_a^B (cm^3/cm^3)	Stratum C soil air-filled porosity, θ_a^C (cm^3/cm^3)	Stratum A effective total fluid saturation, S_{te} (cm^3/cm^3)	Stratum A soil intrinsic permeability, k_i (cm^2)	Stratum A soil relative air permeability, k_{rg} (cm^2)	Stratum A soil effective vapor permeability, k_v (cm^2)	Floor-wall seam perimeter, X_{crack} (cm)	Initial soil concentration used, C_R (µg/kg)	Bldg. ventilation rate, $Q_{building}$ (cm^3/s)
7.88E+08	1	0.280	ERROR	ERROR	0.257	1.01E-07	0.703	7.10E-08	3,844	1.00E+00	6.26E+05

Area of enclosed space below grade, A_B (cm^2)	Crack-to-total area ratio, η (unitless)	Crack depth below grade, Z_{crack} (cm)	Enthalpy of vaporization at ave. soil temperature, $\Delta H_{v,TS}$ (cal/mol)	Henry's law constant at ave. soil temperature, H_{TS} (atm·m^3/mol)	Henry's law constant at ave. soil temperature, H'_{TS} (unitless)	Vapor viscosity at ave. soil temperature, μ_{TS} (g/cm·s)	Stratum A effective diffusion coefficient, D^{eff}_A (cm^2/s)	Stratum B effective diffusion coefficient, D^{eff}_B (cm^2/s)	Stratum C effective diffusion coefficient, D^{eff}_C (cm^2/s)	Total overall effective diffusion coefficient, D^{eff}_T (cm^2/s)	Diffusion path length, L_d (cm)	Convection path length, L_p (cm)
9.24E+05	4.16E-04	15	13,115	9.73E-04	4.05E-02	1.78E-04	2.34E-03	0.00E+00	0.00E+00	2.34E-03	1	15

Soil-water partition coefficient, K_d (cm^3/g)	Source vapor conc., C_{source} (µg/m^3)	Crack radius, r_{crack} (cm)	Average vapor flow rate into bldg., Q_{soil} (cm^3/s)	Crack effective diffusion coefficient, D^{crack} (cm^2/s)	Area of crack, A_{crack} (cm^2)	Exponent of equivalent foundation Peclet number, exp(Pe^f) (unitless)	Infinite source indoor attenuation coefficient, α (unitless)	Infinite source bldg. conc., $C_{building}$ (µg/m^3)	Finite source β term (unitless)	Finite source ψ term $(sec)^{-1}$	Time for source depletion, τ_D (sec)	Exposure duration > time for source depletion (YES/NO)
1.07E+01	3.75E+00	0.10	6.74E+01	2.34E-03	3.84E+02	#NUM!	NA	NA	3.31E+01	5.86E-06	2.15E+10	NO

Finite source indoor attenuation coefficient, <α> (unitless)	Mass limit bldg. conc., $C_{building}$ (µg/m^3)	Finite source bldg. conc., $C_{building}$ (µg/m^3)	Final finite source bldg. conc., $C_{building}$ (µg/m^3)	Unit risk factor, URF $(\mu g/m^3)^{-1}$	Reference conc., RfC (mg/m^3)
5.13E-05	NA	1.92E-04	1.92E-04	NA	2.0E-01

END

RISK-BASED SOIL CONCENTRATION CALCULATIONS:

Indoor exposure soil conc., carcinogen (µg/kg)	Indoor exposure soil conc., noncarcinogen (µg/kg)	Risk-based indoor exposure soil conc., (µg/kg)	Soil saturation conc., C_{sat} (µg/kg)	Final Indoor exposure soil conc., (µg/kg)
NA	1.52E+06	1.52E+06	3.24E+06	1.52E+06

INCREMENTAL RISK CALCULATIONS:

Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
NA	NA

MESSAGE AND ERROR SUMMARY BELOW: (DO NOT USE RESULTS IF ERRORS ARE PRESENT)

MESSAGE: The values of Csource and Cbuilding on the INTERCALCS worksheet are based on unity and do not represent actual values.

SCROLL DOWN TO "END"

END

DATA ENTRY SHEET

CALCULATE RISK-BASED SOIL CONCENTRATION (enter "X" in "YES" box)

SL-ADV
Version 2.3; 03/01

YES [X]

OR

CALCULATE INCREMENTAL RISKS FROM ACTUAL SOIL CONCENTRATION (enter "X" in "YES" box and initial soil conc. below)

YES [ ]

ENTER Chemical CAS No. (numbers only, no dashes)	ENTER Initial soil conc., C_R (µg/kg)	Chemical
75694		Trichlorofluoromethane

MORE ↓

ENTER Average soil temperature, T_S (°C)	ENTER Depth below grade to bottom of enclosed space floor, L_F (cm)	ENTER Depth below grade to top of contamination, L_t (cm)	ENTER Depth below grade to bottom of contamination, (enter value of 0 if value is unknown) L_b (cm)	ENTER Totals must add up to value of L_t (cell D28) Thickness of soil stratum A, h_A (cm)	ENTER Thickness of soil stratum B, (Enter value or 0) h_B (cm)	ENTER Thickness of soil stratum C, (Enter value or 0) h_C (cm)	ENTER Soil stratum A SCS soil type (used to estimate soil vapor permeability)	OR	ENTER User-defined stratum A soil vapor permeability, k_v (cm^2)
20	15	15	485	15	0	0	S		

MORE ↓

ENTER Stratum A soil dry bulk density, ρ_b^A (g/cm^3)	ENTER Stratum A soil total porosity, n^A (unitless)	ENTER Stratum A soil water-filled porosity, θ_w^A (cm^3/cm^3)	ENTER Stratum A soil organic carbon fraction, f_{oc}^A (unitless)	ENTER Stratum B soil dry bulk density, ρ_b^B (g/cm^3)	ENTER Stratum B soil total porosity, n^B (unitless)	ENTER Stratum B soil water-filled porosity, θ_w^B (cm^3/cm^3)	ENTER Stratum B soil organic carbon fraction, f_{oc}^B (unitless)	ENTER Stratum C soil dry bulk density, ρ_b^C (g/cm^3)	ENTER Stratum C soil total porosity, n^C (unitless)	ENTER Stratum C soil water-filled porosity, θ_w^C (cm^3/cm^3)	ENTER Stratum C soil organic carbon fraction, f_{oc}^C (unitless)
1.5	0.43	0.15	0.006								

MORE ↓

ENTER Enclosed space floor thickness, L_{crack} (cm)	ENTER Soil-bldg. pressure differential, ΔP ($g/cm \cdot s^2$)	ENTER Enclosed space floor length, L_B (cm)	ENTER Enclosed space floor width, W_B (cm)	ENTER Enclosed space height, H_B (cm)	ENTER Floor-wall seam crack width, w (cm)	ENTER Indoor air exchange rate, ER (1/h)
15	40	961	961	488	0.1	2

ENTER Averaging time for carcinogens, AT_C (yrs)	ENTER Averaging time for noncarcinogens, AT_{NC} (yrs)	ENTER Exposure duration, ED (yrs)	ENTER Exposure frequency, EF (days/yr)	ENTER Target risk for carcinogens, TR (unitless)	ENTER Target hazard quotient for noncarcinogens, THQ (unitless)
70	30	30	350	1.0E-06	1

Used to calculate risk-based soil concentration.

END

Diffusivity in air, D_a (cm^2/s)	Diffusivity in water, D_w (cm^2/s)	Henry's law constant at reference temperature, H ($atm \cdot m^3/mol$)	Henry's law constant reference temperature, T_R (°C)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Normal boiling point, T_B (°K)	Critical temperature, T_C (°K)	Organic carbon partition coefficient, K_{oc} (cm^3/g)	Pure component water solubility, S (mg/L)	Unit risk factor, URF ($\mu g/m^3)^{-1}$	Reference conc., RfC (mg/m^3)	Physical state at soil temperature, (S,L,G)
8.62E-02	9.30E-06	8.21E-02	25	6,805	296.78	445.17	1.46E+02	1.24E+03	0.0E+00	1.1E-01	L

END

INTERMEDIATE CALCULATIONS SHEET

Exposure duration, τ (sec)	Source-building separation, L_T (cm)	Stratum A soil air-filled porosity, θ_a^A (cm^3/cm^3)	Stratum B soil air-filled porosity, θ_a^B (cm^3/cm^3)	Stratum C soil air-filled porosity, θ_a^C (cm^3/cm^3)	Stratum A effective total fluid saturation, S_{te} (cm^3/cm^3)	Stratum A soil intrinsic permeability, k_i (cm^2)	Stratum A soil relative air permeability, k_{rg} (cm^2)	Stratum A soil effective vapor permeability, k_v (cm^2)	Floor-wall seam perimeter, X_{crack} (cm)	Initial soil concentration used, C_R (µg/kg)	Bldg. ventilation rate, $Q_{building}$ (cm^3/s)
9.46E+08	1	0.280	ERROR	ERROR	0.257	1.01E-07	0.703	7.10E-08	3,844	1.00E+00	2.50E+05

Area of enclosed space below grade, A_B (cm^2)	Crack-to-total area ratio, η (unitless)	Crack depth below grade, Z_{crack} (cm)	Enthalpy of vaporization at ave. soil temperature, $\Delta H_{v,TS}$ (cal/mol)	Henry's law constant at ave. soil temperature, H_{TS} (atm·m^3/mol)	Henry's law constant at ave. soil temperature, H'_{TS} (unitless)	Vapor viscosity at ave. soil temperature, μ_{TS} (g/cm·s)	Stratum A effective diffusion coefficient, D^{eff}_A (cm^2/s)	Stratum B effective diffusion coefficient, D^{eff}_B (cm^2/s)	Stratum C effective diffusion coefficient, D^{eff}_C (cm^2/s)	Total overall effective diffusion coefficient, D^{eff}_T (cm^2/s)	Diffusion path length, L_d (cm)	Convection path length, L_p (cm)
9.24E+05	4.16E-04	15	6,867	6.74E-02	2.80E+00	1.78E-04	6.73E-03	0.00E+00	0.00E+00	6.73E-03	1	15

Soil-water partition coefficient, K_d (cm^3/g)	Source vapor conc., C_{source} (µg/m^3)	Crack radius, r_{crack} (cm)	Average vapor flow rate into bldg., Q_{soil} (cm^3/s)	Crack effective diffusion coefficient, D^{crack} (cm^2/s)	Area of crack, A_{crack} (cm^2)	Exponent of equivalent foundation Peclet number, exp(Pe^f) (unitless)	Infinite source indoor attenuation coefficient, α (unitless)	Infinite source bldg. conc., $C_{building}$ (µg/m^3)	Finite source β term (unitless)	Finite source ψ term $(sec)^{-1}$	Time for source depletion, τ_D (sec)	Exposure duration > time for source depletion (YES/NO)
8.77E-01	1.87E+03	0.10	6.74E+01	6.73E-03	3.84E+02	5.78E+169	NA	NA	9.32E+01	8.37E-03	1.84E+07	YES

Finite source indoor attenuation coefficient, <α> (unitless)	Mass limit bldg. conc., $C_{building}$ (µg/m^3)	Finite source bldg. conc., $C_{building}$ (µg/m^3)	Final finite source bldg. conc., $C_{building}$ (µg/m^3)	Unit risk factor, URF $(\mu g/m^3)^{-1}$	Reference conc., RfC (mg/m^3)
NA	2.75E-03	NA	2.75E-03	NA	1.1E-01

END

RISK-BASED SOIL CONCENTRATION CALCULATIONS:

Indoor exposure soil conc., carcinogen (µg/kg)	Indoor exposure soil conc., noncarcinogen (µg/kg)	Risk-based indoor exposure soil conc., (µg/kg)	Soil saturation conc., C_{sat} (µg/kg)	Final indoor exposure soil conc., (µg/kg)
NA	3.98E+04	3.98E+04	1.86E+06	3.98E+04

INCREMENTAL RISK CALCULATIONS:

Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
NA	NA

MESSAGE AND ERROR SUMMARY BELOW: (DO NOT USE RESULTS IF ERRORS ARE PRESENT)
MESSAGE: The values of Csource and Cbuilding on the INTERCALCS worksheet are based on unity and do not represent actual values.

SCROLL DOWN TO "END"

END

DATA ENTRY SHEET

SL-ADV
Version 2.3; 03/01

CALCULATE RISK-BASED SOIL CONCENTRATION (enter "X" in "YES" box)

YES [X]

OR

CALCULATE INCREMENTAL RISKS FROM ACTUAL SOIL CONCENTRATION (enter "X" in "YES" box and initial soil conc. below)

YES [ ]

ENTER Chemical CAS No. (numbers only, no dashes)	ENTER Initial soil conc., C_R (µg/kg)	Chemical
75694		Trichlorofluoromethane

MORE ↓

ENTER Average soil temperature, T_S (°C)	ENTER Depth below grade to bottom of enclosed space floor, L_F (cm)	ENTER Depth below grade to top of contamination, L_t (cm)	ENTER Depth below grade to bottom of contamination, (enter value of 0 if value is unknown) L_b (cm)	ENTER Totals must add up to value of L_t (cell D28): Thickness of soil stratum A, h_A (cm)	ENTER Thickness of soil stratum B, (Enter value or 0) h_B (cm)	ENTER Thickness of soil stratum C, (Enter value or 0) h_C (cm)	ENTER Soil stratum A SCS soil type (used to estimate soil vapor permeability)	OR	ENTER User-defined stratum A soil vapor permeability, k_v (cm^2)
20	15	15	485	15	0	0	S		

MORE ↓

ENTER Stratum A soil dry bulk density, ρ_b^A (g/cm^3)	ENTER Stratum A soil total porosity, n^A (unitless)	ENTER Stratum A soil water-filled porosity, θ_w^A (cm^3/cm^3)	ENTER Stratum A soil organic carbon fraction, f_{oc}^A (unitless)	ENTER Stratum B soil dry bulk density, ρ_b^B (g/cm^3)	ENTER Stratum B soil total porosity, n^B (unitless)	ENTER Stratum B soil water-filled porosity, θ_w^B (cm^3/cm^3)	ENTER Stratum B soil organic carbon fraction, f_{oc}^B (unitless)	ENTER Stratum C soil dry bulk density, ρ_b^C (g/cm^3)	ENTER Stratum C soil total porosity, n^C (unitless)	ENTER Stratum C soil water-filled porosity, θ_w^C (cm^3/cm^3)	ENTER Stratum C soil organic carbon fraction, f_{oc}^C (unitless)
1.5	0.43	0.15	0.006								

MORE ↓

ENTER Enclosed space floor thickness, L_{crack} (cm)	ENTER Soil-bldg. pressure differential, ΔP ($g/cm \cdot s^2$)	ENTER Enclosed space floor length, L_B (cm)	ENTER Enclosed space floor width, W_B (cm)	ENTER Enclosed space height, H_B (cm)	ENTER Floor-wall seam crack width, w (cm)	ENTER Indoor air exchange rate, ER (1/h)
15	40	961	961	488	0.1	5

ENTER Averaging time for carcinogens, AT_C (yrs)	ENTER Averaging time for noncarcinogens, AT_{NC} (yrs)	ENTER Exposure duration, ED (yrs)	ENTER Exposure frequency, EF (days/yr)	ENTER Target risk for carcinogens, TR (unitless)	ENTER Target hazard quotient for noncarcinogens, THQ (unitless)
70	25	25	250	1.0E-06	1

Used to calculate risk-based soil concentration.

END

Diffusivity in air, D_a (cm^2/s)	Diffusivity in water, D_w (cm^2/s)	Henry's law constant at reference temperature, H ($atm \cdot m^3/mol$)	Henry's law constant reference temperature, T_R (°C)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Normal boiling point, T_B (°K)	Critical temperature, T_C (°K)	Organic carbon partition coefficient, K_{oc} (cm^3/g)	Pure component water solubility, S (mg/L)	Unit risk factor, URF ($\mu g/m^3)^{-1}$	Reference conc., RfC (mg/m^3)	Physical state at soil temperature, (S,L,G)
8.62E-02	9.30E-06	8.21E-02	25	6,805	296.78	445.17	1.46E+02	1.24E+03	0.0E+00	1.1E-01	L

END

INTERMEDIATE CALCULATIONS SHEET

Exposure duration, τ (sec)	Source-building separation, L_T (cm)	Stratum A soil air-filled porosity, θ_a^A (cm^3/cm^3)	Stratum B soil air-filled porosity, θ_a^B (cm^3/cm^3)	Stratum C soil air-filled porosity, θ_a^C (cm^3/cm^3)	Stratum A effective total fluid saturation, S_{te} (cm^3/cm^3)	Stratum A soil intrinsic permeability, k_i (cm^2)	Stratum A soil relative air permeability, k_{rg} (cm^2)	Stratum A soil effective vapor permeability, k_v (cm^2)	Floor-wall seam perimeter, X_{crack} (cm)	**Initial soil concentration used, C_R (µg/kg)**	Bldg. ventilation rate, $Q_{building}$ (cm^3/s)
7.88E+08	1	0.280	ERROR	ERROR	0.257	1.01E-07	0.703	7.10E-08	3,844	**1.00E+00**	6.26E+05

Area of enclosed space below grade, A_B (cm^2)	Crack-to-total area ratio, η (unitless)	Crack depth below grade, Z_{crack} (cm)	Enthalpy of vaporization at ave. soil temperature, $\Delta H_{v,TS}$ (cal/mol)	Henry's law constant at ave. soil temperature, H_{TS} (atm·m^3/mol)	Henry's law constant at ave. soil temperature, H'_{TS} (unitless)	Vapor viscosity at ave. soil temperature, μ_{TS} (g/cm-s)	Stratum A effective diffusion coefficient, D^{eff}_A (cm^2/s)	Stratum B effective diffusion coefficient, D^{eff}_B (cm^2/s)	Stratum C effective diffusion coefficient, D^{eff}_C (cm^2/s)	Total overall effective diffusion coefficient, D^{eff}_T (cm^2/s)	Diffusion path length, L_d (cm)	Convection path length, L_p (cm)
9.24E+05	4.16E-04	15	6,867	6.74E-02	2.80E+00	1.78E-04	6.73E-03	0.00E+00	0.00E+00	6.73E-03	1	15

Soil-water partition coefficient, K_d (cm^3/g)	Source vapor conc., C_{source} (µg/m^3)	Crack radius, r_{crack} (cm)	Average vapor flow rate into bldg., Q_{soil} (cm^3/s)	Crack effective diffusion coefficient, D^{crack} (cm^2/s)	Area of crack, A_{crack} (cm^2)	Exponent of equivalent foundation Peclet number, exp(Pe^f) (unitless)	Infinite source indoor attenuation coefficient, α (unitless)	Infinite source bldg. conc., $C_{building}$ (µg/m^3)	**Finite source β term (unitless)**	**Finite source ψ term ($sec)^{-1}$**	Time for source depletion, τ_D (sec)	Exposure duration > time for source depletion (YES/NO)
8.77E-01	1.87E+03	0.10	6.74E+01	6.73E-03	3.84E+02	5.78E+169	NA	NA	**9.32E+01**	**8.37E-03**	1.84E+07	YES

Finite source indoor attenuation coefficient, <α> (unitless)	Mass limit bldg. conc., $C_{building}$ (µg/m^3)	Finite source bldg. conc., $C_{building}$ (µg/m^3)	Final finite source bldg. conc., $C_{building}$ (µg/m^3)	Unit risk factor, URF (µg/m^3)$^{-1}$	Reference conc., RfC (mg/m^3)
NA	1.32E-03	NA	1.32E-03	NA	1.1E-01

END

RISK-BASED SOIL CONCENTRATION CALCULATIONS:

Indoor exposure soil conc., carcinogen (µg/kg)	Indoor exposure soil conc., noncarcinogen (µg/kg)	Risk-based indoor exposure soil conc., (µg/kg)	Soil saturation conc., C_{sat} (µg/kg)	Final indoor exposure soil conc., (µg/kg)
NA	1.16E+05	1.16E+05	1.86E+06	1.16E+05

INCREMENTAL RISK CALCULATIONS:

Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
NA	NA

MESSAGE AND ERROR SUMMARY BELOW: (DO NOT USE RESULTS IF ERRORS ARE PRESENT)

MESSAGE: The values of Csource and Cbuilding on the INTERCALCS worksheet are based on unity and do not represent actual values.

SCROLL DOWN TO "END"

END

APPENDIX F

RESPONSES TO COMMENT LETTERS FROM THE DTSC AND RWQCB

APPENDIX F

RESPONSES TO COMMENT LETTERS FROM THE DTSC AND RWQCB

30 October 2002

THE PRESIDIO TRUST

James D. Ponton, R.G.
Regional Water Quality Control Board
1515 Clay Street, Suite 1400
Oakland, California 94612

Subject: Response to RWQCB Comments on *Draft Development of Presidio-wide Cleanup Levels for Soil, Sediment, Groundwater, and Surface Water*
Presidio of San Francisco, California
Regional Water Quality Control Board Letter, dated 22 January 2002

Dear Mr. Ponton:

The Presidio Trust ("Trust") has received draft comments by the Regional Water Quality Control Board ("RWQCB"), in a letter dated 22 January 2002, regarding the document entitled *Draft Development of Presidio-wide Cleanup Levels for Soil, Sediment, Groundwater, and Surface Water*, Presidio of San Francisco, California and dated August 2001. The RWQCB comments have been reproduced in *italics* in this letter.

Comment No. 1 – Table 3-1, reference to Note (l)

Note (l) refers back to Tables 1 through 5 of RWQCB Order No. 96-070, Site Cleanup Requirements of Petroleum Impacted Soils, U.S. Army, Presidio of San Francisco, dated October 1995 (the Order). Regional Board staff have reviewed the Tables 1 through Table 5 of the Order and do not see soil cleanup levels for motor oil as is shown throughout Table 3-1.

Please fix Table 3-1 so that it accurately reflects the petroleum cleanup numbers for soil presented in the Order. It is Regional Board staff's understanding that soil cleanup numbers presented in the Order are for gasoline, diesel and fuel oil range hydrocarbons.

The Trust has revised all tables in this document to reflect the fact that fuel oil, rather than motor oil, is the regulated compound in the RWQCB's Order 96-070. The listing of Site Cleanup Requirements of Petroleum Impacted Soils in former Table 3–1 have been moved to a new Table 3-3 (note b) and the references to motor oil have been changed to fuel oil.

Comment No. 2 – Table 3-1, reference to Note (m)

Note (m) refers back to Table E-12 of the Final Fuel Product Action Level Development Report (FPALDR), Presidio of San Francisco, California, dated October 1995.

Table E-12 presents water quality goals for total petroleum hydrocarbons (TPH) qualified as gasoline, diesel, fuel oil and other specific chemicals. There is no mention of TPH as motor oil as shown on Table 3-1.

Please fix Table 3-1 so that it accurately reflects the water quality goals for hydrocarbons presented in the FPALDR. It is Regional Board staff's understanding that the water quality goals presented in the FPALDR are for gasoline, diesel and fuel oil range hydrocarbons.

As mentioned in response to comment 1, the Trust has revised all tables in this document to reflect the fact that fuel oil, rather than motor oil, is the referenced compound in the FPALDR. The values in new Table 3-3 (note d) have been corrected.

Comment No. 3 – Table 3-1, Note (n)

Note (n) refers back to Table 16 of the Petroleum Hydrocarbon Bioassay and Point-of-Compliance Concentration Determinations, Saltwater Ecological Protection Zone, Presidio of San Francisco, California, dated December 1997. Table 16 presents a summary of the point of compliance concentrations in soil and water for petroleum hydrocarbons, BTEX and MTBE for saltwater ecological protection zone.

Although Table 3-1 lists numeric cleanup values for TPH as diesel, gasoline and motor oil, the point of compliance values on Table 16 list only TPH as gasoline and fuel oil. Furthermore, Table 3-1 does not list MTBE as is shown on Table 16. Please fix Table 3-1 so that it accurately reflects the saltwater ecological protection values presented on Table 16.

Table 3-3 has been revised to accurately reflect the saltwater ecological protection values presented in Table 16 of the *Petroleum Hydrocarbon Bioassay and Point-of-Compliance Concentration Determinations* document. The changes include the values for gasoline, fuel oil, and MTBE. New note (e) reflects the source of these changes.

Verbal Comment

Cleanup levels for volatile organic compounds ("VOCs") should consider the protection of groundwater resources through the leaching pathway.

The soil cleanup levels for VOCs have been modified to reflect the more stringent value based on the protection of human health (through direct contact and volatilization to indoor air pathways) or protection of groundwater resources (leaching to groundwater), as described in Sections 4.2.7 and 4.2.9. The soil cleanup levels for protection of groundwater were obtained from the RWQCB Risk-Based Screening Levels ("RBSLs")

guidance document (December 2001). If a compound was not listed in the RBSL document, then values were calculated using the same assumptions as the compounds included in the guidance document. These values are presented in new Table 4-7 of the revised Cleanup Level Document.

Recognizing that the groundwater protection RBSLs are not site-specific, the text states that if VOCs are found at a Presidio site, VOC cleanup levels may be re-calculated to be site-specific. Factors that could affect a site-specific calculation include the type of soil, depth to groundwater, among others. Any recalculation of cleanup levels for VOCs would be conducted in conjunction with discussions with regulatory agencies.

We trust these revisions address your concerns. If you have any questions, please do not hesitate to call.

Very truly yours,

Craig Cooper

Craig Cooper
THE PRESIDIO TRUST

cc: Brian Ullensvang, P.E., NPS
Robert Boggs, Jr., P.E.
Doug Kern, Presidio RAB
Mark Youngkin, Presidio RAB
Chris Nelson, Presidio Trust
Michelle King, Ph.D., EKI

30 October 2002

THE PRESIDIO TRUST

Mr. Robert Boggs, Jr., P.E.
Department of Toxic Substances Control
700 Heinz, Building F, Suite 200
Berkeley, California 94710-2721

Subject: Response to Comments re: Draft Development of Presidio-Wide Cleanup Levels for Soil, Sediment, Groundwater, and Surface Water
Department of Toxic Substances Control Letters, dated 9 November 2001

Dear Mr. Boggs:

The Presidio Trust ("Trust") has reviewed comments by the Department of Toxic Substances Control ("DTSC"), dated 9 November 2001, regarding the document, entitled *Draft Development of Presidio-Wide Cleanup Levels for Soil, Sediment, Groundwater, and Surface Water* and dated August 2001. The comments consisted of three separate documents: (1) The 9 November 2001 transmittal letter to Sharron Reackhof of the Trust from Robert Boggs; (2) a 26 October 2001 memorandum from James M. Polisini, Ph.D., Human and Ecological Risk Division ("HERD") to Robert Boggs regarding ecological issues; and (3) a 26 October 2001 memorandum from Kimiko Klein, Ph.D., HERD, to Robert Boggs regarding human health issues.

On 12 December 2001, the Trust hosted a meeting and teleconference that included the authors of the comment letters from DTSC, and representatives of the Trust, the National Park Service ("NPS"), Harding ESE, and Erler & Kalinowski, Inc. ("EKI"). Many of the comments were discussed in the course of the meeting. However, several additional meetings and telephone conversations were held to discuss the cleanup levels, including a 4 March 2002 meeting at DTSC's Berkeley office. Through these follow-up meetings and discussions, the Trust and DTSC reached agreements regarding cleanup levels. Although many of the issues presented in this letter have been resolved verbally and through changes in the document, this letter provides responses to address specific DTSC comments, which are printed in italics.

Comments from Mr. Robert Bogg's 9 November 2001 Transmittal Letter

DTSC has concerns regarding the calculation of background metals concentrations. DTSC has been unable to duplicate EKI's calculation for the Serpentinite lithology. In addition, one of our risk assessors has pointed out that some of the "site" data used to calculate background metals concentrations may not be appropriate for use in the calculations.

EKI recalculated the background metals concentrations based on the data set provided in Table C-1 of Appendix C. EKI arrives at the same concentrations presented in Table 6-1. EKI's calculations were performed using MINITAB Version 12, with the program Probability Plot. A lognormal distribution was assumed, as agreed in previous meetings. Based on our telephone discussion on 14 January 2002, we identified the discrepancy between the Trust's and DTSC's calculations, and no changes are proposed for Table 6-1 or the tables in Appendix C.

The site data set was agreed to in a series of 6 meetings and 4 conference calls in the winter and spring of 2001 between the Trust and the DTSC Remediation Project Manager ("RPM"). The Trust understood that the RPM was receiving feedback from appropriate personnel within DTSC regarding the background metals concentrations discussions and analyses.

Comments from Dr. James M. Polisini's Memorandum Dated 26 October 2001

General Comment

Some of the risk-based Ecological Preliminary Remediation Goals ("PRGs") are extremely high. The methodology for evaluation of potential action should include some comparison of a 'background' concentration to the risk-based PRG. For example, if the soil concentration is less than a risk-based concentration, but exceeds the 'background' concentration by some factor (e.g., 2 or 5), then the evaluation area should be more carefully assessed.

Dr. Polisini has commented that some of the Ecological Preliminary Remediation Goals ("PRGs") are extremely high and that the methodology for potential action should include a comparison to background concentrations, or some factor greater than background to determine if additional assessment is required. As discussed in Section 6.2.3 of the Cleanup Level Document, the Trust has developed metals "screening" levels and metals "threshold" levels, as requested by DTSC. All metals data are initially screened against the "screening levels" to identify potential chemicals of concern ("PCOCs"). The PCOC data set is then qualitatively evaluated to determine if a release has potentially occurred, or if we may be at the edge of a release, etc. The next level of screening is for chemicals of concern ("COCs"), which is accomplished by screening against the site-specific cleanup levels that may be based on the background threshold levels, as discussed in the Cleanup Level Document (Section 7). The two-step screening process is intended to identify sites that may require potential action (e.g., additional investigation to better characterize a site), even if the concentrations are less than the site-specific cleanup levels.

Specific Comments

1. *The federal Ambient Water Quality Criterion (AWQC) value for water with salinity less than 5 parts per thousand (Table 3-1) are adjusted for a calcium carbonate concentration of 100 mg/l. Please provide the actual water hardness as calcium carbonate equivalents of the Presidio water surface waters evaluated in this report. Hardness for each particular water source should be used rather than a default value.*

   The Trust reviewed available hardness data, and found that the use of 100 mg/L results in conservative water quality criteria. Hardness concentrations at the Presidio have ranged from 93 to 772 mg/L, with an average of 325 mg/L. A footnote has been added to the table to clarify this point.

2. *HERD does not agree that potential habitat damage due to extensive remedial efforts is an appropriate criterion for selecting the ecological risk level used to develop Ecological RAOs (ERAOs) (Section 5.1, page 5-1 and Section 5.4, page 5-6). Consideration of the potential negative ecological impact of any remedial action is a risk management function, not a risk assessment function. HERD has advised DTSC Risk Managers regarding the potential negative ecological impacts associated with proposed remedial actions at Department of Defense (DoD) sites in California and has sometimes recommended no remedial action.*

   The Trust agrees with DTSC that the negative ecological impacts of implementing a remedial action should be considered as part of risk management. The Ecological PRGs were not adjusted in any way to protect against habitat damage during remediation. Rather, these statements were made in the text to indicate that ultimately habitat damage should be considered in the process (i.e., referenced statement on p. 5-1). The similar statement in Section 5.4 (p. 5-7) has been deleted because it could be interpreted to mean that the Ecological PRGs were somehow modified to reflect potential habitat damage.

3. *We understand the logical argument being made by the Presidio Trust, that protection of populations is the assessment endpoint for species and communities which are not Rare, Threatened or Endangered (RTE) or California Species of Special Concern (CSSC) (Section 5.1, page 5-2). However, no justification for the specific uncertainty factors are supplied, nor have any site-specific studies been proposed or reported and conducted, which document the steady-state population levels of any non-protected, RTE, or CSSC at the Presidio of San Francisco. Please see the subsequent comments regarding the uncertainty factors applied for terrestrial vertebrate species.*

Uncertainty factors used by the Army were carried through to the cleanup level development process. The Army applied uncertainty factors to the Low Toxicity Benchmark Value ("TBV_{low}") only, as agreed to in discussions with the regulatory agencies. An additional factor of 10 was added by the Trust to convert from a LD50 to a No Observed Adverse Effects Level ("NOAEL") (see Response to Comment 5). In assessing RTE species, TBVs were further evaluated (see Sections 5.8.2 and 5.9.2 of the text). A table that describes the uncertainty factors is presented below. This table and the accompanying text have been added to Section 5.5.2 of the document.

Insert for Section 5.5.2, 2nd paragraph, following sentence 4: "Uncertainty factors ("UFs") developed by the Army are shown in the table below. UFs were used to convert all toxicity endpoints to chronic NOAELs based on sensitive endpoints (e.g., growth, reproduction, development)."

Insert for Section 5.5.2, following 2nd paragraph:

"Uncertainty Factors Used in the Calculation of TBV_{low} values (a)

Type of UF	UF	Comments
Study Duration	5	Converts acute to chronic
	2	Converts subchronic to chronic
Endpoint	2	Converts from less to more sensitive endpoint
	5	Converts LOAEL to NOAEL
	10	Converts LD50 to NOAEL (Army)
	10	Additional factor 10 for mortality endpoints (LD50s) was applied to <u>both</u> the TBV_{low} and TBV_{high} by the Trust
Intertaxon	3	Converts between species in same family, different genus
	4	Converts between species in same order, different families
	5	Converts between species in different orders
	10	Converts between species in different orders with an additional factor of 2 for special-status species (raptors)

(a) Uncertainty factors were those developed by the Army, except where noted.

4. *HERD agrees that '...complete or potentially complete exposure pathways should be evaluated quantitatively.' (Section 5.3, page 5-5). We agree that dermal exposure should be evaluated (Section 5.3.1, page 5-6) for terrestrial receptors. Dermal uptake of pesticides has been shown to be significant for raptors in certain exposure scenarios and should be considered for inclusion on a site by site basis.*

   As indicated in Section 5.3.1 and 5.3.2, the dermal contact pathway was included in the development of the ecological PRGs.

5. *HERD will require additional time to evaluate the Toxicity Based Value-High (TBV $_{high}$) values proposed by the Presidio Trust as cleanup concentrations. Toxicity experiments which reflect a lethal dose for 50 percent of the animals exposed (LD $_{50}$) are unacceptable to HERD without incorporation of uncertainty factors for definition of areas of ecological concern. For Contaminants of Concern (COCs) where the Biological Technical Assistance Group (BTAG) / Navy Toxicity Reference Values (TRVs) are used, the description of the level of concern is incorrect (Section 5.5, page 5-7). BTAG/NAVY TRV $_{high}$ values are meant to indicate an [sic] dose which would be a high level of concern to regulatory agencies and natural resource trustees.*

   Dr. Polisini was contacted by email several times to request an estimate of when the HERD evaluation will be completed. Given the extent of discussions throughout the winter and spring of 2002 regarding ecological cleanup levels, which culminated in an agreement on the values as presented in Tables 5-24 and 7-2 of the revised Cleanup Level Document, the Trust assumes that no further review of the TBVs is warranted.

   Uncertainty factors used by the Army included a factor of 10 to convert from a LD50 to a NOAEL (see Response to Comment 3). An additional factor of 10 was added by the Trust (see Section 5.5.2 of the text). The Trust added this factor to both the TBV_{low} and TBV_{high}. The text in Section 5.5 that describes the level of concern associated with the TBV_{high} will be revised as follows:

   "According to the Army, the TBV_{high} was developed to represent the upper bound of 'acceptable or safe daily intakes'. Where BTAG high toxicity values (PRC, 1997) were used, the TBV_{high} is considered a level of high concern to regulatory agencies and natural resource trustees."

6. *Please provide the reference for use of an uncertainty factor (UF) of 10 for TBVs based on mortality (Section 5.5.2, page 5-9) to convert the TBV to a Lowest Observable Adverse Effect Level (LOAEL). HERD would normally require a UF*

greater than 10 for adjustment of mortality endpoints unless chemical-specific information is available regarding the dose-response curve.

See Responses to Comments 3 and 5. An additional factor of 10 was added for mortality endpoints (Section 5.5.2), making the total UF 100 for the TBV_{low} and 10 for the TBV_{high}.

7. *Please provide the source of the information used to set the dietary intake factors (Section 5.7.1, page 5-13) for terrestrial vertebrate receptors. If the dietary intake factor is meant to indicate the most conservative assumption, based on best scientific judgement, please indicate that in the text.*

   Dietary intake factors developed by the Army were used. These values were 95th percentiles of data presented by USEPA (1993), as indicated in Section 5.7 (first bullet).

8. *Please provide the citations and scientific support for assuming the Bioaccumulation Factor (BAF) of 2 for invertebrates, 1 for birds, 0.5 omnivorous mammals and 0.1 for herbivorous mammals (Section 5.7.2, page 5-14) for pesticide and herbicide COCs without published BAFs.*

   Not all chemicals evaluated had BAF values readily available from the literature. For these chemicals, the approach was to assign default BAF values for these chemicals, rather than not evaluating the food chain pathways and documenting uncertainties. Chemicals without BAFs included the following pesticides/herbicides: alpha-, beta-, delta-, and gamma-BHC, dicamba, endosulfan, endosulfan sulfate, endrin, endrin aldehyde, endrin ketone, MCPP, and methoxychlor. To set default values, the median of the available BAFs for pesticides/herbicides was calculated and a default value set based on the results of that calculation as shown in the table below. This table has been added to the footnotes of Table 5-11.

Calculation of BAFs for chemicals without literature based BAFs

Potential Chemical of Concern	Bioaccumulation Factor (unitless)				
	Plant	Soil Invertebrate	Bird	Mammal Omnivore	Mammal Herbivore
Pesticides/herbicides with BAFs					
Dieldrin	0.03	4.29	0.477	0.02	0.02
Chlordane	0.02	5	0.352	0.04	0.04
4,4'-DDT	0.01	1.98	0.905	0.45	0.45
Heptachlor	0.086	1.67	2.25	0.11	0.11
Statistics					
Range	0.01-0.09	1.67-5	0.35-2.25	0.02-0.45	0.02-0.45
Median	0.025	3.135	0.691	0.075	0.075
Assumed BAFs (for chemicals with no literature BAF)	**0 (a)**	**3 (b)**	**1 (c)**	**0.5 (d)**	**0.1 (e)**

(a) Assumed to be 0 based on BAFs for other pesticides all below 0.1.
(b) Assumed to be 3 based on median BAF for other pesticides of 3.1.
(c) Assumed to be 1 based on median BAF for other pesticides of 0.7.
(d) Assumed to be 0.5 based on median BAF for other pesticides of 0.075 and conservative assumption that omnivores should have a higher BAF.
(e) Assumed to be 0.1 based on median BAF for other pesticides of 0.075.

As a result of re-evaluation of these values, the soil invertebrate BAF has been revised from 2 to 3. This change is reflected in the cleanup level derivation tables.

9. *Using the arithmetic mean of the Ecological Preliminary Remediation Goal-Low (PRG_{low}) and the PRG_{high} (Section 5.8.1, page 5-14) for non-RTE species would seem to eliminate information which would be useful to the risk manager. At several Department of Defense (DoD) sites in the San Francisco area, the difference in area considered for remedial action was small when areas based on the PRG_{low} were compared to areas based on the PRG_{high}. The areas identified as areas of concern based on both the PRG_{low} and the PRG_{high} should be presented for evaluation by the risk managers.*

The Trust recognizes the DTSC's rationale for recommending a site-by-site assessment of the PRG_{low} and PRG_{high} as part of the decision making process. To assist in the risk manager's assessment, the Trust has prepared a new Table 7-2 that includes PRG_{low}, PRG_{high}, and PRG_{mean} for both plant and soil fauna and wildlife receptors. This table shows the proposed buffer zone PRGs and proposed special status species PRGs, as well as human health proposed PRGs and background metals concentrations. The Trust feels the risk manager has the necessary data to evaluate cleanup level selection with this table.

In further discussions with the DTSC, the Trust agreed to significantly modify the ecological PRGs originally presented in the Cleanup Level Document, as described in new Section 5.10 of the revised Cleanup Level Document. The modified values are presented in Tables 5-24 and 7-2 and are described below:

- The areas of the Presidio where non-special status species PRGs would be applied were renamed "buffer zone" areas because these areas are generally adjacent to special status species areas and developed areas of the Presidio where ecological PRGs are not applicable (see Section 7.1.2 and Figure 7-2). Proposed soil PRGs for these buffer zone areas were redefined as the lowest value of (1) the special status species PRG identified in Table 5-21, (2) the arithmetic mean of the PRG_{low} and PRG_{high} for plant and soil fauna, (3) the arithmetic mean of the PRG_{low} and PRG_{high} wildlife PRGs, or (4) 5 mg/kg for pesticides or herbicides for which not enough toxicological data exists to calculate a PRG_{low} and PRG_{high} (i.e., 2,4-D, Dicamba, and MCPP).

- Special status species PRGs were redefined as the lower value of (1) the PRG_{low} for plant and soil fauna or (2) the PRG_{low} for wildlife, unless the PRG_{low} is less than the laboratory method detection limit. In such cases, the method detection limit was established as the special status species PRG. If no PRG could be calculated for pesticides or herbicides due to a lack of toxicological data (i.e., 2,4-D, Dicamba, and MCPP), the special status species PRG was established as the method detection limit. For mercury, the special status species PRG was established as two times the typical method detection limit.

10. *The table listing the uncertainty factors (UFs) applied in development of the TBV_{low} and TBV_{high} for vertebrate receptors (Table 5-4) refers to Table 5-9 as the source of the varying uncertainty factors used in footnote a. Table 5-9 provides the formulae for calculation of the PRG, but does not outline the strategy for using differing UFs. The UFs appear to follow a taxonomic pattern. Please provide this information regarding the UFs.*

Footnote (a) has been revised as follows: "Toxicity values are obtained from studies described in Table 5-3; uncertainty factors are discussed in Section 5.5."

11. *The TBV $_{low}$ and TBV $_{high}$ do not appear to follow a similar pattern across the differing taxonomic groups of representative species (Tables 5-5 and 5-6). The TBV $_{low}$ for arsenic, as an example, for the western harvest mouse is 1.27 mg/kg-day and for the valley pocket gopher is 0.95 mg/kg-day. This difference can be arithmetically tracked back to the differing UFs (Table 5-4). The TBV $_{high}$ for these two species is 22.5 mg/kg-day (Table 5-6) respectively. It is difficult to believe that a varying UF is appropriate for the TBV $_{low}$ but not for the TBV $_{high}$.*

As discussed in Response to Comment 3, the Army applied uncertainty factors to the TBV_{low} only, as agreed to in discussions with the regulatory agencies. The following footnotes have been added to Tables 5-5 and 5-6:

Table 5-5: "Low toxicity values incorporate uncertainty factors, as discussed in Section 5.5."
Table 5-6: "With the exception of the factor of 10 used for toxicity values based on mortality endpoints, high toxicity values do not incorporate the use of uncertainty factors (see Section 5.5)."

12. *The tables comparing the Preliminary Remediation Goals (PRGs) for non-special status species and special status species are somewhat confusing (e.g., Table 5-21). Footnote 'c', which refers to the column labeled 'Special Status PRGS Proposed for Use as Cleanup Levels', states that Non-special status species can be more sensitive to some of the potential chemicals of concern ("PCOCs") evaluated. For PCOCs where special status PRGs are not proposed as cleanup levels, soil PRGs for non-special status species will be applied as cleanup levels for protection of special status species as well." First, HERD does not agree that special status species can be categorized as less sensitive than non-special status species. Toxicological tests are not performed and special status species because of their listing, and therefore an apparent difference in PRGs may be an illusion based on the life history parameters. Second, use of a non-special species PRG as protective of special status species would be appropriate only if it is demonstrated that the range of seed dispersal for plants and the home range for vertebrates could not overlap from the current distribution of special status species onto the area where non-special species PRGs are proposed.*

For some chemicals, non-special status PRGs were lower than those for special status species. For example, for many chemicals, aquatic life toxicity values for sediment (Tables 5-7 and 5-8) were below the sediment PRGs for western sandpiper presented

in Table 5-20. In these cases, the final PRGs were the aquatic life values and not the higher western sandpiper values.

Footnotes [(c) on Table 5-21 and (b) on Tables 5-22 and 5-23] have been revised to clarify as follows: "PRGs for special status species that are proposed as soil/sediment PRGs for special status species. Receptors that are not special status species may have lower PRGs because of higher exposure or different sensitivity to potential chemicals of concern ("PCOCs"). For PCOCs where special status PRGs are not the lowest PRGs, soil/sediment PRGs for non-special status species will be applied as cleanup levels and considered protective of special status species as well."

The text in Section 5.8.2 has also been modified (5th paragraph 4th sentence) as follows: "Non-special status PRGs may be lower for some of the PCOCs evaluated because (1) the non-special status species evaluated may have higher exposure to chemicals than the special status species (e.g., American robin vs. peregrine falcon), or (2) the toxicity value for a non-special status species for a particular chemical is lower (e.g., mammal vs. bird toxicity values)."

The comment also discusses the issue of seed dispersal and the home range of special status species. The concern is the application of non-special status PRGs to sites and whether special status plants or wildlife, although not currently present at the site, be exposed to chemicals there in the future due to seed dispersal or expansion of their home range. It should be noted that most areas surrounding specific sites are not contaminated areas (see new Figure 2-2). Therefore, there is already a "buffer zone" of clean material around most, if not all sites. In addition, Figure 7-2 has been revised to depict areas where special status cleanup levels will be applied. As shown on Figure 7-2, special status species PRGs are applicable to the "undeveloped" areas of the Presidio and areas *planned* for habitat restoration (e.g., near the Baker Beach Apartments). Landscaped areas like the golf course, the cemetery, and the restored airfield at Crissy Field have been established as "buffer zone" ecological areas (Figure 7-2). These delineations on the map coupled with the revised, more stringent cleanup levels (the "buffer zone" PRGs are based on the old special status values) should address the issue of potential seed dispersion and expanded home ranges.

13. *Please indicate whether the figure presenting the surface distribution of the primary soil types of serpentinite, Colma Formation, and beach/dune (Section 6.1, page 6-1), and the five secondary geological units (Figure 6-1) has been 'ground truthed'. By this we mean, have the proposed boundaries between different soil types been checked to determine if the field observations by a registered geologist agree with the figure.*

The boundaries of the map have not been specifically ground-truthed. However, when environmental samples are collected at a Presidio site, the soil lithology is logged under the oversight of a registered geologist. The soil type at a given site may vary spatially, as a function of depth, or due the presence of fill. Figure 6-1 is intended to be used as a starting point to identify the site lithology. The actual field observations are used to determine site lithology. The text has been modified to this effect.

14. *Please identify the Department of Toxic Substance Control (DTSC) document in which it was agreed that selected site data could be included in the 'background' data set (Section 6.2.2, page 6-5) and agreement to the 'background' threshold levels (Section 6.2.4, page 6-7). This reviewer is unable to locate any member of HERD who reviewed the methodology or data used to set the 'background' concentrations.*

    The Trust held a series of meetings (6 meetings, 4 conference calls) with the DTSC RPM (Robert Boggs), the RWQCB RPM, a representative of the NPS, and members of the Restoration Advisory Board ("RAB") to identify which site data were appropriate and to develop the methodology for calculating background screening and threshold levels. It was the Trust's understanding that the DTSC RPM was conferring with technical staff at HERD throughout this process. The agreement on the data set and the screening and threshold levels was made verbally during these meetings, after the DTSC had the opportunity to review all data, relevant scatter plots, and tables with results of calculations.

15. *A footnote annotation of '2' appears in the text with no footnote (Section 6.2.3, page 6-6) on the third line of the page. Please include the appropriate footnote referring the 95 percent upper confidence level of the 80th percentile of the data set used for screening levels.*

    The footnotes have been renumbered to accurately reflect the item to which they refer.

16. *Please define the term 'common detection limit' as one method of establishing the 'background' threshold levels by soil type (Section 6.2.5, page 6-8).*

    The "common detection limit" is the reporting limit typically achieved by analytical laboratories that have analyzed soil samples at the Presidio. During the series of meetings discussed in the response to Comment 14, the Trust, DTSC, and other stakeholders agreed on the "common detection limit" for metals that were generally

not detected above the laboratory reporting limit. A footnote has been added to the text clarifying the meaning of the common detection limit.

17. *The declaration that hexavalent chromium is 'naturally occurring' in groundwater and surface water at the Presidio of San Francisco (Section 6.4, pages 6-9 through 6-12) due to serpentinite soils is unconvincing. This mechanism has not been proposed to explain hexavalent chromium at DoD sites in the San Francisco Bay area. HERD defers to the DTSC Geological Services Unit regarding this explanation for hexavalent chromium in groundwater and surface waters.*

    The discussion on the natural occurrence of hexavalent chromium in groundwater is intended to be a summary of available Presidio data that support this hypothesis. These data were presented to Mark Vest and Michael Kenning of DTSC's Geological Services Unit in a May 2000 meeting. Based on the data presented to the DTSC in May 2000 (which are summarized in Section 6.4 of the Cleanup Level Document), the DTSC sent the Trust a letter (dated 13 July 2000) concurring that the hexavalent chromium in groundwater that contacts serpentinite appears to be naturally occurring.

18. *The detection limit of 3.0 mg/kg for antimony (Table 6-1), which is adopted as the screening level and threshold level concentration, appears elevated. In comparison the most recent 'background' soil study, performed for the BRAC Property at Hamilton Army Airfield, lists a minimum detected value of 0.06 mg/kg (Table 6-6) and the California Soils study (Bradford, et al., 1996) achieved detected concentrations of antimony at 0.15 mg/kg. Please explain the reason for the apparently elevated antimony detection limits at the Presidio of San Francisco.*

    The actual detection limits for antimony from the Hamilton Field data range from 0.06 to 19.6 mg/kg. EKI contacted Dr. Carla Kagel of KPrime Inc., a consulting and analytical laboratory in Santa Rosa, who indicated that a low detection limit of 0.06 mg/kg for antimony probably reflected a calculation error or could not be supported if the backup data were requested.

    The Trust understands that a detection limit of less than 1 mg/kg is not routinely achievable. Under specialized conditions in a research setting, i.e., the conditions under which Bradford generated his California Soils data using ICP-MS, a detection limit of 0.15 mg/kg is likely the best detection limit achievable. For standard, commercial laboratory analyses, these low detection limits are not commonly achieved. This is reflected in the fact that a range of detection limits was produced for the existing data. A detection limit of 3 mg/kg was selected as typically achievable for antimony with the concurrence of representatives from the DTSC, RWQCB, NPS, and RAB.

19. *A bicoordinate plot of barium and manganese concentrations is offered as an example of the data evaluation methods employed to set the 'background' soil concentrations for the differing major and secondary soil types (Figure 6-2). The outlier value for barium and manganese is fairly obvious. However, all of the 'background' samples appear to lie at the lower concentrations of the proposed relationship, while the site-related samples cover the entire range and no 'background' barium or manganese concentrations appear to exceed 20 mg/kg for barium and 300 mg/kg for manganese. Please explain the apparent discrepancy between site-related and 'background' data for whichever soil type of which this is an example.*

    Based on the discussions during the 12 December 2001 teleconference, the Trust understands that DTSC is concerned that this Figure 6-2 does not support the argument the text is trying to make about outliers from the trend. Another figure that more clearly demonstrates outliers has been substituted in its place.

20. *Future land use which is not evaluated based on the residential use scenario (Section 7.1.1, page 7-1) must have a deed restriction in place restricting that area to recreational, institutional or industrial uses.*

    The Trust agrees that residential use is not appropriate for sites that are evaluated and/or remediated based on recreational or commercial/industrial cleanup levels. The Trust anticipates implementing institutional controls at locations where residual chemical concentrations exceed residential cleanup levels or in other cases where residual chemicals are left in place. However, Trust policy does not allow the use of deed restrictions or land use covenants; rather, the Trust adopts and enforces institutional controls through the implementation of land use restrictions. These land use restrictions are incorporated into the Trust's planning documents (e.g., the Presidio Trust Management Plan) and the Trust's leasing documents. For example, the Trust's Rules for Non-Residential Use and Occupancy, which must be followed by tenants at the non-residential buildings, states "Residency in or overnight use and occupancy of any portion of Buildings is strictly prohibited, unless specifically authorized in advance by the Trust."

    In addition, the Trust will prepare a Presidio-wide Institutional Control Management Plan ("ICMP"). A separate Institutional Control Plan ("ICP") will be prepared for each individual site that requires institutional controls. The ICP will include a figure depicting the site location and area and will summarize the specific COCs encountered at a site, the actions taken to remediate the site, and the levels of COCs remaining at the site that required the implementation of ICs. In addition, these ICPs

will discuss unallowed land uses at the site and any special requirements if residual chemicals are left in place in an inaccessible area (e.g., health and safety requirements if the area is disturbed in the future). The individual ICPs will become an attachment to the Trust's ICMP. As such, the ICMP will effectively be a "working document", supplemented with additional information as it becomes available.

21. *Concurrence should be obtained from State and Federal natural resource trustees regarding areas where '... a new site is identified in an area that is not currently designated for ecological cleanup levels on Figure 2...' (Section 7.1.2, page 7-3). Crissy field was once a paved site, prior to conversion to a wetland.*

    The identification of sites that may be classified as buffer zone or special status ecological has been simplified by creating a map (Figure 7-2) that delineates such areas. As discussed above in the response to comment #12, special status species PRGs are applicable to the "undeveloped" areas of the Presidio and areas planned for habitat restoration (e.g., near the Baker Beach Apartments). Landscaped areas like the golf course, the cemetery, and the restored airfield at Crissy Field have been established as "buffer zone" ecological areas (Figure 7-2). This map was developed using the NPS and Trust's Vegetation Management Plan, which identifies zones that correlate to ecological land uses. The Native Plant Communities Zone, Historic Forest Zone, and Special Management Zone were all established as ecological special status species areas. The remaining zone (Landscape Vegetation Zone) was established as either a buffer zone area or as non-ecological, depending on the specific area. In the event that Trust or NPS natural resource staff indicate that a site should be classified differently, State and Federal natural resource trustees will be consulted, as appropriate.

22. *Species listed as California Species of Special Concern by the California Department of Fish and Game should be included in the definition of 'special status species' in footnote 5 (Section 7.1.2, page 7-3).*

    The footnote in Section 7.1.2 has been modified to include California Species of Special Concern as defined by the California Department of Fish and Game; these species are also identified in Table 5-2.

23. *Please insert the word <u>inorganic</u> in the fourth line of the last paragraph to read '... remediated to concentration below <u>inorganic</u> background levels.' (Section 7.3, page 7-4).*

    The text has been modified to include the word "inorganic" in the fourth line of the referenced paragraph.

24. *Evaluation of Firing Range sites (Section 7.3, page 7-5) may require evaluation of the percentage of bulk lead pellets in addition to consideration of the lead soil concentration. Please advise HERD of the evaluation of Firing Range sites and the 'discovery' of additional Firing Range sites.*

    The Trust is planning to work with DTSC staff when it evaluates data from the Firing Range sites. The Trust would not proceed with the evaluation of Firing Ranges without DTSC input.

25. *HERD is not concerned about levels set in the Toxic Substance Control Act (TSCA) when assessing risk or hazard (Section 7.3.1, page 7-6). Residential areas with soil concentrations of lead at 370 mg/kg should be deed restricted to exclude the home grown produce/fruit pathway and generation of fugitive dusts. Based on the HERD lead spreadsheet, HERD would recommend a maximum soil lead concentration of approximately 170 mg/kg to 180 mg/kg based on site specific criteria (e.g., tap water lead concentration) for unrestricted use.*

    The residential lead preliminary remediation goal ("PRG") calculated in Section 4.2.10 accounts for potential exposure to lead in soil, water, air, food, and fugitive dust. The text (Section 4.2.10) has been clarified to say that the calculation includes inhalation of lead in fugitive dust.

    With regard to the home grown produce pathway, landscaping at the Presidio is maintained by the Trust; in-ground planting of vegetation by residents and tenants at the Presidio is prohibited in its lease agreements. The Trust and NPS control plantings at the Presidio because of their efforts to restore native plants and maintain historic plantings, as described in the Vegetation Management Plan, (NPS and Trust, May 2001). A copy of the Presidio Trust's planting guidelines for residents is attached. Presidio residents are required to follow these guidelines in accordance with their lease agreements. Thus, land use restrictions preventing in-ground planting of home grown produce are already in place. A footnote has been added to Section 4.2.10 that states: "Use restrictions prohibiting the in-ground planting of home grown produce are already in place at the Presidio."

    Accounting for the above comments, the PRG of 370 mg/kg for lead in soil is appropriate for residential sites at the Presidio. Because 370 mg/kg is so close to the TSCA value of 400 mg/kg, the DTSC RPM agreed that from a risk management perspective, it was appropriate to use 400 mg/kg as a not-to-exceed value and 370 mg/kg as the maximum average value for lead at residential sites.

26. *The presentation of the multiple HERD spreadsheets regarding the analysis for lead (Appendix A) is confusing. The heading of the second spreadsheet is 'Blood Lead Concentration for Exposure of Children to Background Lead in Air, Water and Food Under a Recreational Scenario'. However, the percent of home-grown produce is set at zero percent. This second spreadsheet cannot present the exposure from home-grown produce. The lead in soil and dust in this second sheet is set at 0.0 µg/g. Lead in soil and dust is included in the third spreadsheet (Appendix A) with a heading of 'Blood Lead Concentration for Exposure of Children to Background Lead Soil Under a Recreational Scenario', but no other pathways are addressed. Please provide a spreadsheet table which sums all the exposure pathways for the recreational scenario.*

Multiple spreadsheets are used for lead for the recreational exposure scenario because the calculation cannot be completed on one spreadsheet. Former Table 4-6 (now renumbered as Table 4–8) summarizes all of the exposure pathways for the recreational scenario. This table has been added to Appendix A as new Table A–1 to facilitate review of the appendix. As summarized in Table A-1, the first spreadsheet addresses background exposures of the general population to lead in air, water, and food (which occurs 7 days a week, and is the same whether at the Presidio or in other parts of San Francisco).[1] The second spreadsheet quantifies the blood lead concentration due to background exposure to lead in soil when NOT at the Presidio (i.e., four days per week). As described in Section 4.2.10, a background lead value of 66 mg/kg was derived for serpentinite at the Presidio. This concentration may be found as background in other parts of San Francisco and, therefore, is used for the second spreadsheet. Based on the background exposures calculated in spreadsheets 1 and 2, the total blood lead concentration for background exposures is 5.4 µg/dl. Thus, there is a remaining 4.6 µg/dl blood lead concentration that can be attributed to a potential exposure of recreational users to lead in soil (including ingestion and inhalation of fugitive dust) three days a week at the Presidio. The lead concentration in soil corresponding to a blood lead concentration of 4.6 µg/dl is calculated to be 510 mg/kg in the third spreadsheet.

As described in the response to Comment 25, lead in home grown produce is not applicable to potential exposures to lead at the Presidio. For the recreational use scenario, off-site exposure to lead in food is assumed to be limited to "purchased" food because the majority of the regular recreational users of the Presidio are San Francisco residents. Urban populations are not likely to obtain a significant portion of their diet from homegrown produce.

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[1] The lead concentration in tap water was not adjusted to the Presidio value for the recreational user because the recreational user may not drink Presidio water while participating in recreational activities at the Presidio. The lead concentration in tap water for the recreational user was therefore set at the default value of 15 µg/L.

27. *While an example of the outlier testing for 'background' concentrations is provided (Figure 6-2), some of the data sets for 'background' (Appendix D [sic]) contain samples which appear to be outliers for some elements. For example, for the Chert/Shale Lithology (Table C-3) the chromium concentration in sample 950CT002 is 52 mg/kg and BBKGDSB03 is 48.4 mg/kg. The next highest chromium concentration is 11.9 mg/kg at 950SH002 for Chert/Shale. Please identify any samples which were judged to be outliers and eliminated from determination of 'background' concentration in these tables (Tables C-1 through C-4).*

    All outliers were eliminated prior to the compilation of Tables C-1 through C-4. These tables present the data set that was agreed upon by representatives of DTSC, RWQCB, NPS, RAB, and the Trust based on the review of such scatter plots for the fit of the data to multiple chemical distributions, not just that for the range of concentrations of one chemical. Outliers were generally identified when the concentration fell outside the main mass of data or were not on the chemical distribution trend line. The referenced chromium data fall within the data trend lines for chromium and the other metals.

Comments from Dr. Kimiko Klein's Memorandum Dated 26 October 2001

General Comments

The HERD has two editorial comments. First, the numbering of the footnotes in this document is confusing. For example, on page 4-7 of Section 4, there is a footnote designated as footnote "2", but there is apparently no footnote "1". On page 6-7 of Section 6, there is a notation in the text for footnote "2", but there is no explanatory footnote for that notation, and there is no footnote "1" or "4". The numbering of the footnotes should be clarified or corrected. Second, reference is made throughout the text to various study areas, such as "Fill Site 1", "Building 1750", the "Nike facility", etc. However, there is no figure depicting all of these study areas in the document. Such a figure should be included and used as a citation when these study areas are discussed in the text.

The Trust revised the numbering of the footnotes as requested. A new figure, Figure 2-2, has been added to Section 2 that identifies the known sites in the operable units being addressed by the Presidio Trust.

Specific Comments

1. *Page 3-1 Section 3.1 Potential Chemical-Specific ARARS for Water; and Table 3-1 Numeric Values of Potential Chemical-Specific ARARs for Presidio Sites: a) Table 3-1 includes Applicable or Relevant and Appropriate Requirements (ARARs) for water from several different sources. The text summarizes these ARARs. However, the table contains a list of Maximum Contaminant Level Goals (MCLGs) which are not defined or discussed in the text. Since MCLGs are risk-based values, they should be discussed in the text. b) The drinking water standards for copper and lead are listed as MCLs. However, a footnote should be added to each, identifying the values for these metals as "Action Levels". c) A paragraph should be added to Section 3.1 briefly discussing the Public Health Goal for chromium published by the Office of Environmental Health Hazard Assessment (OEHHA) of the California Environmental Protection Agency (Cal/EPA) with regard to the oral carcinogenicity of hexavalent chromium. A footnote should also be included on Table 3-1.*

   (a) A brief discussion of Maximum Contaminant Level Goals ("MCLGs") has been added to the text in Section 3.1. (b) The footnotes to Table 3-1 have been re-organized to better clarify that the copper and lead values are Action Levels. (c) Additional information about the Public Health Goal for chromium has been included in Section 3.1.

2. *Page 4-2 Section 4.2.2 Potential Human Health Exposure Pathways: According to the text, less than two percent of the potential total exposure to potential chemicals of concern, metals and polycyclic aromatic hydrocarbons (PAHs), is via inhalation. Therefore, the inhalation exposure pathway is not included in the estimation of cleanup goals. a) Summarize the supporting documentation for this statement and provide a citation. b) For those areas of the site where large construction projects will occur, the inhalation of the increased dust generated may pose a risk. Therefore, in those areas, inhalation exposure of construction workers may have to be evaluated. c) Inhalation of vapors is an exceedingly important route of exposure for volatile chemicals and must be evaluated for the volatile chemicals listed in the tables of preliminary remediation goals in this section as well as the tables in Section 7.*

   (a) EKI calculated the residential PRG for arsenic including and excluding the inhalation pathway. Arsenic is a conservative test case because it is significantly more toxic via the inhalation route compared with the oral route (i.e., slope factor of 12 $(mg/kg\text{-}day)^{-1}$ for inhalation versus 1.5 $(mg/kg\text{-}day)^{-1}$ for ingestion). Assuming a fugitive dust concentration of 0.05 mg/m^3 and breathing rates of 10 and 20 m^3/day for children and adults, respectively, the inhalation pathway accounts for 3 percent of the total exposure. For other compounds where the ingestion and inhalation slope factors are the same, the inhalation

pathway comprises less than 1 percent of the exposure. The text in Section 4.2.2 has been changed to say that inhalation is estimated to be less than 3 percent of the total exposure to PCOCs and a footnote has been added summarizing the documentation presented above.

(b) EKI agrees that under the construction scenario, inhalation of fugitive dust can play a more significant role in exposure than for the residential and recreational scenarios. However, the residential and recreational cleanup levels being used throughout the Presidio should also be protective of construction workers (i.e., residential and recreational cleanup levels are applicable at all areas where potential future large construction projects would occur; commercial/industrial cleanup levels are only applicable at the water treatment plant and at Building 1750). Using arsenic as the test case, with a fugitive dust concentration of 1 mg/m^3, a soil ingestion rate of 480 mg/day, and a 1-year exposure duration, the inhalation pathway accounts for 20 percent of the total exposure to arsenic. The resulting arsenic PRG for this hypothetical construction scenario is 7.8 mg/kg. The residential and recreational PRGs calculated in the Cleanup Level Document are 0.36 and 0.88 mg/kg, respectively. These are both more stringent than the value calculated above for construction workers. Similarly, for non-carcinogens, such as mercury, the inhalation exposure under the construction scenario described above accounts for approximately 12 percent of the total exposure. The hypothetical construction PRG for mercury is 60 mg/kg, which is less stringent than the respective residential and recreational PRGs of 20 and 52 mg/kg. Based on the evaluation presented herein, no modification to the text or cleanup levels is proposed.

(c) The Trust recognizes the inhalation of vapors is an important exposure route for volatile chemicals. However, as discussed at the 12 December 2001 meeting, VOCs generally have not been detected in soil samples at the Presidio, with the exception of Crissy Field. Therefore, a protective set of screening levels has been added to the Cleanup Level Document to replace the residential and commercial/industrial cleanup levels for VOCs. The screening levels were based on the RWQCB Risk-Based Screening Levels ("RBSLs"), using lookup tables for available chemicals, and calculating values using the same assumptions for chemicals not listed in the RBSL guidance document. Available values came from the RBSL Table E-1a, Vadose-Zone Soil Screening Levels for Protection of Indoor Air Quality, assuming course soils Copies of the Johnson and Ettinger model output (version 2.3, 3/01) are included as a new Appendix E.

In addition, in response to your comment #8 and a request by the RWQCB, the PRGs for VOCs were modified to also consider protection of groundwater

through leaching. The Trust assessed the leaching pathway for VOCs through the use of the RBSLs. Tables 4-3, 4-4, and 4-5 have been revised to direct the reader to new Table 4-6, where potential impacts of indoor air exposures are calculated to generate human health PRGs for VOCs. These values are transferred to new Table 4-7, where the combined direct contact/indoor air PRGs are compared to the RBSLs for groundwater protection. The most stringent values are retained as the human health PRG in Table 4-7 and are carried forward to Table 7-2.

Recognizing that the PRGs calculated for indoor air and groundwater protection are not site-specific, the text states that if VOCs are found at a Presidio site, VOC cleanup levels may be re-calculated to be site-specific. Factors that could affect a site-specific calculation include the type of soil, depth to groundwater, presence of buildings, and number and concentrations of VOCs present in soil, among others. Any recalculation of PRGs for VOCs would be conducted in conjunction with discussions with regulatory agencies.

3. *Page 4-2, Section 4.2.2 Potential Human Health Exposure Pathways: The ingestion of groundwater, surface water, and organisms inhabiting surface water bodies will be accounted for by adoption of chemical-specific ARARs as cleanup levels. The ARARs for ingestion by humans of groundwater or surface water will be MCLs. MCLs are not risk-based levels. As stated in Specific Comment one above, MCLGs are based on risk. MCLGs for specific carcinogens are usually set to zero and for non-carcinogens on a Hazard Index of one. Therefore, a discussion should be added to this section explaining the risk consequences of the application of MCLs and explaining the approach that will be used to clean up to an overall target risk level and/or Hazard Index if the ground or surface water contains multiple chemicals of concern.*

The Trust has added text to state the following: "The ARARs being used as cleanup levels include MCLs and aquatic criteria for protection of human health, where applicable. Although MCLs are not explicitly risk-based numbers like MCLGs, they are set as close to MCLGs as feasible using the best available treatment technology and taking cost into consideration. The aquatic criteria for protection of human health are risk-based values that include ingestion of water and consumption of aquatic organisms."

It should be noted that all of the cleanup levels are based on a target risk level applied to each chemical; the cleanup levels do not directly consider cumulative effects. The target risk levels are discussed in Sections 4.2.3 through 4.2.5 of the Cleanup Level Document. This approach is considered to be protective because there are typically only a few chemicals driving the cleanup at a given site.

4. *Page 4-5, Section 4.2.6 Human Health Toxicity Values: Copper is listed as a chemical for which no published toxicity values were found. However, the US EPA Region 9 office lists a copper oral Reference Dose (RfD) from the Health Effects Assessment Summary Tables (HEAST). This RfD should be used to calculate a human-health-based cleanup level for copper in soil and water. The uncertainty of using this RfD may be discussed in the text.*

   The reference dose for copper (0.037 mg/kg-day) included in the U.S. EPA Region IX PRG tables is reportedly based on a value from HEAST. However, the value in the PRG tables appears to be calculated from the drinking water standard of 1.3 mg/L, which is presented in HEAST. HEAST states that the "toxicity data were inadequate for calculation of an RfD for copper." Thus, it seems inappropriate to use the value in HEAST to calculate a PRG for copper. The following footnote has been added to Tables 4-3 through 4-5 to clarify the toxicity information available for copper: "According to HEAST, the toxicity data for copper are inadequate for calculation of an RfD."

   At the 12 December 2002 meeting, the DTSC asked the Trust to review the basis of the copper drinking water standard. If the standard was based on impacts to organolipids, then the DTSC recommended calculating a cleanup level using the approach in the Region IX PRG tables. According to the 18 August 1988 Federal Register that discusses the basis for the Lead and Copper Rule, "acute exposure to high copper levels in test animals and humans can cause gastrointestinal disturbances, liver damage, renal damage, hemolytic anemia, and glucose-6-phosphate dehydrogenase (G6PD) inhibition. Chronic toxicity data are limited." The Federal Register further states that people with Wilson's disease, an inborn error in copper metabolism, and individuals with existing G6PD deficiencies are at risk of experiencing toxic effects from copper exposure. Considering the impacts described in the Federal Register, a cleanup level for copper was not derived.

5. *Page 4-6, Section 4.2.9 Human Health PRGs for Potential Chemicals of Concern (PCOCs) Other than Lead in Soil: This section does not mention how these PRGs will be used at the site. The HERD stresses that human health remediation goals for soil applies to soils to a depth of ten feet below ground surface. Soils contaminated below ten feet may still require remediation based on other objectives, such as, protection of groundwater resources.*

   The Trust agrees that cleanup levels should be applied to a depth of 10 feet below ground surface. The text in Section 7.1.1 has been revised.

6. *Page 4-7, Section 4.2.10 Human Health PRGs for Lead in Soil; Appendix A: a) A sentence should be added to this section stating that the lead PRG chosen represents the 99th percentile value and explaining the protective nature of that value. b) The concentration values used in the DTSC Lead Spread Version 7 model are given in this section, and Appendix A contains the lead results from sampling water from the tap in residences on site. The 95 percent upper confidence level of the mean of these results is used in the lead spreadsheets. However, it is not stated in the text or in the appendix whether the water samples represent the first draw of the day or whether water was allowed to run for a certain length of time before samples were collected. A summary of the method used to collect samples should be included in the appendix. For any future sampling of tap water, first draw of the day should be collected and analyzed separately in order to obtain a worst case estimate of the potential impact of plumbing piping and fixtures on lead levels.*

   (a) Text has been added to the first paragraph of Section 4.2.10 stating that the lead PRGs are based on the 99th percentile. Section 4.2.5 presents a discussion of the target risk level for lead (i.e., 10 mg/dl at the 99th percentile). A sentence has been added to Section 4.2.5 explaining that the protective nature of the 99th percentile. (b) The water samples collected by the Trust for lead analysis were from the first draw of the day. A footnote to this effect has been added to Table A-2.

7. *Table 4-1 Exposed Populations and Exposure Pathways Used to Develop PRGs: Ingestion of homegrown produce is not considered in calculating PRGs for this site, because landscaping at the Presidio is maintained by the Presidio Trust (the Trust), and produce grown at the Presidio would be in "community gardens at locations specifically designated by the Trust". Provide information on the criteria that will be used to choose these locations and what precautions will be taken to ensure that produce will not be grown in soil with elevated levels of on-site contaminants.*

   As discussed in the response to Jim Polisini's comment 25, in-ground planting of vegetation by residents and tenants at the Presidio is prohibited through its lease agreements. The Trust and NPS control plantings at the Presidio because of their efforts to restore native plants and maintain historic plantings, as described in the Vegetation Management Plan, (NPS and Trust, May 2001). A copy of the Presidio Trust's planting guidelines for residents is attached. Presidio residents are required to follow these guidelines in accordance with their lease agreements.

   One community garden is located at the Presidio, near Kobbe Terrace. This community garden is not located at a known chemical release site. Currently, the garden has space available in it. If there were a future need for an additional community garden, the Trust would not locate the garden at a known chemical release site. Moreover, due to the Trust and NPS' efforts to restore native plants at the

Presidio, the community garden would likely be planted in raised beds to limit the propagation of non-native plant species.

8. *Figure 4-1 Potential Human Health Exposure Pathways: As depicted in this figure, chemicals in soil may leach to groundwater. However, nowhere in this document is there any summary discussion on any studies or modeling performed to evaluate the leachability of the chemicals found in soil at the Presidio. A discussion should be added to this section on the concentrations of chemicals that can be left in soil and not impact groundwater at levels above their MCLs.*

   A discussion of potential leaching of chemicals in soil to groundwater has been added to Section 4.2.2. In addition, see response to your comment #2. The human health PRGs for VOCs have been modified to consider protection of groundwater resources through leaching (new Table 4-7).

9. *Page 6-1 Section 6.1 Presidio Geology; Figure 6-1 Surface Deposits at the Presidio: The locations and boundaries of the various lithologies or soil types as described in the text and depicted in Figure 6-1 should be verified either before or during remedial activities. This is particularly important, since a different suite of Threshold Levels for inorganic chemicals will be applied to different areas of the site, depending on the lithology.*

   As discussed above, in the response to Jim Polisini's comment 13, the boundaries of the map have not been specifically ground-truthed. However, when environmental samples are collected at a Presidio site, the soil lithology is logged under the oversight of a registered geologist. The soil type at a given site may vary spatially, as a function of depth, or due the presence of fill. Figure 6-1 is intended to be used as a starting point to identify the site lithology. The actual field observations are used to determine site lithology. The text in Section 6.1 has been modified to clarify this point.

10. *Page 6-2, Section 6.1.1 Serpentinite: As stated in this section, chrysotile is a component of serpentinite. However, it should also be stated that chrysotile is a form of asbestos. If areas with exposed serpentinite are subjected to construction or movement of heavy machinery, asbestos fibers and fine particulates containing elevated metal concentrations may be released into the air. Therefore, it should be stated here and in the summary discussion of this document that any health and safety plan will include protective measures preventing potential exposure to these fibers and particulate matter.*

A parenthetical phrase has been added to Section 6.1.1, after "chrysotile", to indicate that chrysotile is a form of asbestos. The Trust agrees that the health and safety plans for workers performing excavations in areas with serpentinite should describe measures to mitigate potential exposures to asbestos and any associated monitoring that would be performed, unless it is shown that asbestos is not present in the serpentinite at the Presidio. However, the Cleanup Level Document will not be modified to discuss health and safety issues because such matters are outside the purview of this document.

11. *Page 6-4 Section 6.1.5 Greenstone; Figure 6-1 Surface Deposits at the Presidio: The text states that greenstone may be present in fill at Area 9 and the Transfer Station sites. Greenstone has naturally elevated levels of some potentially hazardous metals. However, neither greenstone nor these specific locations are identified in Figure 6-1. The figure should be revised to show the probable locations of greenstone-containing fill.*

    A sentence has been added to the text stating that greenstone is not specifically mapped on Figure 6-1; reference is also made to new Figure 2-2 which identifies the locations of the known CERCLA sites at the Presidio. Figure 6-1 has not been modified because the primary greenstone observed at the Presidio is part of the surficial fill, rather than the native soil.

12. *Page 6-7, Section 6.2.3 Determining Metals Screening (PCOC) Levels; Table 6-1 Summary of Background Data, Screening Levels, and Threshold Levels- Serpentinite Soil: The possibility of naturally occurring hexavalent chromium being present in Serpentinite should be addressed either in the text or as a footnote to Table 6-1 with a statement that further discussion appears in Section 6.4.*

    A footnote has been added to Table 6-1 that indicates the concentrations of hexavalent chromium detected in serpentinite bedrock samples. These concentrations have also been added to Section 6.4.2.2.

13. *Page 6-10, Section 6.4.2.2 Serpentinite Geochemistry; Section 6.4.2.3 Leaching Test Results: In Section 6.4.2.2, the text states that hexavalent chromium was detected in bedrock samples, but there is no summary of the concentrations found or the fraction of total chromium present in the hexavalent form. This information should be included in the text. In Section 6.4.2.3, the text states that hexavalent chromium was measured in leachate from the serpentinite samples, but, again, there is no summary of the concentrations found in the leachate or the amount of chromium in the serpentinite. These sections should be revised to include this information.*

The hexavalent chromium studies were performed by Montgomery Watson, on behalf of the Army. The results of their studies are included as new Appendix D to the Cleanup Level Document. Sections 6.4.2.2 and 6.4.2.3 have been revised to refer to the results included in this new appendix.

14. *Page 6-10, Section 6.4.2 Evidence that Serpentinite is a Natural Source of chromium in Water: This section relies on a study performed by Montgomery, Watson entitled "Hexavalent Chromium in Serpentinite Bedrock and Groundwater in Upland Areas" (July 1999) to support the hypothesis that the presence of hexavalent chromium in water at this site is a natural consequence of contact with serpentinite. It is recognized in this section that further assessment will be required to determine if other metals found in water are also naturally occurring and if hexavalent chromium found in other areas have been transported by groundwater flow from serpentinite areas. A DTSC geologist should consulted on any future assessment to be performed, particularly with regard to sampling locations and data collection approaches.*

    The occurrence of hexavalent chromium in non-upland areas will be discussed on a site-by-site basis in the Revised Final Feasibility Study for Main Installation sites. Additional evaluation of the background occurrence of other metals would likely be performed through the groundwater monitoring program established as part of site remedial actions. Such a groundwater monitoring program would be developed in consultation with a DTSC geologist.

15. *Page 7-4 Section 7.3 Presidio Cleanup Levels Applicable to Specific Sites: This section describes the chemical-specific applicable cleanup levels, and the tables in Section 7 lists those levels. However, the section does not summarize the basis for compilation of the complete list of potential chemicals of concern. The text of this section should be revised to include a summary of the criteria used to compile this list.*

    The list of chemicals included in the Cleanup Level Document is based on the chemicals detected in soil, sediment, groundwater, and surface water samples collected at the Main Installation and Public Health Service Hospital sites, as included in the database given to the Trust from the Army. This list also includes chemicals that have been detected at the Firing Ranges and at petroleum release sites. Section 2 of the Cleanup Level Document has been modified to state the source of the list of chemicals.

16. *Table 7-2 Human Health Cleanup Levels for Non-Petroleum Compounds in Soil at the Presidio of San Francisco: There are landfill areas that may be remediated at this site. As mentioned in a previous memorandum from the HERD, dated June 5, 2000, vinyl chloride is often found associated with landfills, but a cleanup goal has not been calculated for this chemical. Explain why vinyl chloride has not been included as a potential chemical of concern.*

    Vinyl chloride was not included as a potential chemical of concern in the Cleanup Level Document because it has not been detected in soil or water samples collected at any of the Main Installation sites. Very few chlorinated VOCs have been detected at Main Installation sites, including landfills. Therefore, based on the available data, vinyl chloride is unlikely to be encountered these sites. As stated in Section 7.3.6, if new chemicals are identified at a site, cleanup levels will be calculated for such chemicals.

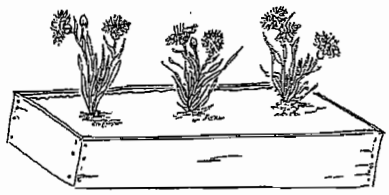
If you have any questions, please do not hesitate to call.

Very truly yours,

Craig Cooper

Craig Cooper
THE PRESIDIO TRUST

cc: James Polisini, Ph.D., DTSC
A. Kimiko Klein, Ph.D., DTSC
Brian Ullensvang, P.E., NPS
James Ponton, R.G., RWQCB
Doug Kern, Presidio RAB
Mark Youngkin, Presidio RAB
Chris Nelson, Presidio Trust
Michelle King, Ph.D., EKI



PRESIDIO POTTED PLANT GUIDELINES

(updated Spring 2001)

1. CONTAINERS

- A reasonable number of containers may be placed outside of each unit. The Presidio Trust will, in its sole discretion, determine if inappropriate or an unreasonable number of containers/plants exists. If such a determination is made, the resident will be so notified and asked to remedy the situation.
- Containers must be placed in areas where they will not fall during an earthquake or heavy winds (this includes banisters, railing, etc.) or impede emergency access to buildings.
- Residents are encouraged to grow kitchen herbs and container-sized vegetable plants, since home gardening is an important component of a sustainable community.
- To protect sensitive ecological areas, residents may not discard soil or plant material anywhere on the grounds of the Presidio.
- The use of pesticides or herbicides is prohibited.

2. SUGGESTED PLANTS

Attached is a *partial* list of plants that grow in harmony with the Presidio's native species. Most vegetables and kitchen herbs are also acceptable, since they do not easily cross-pollinate or hybridize with native plants. A more detailed listing of acceptable plants is available at the John Stewart Company leasing offices.

3. PROHIBITED PLANTS

Certain commercial nursery species are difficult to confine to containers since they can spread via seeds or runners. They become aggressive competitors with native species and are difficult to eradicate once established.
Please check the attached list for prohibited plants.

In addition, some commercially available plants labeled "California Native" have the potential to cross-pollinate/hybridize with native plants in natural areas of the Presidio. This is a serious threat to native plants.

PLEASE DO **NOT** BUY PLANTS LABELED "CALIFORNIA NATIVE."
(If you have questions related to plants in the Presidio, please contact the Presidio Trust Natural Resources Program at 415.561.4494 or e-mail us at Nature@presidio.gov.)

SUGGESTED CONTAINER PLANT LIST FOR PRESIDIO RESIDENCES

Scientific name (spp. = species)	**Common Name**
Large Shrubs (>2 m tall)	
Buddleia spp.	butterfly bush
Callistemon citrinus	bottlebrush
Tibouchina semidecandra	princess flower
Small Shrubs (0.5-2 m tall)	
Berberis spp.	Darwin barberry
Fuchsia cultivars	fuchsia
Lavandula spp.	lavender
Nandina domestica	heavenly bamboo
Vines	
Clematis spp., cultivars	clematis
Hardenbergia violacea	hardenbergia
Rosa banksiae	*Lady Banks rose*
Sollya heterophylla	Australian bluebell creeper
Trachelospermum jasminoides	star-jasmine
Wisteria	wisteria
Ferns	
Rumohra adiantiformis	leatherleaf fern
Flowering perennials	
Aquilegia spp.	columbine
Coreopsis spp.	coreopsis
Delphinium spp.	larkspur
Echinacea	echinacea
Lantana spp.	lantana
Penstemon spp., cultivars	beardtongue
Phlox spp.	phlox
Salvia spp. , cultivars	sage
Annuals	
Helianthus cultivars	sunflower
Lobelia spp.	lobelia
Salvia spp., cultivars	sage
Viola spp.	violets, pansies
Zinnia	zinnia

NOAA Tide Predictions

SAN FRANCISCO,California,2015

The NOAA Tide Predictions application provides predictions in both graphical and tabular formats, with many user selected options, for over 3000 stations broken down by key areas in each state. Users can also access stations via the Google map interface. Additional information can be found in the help page.

Station Types: The NOAA Tide Predictions application provides predictions from 2 distinct categories of stations at over 3000 locations:
Harmonic - The predicted height values for Harmonic stations are conducted by combining the harmonic constituents into a single tide curve.
Subordinate - The high and low height values for Subordinate stations are obtained by means and differences, and ratios applied to the full harmonic constant predictions at a specific Harmonic station (a Reference station).

Disclaimer: The official Tide prediction tables are published annually on October 1, for the following calendar year. Tide predictions generated prior to the publishing date of the official tables are subject to change. The predictions from the web based NOAA Tidal Predictions are based upon the latest information available as of the date of your request. Tide predictions generated may differ from the official published predictions if information for the station requested has been updated since the publishing date of the official published tables.

StationId:9414290
Source:NOAA/NOS/CO-OPS
Station Type:Harmonic
Time Zone:LST/LDT
Datum:mean lower low water (MLLW) which is the chart datum of soundings

NOAA Tide Predictions

SAN FRANCISCO,California,2015

Times and Heights of High and Low Waters

January

	Time (h m)	Height (ft)	Height (cm)
1 Th	01:43 AM	2.2	67
	08:15 AM	6.5	198
	03:08 PM	-0.3	-9
	10:03 PM	4.7	143
2 F	02:38 AM	2.4	73
	08:59 AM	6.5	198
	03:52 PM	-0.6	-18
	10:54 PM	4.9	149
3 Sa	03:28 AM	2.5	76
	09:41 AM	6.5	198
	04:32 PM	-0.7	-21
	11:39 PM	5.0	152
4 Su	04:15 AM	2.6	79
	10:21 AM	6.4	195
	05:08 PM	-0.7	-21
5 M ○	12:20 AM	5.1	155
	04:59 AM	2.6	79
	10:59 AM	6.2	189
	05:43 PM	-0.6	-18
6 Tu	12:57 AM	5.1	155
	05:41 AM	2.6	79
	11:35 AM	6.0	183
	06:17 PM	-0.4	-12
7 W	01:32 AM	5.1	155
	06:23 AM	2.7	82
	12:12 PM	5.7	174
	06:51 PM	-0.2	-6
8 Th	02:06 AM	5.1	155
	07:07 AM	2.7	82
	12:51 PM	5.4	165
	07:25 PM	0.1	3
9 F	02:39 AM	5.1	155
	07:55 AM	2.6	79
	01:32 PM	5.0	152
	08:01 PM	0.5	15
10 Sa	03:13 AM	5.1	155
	08:48 AM	2.5	76
	02:19 PM	4.6	140
	08:39 PM	0.9	27
11 Su	03:50 AM	5.2	158
	09:48 AM	2.4	73
	03:15 PM	4.2	128
	09:21 PM	1.4	43
12 M	04:30 AM	5.3	162
	10:52 AM	2.1	64
	04:25 PM	3.8	116
	10:08 PM	1.8	55
13 Tu ◑	05:13 AM	5.4	165
	11:56 AM	1.7	52
	05:54 PM	3.6	110
	11:04 PM	2.2	67
14 W	05:59 AM	5.6	171
	12:54 PM	1.2	37
	07:27 PM	3.7	113
15 Th	12:05 AM	2.5	76
	06:47 AM	5.8	177
	01:45 PM	0.6	18
	08:41 PM	3.9	119
16 F	01:05 AM	2.7	82
	07:35 AM	6.1	186
	02:31 PM	0.1	3
	09:37 PM	4.3	131
17 Sa	02:01 AM	2.7	82
	08:23 AM	6.4	195
	03:15 PM	-0.4	-12
	10:24 PM	4.6	140
18 Su	02:52 AM	2.7	82
	09:10 AM	6.7	204
	03:57 PM	-0.9	-27
	11:06 PM	4.9	149
19 M	03:42 AM	2.5	76
	09:58 AM	6.9	210
	04:39 PM	-1.1	-34
	11:47 PM	5.2	158
20 Tu ●	04:31 AM	2.3	70
	10:46 AM	6.9	210
	05:22 PM	-1.2	-37
21 W	12:27 AM	5.4	165
	05:21 AM	2.1	64
	11:36 AM	6.8	207
	06:05 PM	-1.2	-37
22 Th	01:08 AM	5.6	171
	06:14 AM	1.9	58
	12:27 PM	6.5	198
	06:49 PM	-0.9	-27
23 F	01:50 AM	5.8	177
	07:11 AM	1.7	52
	01:21 PM	6.1	186
	07:35 PM	-0.4	-12
24 Sa	02:34 AM	6.0	183
	08:12 AM	1.6	49
	02:21 PM	5.5	168
	08:23 PM	0.2	6
25 Su	03:21 AM	6.1	186
	09:20 AM	1.4	43
	03:30 PM	4.9	149
	09:15 PM	0.9	27
26 M	04:11 AM	6.1	186
	10:34 AM	1.2	37
	04:51 PM	4.4	134
	10:13 PM	1.5	46
27 Tu ◐	05:04 AM	6.1	186
	11:50 AM	0.9	27
	06:22 PM	4.2	128
	11:18 PM	2.0	61
28 W	06:01 AM	6.2	189
	01:00 PM	0.5	15
	07:48 PM	4.2	128
29 Th	12:27 AM	2.4	73
	06:58 AM	6.2	189
	02:02 PM	0.2	6
	08:58 PM	4.5	137
30 F	01:32 AM	2.6	79
	07:52 AM	6.2	189
	02:54 PM	-0.1	-3
	09:53 PM	4.7	143
31 Sa	02:30 AM	2.6	79
	08:42 AM	6.2	189
	03:38 PM	-0.2	-6
	10:39 PM	4.9	149

February

	Time (h m)	Height (ft)	Height (cm)
1 Su	03:20 AM	2.5	76
	09:27 AM	6.2	189
	04:16 PM	-0.3	-9
	11:18 PM	5.1	155
2 M	04:05 AM	2.5	76
	10:08 AM	6.1	186
	04:50 PM	-0.3	-9
	11:52 PM	5.1	155
3 Tu ○	04:46 AM	2.4	73
	10:46 AM	6.0	183
	05:21 PM	-0.2	-6
4 W	12:23 AM	5.2	158
	05:24 AM	2.3	70
	11:22 AM	5.9	180
	05:52 PM	0.0	0
5 Th	12:51 AM	5.2	158
	06:01 AM	2.2	67
	11:58 AM	5.6	171
	06:22 PM	0.2	6
6 F	01:18 AM	5.2	158
	06:39 AM	2.1	64
	12:35 PM	5.4	165
	06:52 PM	0.5	15
7 Sa	01:46 AM	5.2	158
	07:18 AM	2.0	61
	01:14 PM	5.0	152
	07:23 PM	0.9	27
8 Su	02:16 AM	5.3	162
	08:02 AM	1.9	58
	01:59 PM	4.6	140
	07:57 PM	1.3	40
9 M	02:50 AM	5.3	162
	08:52 AM	1.8	55
	02:51 PM	4.2	128
	08:34 PM	1.7	52
10 Tu	03:29 AM	5.4	165
	09:50 AM	1.6	49
	03:57 PM	3.9	119
	09:18 PM	2.1	64
11 W	04:13 AM	5.4	165
	10:54 AM	1.4	43
	05:25 PM	3.7	113
	10:15 PM	2.5	76
12 Th ◑	05:05 AM	5.5	168
	12:01 PM	1.0	30
	07:02 PM	3.7	113
	11:26 PM	2.8	85
13 F	06:02 AM	5.7	174
	01:02 PM	0.6	18
	08:17 PM	4.0	122
14 Sa	12:38 AM	2.9	88
	07:01 AM	5.9	180
	01:57 PM	0.1	3
	09:12 PM	4.4	134
15 Su	01:42 AM	2.7	82
	07:58 AM	6.2	189
	02:46 PM	-0.3	-9
	09:56 PM	4.7	143
16 M	02:38 AM	2.5	76
	08:53 AM	6.5	198
	03:32 PM	-0.7	-21
	10:36 PM	5.1	155
17 Tu	03:29 AM	2.1	64
	09:46 AM	6.7	204
	04:16 PM	-0.9	-27
	11:14 PM	5.4	165
18 W ●	04:19 AM	1.7	52
	10:38 AM	6.8	207
	04:59 PM	-0.9	-27
	11:52 PM	5.7	174
19 Th	05:09 AM	1.3	40
	11:29 AM	6.6	201
	05:42 PM	-0.7	-21
20 F	12:31 AM	6.0	183
	06:01 AM	1.0	30
	12:22 PM	6.3	192
	06:25 PM	-0.3	-9
21 Sa	01:11 AM	6.1	186
	06:54 AM	0.8	24
	01:17 PM	5.9	180
	07:10 PM	0.2	6
22 Su	01:53 AM	6.2	189
	07:51 AM	0.6	18
	02:17 PM	5.3	162
	07:57 PM	0.8	24
23 M	02:38 AM	6.2	189
	08:53 AM	0.6	18
	03:25 PM	4.8	146
	08:49 PM	1.5	46
24 Tu	03:27 AM	6.1	186
	10:01 AM	0.6	18
	04:44 PM	4.4	134
	09:50 PM	2.0	61
25 W ◐	04:23 AM	5.9	180
	11:14 AM	0.6	18
	06:13 PM	4.2	128
	11:01 PM	2.4	73
26 Th	05:24 AM	5.7	174
	12:28 PM	0.5	15
	07:34 PM	4.4	134
27 F	12:17 AM	2.6	79
	06:28 AM	5.7	174
	01:33 PM	0.3	9
	08:39 PM	4.6	140
28 Sa	01:25 AM	2.6	79
	07:30 AM	5.6	171
	02:27 PM	0.2	6
	09:29 PM	4.8	146

March

	Time (h m)	Height (ft)	Height (cm)
1 Su	02:23 AM	2.4	73
	08:25 AM	5.7	174
	03:12 PM	0.2	6
	10:09 PM	5.0	152
2 M	03:11 AM	2.2	67
	09:13 AM	5.7	174
	03:49 PM	0.2	6
	10:44 PM	5.1	155
3 Tu	03:53 AM	2.0	61
	09:56 AM	5.7	174
	04:22 PM	0.2	6
	11:13 PM	5.2	158
4 W	04:30 AM	1.8	55
	10:35 AM	5.6	171
	04:53 PM	0.3	9
	11:40 PM	5.2	158
5 Th ○	05:05 AM	1.6	49
	11:12 AM	5.5	168
	05:22 PM	0.5	15
6 F	12:04 AM	5.3	162
	05:39 AM	1.4	43
	11:49 AM	5.3	162
	05:50 PM	0.7	21
7 Sa	12:29 AM	5.3	162
	06:13 AM	1.3	40
	12:26 PM	5.1	155
	06:19 PM	1.0	30
8 Su	12:56 AM	5.4	165
	07:48 AM	1.1	34
	02:06 PM	4.8	146
	07:49 PM	1.3	40
9 M	02:25 AM	5.4	165
	08:27 AM	1.0	30
	02:51 PM	4.5	137
	08:22 PM	1.7	52
10 Tu	02:58 AM	5.4	165
	09:11 AM	0.9	27
	03:43 PM	4.2	128
	08:58 PM	2.1	64
11 W	03:37 AM	5.4	165
	10:03 AM	0.9	27
	04:48 PM	3.9	119
	09:44 PM	2.4	73
12 Th	04:23 AM	5.3	162
	11:04 AM	0.8	24
	06:09 PM	3.8	116
	10:46 PM	2.7	82
13 F ◑	05:19 AM	5.3	162
	12:11 PM	0.6	18
	07:36 PM	3.9	119
14 Sa	12:05 AM	2.9	88
	06:24 AM	5.4	165
	01:18 PM	0.3	9
	08:45 PM	4.2	128
15 Su	01:24 AM	2.8	85
	07:32 AM	5.5	168
	02:19 PM	0.1	3
	09:36 PM	4.6	140
16 M	02:30 AM	2.4	73
	08:38 AM	5.8	177
	03:13 PM	-0.2	-6
	10:19 PM	5.0	152
17 Tu	03:27 AM	1.9	58
	09:40 AM	6.0	183
	04:02 PM	-0.4	-12
	10:58 PM	5.3	162
18 W	04:19 AM	1.4	43
	10:37 AM	6.2	189
	04:48 PM	-0.4	-12
	11:36 PM	5.7	174
19 Th	05:08 AM	0.8	24
	11:32 AM	6.2	189
	05:32 PM	-0.3	-9
20 F ●	12:14 AM	6.0	183
	05:57 AM	0.3	9
	12:26 PM	6.1	186
	06:15 PM	0.0	0
21 Sa	12:52 AM	6.2	189
	06:46 AM	-0.1	-3
	01:20 PM	5.8	177
	06:59 PM	0.4	12
22 Su	01:31 AM	6.3	192
	07:36 AM	-0.2	-6
	02:16 PM	5.5	168
	07:44 PM	0.9	27
23 M	02:13 AM	6.3	192
	08:29 AM	-0.3	-9
	03:16 PM	5.1	155
	08:33 PM	1.5	46
24 Tu	02:57 AM	6.1	186
	09:25 AM	-0.2	-6
	04:21 PM	4.7	143
	09:28 PM	2.0	61
25 W	03:46 AM	5.8	177
	10:26 AM	0.0	0
	05:35 PM	4.4	134
	10:32 PM	2.4	73
26 Th	04:41 AM	5.5	168
	11:34 AM	0.2	6
	06:54 PM	4.4	134
	11:48 PM	2.6	79
27 F ◐	05:44 AM	5.2	158
	12:44 PM	0.4	12
	08:07 PM	4.5	137
28 Sa	01:06 AM	2.6	79
	06:53 AM	5.0	152
	01:49 PM	0.5	15
	09:05 PM	4.7	143
29 Su	02:13 AM	2.4	73
	08:02 AM	4.9	149
	02:45 PM	0.5	15
	09:50 PM	4.8	146
30 M	03:09 AM	2.1	64
	09:03 AM	4.9	149
	03:31 PM	0.5	15
	10:28 PM	5.0	152
31 Tu	03:55 AM	1.7	52
	09:56 AM	5.0	152
	04:11 PM	0.6	18
	10:59 PM	5.1	155

Disclaimer: These data are based upon the latest information available as of the date of your request, and may differ from the published tide tables.

StationId:9414290
Source:NOAA/NOS/CO-OPS
Station Type:Harmonic
Time Zone:LST/LDT
Datum:mean lower low water (MLLW) which is the chart datum of soundings

NOAA Tide Predictions

SAN FRANCISCO,California,2015

Times and Heights of High and Low Waters

April

Day	Time (h m)	Height (ft)	Height (cm)
1 W	04:35 AM	1.4	43
	10:42 AM	5.0	152
	04:45 PM	0.7	21
	11:26 PM	5.2	158
2 Th	05:11 AM	1.1	34
	11:24 AM	5.0	152
	05:17 PM	0.9	27
	11:51 PM	5.3	162
3 F	05:44 AM	0.8	24
	12:04 PM	5.0	152
	05:47 PM	1.0	30
4 Sa ○	12:16 AM	5.4	165
	06:17 AM	0.6	18
	12:43 PM	4.9	149
	06:17 PM	1.3	40
5 Su	12:42 AM	5.5	168
	06:49 AM	0.3	9
	01:23 PM	4.7	143
	06:47 PM	1.5	46
6 M	01:10 AM	5.5	168
	07:23 AM	0.2	6
	02:05 PM	4.6	140
	07:18 PM	1.8	55
7 Tu	01:41 AM	5.5	168
	08:01 AM	0.1	3
	02:52 PM	4.4	134
	07:53 PM	2.1	64
8 W	02:16 AM	5.4	165
	08:43 AM	0.0	0
	03:45 PM	4.2	128
	08:34 PM	2.4	73
9 Th	02:56 AM	5.3	162
	09:33 AM	0.0	0
	04:47 PM	4.1	125
	09:26 PM	2.7	82
10 F	03:45 AM	5.2	158
	10:29 AM	0.0	0
	05:57 PM	4.1	125
	10:36 PM	2.8	85
11 Sa	04:44 AM	5.1	155
	11:33 AM	0.1	3
	07:07 PM	4.2	128
	11:58 PM	2.8	85
12 Su ◑	05:54 AM	5.0	152
	12:38 PM	0.0	0
	08:06 PM	4.5	137
13 M	01:16 AM	2.4	73
	07:10 AM	5.0	152
	01:41 PM	0.0	0
	08:56 PM	4.9	149
14 Tu	02:21 AM	1.9	58
	08:23 AM	5.1	155
	02:37 PM	0.0	0
	09:39 PM	5.3	162
15 W	03:18 AM	1.2	37
	09:31 AM	5.3	162
	03:29 PM	0.1	3
	10:19 PM	5.7	174
16 Th	04:09 AM	0.5	15
	10:32 AM	5.4	165
	04:16 PM	0.2	6
	10:58 PM	6.0	183
17 F	04:58 AM	-0.1	-3
	11:30 AM	5.5	168
	05:02 PM	0.5	15
	11:36 PM	6.2	189
18 Sa ●	05:45 AM	-0.6	-18
	12:26 PM	5.4	165
	05:48 PM	0.8	24
19 Su	12:15 AM	6.4	195
	06:32 AM	-0.9	-27
	01:21 PM	5.3	162
	06:33 PM	1.2	37
20 M	12:55 AM	6.4	195
	07:19 AM	-1.0	-30
	02:16 PM	5.1	155
	07:21 PM	1.6	49
21 Tu	01:36 AM	6.2	189
	08:08 AM	-0.9	-27
	03:14 PM	4.9	149
	08:11 PM	2.0	61
22 W	02:20 AM	5.9	180
	08:59 AM	-0.7	-21
	04:14 PM	4.7	143
	09:08 PM	2.3	70
23 Th	03:07 AM	5.5	168
	09:53 AM	-0.4	-12
	05:18 PM	4.6	140
	10:14 PM	2.5	76
24 F	04:00 AM	5.1	155
	10:51 AM	-0.1	-3
	06:24 PM	4.5	137
	11:30 PM	2.6	79
25 Sa ◐	05:01 AM	4.7	143
	11:53 AM	0.3	9
	07:26 PM	4.6	140
26 Su	12:45 AM	2.4	73
	06:10 AM	4.4	134
	12:54 PM	0.5	15
	08:18 PM	4.7	143
27 M	01:51 AM	2.1	64
	07:23 AM	4.2	128
	01:50 PM	0.7	21
	09:00 PM	4.9	149
28 Tu	02:46 AM	1.7	52
	08:32 AM	4.2	128
	02:39 PM	0.9	27
	09:36 PM	5.0	152
29 W	03:32 AM	1.3	40
	09:32 AM	4.3	131
	03:22 PM	1.0	30
	10:07 PM	5.2	158
30 Th	04:12 AM	0.9	27
	10:25 AM	4.3	131
	04:00 PM	1.2	37
	10:35 PM	5.3	162

May

Day	Time (h m)	Height (ft)	Height (cm)
1 F	04:48 AM	0.5	15
	11:12 AM	4.4	134
	04:35 PM	1.4	43
	11:02 PM	5.5	168
2 Sa	05:22 AM	0.2	6
	11:56 AM	4.5	137
	05:09 PM	1.6	49
	11:30 PM	5.6	171
3 Su	05:54 AM	-0.2	-6
	12:39 PM	4.5	137
	05:42 PM	1.8	55
4 M ○	12:00 AM	5.7	174
	06:27 AM	-0.4	-12
	01:22 PM	4.5	137
	06:16 PM	2.0	61
5 Tu	12:32 AM	5.7	174
	07:03 AM	-0.6	-18
	02:06 PM	4.4	134
	06:52 PM	2.3	70
6 W	01:07 AM	5.7	174
	07:41 AM	-0.7	-21
	02:53 PM	4.4	134
	07:32 PM	2.5	76
7 Th	01:45 AM	5.6	171
	08:24 AM	-0.7	-21
	03:44 PM	4.4	134
	08:20 PM	2.6	79
8 F	02:29 AM	5.5	168
	09:11 AM	-0.7	-21
	04:39 PM	4.4	134
	09:19 PM	2.7	82
9 Sa	03:21 AM	5.2	158
	10:04 AM	-0.5	-15
	05:36 PM	4.5	137
	10:31 PM	2.7	82
10 Su	04:22 AM	5.0	152
	11:02 AM	-0.3	-9
	06:33 PM	4.7	143
	11:51 PM	2.5	76
11 M ◑	05:34 AM	4.7	143
	12:03 PM	-0.1	-3
	07:26 PM	5.0	152
12 Tu	01:06 AM	2.0	61
	06:53 AM	4.5	137
	01:04 PM	0.1	3
	08:14 PM	5.3	162
13 W	02:11 AM	1.3	40
	08:13 AM	4.5	137
	02:01 PM	0.4	12
	08:59 PM	5.7	174
14 Th	03:08 AM	0.6	18
	09:26 AM	4.6	140
	02:55 PM	0.7	21
	09:42 PM	6.0	183
15 F	04:00 AM	-0.1	-3
	10:32 AM	4.7	143
	03:46 PM	1.0	30
	10:23 PM	6.3	192
16 Sa	04:48 AM	-0.7	-21
	11:33 AM	4.8	146
	04:35 PM	1.3	40
	11:03 PM	6.4	195
17 Su	05:34 AM	-1.1	-34
	12:29 PM	4.9	149
	05:23 PM	1.6	49
	11:44 PM	6.5	198
18 M ●	06:19 AM	-1.3	-40
	01:22 PM	4.9	149
	06:11 PM	1.9	58
19 Tu	12:24 AM	6.4	195
	07:04 AM	-1.3	-40
	02:14 PM	4.9	149
	07:00 PM	2.1	64
20 W	01:06 AM	6.1	186
	07:48 AM	-1.2	-37
	03:06 PM	4.8	146
	07:51 PM	2.4	73
21 Th	01:48 AM	5.8	177
	08:34 AM	-0.9	-27
	03:58 PM	4.8	146
	08:47 PM	2.5	76
22 F	02:33 AM	5.4	165
	09:21 AM	-0.6	-18
	04:51 PM	4.7	143
	09:50 PM	2.6	79
23 Sa	03:22 AM	4.9	149
	10:10 AM	-0.2	-6
	05:43 PM	4.7	143
	11:00 PM	2.6	79
24 Su	04:18 AM	4.5	137
	11:02 AM	0.2	6
	06:34 PM	4.8	146
25 M ◐	12:11 AM	2.4	73
	05:22 AM	4.1	125
	11:55 AM	0.6	18
	07:19 PM	4.9	149
26 Tu	01:17 AM	2.0	61
	06:35 AM	3.8	116
	12:49 PM	0.9	27
	08:00 PM	5.0	152
27 W	02:13 AM	1.6	49
	07:53 AM	3.7	113
	01:40 PM	1.2	37
	08:37 PM	5.2	158
28 Th	03:02 AM	1.1	34
	09:04 AM	3.7	113
	02:27 PM	1.5	46
	09:10 PM	5.4	165
29 F	03:44 AM	0.7	21
	10:06 AM	3.8	116
	03:11 PM	1.7	52
	09:43 PM	5.6	171
30 Sa	04:22 AM	0.2	6
	11:00 AM	4.0	122
	03:52 PM	2.0	61
	10:16 PM	5.7	174
31 Su	04:57 AM	-0.2	-6
	11:47 AM	4.2	128
	04:31 PM	2.1	64
	10:50 PM	5.9	180

June

Day	Time (h m)	Height (ft)	Height (cm)
1 M	05:31 AM	-0.6	-18
	12:32 PM	4.3	131
	05:09 PM	2.3	70
	11:25 PM	6.0	183
2 Tu ○	06:07 AM	-0.9	-27
	01:16 PM	4.4	134
	05:49 PM	2.4	73
3 W	12:02 AM	6.1	186
	06:44 AM	-1.1	-34
	01:59 PM	4.6	140
	06:31 PM	2.5	76
4 Th	12:42 AM	6.1	186
	07:24 AM	-1.2	-37
	02:43 PM	4.6	140
	07:17 PM	2.6	79
5 F	01:25 AM	5.9	180
	08:07 AM	-1.2	-37
	03:29 PM	4.7	143
	08:10 PM	2.6	79
6 Sa	02:13 AM	5.7	174
	08:53 AM	-1.0	-30
	04:17 PM	4.9	149
	09:11 PM	2.6	79
7 Su	03:07 AM	5.4	165
	09:43 AM	-0.7	-21
	05:07 PM	5.0	152
	10:22 PM	2.4	73
8 M	04:09 AM	4.9	149
	10:36 AM	-0.3	-9
	05:57 PM	5.3	162
	11:38 PM	2.1	64
9 Tu ◑	05:22 AM	4.5	137
	11:32 AM	0.1	3
	06:47 PM	5.5	168
10 W	12:52 AM	1.5	46
	06:44 AM	4.2	128
	12:30 PM	0.6	18
	07:36 PM	5.8	177
11 Th	01:59 AM	0.9	27
	08:09 AM	4.1	125
	01:29 PM	1.0	30
	08:23 PM	6.1	186
12 F	02:58 AM	0.2	6
	09:27 AM	4.2	128
	02:26 PM	1.4	43
	09:09 PM	6.3	192
13 Sa	03:51 AM	-0.4	-12
	10:35 AM	4.4	134
	03:21 PM	1.7	52
	09:54 PM	6.5	198
14 Su	04:39 AM	-0.8	-24
	11:35 AM	4.6	140
	04:13 PM	2.0	61
	10:37 PM	6.6	201
15 M	05:24 AM	-1.1	-34
	12:28 PM	4.8	146
	05:04 PM	2.2	67
	11:20 PM	6.5	198
16 Tu ●	06:07 AM	-1.2	-37
	01:17 PM	4.9	149
	05:53 PM	2.3	70
17 W	12:01 AM	6.4	195
	06:48 AM	-1.2	-37
	02:04 PM	4.9	149
	06:42 PM	2.4	73
18 Th	12:42 AM	6.1	186
	07:28 AM	-1.0	-30
	02:48 PM	4.9	149
	07:31 PM	2.5	76
19 F	01:23 AM	5.8	177
	08:08 AM	-0.8	-24
	03:31 PM	4.9	149
	08:22 PM	2.6	79
20 Sa	02:05 AM	5.4	165
	08:49 AM	-0.4	-12
	04:12 PM	4.9	149
	09:18 PM	2.6	79
21 Su	02:50 AM	5.0	152
	09:30 AM	0.0	0
	04:53 PM	4.9	149
	10:18 PM	2.5	76
22 M	03:40 AM	4.5	137
	10:13 AM	0.4	12
	05:34 PM	5.0	152
	11:23 PM	2.4	73
23 Tu	04:37 AM	4.1	125
	10:59 AM	0.8	24
	06:15 PM	5.1	155
24 W ◐	12:29 AM	2.1	64
	05:46 AM	3.7	113
	11:48 AM	1.3	40
	06:55 PM	5.2	158
25 Th	01:29 AM	1.7	52
	07:08 AM	3.5	107
	12:40 PM	1.7	52
	07:35 PM	5.4	165
26 F	02:22 AM	1.2	37
	08:33 AM	3.5	107
	01:32 PM	2.0	61
	08:15 PM	5.6	171
27 Sa	03:09 AM	0.7	21
	09:46 AM	3.7	113
	02:23 PM	2.3	70
	08:56 PM	5.8	177
28 Su	03:50 AM	0.2	6
	10:44 AM	3.9	119
	03:12 PM	2.4	73
	09:36 PM	6.0	183
29 M	04:29 AM	-0.2	-6
	11:33 AM	4.2	128
	03:57 PM	2.6	79
	10:17 PM	6.2	189
30 Tu	05:07 AM	-0.6	-18
	12:16 PM	4.4	134
	04:42 PM	2.6	79
	10:58 PM	6.4	195

Disclaimer: These data are based upon the latest information available as of the date of your request, and may differ from the published tide tables.

StationId:9414290
Source:NOAA/NOS/CO-OPS
Station Type:Harmonic
Time Zone:LST/LDT
Datum:mean lower low water (MLLW) which is the chart datum of soundings

NOAA Tide Predictions

SAN FRANCISCO,California,2015

Times and Heights of High and Low Waters

July

	Time (h m)	Height (ft)	Height (cm)
1 W	05:45 AM	-1.0	-30
	12:58 PM	4.6	140
	05:27 PM	2.6	79
	11:41 PM	6.5	198
2 Th ○	06:25 AM	-1.2	-37
	01:38 PM	4.8	146
	06:13 PM	2.5	76
3 F	12:26 AM	6.5	198
	07:06 AM	-1.2	-37
	02:19 PM	5.0	152
	07:03 PM	2.4	73
4 Sa	01:13 AM	6.3	192
	07:48 AM	-1.1	-34
	03:01 PM	5.2	158
	07:57 PM	2.3	70
5 Su	02:03 AM	6.0	183
	08:33 AM	-0.9	-27
	03:45 PM	5.4	165
	08:58 PM	2.2	67
6 M	02:59 AM	5.6	171
	09:20 AM	-0.5	-15
	04:30 PM	5.6	171
	10:05 PM	1.9	58
7 Tu	04:02 AM	5.0	152
	10:10 AM	0.1	3
	05:18 PM	5.8	177
	11:18 PM	1.6	49
8 W ◑	05:15 AM	4.5	137
	11:05 AM	0.7	21
	06:08 PM	6.0	183
9 Th	12:32 AM	1.2	37
	06:40 AM	4.1	125
	12:03 PM	1.2	37
	07:00 PM	6.2	189
10 F	01:42 AM	0.7	21
	08:09 AM	4.1	125
	01:05 PM	1.7	52
	07:52 PM	6.3	192
11 Sa	02:45 AM	0.1	3
	09:29 AM	4.2	128
	02:07 PM	2.1	64
	08:43 PM	6.5	198
12 Su	03:40 AM	-0.3	-9
	10:35 AM	4.4	134
	03:06 PM	2.3	70
	09:33 PM	6.5	198
13 M	04:29 AM	-0.6	-18
	11:30 AM	4.7	143
	04:01 PM	2.4	73
	10:20 PM	6.5	198
14 Tu	05:12 AM	-0.7	-21
	12:18 PM	4.9	149
	04:52 PM	2.5	76
	11:04 PM	6.5	198
15 W	05:52 AM	-0.8	-24
	01:01 PM	5.0	152
	05:40 PM	2.5	76
	11:45 PM	6.3	192
16 Th ●	06:30 AM	-0.7	-21
	01:40 PM	5.1	155
	06:25 PM	2.5	76
17 F	12:25 AM	6.1	186
	07:06 AM	-0.5	-15
	02:17 PM	5.1	155
	07:09 PM	2.5	76
18 Sa	01:04 AM	5.8	177
	07:41 AM	-0.3	-9
	02:51 PM	5.1	155
	07:54 PM	2.4	73
19 Su	01:43 AM	5.5	168
	08:16 AM	0.0	0
	03:24 PM	5.1	155
	08:41 PM	2.4	73
20 M	02:25 AM	5.1	155
	08:51 AM	0.4	12
	03:57 PM	5.1	155
	09:32 PM	2.3	70
21 Tu	03:10 AM	4.7	143
	09:28 AM	0.8	24
	04:32 PM	5.2	158
	10:28 PM	2.2	67
22 W	04:02 AM	4.2	128
	10:09 AM	1.3	40
	05:10 PM	5.3	162
	11:29 PM	2.0	61
23 Th	05:07 AM	3.8	116
	10:53 AM	1.7	52
	05:52 PM	5.4	165
24 F ◐	12:33 AM	1.7	52
	06:29 AM	3.6	110
	11:46 AM	2.2	67
	06:37 PM	5.5	168
25 Sa	01:33 AM	1.3	40
	08:02 AM	3.6	110
	12:45 PM	2.5	76
	07:25 PM	5.7	174
26 Su	02:26 AM	0.8	24
	09:21 AM	3.8	116
	01:45 PM	2.7	82
	08:14 PM	5.9	180
27 M	03:14 AM	0.4	12
	10:20 AM	4.1	125
	02:41 PM	2.8	85
	09:02 PM	6.1	186
28 Tu	03:58 AM	-0.1	-3
	11:07 AM	4.4	134
	03:33 PM	2.7	82
	09:50 PM	6.4	195
29 W	04:40 AM	-0.5	-15
	11:48 AM	4.7	143
	04:21 PM	2.6	79
	10:38 PM	6.6	201
30 Th	05:21 AM	-0.8	-24
	12:27 PM	5.0	152
	05:09 PM	2.4	73
	11:26 PM	6.7	204
31 F ○	06:01 AM	-0.9	-27
	01:05 PM	5.2	158
	05:58 PM	2.1	64

August

	Time (h m)	Height (ft)	Height (cm)
1 Sa	12:14 AM	6.7	204
	06:43 AM	-0.9	-27
	01:43 PM	5.5	168
	06:48 PM	1.9	58
2 Su	01:04 AM	6.5	198
	07:25 AM	-0.7	-21
	02:23 PM	5.7	174
	07:42 PM	1.7	52
3 M	01:57 AM	6.1	186
	08:09 AM	-0.4	-12
	03:05 PM	5.9	180
	08:40 PM	1.5	46
4 Tu	02:55 AM	5.6	171
	08:56 AM	0.2	6
	03:50 PM	6.1	186
	09:44 PM	1.3	40
5 W	03:59 AM	5.1	155
	09:46 AM	0.8	24
	04:38 PM	6.2	189
	10:53 PM	1.1	34
6 Th	05:14 AM	4.6	140
	10:41 AM	1.4	43
	05:30 PM	6.2	189
7 F ◑	12:07 AM	0.8	24
	06:40 AM	4.3	131
	11:44 AM	1.9	58
	06:26 PM	6.2	189
8 Sa	01:20 AM	0.5	15
	08:08 AM	4.3	131
	12:52 PM	2.3	70
	07:25 PM	6.3	192
9 Su	02:26 AM	0.2	6
	09:23 AM	4.5	137
	02:00 PM	2.5	76
	08:23 PM	6.3	192
10 M	03:24 AM	0.0	0
	10:23 AM	4.7	143
	03:02 PM	2.5	76
	09:17 PM	6.3	192
11 Tu	04:12 AM	-0.2	-6
	11:13 AM	4.9	149
	03:56 PM	2.5	76
	10:07 PM	6.3	192
12 W	04:55 AM	-0.2	-6
	11:55 AM	5.1	155
	04:44 PM	2.4	73
	10:52 PM	6.2	189
13 Th	05:32 AM	-0.2	-6
	12:32 PM	5.2	158
	05:27 PM	2.3	70
	11:33 PM	6.1	186
14 F ●	06:06 AM	-0.1	-3
	01:05 PM	5.2	158
	06:07 PM	2.1	64
15 Sa	12:12 AM	5.9	180
	06:38 AM	0.1	3
	01:34 PM	5.2	158
	06:46 PM	2.0	61
16 Su	12:50 AM	5.7	174
	07:10 AM	0.4	12
	02:02 PM	5.3	162
	07:25 PM	2.0	61
17 M	01:27 AM	5.4	165
	07:41 AM	0.7	21
	02:30 PM	5.3	162
	08:05 PM	1.9	58
18 Tu	02:07 AM	5.1	155
	08:13 AM	1.0	30
	03:00 PM	5.3	162
	08:48 PM	1.8	55
19 W	02:51 AM	4.7	143
	08:47 AM	1.4	43
	03:33 PM	5.3	162
	09:35 PM	1.7	52
20 Th	03:41 AM	4.3	131
	09:24 AM	1.8	55
	04:10 PM	5.4	165
	10:30 PM	1.6	49
21 F	04:43 AM	4.0	122
	10:07 AM	2.3	70
	04:54 PM	5.4	165
	11:32 PM	1.5	46
22 Sa ◐	06:03 AM	3.8	116
	11:02 AM	2.6	79
	05:44 PM	5.4	165
23 Su	12:37 AM	1.2	37
	07:35 AM	3.8	116
	12:10 PM	2.9	88
	06:40 PM	5.6	171
24 M	01:38 AM	0.9	27
	08:52 AM	4.0	122
	01:20 PM	2.9	88
	07:38 PM	5.8	177
25 Tu	02:34 AM	0.5	15
	09:47 AM	4.3	131
	02:22 PM	2.8	85
	08:35 PM	6.0	183
26 W	03:23 AM	0.1	3
	10:31 AM	4.7	143
	03:16 PM	2.6	79
	09:30 PM	6.3	192
27 Th	04:08 AM	-0.3	-9
	11:10 AM	5.0	152
	04:06 PM	2.2	67
	10:22 PM	6.5	198
28 F	04:51 AM	-0.5	-15
	11:47 AM	5.3	162
	04:55 PM	1.8	55
	11:14 PM	6.6	201
29 Sa ○	05:34 AM	-0.5	-15
	12:25 PM	5.7	174
	05:43 PM	1.4	43
30 Su	12:06 AM	6.6	201
	06:16 AM	-0.4	-12
	01:02 PM	5.9	180
	06:33 PM	1.0	30
31 M	12:59 AM	6.4	195
	06:59 AM	-0.1	-3
	01:42 PM	6.1	186
	07:25 PM	0.7	21

September

	Time (h m)	Height (ft)	Height (cm)
1 Tu	01:54 AM	6.0	183
	07:43 AM	0.4	12
	02:24 PM	6.3	192
	08:20 PM	0.5	15
2 W	02:53 AM	5.6	171
	08:31 AM	0.9	27
	03:08 PM	6.3	192
	09:20 PM	0.5	15
3 Th	03:59 AM	5.1	155
	09:23 AM	1.5	46
	03:58 PM	6.2	189
	10:26 PM	0.5	15
4 F	05:14 AM	4.7	143
	10:23 AM	2.0	61
	04:53 PM	6.1	186
	11:38 PM	0.5	15
5 Sa ◑	06:37 AM	4.5	137
	11:33 AM	2.4	73
	05:54 PM	5.9	180
6 Su	12:51 AM	0.5	15
	07:57 AM	4.6	140
	12:48 PM	2.6	79
	06:59 PM	5.8	177
7 M	01:59 AM	0.4	12
	09:05 AM	4.8	146
	01:58 PM	2.6	79
	08:04 PM	5.8	177
8 Tu	02:57 AM	0.3	9
	09:58 AM	5.0	152
	02:58 PM	2.4	73
	09:03 PM	5.8	177
9 W	03:46 AM	0.3	9
	10:42 AM	5.2	158
	03:49 PM	2.2	67
	09:55 PM	5.8	177
10 Th	04:27 AM	0.3	9
	11:19 AM	5.3	162
	04:33 PM	1.9	58
	10:41 PM	5.8	177
11 F	05:03 AM	0.4	12
	11:51 AM	5.3	162
	05:12 PM	1.7	52
	11:23 PM	5.7	174
12 Sa	05:35 AM	0.6	18
	12:20 PM	5.4	165
	05:49 PM	1.5	46
13 Su ●	12:02 AM	5.6	171
	06:06 AM	0.8	24
	12:45 PM	5.4	165
	06:23 PM	1.4	43
14 M	12:39 AM	5.4	165
	06:35 AM	1.0	30
	01:10 PM	5.4	165
	06:58 PM	1.2	37
15 Tu	01:17 AM	5.2	158
	07:05 AM	1.3	40
	01:37 PM	5.4	165
	07:33 PM	1.1	34
16 W	01:57 AM	4.9	149
	07:36 AM	1.7	52
	02:06 PM	5.4	165
	08:11 PM	1.1	34
17 Th	02:42 AM	4.7	143
	08:09 AM	2.0	61
	02:39 PM	5.4	165
	08:54 PM	1.0	30
18 F	03:33 AM	4.4	134
	08:46 AM	2.4	73
	03:17 PM	5.4	165
	09:43 PM	1.0	30
19 Sa	04:34 AM	4.2	128
	09:32 AM	2.7	82
	04:02 PM	5.3	162
	10:40 PM	1.0	30
20 Su	05:49 AM	4.0	122
	10:33 AM	3.0	91
	04:57 PM	5.3	162
	11:45 PM	0.9	27
21 M ◐	07:09 AM	4.1	125
	11:50 AM	3.1	94
	05:59 PM	5.3	162
22 Tu	12:51 AM	0.7	21
	08:16 AM	4.3	131
	01:05 PM	2.9	88
	07:06 PM	5.4	165
23 W	01:51 AM	0.4	12
	09:07 AM	4.7	143
	02:09 PM	2.6	79
	08:12 PM	5.6	171
24 Th	02:45 AM	0.2	6
	09:50 AM	5.0	152
	03:03 PM	2.1	64
	09:13 PM	5.9	180
25 F	03:33 AM	0.0	0
	10:28 AM	5.4	165
	03:54 PM	1.5	46
	10:11 PM	6.1	186
26 Sa	04:19 AM	0.0	0
	11:06 AM	5.8	177
	04:42 PM	0.9	27
	11:07 PM	6.2	189
27 Su	05:03 AM	0.1	3
	11:43 AM	6.1	186
	05:30 PM	0.4	12
28 M ○	12:01 AM	6.1	186
	05:47 AM	0.3	9
	12:21 PM	6.3	192
	06:18 PM	0.0	0
29 Tu	12:56 AM	6.0	183
	06:31 AM	0.7	21
	01:01 PM	6.5	198
	07:08 PM	-0.3	-9
30 W	01:53 AM	5.7	174
	07:17 AM	1.2	37
	01:44 PM	6.5	198
	08:00 PM	-0.4	-12

Disclaimer: These data are based upon the latest information available as of the date of your request, and may differ from the published tide tables.

StationId:9414290
Source:NOAA/NOS/CO-OPS
Station Type:Harmonic
Time Zone:LST/LDT
Datum:mean lower low water (MLLW) which is the chart datum of soundings

NOAA Tide Predictions

SAN FRANCISCO,California,2015

Times and Heights of High and Low Waters

October

	Time (h m)	Height (ft)	Height (cm)
1 Th	02:52 AM	5.4	165
	08:07 AM	1.7	52
	02:29 PM	6.4	195
	08:56 PM	-0.3	-9
2 F	03:57 AM	5.0	152
	09:02 AM	2.1	64
	03:19 PM	6.1	186
	09:57 PM	-0.1	-3
3 Sa	05:09 AM	4.8	146
	10:08 AM	2.5	76
	04:15 PM	5.8	177
	11:04 PM	0.2	6
4 Su ◑	06:24 AM	4.8	146
	11:24 AM	2.7	82
	05:20 PM	5.5	168
5 M	12:14 AM	0.4	12
	07:35 AM	4.8	146
	12:42 PM	2.6	79
	06:30 PM	5.2	158
6 Tu	01:20 AM	0.5	15
	08:34 AM	5.0	152
	01:51 PM	2.4	73
	07:40 PM	5.1	155
7 W	02:18 AM	0.6	18
	09:22 AM	5.2	158
	02:49 PM	2.1	64
	08:44 PM	5.1	155
8 Th	03:07 AM	0.7	21
	10:02 AM	5.3	162
	03:37 PM	1.7	52
	09:40 PM	5.2	158
9 F	03:49 AM	0.8	24
	10:36 AM	5.4	165
	04:18 PM	1.4	43
	10:28 PM	5.2	158
10 Sa	04:25 AM	1.0	30
	11:05 AM	5.5	168
	04:55 PM	1.1	34
	11:12 PM	5.1	155
11 Su	04:58 AM	1.2	37
	11:31 AM	5.6	171
	05:29 PM	0.8	24
	11:53 PM	5.1	155
12 M	05:30 AM	1.4	43
	11:56 AM	5.6	171
	06:01 PM	0.6	18
13 Tu ●	12:33 AM	5.0	152
	06:00 AM	1.7	52
	12:22 PM	5.6	171
	06:34 PM	0.4	12
14 W	01:13 AM	4.9	149
	06:31 AM	1.9	58
	12:49 PM	5.6	171
	07:07 PM	0.3	9
15 Th	01:55 AM	4.7	143
	07:03 AM	2.2	67
	01:20 PM	5.6	171
	07:43 PM	0.2	6
16 F	02:40 AM	4.6	140
	07:37 AM	2.5	76
	01:54 PM	5.5	168
	08:23 PM	0.2	6
17 Sa	03:31 AM	4.4	134
	08:17 AM	2.8	85
	02:33 PM	5.4	165
	09:10 PM	0.3	9
18 Su	04:30 AM	4.3	131
	09:08 AM	3.0	91
	03:21 PM	5.3	162
	10:03 PM	0.3	9
19 M	05:34 AM	4.3	131
	10:15 AM	3.1	94
	04:18 PM	5.1	155
	11:04 PM	0.4	12
20 Tu ◐	06:39 AM	4.5	137
	11:36 AM	3.0	91
	05:26 PM	5.0	152
21 W	12:07 AM	0.4	12
	07:36 AM	4.7	143
	12:53 PM	2.7	82
	06:40 PM	5.0	152
22 Th	01:09 AM	0.4	12
	08:25 AM	5.1	155
	01:57 PM	2.2	67
	07:53 PM	5.1	155
23 F	02:06 AM	0.4	12
	09:07 AM	5.4	165
	02:52 PM	1.5	46
	09:01 PM	5.3	162
24 Sa	02:57 AM	0.4	12
	09:47 AM	5.8	177
	03:42 PM	0.8	24
	10:05 PM	5.4	165
25 Su	03:46 AM	0.6	18
	10:26 AM	6.2	189
	04:30 PM	0.1	3
	11:04 PM	5.5	168
26 M	04:32 AM	0.8	24
	11:05 AM	6.5	198
	05:18 PM	-0.5	-15
27 Tu ○	12:01 AM	5.6	171
	05:18 AM	1.1	34
	11:45 AM	6.7	204
	06:05 PM	-0.9	-27
28 W	12:56 AM	5.5	168
	06:05 AM	1.5	46
	12:26 PM	6.7	204
	06:53 PM	-1.0	-30
29 Th	01:53 AM	5.4	165
	06:53 AM	1.8	55
	01:09 PM	6.6	201
	07:42 PM	-1.0	-30
30 F	02:50 AM	5.2	158
	07:45 AM	2.2	67
	01:55 PM	6.3	192
	08:33 PM	-0.8	-24
31 Sa	03:50 AM	5.1	155
	08:43 AM	2.5	76
	02:44 PM	5.9	180
	09:28 PM	-0.4	-12

November

	Time (h m)	Height (ft)	Height (cm)
1 Su	03:54 AM	5.0	152
	08:50 AM	2.7	82
	02:39 PM	5.5	168
	09:27 PM	-0.1	-3
2 M	04:58 AM	4.9	149
	10:07 AM	2.8	85
	03:42 PM	5.0	152
	10:29 PM	0.3	9
3 Tu ◑	05:59 AM	5.0	152
	11:24 AM	2.6	79
	04:52 PM	4.7	143
	11:31 PM	0.6	18
4 W	06:52 AM	5.1	155
	12:33 PM	2.2	67
	06:07 PM	4.5	137
5 Th	12:28 AM	0.9	27
	07:37 AM	5.3	162
	01:29 PM	1.8	55
	07:18 PM	4.4	134
6 F	01:19 AM	1.1	34
	08:14 AM	5.4	165
	02:17 PM	1.4	43
	08:20 PM	4.5	137
7 Sa	02:03 AM	1.3	40
	08:47 AM	5.6	171
	02:58 PM	1.0	30
	09:14 PM	4.5	137
8 Su	02:43 AM	1.5	46
	09:16 AM	5.7	174
	03:34 PM	0.6	18
	10:02 PM	4.6	140
9 M	03:19 AM	1.8	55
	09:44 AM	5.8	177
	04:08 PM	0.3	9
	10:47 PM	4.6	140
10 Tu	03:53 AM	2.0	61
	10:11 AM	5.8	177
	04:40 PM	0.0	0
	11:29 PM	4.7	143
11 W ●	04:27 AM	2.2	67
	10:41 AM	5.9	180
	05:12 PM	-0.2	-6
12 Th	12:10 AM	4.7	143
	05:00 AM	2.4	73
	11:12 AM	5.9	180
	05:46 PM	-0.3	-9
13 F	12:52 AM	4.6	140
	05:35 AM	2.6	79
	11:45 AM	5.9	180
	06:22 PM	-0.4	-12
14 Sa	01:37 AM	4.6	140
	06:13 AM	2.8	85
	12:22 PM	5.7	174
	07:02 PM	-0.4	-12
15 Su	02:25 AM	4.6	140
	06:58 AM	3.0	91
	01:04 PM	5.6	171
	07:46 PM	-0.4	-12
16 M	03:16 AM	4.6	140
	07:53 AM	3.1	94
	01:52 PM	5.4	165
	08:36 PM	-0.2	-6
17 Tu	04:09 AM	4.7	143
	09:01 AM	3.0	91
	02:51 PM	5.1	155
	09:30 PM	0.0	0
18 W	05:03 AM	4.9	149
	10:20 AM	2.8	85
	04:00 PM	4.8	146
	10:29 PM	0.2	6
19 Th ◐	05:54 AM	5.2	158
	11:37 AM	2.4	73
	05:19 PM	4.6	140
	11:29 PM	0.5	15
20 F	06:42 AM	5.5	168
	12:43 PM	1.7	52
	06:39 PM	4.6	140
21 Sa	12:28 AM	0.7	21
	07:27 AM	5.9	180
	01:40 PM	0.9	27
	07:56 PM	4.7	143
22 Su	01:23 AM	1.0	30
	08:10 AM	6.2	189
	02:32 PM	0.2	6
	09:04 PM	4.8	146
23 M	02:15 AM	1.3	40
	08:52 AM	6.6	201
	03:21 PM	-0.5	-15
	10:06 PM	5.0	152
24 Tu	03:06 AM	1.5	46
	09:34 AM	6.8	207
	04:07 PM	-1.0	-30
	11:03 PM	5.1	155
25 W ○	03:55 AM	1.8	55
	10:16 AM	6.9	210
	04:53 PM	-1.3	-40
	11:57 PM	5.2	158
26 Th	04:44 AM	2.1	64
	10:59 AM	6.8	207
	05:39 PM	-1.3	-40
27 F	12:49 AM	5.2	158
	05:34 AM	2.3	70
	11:42 AM	6.6	201
	06:24 PM	-1.2	-37
28 Sa	01:41 AM	5.2	158
	06:26 AM	2.5	76
	12:27 PM	6.3	192
	07:11 PM	-0.9	-27
29 Su	02:34 AM	5.1	155
	07:23 AM	2.7	82
	01:14 PM	5.8	177
	07:59 PM	-0.6	-18
30 M	03:26 AM	5.1	155
	08:26 AM	2.8	85
	02:05 PM	5.3	162
	08:49 PM	-0.1	-3

December

	Time (h m)	Height (ft)	Height (cm)
1 Tu	04:19 AM	5.1	155
	09:36 AM	2.7	82
	03:02 PM	4.8	146
	09:41 PM	0.3	9
2 W	05:10 AM	5.1	155
	10:50 AM	2.5	76
	04:07 PM	4.4	134
	10:35 PM	0.8	24
3 Th ◑	05:58 AM	5.2	158
	11:58 AM	2.2	67
	05:22 PM	4.0	122
	11:30 PM	1.2	37
4 F	06:41 AM	5.4	165
	12:58 PM	1.8	55
	06:42 PM	3.9	119
5 Sa	12:23 AM	1.5	46
	07:19 AM	5.5	168
	01:49 PM	1.3	40
	07:57 PM	3.9	119
6 Su	01:13 AM	1.8	55
	07:54 AM	5.7	174
	02:32 PM	0.8	24
	08:59 PM	4.1	125
7 M	01:58 AM	2.1	64
	08:28 AM	5.8	177
	03:10 PM	0.4	12
	09:52 PM	4.2	128
8 Tu	02:40 AM	2.3	70
	09:01 AM	6.0	183
	03:45 PM	0.0	0
	10:39 PM	4.4	134
9 W	03:20 AM	2.5	76
	09:34 AM	6.1	186
	04:19 PM	-0.3	-9
	11:21 PM	4.5	137
10 Th	03:58 AM	2.6	79
	10:09 AM	6.2	189
	04:53 PM	-0.5	-15
11 F ●	12:02 AM	4.6	140
	04:35 AM	2.7	82
	10:44 AM	6.2	189
	05:27 PM	-0.7	-21
12 Sa	12:42 AM	4.7	143
	05:14 AM	2.8	85
	11:22 AM	6.2	189
	06:04 PM	-0.8	-24
13 Su	01:22 AM	4.8	146
	05:56 AM	2.8	85
	12:03 PM	6.1	186
	06:43 PM	-0.8	-24
14 M	02:05 AM	4.9	149
	06:44 AM	2.9	88
	12:47 PM	5.9	180
	07:26 PM	-0.7	-21
15 Tu	02:49 AM	5.0	152
	07:39 AM	2.8	85
	01:37 PM	5.5	168
	08:12 PM	-0.4	-12
16 W	03:35 AM	5.2	158
	08:45 AM	2.7	82
	02:35 PM	5.1	155
	09:02 PM	-0.1	-3
17 Th	04:23 AM	5.4	165
	09:59 AM	2.4	73
	03:44 PM	4.7	143
	09:56 PM	0.4	12
18 F ◐	05:12 AM	5.6	171
	11:15 AM	1.9	58
	05:05 PM	4.4	134
	10:54 PM	0.8	24
19 Sa	06:01 AM	5.9	180
	12:25 PM	1.3	40
	06:33 PM	4.2	128
	11:54 PM	1.3	40
20 Su	06:50 AM	6.2	189
	01:27 PM	0.6	18
	07:56 PM	4.3	131
21 M	12:54 AM	1.7	52
	07:38 AM	6.5	198
	02:22 PM	-0.1	-3
	09:07 PM	4.5	137
22 Tu	01:52 AM	1.9	58
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	03:12 PM	-0.6	-18
	10:09 PM	4.8	146
23 W	02:47 AM	2.2	67
	09:11 AM	6.9	210
	03:59 PM	-1.0	-30
	11:03 PM	5.0	152
24 Th	03:40 AM	2.3	70
	09:56 AM	6.9	210
	04:43 PM	-1.2	-37
	11:52 PM	5.2	158
25 F ○	04:30 AM	2.4	73
	10:41 AM	6.8	207
	05:26 PM	-1.2	-37
26 Sa	12:38 AM	5.3	162
	05:20 AM	2.5	76
	11:24 AM	6.6	201
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27 Su	01:22 AM	5.3	162
	06:09 AM	2.5	76
	12:07 PM	6.2	189
	06:48 PM	-0.8	-24
28 M	02:05 AM	5.3	162
	07:00 AM	2.6	79
	12:50 PM	5.8	177
	07:29 PM	-0.4	-12
29 Tu	02:47 AM	5.2	158
	07:55 AM	2.6	79
	01:36 PM	5.3	162
	08:10 PM	0.1	3
30 W	03:29 AM	5.2	158
	08:54 AM	2.6	79
	02:25 PM	4.8	146
	08:53 PM	0.6	18
31 Th	04:10 AM	5.2	158
	09:59 AM	2.4	73
	03:22 PM	4.3	131
	09:39 PM	1.1	34

Disclaimer: These data are based upon the latest information available as of the date of your request, and may differ from the published tide tables.

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	Engineering and Design NAVSTAR GLOBAL POSITIONING SYSTEM SURVEYING	
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EM 1110-1-1003
1 August 1996

US Army Corps
of Engineers

ENGINEERING AND DESIGN

NAVSTAR Global Positioning System Surveying

ENGINEER MANUAL

DEPARTMENT OF THE ARMY
U.S. Army Corps of Engineers
Washington, DC 20314-1000

EM 1110-1-1003

CECW-EP

Manual
No. 1110-1-1003

1 August 1996

Engineering and Design
NAVSTAR GLOBAL POSITIONING SYSTEM SURVEYING

1. Purpose. This manual provides technical specifications and procedural guidance for surveying with the NAVSTAR Global Positioning System (GPS). It is intended for use by engineering, topographic, or construction surveyors performing surveys for civil works and military construction projects. Procedural and quality control standards are defined to establish Corps-wide uniformity in GPS survey performance and GPS Architect-Engineer (A-E) contracts.

2. Applicability. This manual applies to HQUSACE elements, major subordinate commands (MSC), districts, laboratories, and field operating activities (FOA) having responsibility for the planning, engineering and design, operations, maintenance, construction, and related real estate and regulatory functions of civil works and military construction projects. It applies to GPS survey performance by both hired labor forces and contracted survey forces. It is also applicable to surveys performed or procured by local interest groups under various cooperative or cost-sharing agreements.

3. General. The NAVSTAR GPS has significantly modified many traditional survey practices found in all aspects of surveying and mapping work. The NAVSTAR GPS, operating in a differential or relative survey mode, is capable of providing far more accurate positions of either static monuments or moving platforms at costs far less than those for conventional survey methods. The goal of this manual is to ensure that GPS survey procedures are efficiently and uniformly practiced to attain more accurate and cost-effective surveying and mapping execution throughout the Corps of Engineers.

FOR THE COMMANDER:

ROBERT H. GRIFFIN
Colonel, Corps of Engineers
Chief of Staff

This manual supersedes EM 1110-1-1003, dated 31 December 1994.

DEPARTMENT OF THE ARMY
U.S. Army Corps of Engineers
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Table of Contents

Subject	Paragraph	Page
Chapter 1		
Introduction		
Purpose	1-1	1-1
Applicability	1-2	1-1
References	1-3	1-1
Explanation of Abbreviations and Terms	1-4	1-1
Trade Name Exclusions	1-5	1-1
Accompanying Guide Specification	1-6	1-1
Background	1-7	1-1
Scope of Manual	1-8	1-1
Life Cycle Project Management Applicability	1-9	1-2
Metrics	1-10	1-2
Manual Development and Proponency	1-11	1-2
Distribution	1-12	1-2
Further Information	1-13	1-2
Chapter 2		
Operational Theory of NAVSTAR GPS		
Global Positioning System (GPS)	2-1	2-1
NAVSTAR Program Background	2-2	2-2
NAVSTAR System Configuration	2-3	2-2
GPS Broadcast Frequencies and Codes	2-4	2-3
GPS Broadcast Messages and Ephemeris Data	2-5	2-4
Chapter 3		
GPS Applications in USACE		
General	3-1	3-1
Project Control Densification	3-2	3-1
Geodetic Control Densification	3-3	3-1
Vertical Control Densification	3-4	3-1
Structural Deformation Studies	3-5	3-1
Photogrammetry	3-6	3-1
Dynamic Positioning and Navigation	3-7	3-2
GIS Integration	3-8	3-2
Chapter 4		
GPS Reference Systems		
General	4-1	4-1
Geodetic Coordinate Systems	4-2	4-1
WGS 84 Reference Ellipsoid	4-3	4-1
Horizontal Positioning Datums	4-4	4-1
Orthometric Elevations	4-5	4-3
GPS WGS 84 Ellipsoidal Heights	4-6	4-3
Orthometric-WGS 84 Elevation Relationship	4-7	4-3
Chapter 5		
GPS Absolute Positioning Determination Concepts, Errors, and Accuracies		
General	5-1	5-1
Absolute Positioning	5-2	5-1
Pseudo-Ranging	5-3	5-1
GPS Error Sources	5-4	5-3
User Equivalent Range Error	5-5	5-5
Absolute GPS Accuracies	5-6	5-5
Chapter 6		
GPS Relative Positioning Determination Concepts		
General	6-1	6-1
Differential (Relative) Positioning	6-2	6-1
Differential Positioning (Code Pseudo-Range Tracking)	6-3	6-1
Differential Positioning (Carrier Phase Tracking)	6-4	6-1
Vertical Measurements with GPS	6-5	6-3
Differential Error Sources	6-6	6-4
Differential GPS Accuracies	6-7	6-4
Chapter 7		
GPS Survey Equipment		
GPS Receiver Selection	7-1	7-1

Subject	Paragraph	Page
Conventional GPS Receiver Types	7-2	7-1
Receiver Manufacturers	7-3	7-3
Other Equipment	7-4	7-3
GPS Common Exchange Data Format	7-5	7-3
Chapter 8		
Planning GPS Control Surveys		
General	8-1	8-1
Required Project Control Accuracy	8-2	8-1
General GPS Network Design Factors	8-3	8-2
GPS Network Design and Layout	8-4	8-12
GPS Techniques Needed for Survey	8-5	8-14
Chapter 9		
Conducting GPS Field Surveys		
Section I		
Introduction		
General	9-1	9-1
General GPS Field Survey Procedures	9-2	9-1
Section II		
Absolute GPS Positioning Techniques		
General	9-3	9-2
Absolute (Point Positioning) Techniques	9-4	9-2
Section III		
Differential Code Phase GPS Positioning Techniques		
General	9-5	9-2
Relative Code Phase Positioning	9-6	9-3
Section IV		
Differential Carrier Phase GPS Horizontal Positioning Techniques		
General	9-7	9-4
Static GPS Survey Techniques	9-8	9-5
Stop-and-Go Kinematic GPS Survey Techniques	9-9	9-6
Kinematic GPS Survey Techniques	9-10	9-8
Pseudo-Kinematic GPS Survey Techniques	9-11	9-9
Rapid Static Surveying Procedures	9-12	9-10
OTF/RTK Surveying Techniques	9-13	9-10
Chapter 10		
Post-processing Differential GPS Observational Data		
General	10-1	10-1
Pseudo-Ranging	10-2	10-1
Carrier Beat Phase Observables	10-3	10-1
Baseline Solution by Linear Combination	10-4	10-1
Baseline Solution by Cycle Ambiguity Recovery	10-5	10-3
Field/Office Data Processing and Verification	10-6	10-3
Post-processing Criteria	10-7	10-4
Field/Office Loop Closure Checks	10-8	10-5
Data Management (Archival)	10-9	10-15
Flow Diagram	10-10	10-15
Chapter 11		
Adjustment of GPS Surveys		
General	11-1	11-1
GPS Error Measurement Statistics	11-2	11-1
Adjustment Considerations	11-3	11-1
Survey Accuracy	11-4	11-2
Internal versus External Accuracy	11-5	11-3
Internal and External Adjustments	11-6	11-3
Internal or Geometric Adjustment	11-7	11-3
External or Fully Constrained Adjustment	11-8	11-5
Partially Constrained Adjustments	11-9	11-6
Approximate Adjustments of GPS Networks	11-10	11-7
Geocentric Coordinate Conversions	11-11	11-10
Rigorous Least Squares Adjustments of GPS Surveys	11-12	11-12
Evaluation of Adjustment Results	11-13	11-25
Final Adjustment Reports and Submittals	11-14	11-26
Chapter 12		
Estimating Costs For Contracted GPS Surveys		
General	12-1	12-1
Hired Labor Surveys	12-2	12-1
Contracted GPS Survey Services	12-3	12-1
Verification of Contractor Cost or Pricing Data	12-4	12-2
Sample Cost Estimate for Contracted GPS Survey Services	12-5	12-2
Appendix A		
References		
Appendix B		
Glossary		
Appendix C		
Sources of GPS Information		

Subject	Paragraph	Page
Appendix D		
Static GPS Survey Examples		
Appendix E		
Horn Lake, Mississippi Stop-and-Go GPS Survey		
Appendix F		
Field Reduction and Adjustment of GPS Surveys		
Appendix G		
Guide Specification for NAVSTAR Global Positioning System (GPS) Surveying Services		
Appendix H		
Guide Specification for "Geodetic Quality" NAVSTAR Global Positioning System (GPS) Survey Receivers and Related Equipment/ Instrumentation		
Appendix I		
Guide Specification for Code Phase Differential NAVSTAR Global Positioning System (GPS) Survey Receivers and Related Equipment/ Instrumentaion		

Chapter 1
Introduction

1-1. Purpose

This manual provides technical specifications and procedural guidance for surveying with the NAVSTAR Global Positioning System (GPS). It is intended for use by engineering, topographic, or construction surveyors performing surveys for civil works and military construction projects. Procedural and quality control standards are defined to establish Corps-wide uniformity in GPS survey performance and GPS architect-engineer (A-E) contracts.

1-2. Applicability

This manual applies to HQUSACE elements, major subordinate commands, districts, laboratories, and field operating activities having responsibility for the planning, engineering and design, operations, maintenance, construction, and related real estate and regulatory functions of civil works and military construction projects. It applies to GPS survey performance by both hired-labor forces and contracted survey forces. It is also applicable to surveys performed or procured by local interest groups under various cooperative or cost-sharing agreements.

1-3. References

Required and related publications are listed in Appendix A.

1-4. Explanation of Abbreviations and Terms

GPS surveying terms and abbreviations used in this manual are explained in the Glossary (Appendix B).

1-5. Trade Name Exclusions

The citation or illustration in this manual of trade names of commercially available GPS products, including other auxiliary surveying equipment, instrumentation, and adjustment software, does not constitute official endorsement or approval of the use of such products.

1-6. Accompanying Guide Specification

A guide specification for the preparation of A-E contracts for GPS survey services is contained in Appendix G.

1-7. Background

GPS surveying is a process by which highly accurate, three-dimensional (3D) point positions are determined from signals received from NAVSTAR satellites. GPS-derived positions may be used to provide the primary reference control monument locations for engineering and construction projects, from which detailed site plan topographic mapping, boundary demarcation, and construction alignment work may be performed using conventional surveying instruments and procedures. GPS surveying also has application in the continuous positioning of marine floating plants. GPS surveying can also be used for input to Geographic Information System (GIS) and mapping projects.

1-8. Scope of Manual

This manual deals primarily with the use of differential carrier phase GPS survey techniques for establishing and/or extending project construction or boundary control. Both static and kinematic survey methods are covered, along with related GPS data reduction, post-processing, and adjustment methods. Differential code phase GPS positioning and navigation methods supporting hydrographic surveying and dredge control are covered to a lesser extent (see EM 1110-2-1003 for further information on hydrographic surveying with GPS). Kinematic (or dynamic) real-time differential carrier phase GPS surveying applications are covered in detail in this manual. Absolute GPS point positioning methods (i.e., nondifferential) are also described since these techniques have an application in some USACE surveying and mapping projects.

a. This manual is intended to be a comprehensive reference guide for differential carrier phase GPS surveying, whether performed by in-house, hired-labor forces, contracted forces, or combinations thereof. General planning criteria, field and office execution procedures, and required accuracy specifications for performing differential GPS surveys in support of USACE engineering, construction, operations, planning, and real estate activities are provided. Accuracy specifications, procedural criteria, and quality control requirements contained in this manual shall be directly referenced in the scopes of work for A-E survey services or other third-party survey services. This is intended to ensure that uniform and standardized procedures are followed by both hired-labor and contract service sources throughout USACE.

b. The primary emphasis of the manual centers on performing second- and third-order accuracy surveys. This accuracy level will provide adequate reference control from which supplemental real estate, engineering, construction layout surveying, and site plan topographic mapping work may be performed using conventional survey techniques. Therefore, the survey criteria given in this manual will not necessarily meet the Federal Geodetic Control Subcommittee (FGCS) standards and specifications required for the National Geodetic Reference System (NGRS). However, it should be understood that following the methods and procedures given in this manual will give final results generally equal to or exceeding FGCS second-order relative accuracy criteria. This is adequate for the majority of USACE projects.

c. Chapter 12 herein on GPS cost estimating is intended to assist those USACE Commands which primarily contract out survey services. Refer to Appendix G for further information concerning the contracting of GPS services.

d. This manual briefly covers the theory and physical concepts of NAVSTAR GPS positioning. Consult the related publications in Appendix A for further information.

1-9. Life Cycle Project Management Applicability

Project control established by GPS survey methods may be used through the entire life cycle of a project, spanning decades in many cases. During initial reconnaissance surveys of a project, control established by GPS should be permanently monumented and situated in areas that are conducive to the performance or densification of subsequent surveys for contract plans and specifications, construction, and maintenance. During the early planning phases of a project, a comprehensive survey control plan should be developed which considers survey requirements over a project's life cycle, with a goal of eliminating duplicative or redundant surveys to the maximum extent possible.

1-10. Metrics

Metric units are used in this manual. Metric units are commonly used in geodetic surveying applications, including the GPS survey work covered herein. GPS-derived geographical or metric Cartesian coordinates are generally transformed to non-SI units of measurements for use in local project reference and design systems, such as State Plane Coordinate System (SPCS) grids. In all cases, the use of metrics shall follow local engineering and construction practices. Non-SI/metric equivalencies are noted where applicable, including the critical--and often statutory--distinction between the U.S. Survey Foot (1,200/3,937 m exactly) and International Foot (30.48/100 m exactly) conversions.

1-11. Manual Development and Proponency

The HQUSACE proponent for this manual is the Surveying and Analysis Section, General Engineering Branch, Civil Works Directorate. The manual was developed by the U.S. Army Topographic Engineering Center (USATEC) during the period 1992-1994 under the Civil Works Guidance Update Program, U.S. Army Engineer Waterways Experiment Station. Primary technical authorship and/or review was provided by the U.S. Army Engineer Districts, Pittsburgh, Tulsa, Detroit, New Orleans, and St. Louis. Recommended corrections or modifications to this manual should be directed to HQUSACE, ATTN: CECW-EP-S, 20 Massachusetts Ave. NW, Washington, DC 20324-1000.

1-12. Distribution

Copies of this document or any other Civil Works Criteria Documents can be obtained from: U.S. Army Corps of Engineers, Publications Depot, 2803 52nd Ave, Hyattsville, MD 20781-1102, Phone: (301) 394-0081.

1-13. Further Information

Further information on the technical contents of this manual can be obtained from:

U.S. Army Topographic Engineering Center
ATTN: CETEC-TD-AG
Surveying Division
7701 Telegraph Road
Alexandria, VA 22315-3864

Phone: (703) 428-6766
Fax: (703) 428-8176

Chapter 2
Operational Theory of NAVSTAR GPS

This chapter provides a general overview of the basic operating principles and theory of the NAVSTAR GPS. The references listed in Appendix A should be used for more detailed background of all the topics covered in this chapter.

2-1. Global Positioning System (GPS)

The NAVSTAR GPS is a passive, satellite-based, navigation system operated and maintained by the Department of Defense (DoD). Its primary mission is to provide passive global positioning/navigation for land-, air-, and sea-based strategic and tactical forces. A GPS receiver is simply a range measurement device; distances are measured between the receiver antenna and the satellites, and the position is determined from the intersections of the range vectors. These distances are determined by a GPS receiver which precisely measures the time it takes a signal to travel from the satellite to the station. This measurement process is similar to that used in conventional pulsing marine navigation systems and in phase comparison electronic distance measurement (EDM) land surveying equipment.

a. GPS operating and tracking modes. There are basically two general operating modes from which GPS-derived positions can be obtained: absolute positioning and relative or differential positioning. Within each of these two modes, range measurements to the satellites can be performed by tracking either the phase of the satellite's carrier signal or the pseudo-random noise codes modulated on the carrier signal. In addition, GPS positioning can be performed with the receiver operating in a static or dynamic (kinematic) environment. This variety of operational options results in a wide range of accuracy levels which may be obtained from the NAVSTAR GPS. Accuracies can range from 100 m down to the sub-centimeter level, as shown in Figure 2-1. Increased accuracies to the sub-centimeter level require additional observing time and, until recently, could not be achieved in real time. Selection of a particular GPS operating and tracking mode (i.e., absolute, differential, code, carrier, static, kinematic, or combinations thereof) depends on the user application. USACE survey applications typically require differential positioning using carrier phase tracking. Some dredge control and hydrographic applications can use differential code measurements. Absolute modes are rarely used for geodetic surveying applications except when worldwide reference control is being established.

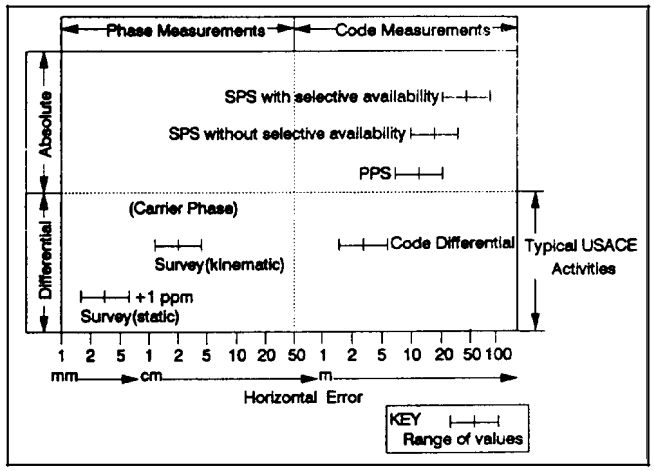

Figure 2-1. GPS operating modes and accuracies

b. Absolute positioning. The most common military and civil (i.e., commercial) application of GPS is "absolute positioning" for real-time navigation. When operating in this passive, real-time navigation mode, ranges to NAVSTAR satellites are observed by a single receiver positioned on a point for which a position is desired. This receiver may be positioned to be stationary over a point (i.e., static, Figure 2-2) or in motion (i.e., kinematic positioning, such as on a vehicle, aircraft, missile, or backpack). Two levels of absolute positioning accuracy may be obtained from the NAVSTAR GPS. These are called the (1) Standard Positioning Service (SPS) and (2) Precise Positioning Service (PPS).

(1) Using the SPS, the user is able to achieve real-time 3D absolute point positioning on the order of 100 m. The SPS is the GPS signal that the DoD authorizes to civil users. This level of accuracy, achievable by the civil user, is due to the deliberate degradation of the GPS signal by the DoD for national security reasons. DoD degradation of the GPS signal is referred to as "Selective Availability" or S/A. DoD has also implemented Anti-Spoofing or A-S which will deny the SPS user the more accurate P-code. S/A and A-S will be discussed further in Chapter 5.

(2) Use of the PPS requires authorization by DoD to have a decryption device capable of deciphering the encrypted GPS signals. USACE is an authorized user; however, actual use of the equipment has security implications. Real-time 3D absolute positional accuracies of 16-20 m are attainable through use of the PPS.

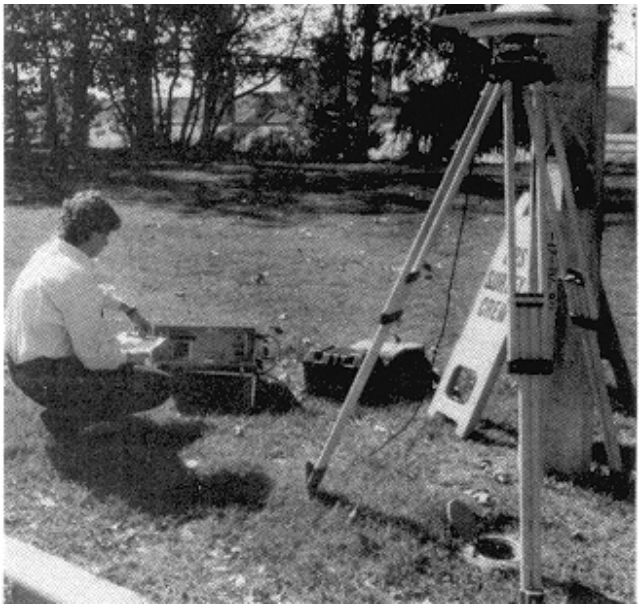

Figure 2-2. Performing static differential GPS surveys

(3) With certain specialized GPS receiving equipment, data processing refinements, and long-term static observations, absolute positional coordinates may be determined to accuracy levels less than a meter. Applications of this are usually limited to worldwide geodetic reference surveys.

(4) These absolute point positioning accuracy levels are not suitable for USACE surveying applications other than rough reconnaissance work or general vessel navigation. They may be useful for some military topographic surveying applications (e.g., artillery surveying).

c. Differential or relative GPS positioning. Differential positioning is simply a process of measuring the differences in coordinates between two receiver points, each of which is simultaneously observing/measuring satellite code ranges and/or carrier phases from the NAVSTAR GPS constellation. The process actually involves the measurement of the difference in ranges between the satellites and two or more ground observing points. The range measurement is performed by a phase difference comparison, using either the carrier phase or code phase. The basic principle is that the absolute positioning errors at the two receiver points will be approximately the same for a given instant. The resultant accuracy of these coordinate differences is at the meter level for code phase observations and at the centimeter level for carrier phase tracking. These coordinate differences are usually expressed as 3D "baseline vectors," which are comparable to conventional survey azimuth/distance measurements. Differential GPS (DGPS) positioning can be performed in either a static or kinematic mode. Further information on DGPS can be found in Chapter 6.

2-2. NAVSTAR Program Background

A direct product of the "space race" of the 1960's, the NAVSTAR GPS is actually the result of the merging of two independent programs that were begun in the early 1960's: the U.S. Navy's TIMATION Program and the U.S. Air Force's 621B Project. Another system similar in basic concept to the current NAVSTAR GPS was the U.S. Navy's TRANSIT program, which was also developed in the 1960's. Currently, the entire system is maintained by the NAVSTAR GPS Joint Program Office (JPO), a North Atlantic Treaty Organization (NATO) multiservice type organization. DoD originally designed the NAVSTAR GPS to provide sea, air, and ground forces of the United States and members of NATO with a unified, high-precision, all-weather, worldwide, real-time positioning system. Mandated by Congress, GPS is freely used by both the military and civilian public for real-time absolute positioning of ships, aircraft, and land vehicles, as well as highly precise differential point positioning.

2-3. NAVSTAR System Configuration

The NAVSTAR GPS consists of three distinct segments: the space segment (satellites), the control segment (ground tracking and monitoring stations), and the user segment (air-, land-, and sea-based receivers). See Figure 2-3 for a representation of the basic GPS system segments.

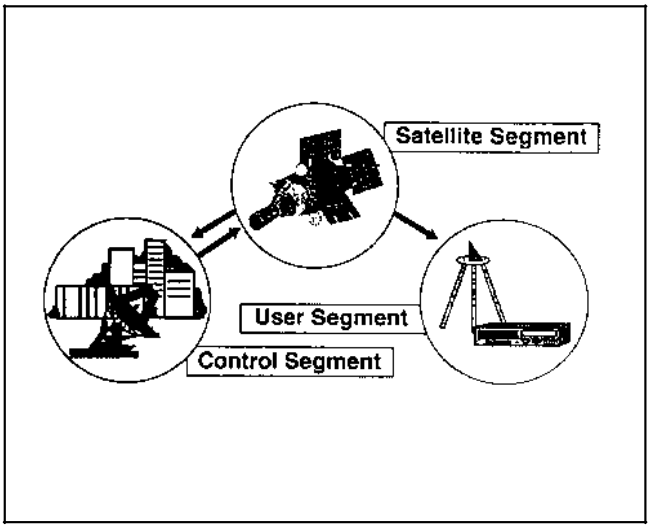

Figure 2-3. GPS system segments

a. Space segment. The space segment consists of all GPS satellites in orbit. The first generation of satellites was the Block I or developmental. Several of these are still operational. A full constellation of Block II or production satellites is presently being put into orbit using Delta II launch vehicles. *The full 24-satellite constellation is scheduled to be in orbit by early FY94.* When this full constellation is implemented, there will be 24 Block II operational satellites (21 primary with 3 active on-orbit spares). There will be four satellites in each of six orbital planes inclined at 55 deg to the equator. The satellites will be at altitudes of 10,898 nm (20,183 km), and have 11-hr-56-minute orbital periods. The three active spares will be transparent to the user on the ground; i.e., the user will not be able to tell which are operational satellites and which are spares. A procurement action for Block IIR (R is for replacement) satellites is underway, thus ensuring full system performance through the year 2025. Figure 2-4 illustrates some of the common design characteristics of the NAVSTAR GPS fully configured Block IIR constellation.

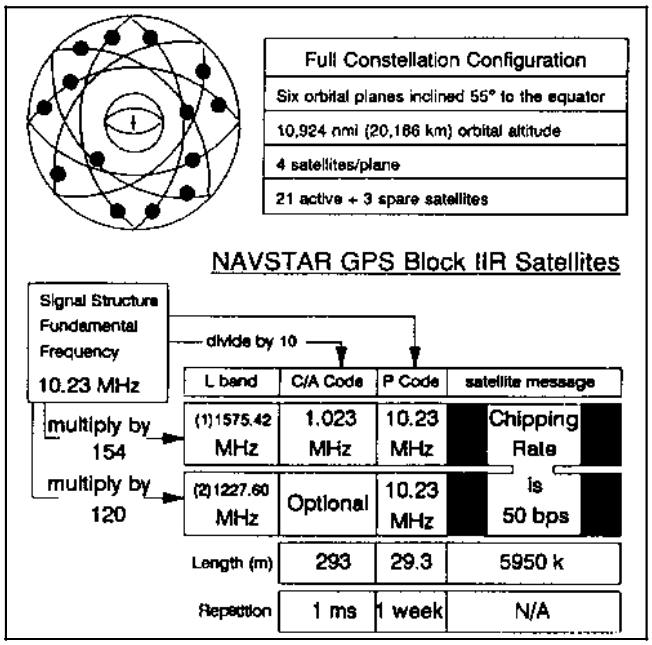

Figure 2-4. NAVSTAR GPS Block IIR constellation

b. Control segment. The GPS control segment consists of five tracking stations located throughout the world (Figure 2-5). These stations are in Hawaii, Colorado, Ascension Island, Diego Garcia, and Kwajalein. The information obtained from tracking the satellites is used in controlling the satellites and predicting their orbits. Three of the stations (Ascension, Diego Garcia, and Kwajalein) are used for transmitting information back to the satellites. The Master Control Station is located at Colorado Springs, Colorado. All data from the tracking stations are transmitted to the Master Control Station where they are processed and analyzed. Ephemerides, clock corrections, and other message data are then transmitted back to the three stations for subsequent transmittal back to the satellites. The Master Control Station is also responsible for the daily management and control of the GPS satellites and the overall control segment.

c. User segment. The user segment represents the ground-based receiver units that process the NAVSTAR satellite signals and arrive at a position of the user. It consists of both military and civil activities for an almost unlimited number of applications in a variety of air-, sea-, or land-based platforms. Land surveying applications (including those of USACE) represent a small percentage of current and potential GPS users.

2-4. GPS Broadcast Frequencies and Codes

Each NAVSTAR satellite transmits signals on two L-band frequencies, designated as L1 and L2. The L1 carrier frequency is 1575.42 megahertz (MHz) and has a wavelength of approximately 19 centimeters (cm). The L2 carrier frequency is 1227.60 MHz and has a wavelength of approximately 24 cm. The L1 signal is modulated with a Precise Code (P-code) and a Coarse Acquisition Code (C/A-code). The L2 signal is modulated with only the P-code. Each satellite carries precise atomic clocks to generate the timing information needed for precise positioning. A navigation message is also transmitted on both frequencies. This message contains ephemerides, clock correction and coefficients, health and status of satellites, almanacs of all GPS satellites, and other general information.

a. Pseudo-random noise. The modulated C/A- and P-codes are referred to as pseudo-random noise (PRN). This pseudo-random code is actually a sequence of very precise time marks that permit the ground receivers to compare and compute the time of transmission between the satellite and ground station. From this transmission time, the range to the satellite can be derived. This is the basis behind GPS range measurements. The C/A-code pulse intervals are approximately every 300 m in range and the more accurate P-code every 30 m.

b. Pseudo-ranges. A pseudo-range is the time delay between the satellite clock and the receiver clock, as determined from C/A- or P-code pulses. This time

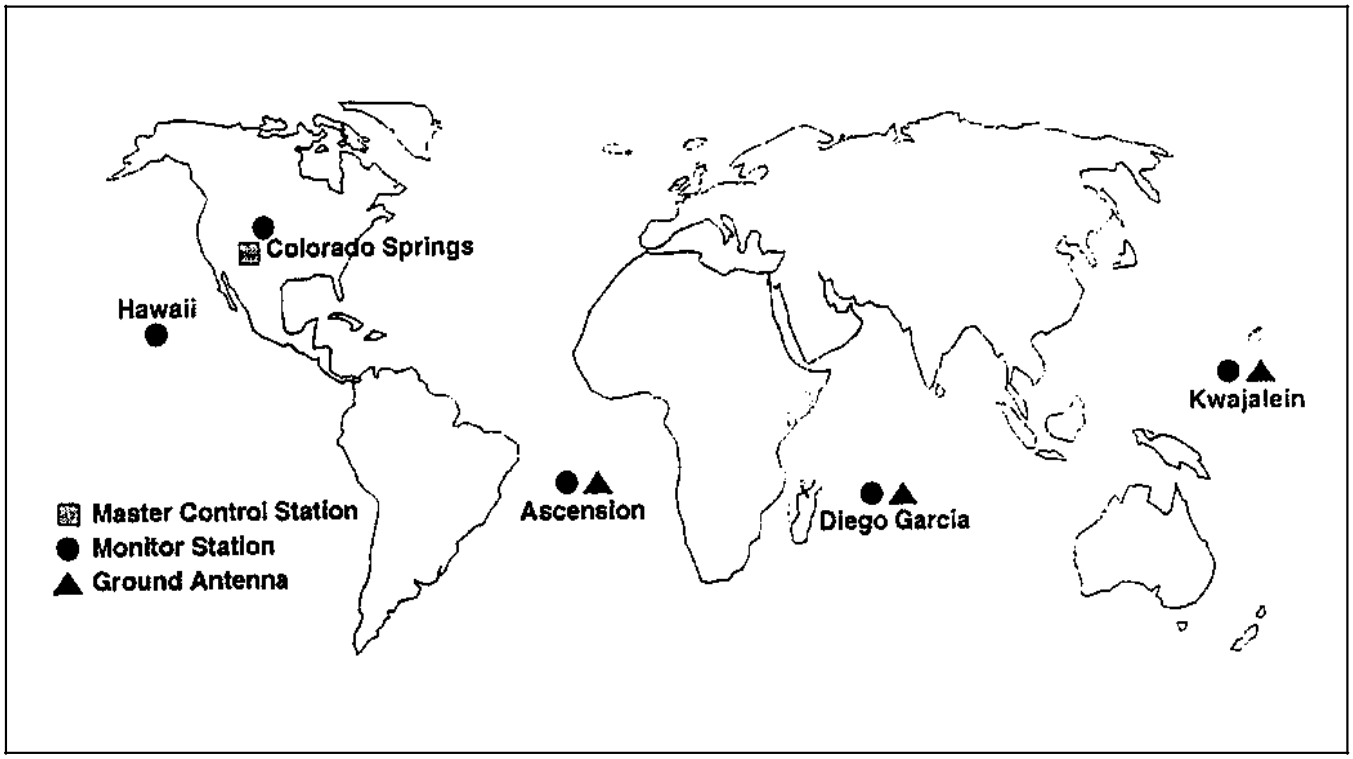

Figure 2-5. GPS control station network

difference equates to the range measurement but is called a pseudo-range since at the time of the measurement, the receiver clock is not synchronized to the satellite clock. In most cases, an absolute 3D real-time navigation position can be obtained by observing at least four simultaneous pseudo-ranges.

c. SPS. The SPS uses the less precise C/A-code pseudo-ranges for real-time GPS navigation. Due to deliberate DoD degradation of the C/A-code accuracy, 100 m in horizontal and 156 m in vertical accuracy levels result. These accuracy levels are adequate for most civil or nonmilitary applications, where only approximate real-time navigation is required.

d. PPS. The PPS is the fundamental military real-time navigation use of GPS. Pseudo-ranges are obtained using the higher pulse rate (i.e., higher accuracy) P-code on both frequencies (L1 and L2). Real-time 3D accuracies at the 16-m level (and 10 m horizontal) can be achieved with the PPS. The P-code is encrypted to prevent unauthorized civil or foreign use. This encryption will require a special key to obtain this 16-m accuracy. These accuracies are adequate for some USACE surveying and mapping projects (i.e. GIS database input).

e. Carrier phase measurements. Carrier frequency tracking measures the phase differences between the Doppler shifted satellite and receiver frequencies. The phase differences are continuously changing due to the changing satellite earth geometry. However, such effects are resolved in the receiver and subsequent data post-processing. When carrier phase measurements are observed and compared between two stations (i.e., relative or differential mode), baseline vector accuracy between the stations below the centimeter level is attainable in three dimensions. New receiver technology and processing techniques have allowed for carrier phase measurements to be used in real-time centimeter positioning.

2-5. GPS Broadcast Messages and Ephemeris Data

Each NAVSTAR GPS satellite periodically broadcasts data concerning clock corrections, system/satellite status, and most critically, its position or ephemeris data. There are two basic types of ephemeris data: broadcast and precise.

a. Broadcast ephemerides. The broadcast ephemerides are actually predicted satellite positions broadcast

within the navigation message that are transmitted from the satellites in real time. The ephemerides can be acquired in real time by a receiver capable of acquiring either the C/A- or P-code. The broadcast ephemerides are computed using past tracking data of the satellites. The satellites are tracked continuously by the monitor stations to obtain more recent data to be used for the orbit predictions. The data are analyzed by the Master Control Station, and new parameters for the satellite orbits are transmitted back to the satellites. This upload is performed daily with new predicted orbital elements transmitted every hour by the navigation message.

b. *Precise ephemerides.* The precise ephemerides are based on actual tracking data that are post-processed to obtain the more accurate satellite positions. These ephemerides are available at a later date and are more accurate than the broadcast ephemerides because they are based on actual tracking data and not predicted data. Nonmilitary users can obtain this information from the National Geodetic Survey (NGS) or from private sources that maintain their own tracking networks and provide information for a fee. For most USACE survey applications, the broadcast ephemerides are adequate to obtain the needed accuracies.

c. See Appendix D for sources of GPS information and its status.

Chapter 3
GPS Applications in USACE

3-1. General

Currently, surveyors use GPS to increase their efficiency, productivity, and to produce more accurate results. GPS can be used for real estate surveys, regulatory enforcement actions, horizontal and vertical control densification, structural deformation studies, airborne photogrammetry, dynamic positioning and navigation for hydrographic survey vessels and dredges, hydraulic study/survey location, river/floodplain cross-section location, core drilling location, environmental studies, levee overbank surveys, and levee profiling. Future construction uses of dynamic GPS are unlimited: levee grading and revetment placement, disposal area construction, grade control, etc. Additionally, GPS has application in developing various levels of GIS spatial data. A few of these applications are briefly described in this chapter.

3-2. Project Control Densification

Establishing or densifying project control with GPS is often cost-effective, faster, more accurate, and more reliable than conventional survey methods. The quality control statistics and large number of redundant measurements in GPS networks help to ensure reliable results. Field operations to perform a GPS survey are relatively easy and can generally be performed by one person per receiver. GPS is particularly attractive for control networks as compared with conventional surveys because intervisibility is not required between adjacent stations.

3-3. Geodetic Control Densification

GPS can be used for wide-area high-order geodetic control densification. GPS provides very precise point positioning (when used in a relative mode), producing baseline results on the order of 5 to 10 ppm under average conditions.

3-4. Vertical Control Densification

GPS uses the World Geodetic System of 1984 (WGS 84) ellipsoid as the optimal mathematical model describing the shape of the earth on an ellipsoid of rotation. There is no direct mathematical relation between heights obtained from GPS and orthometric elevations obtained from conventional spirit leveling. However, a model can be determined from benchmark data and corresponding GPS data. This model can then be used to derive the unknown orthometric heights of stations occupied during a GPS observation period to densify supplemental small-scale topographic mapping. Geoid modeling software also exists and is used to determine orthometric heights from GPS. Extreme caution should be taken in using GPS for vertical densification. The procedures for vertical densification are described in further detail in Chapter 6.

3-5. Structural Deformation Studies

GPS survey techniques can be used to monitor the motion of points on a structure relative to stable monuments. This can be done with an array of antennae positioned at selected points on the structure and on remote stable monuments. Baselines are formulated between the occupied points to monitor differential movement. The relative precision of the measurements is on the order of ±5 mm over distances averaging between 5 and 10 km. Measurements can be made on a continuous basis. A GPS structural deformation system can operate unattended and is relatively easily installed and maintained.

3-6. Photogrammetry

The use of an airborne GPS receiver employing on-the-fly (OTF) techniques combined with specialized photogrammetric procedures has the potential to significantly reduce the amount of ground control for typical photogrammetric projects. Currently, these projects require a significant amount of manpower and monetary resources for the establishment of the control points. Therefore, the use of this GPS Controlled Photogrammetry (GCP) technology in the USACE civil works programs should reduce the production costs associated with large scale maps. The benefits of GCP will be realized in the savings estimation based on the premise that most of the USACE photogrammetry activities require USACE personnel to do much planning and surveying in preparation for the actual photogrammetry flight, and the GCP procedure has the potential for the reduction, or even elimination, of this surveying activity. Tests have shown that ground control coordinates can be developed from an airborne platform using adapted GPS kinematic techniques to centimeter-level precision in all three axes if system-related errors are minimized and care is taken in conduct of the GPS and photogrammetric portions of the procedures. High quality photogrammetric results can also be achieved with DGPS based on carrier-smoothed code phase positioning.

3-7. Dynamic Positioning and Navigation

Dynamic, real-time GPS code and carrier phase positioning of construction and surveying platforms has the potential for revolutionizing many current USACE design and construction functions. This includes dredge control systems, site investigation studies/surveys, horizontal and vertical construction placement, hydraulic studies, or any other activity requiring dimensional control. Real-time, centimeter-level 3D (based on the WGS 84 Ellipsoid) control may be achieved using carrier phase differential GPS; this method can be used for any type of construction or survey platform (e.g., dredges, graders, survey vessels, etc.). This method is discussed further in Chapter 6.

3-8. GIS Integration

A GIS is an effective means to correlate and store diverse information on natural or man-made characteristics of geographic positions. In order for a GIS to be reliably oriented, it should be based on a coordinate system. A standardized GIS network enables a more accurate exchange of GIS information between databases. In recent years, GPS has demonstrated its efficiency, cost effectiveness, and accuracy in precise surveying and mapping support.

Chapter 4
GPS Reference Systems

4-1. General

In order to fully understand GPS, and its positional information, it is important to understand the reference system on which it is based. The GPS satellites are referenced to the WGS 84 ellipsoid. For surveying purposes, this earth-centered WGS 84 coordinate system must be converted (i.e., transformed) to a user-defined ellipsoid/datum, such as the Clarke 1866 (North American Datum of 1927 (NAD 27)) or Geodetic Reference System of 1980 (GRS 80) reference ellipsoids. Differential positioning provides this conversion by locating one of the receivers at a known point on the user's datum. This chapter deals with GPS reference systems and datums to which GPS coordinates can be transformed.

4-2. Geodetic Coordinate Systems

The absolute positions obtained directly from GPS pseudo-range measurements are based on the 3D, earth-centered WGS 84 ellipsoid. Coordinate outputs are on a Cartesian system (X, Y, and Z) relative to an Earth Centered Earth Fixed (ECEF) Rectangular Coordinate System having the same origin as the WGS 84 ellipsoid, i.e. geocentric. This geocentric X-Y-Z coordinate system should not be confused with the X-Y plane coordinates established on local grids; local systems usually have entirely different definitions, origins, and orientations which require certain transformations to be performed. WGS 84 Cartesian coordinates can be easily converted into WGS 84 ellipsoid coordinates (i.e., , , and *h*, geodetic latitude, longitude, and height, respectively).

4-3. WGS 84 Reference Ellipsoid

a. The origin of the WGS 84 Cartesian system is the earth's center of mass. The Z-axis is parallel to the direction of the Conventional Terrestrial Pole (CTP) for polar motion, as defined by the Bureau International Heure (BIH), and equal to the rotation axis of the WGS 84 ellipsoid. The X-axis is the intersection of the WGS 84 reference meridian plane and the CTP's equator, the reference meridian being parallel to the zero meridian defined by the BIH and equal to the X-axis of the WGS 84 ellipsoid. The Y-axis completes a right-handed, earth-centered, earth-fixed orthogonal coordinate system, measured in the plane of the CTP equator 90 deg east of the X-axis and equal to the Y-axis of the WGS 84 ellipsoid. This system is illustrated in Figure 4-1.

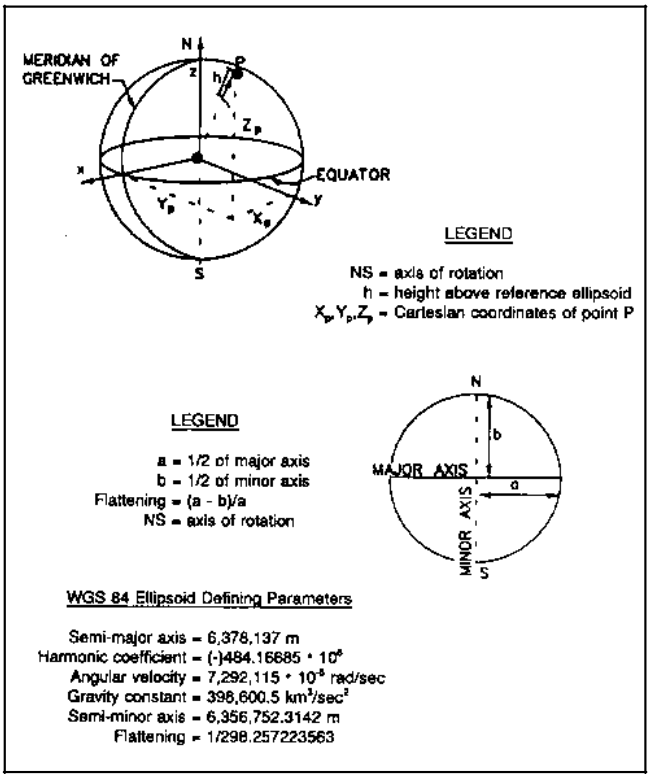

Figure 4-1. GPS WGS 84 reference ellipsoid

b. Prior to development of WGS 84, there were several reference ellipsoids and interrelated coordinate systems (datums) that were used by the surveying community. Table 4-1 lists just a few of these systems, some of which are widely used even today.

Table 4-1
Reference Ellipsoids and Related Coordinate Systems

Reference Ellipsoid	Coordinate System (Datum)
Clarke 1866	NAD 27
WGS 72	WGS 72
GRS 80	NAD 83
WGS 84	WGS 84

4-4. Horizontal Positioning Datums

One USACE application of differential GPS surveying is in densifying military construction and civil works project control. This densification is usually done relative to an existing datum (NAD 27, NAD 83, or local). Even though GPS measurements are made relative to the WGS 84 ellipsoidal coordinate system, coordinate differences (i.e., baseline vectors) on this system can, for

practical engineering purposes, be used directly on any local user datum. Thus, a GPS-coordinated WGS 84 baseline can be directly used on an NAD 27, NAD 83, or even a local project datum. Minor variations between these datums will be minimal when GPS data are adjusted to fit between local datum stations. Such assumptions may not be valid when high-order NGRS network densification work is being performed.

a. North American Datum of 1927 (NAD 27). NAD 27 is a horizontal datum based on a comprehensive adjustment of a national network of traverse and triangulation stations. NAD 27 is a best fit for the continental United States. The fixed datum reference point is located at Meades Ranch, Kansas. The longitude origin of NAD 27 is the Greenwich Meridian with a south azimuth orientation. The original network adjustment used 25,000 stations. The relative precision between initial point monuments of NAD 27 is by definition 1:100,000, but coordinates on any given monument in the network contain errors of varying degrees. As a result, relative accuracy between points on NAD 27 may be far less than the nominal 1:100,000. The reference units for NAD 27 are U.S. Survey Feet.

b. North American Datum of 1983 (NAD 83). NAD 83 uses many more stations and observations than NAD 27, including some satellite-derived coordinates, to readjust the national network (a total of approximately 250,000 stations were used). The longitude origin of NAD 83 is the Greenwich Meridian with a north azimuth orientation. NAD 83 has an average precision of 1:300,000. NAD 83 is based upon the GRS 80, an earth-centered reference ellipsoid, and for most practical purposes is equivalent to WGS 84, which is currently the best available geodetic model of the shape of the earth surface worldwide. The reference units for NAD 83 are meters.

c. HARNs Network Survey Datum. The nationwide horizontal reference network was redefined in 1983 and readjusted in 1986 by the NGS. It is known as the North American Datum of 1983, adjustment of 1986, and is referred to as NAD 83 (86). It is accurate to 1 part in 100,000 which normally satisfies USACE surveying, mapping, and related spatial database requirements. USACE adopted this datum on 5 March 1990. Since that time, several states and the NGS have begun developing High Accuracy Reference Networks (HARNs) for surveying, mapping, and related spatial database projects. These networks, developed exclusively with GPS, are accurate to 1 part in 1,000,000. HARNs have a slightly different coordinate, usually within one meter of those in NAD 83 (86), resulting in two coordinate values for the same survey point. Since the confusion and potential litigation inherent with multiple coordinates with the same point can adversely impact design, construction, boundary location, and other functions, use of HARNS is not recommended.

d. Geodetic survey datums. GPS uses the WGS 84 reference ellipsoid for geodetic survey purposes. GPS routinely provides differential horizontal positional results on the order of 1 ppm, compared to the accepted results of 1:300,000 for NAD 83 and (approximately) 1:100,000 for NAD 27. Even though GPS has such a high degree of precision, it provides only coordinate differences; therefore, ties to the national network to obtain coordinates of all GPS stations must be done without distorting the established control network (i.e., degrade the GPS-derived vectors during the adjustment). Generally, on midsize survey projects, three or more horizontal control stations from the national network can be used during the GPS observation scheme. In order to facilitate a tie between GPS and existing networks for horizontal control, an adjustment of the whole network scheme (all control and GPS-derived points) should be completed. There are many commercial software packages that can be used to perform this adjustment. Once a network adjustment meets the accuracy requirement, those values should not be readjusted with additional points or observations.

e. Local project datums. Several projects can be based on local project datums. These local datums might be accurate within a small area, but can become distorted over larger areas. Most local project datums are not connected to any other datums, but can be tied to outside control and related and transformed to another datum. It is important to understand how this local datum was established in order to relate it or perform a transformation to some other datum.

f. State Plane Coordinate System. The SPCS was developed by the NGS to provide a planar representation of the earth's surface. To properly relate spherical coordinates (,) to a planar system (Northings and Eastings), a developable surface must be constructed. A developable surface is defined as a surface that can be expanded without stretching or tearing. The two most common developable surfaces or map projections used in surveying and mapping are the cone and cylinder. The projection of choice is dependent on the north-south or east-west extent of the region. Areas with limited east-west dimensions and elongated north-south extent utilize the Transverse Mercator projection. Areas with limited north-south dimensions and elongated east-west extent utilize the

Lambert projection. For further information on the State Plane Coordinate System see EM 1110-1-1004.

4-5. Orthometric Elevations

Orthometric elevations are those corresponding to the earth's irregular geoidal surface. Measured differences in elevation from spirit leveling are generally relative to geoidal heights--a spirit level bubble (or pendulum) positions the instrument normal to the direction of gravity, and thus parallel with the local slope of the geoid. Elevation differences between two points are orthometric differences, a distinction particularly important in river/channel hydraulics. Orthometric heights for the continental United States (CONUS) are generally referenced to the National Geodetic Vertical Datum of 1929 (NGVD 29) or the North American Vertical Datum of 1988 (NAVD 88); however, other vertical datums may be used in some projects (e.g., the International Great Lakes Datum of 1955 (IGLD 55) or International Great Lakes Datum of 1985 (IGLD 85)), which is a dynamic/hydraulic-based datum, not an orthometric datum).

4-6. GPS WGS 84 Ellipsoidal Heights

GPS-determined heights or height differences are referenced to an idealized mathematical ellipsoid, i.e., WGS 84. This WGS 84 ellipsoid differs significantly from the geoid; thus, GPS heights are not the same as the orthometric heights which are needed for standard USACE projects (i.e. local engineering, construction, and hydraulic measurement functions). (See Figure 4-2.) Accordingly, any WGS-84-referenced height obtained using GPS must be transformed to the local orthometric vertical datum. This requires adjusting and interpolating GPS-derived heights relative to fixed orthometric elevations. Such a process may or may not be of suitable accuracy (i.e. reliability) for some engineering and construction work. See Table 6-1 in Chapter 6.

4-7. Orthometric-WGS 84 Elevation Relationship

The relationship between a WGS 84 ellipsoidal height and an orthometric height relative to the geoid can be obtained from the following equation:

$$h = H + N \qquad (4\text{-}1)$$

where

h = ellipsoidal height

H = elevation (orthometric)

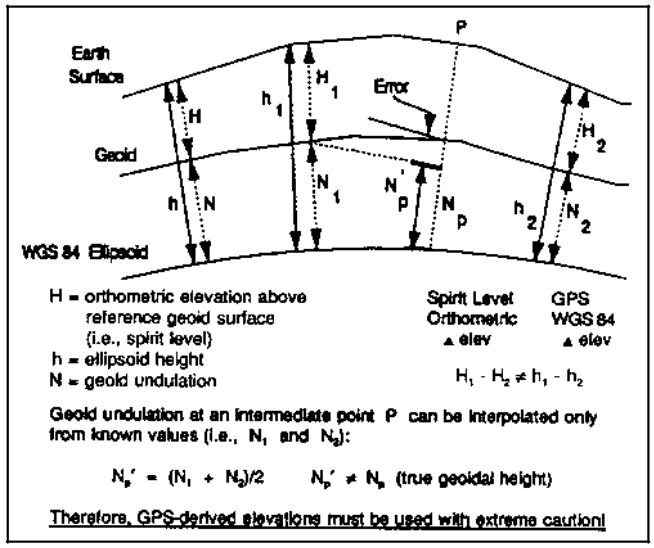

Figure 4-2. GPS ellipsoid heights

N = geoid undulation

a. Due to significant variations in the geoid, even over small distances, elevation differences obtained by GPS cannot be directly equated to orthometric (or spirit level) differences. Geoid modeling techniques are often used to obtain the parameter N in Equation 4-1; however, accuracies may not be adequate for engineering purposes. Some small project areas where the geoid stays fairly constant or local geoid modeling can be performed, elevation differences obtained by GPS can be used. See Chapter 6 for further information on the concept of vertical densification with GPS.

b. GPS surveys can be designed to provide elevations of points on the local vertical datum. This requires connecting to a sufficient number of existing orthometric benchmarks from which the elevations of unknown points can be "best fit" by some adjustment method--usually a least squares minimization. This is essentially an interpolation process and assumes linearity in the geoid slope between two established benchmarks. If the geoid variation is not linear, then the adjusted (interpolated) elevation of an intermediate point will be in error. Depending on the station spacing, location, local geoid undulations, and numerous other factors, the resultant interpolated/adjusted elevation accuracy is usually not suitable for construction surveying purposes; however, GPS-derived elevations may be adequate for small-scale topographic mapping control.

Chapter 5
GPS Absolute Positioning Determination Concepts, Errors, and Accuracies

5-1. General

NAVSTAR GPS determination of a point position on the earth actually uses techniques common to conventional surveying trilateration: an electronic distance measurement resection. The user's receiver simply measures the distance (i.e., ranges) between the earth and the NAVSTAR GPS satellite(s). The user's position is determined by the resected intersection of the observed ranges to the satellites. Each satellite range creates a sphere which forms a circle (approximately) upon intersection with the earth's surface. Given observed ranges to two different satellites, two intersecting circles result from which a horizontal (2D) position on the earth can be computed. Adding a third satellite range creates three spheres, the intersection point of which will provide the X-Y-Z geocentric coordinates of a point. Adding more satellite ranges will provide redundancy in the positioning, which allows adjustment. In actual practice, at least four satellite observations are required in order to resolve timing variations for a 3D position.

5-2. Absolute Positioning

Absolute positioning involves the use of only a single passive receiver at one station location to collect data from multiple satellites in order to determine the station's location. It is not sufficiently accurate for precise surveying or hydrographic positioning uses. It is, however, the most widely used military and commercial GPS positioning method for real-time navigation and location (see paragraph 2-1*b*).

a. The accuracies obtained by GPS absolute positioning are dependent on the user's authorization. The SPS user can obtain real-time point positional accuracies of 100 m. The lower level of accuracies achievable using SPS is due to intentional degradation of the GPS signal by the DoD (S/A). The PPS user (usually a DoD-approved user) can use a decryption device to achieve a point positional (3D) accuracy in the range of 10-16 m with a single-frequency receiver. Accuracies to less than a meter can be obtained from absolute GPS measurements when special equipment and post-processing techniques are employed.

b. Absolute point positioning with the carrier phase. By using broadcast ephemerides, the user is able to use pseudo-range values in real time to determine absolute point positions with an accuracy of between 3 m in the best of conditions and 80 m in the worst. By using a post-processed ephemerides (i.e., precise), the user can expect absolute point positions with an accuracy of near 1 m in the best of conditions and 40 m in the worst.

5-3. Pseudo-Ranging

When a GPS user performs a GPS navigation solution, only an approximate range, or pseudo-range, to selected satellites is measured. In order for the GPS user to determine his/her precise location, the known range to the satellite and the position of those satellites must be known. By pseudo-ranging, the GPS user measures an approximate distance between the antenna and the satellite by correlation of a satellite-transmitted code and a reference code created by the receiver, without any corrections for errors in synchronization between the clock of the transmitter and that of the receiver. The distance the signal has traveled is equal to the velocity of the transmission of the satellite multiplied by the elapsed time of transmission, with satellite signal velocity changes due to tropospheric and ionospheric conditions being considered. Refer to Figure 5-1 for an illustration of the pseudo-ranging concept. (See also paragraph 2-4*a,b*.)

a. The accuracy of the positioned point is a function of the range measurement accuracy and the geometry of the satellites, as reduced to spherical intersections with the earth's surface. A description of the geometrical magnification of uncertainty in a GPS-determined point position is Dilution of Precision (DOP), which is discussed in section 5-6*d*(2). Repeated and redundant range observations will generally improve range accuracy. However, the dilution of precision remains the same. In a static mode (meaning the GPS antenna stays stationary), range measurements to each satellite may be continuously remeasured over varying orbital locations of the satellite(s). The varying satellite orbits cause varying positional intersection geometry. In addition, simultaneous range observations to numerous satellites can be adjusted using weighting techniques based on the elevation and pseudo-range measurement reliability.

b. Four pseudo-range observations are needed to resolve a GPS 3D position. (Only three pseudo-range observations are needed for a 2D location.) In practice there are often more than four. This is due to the need to

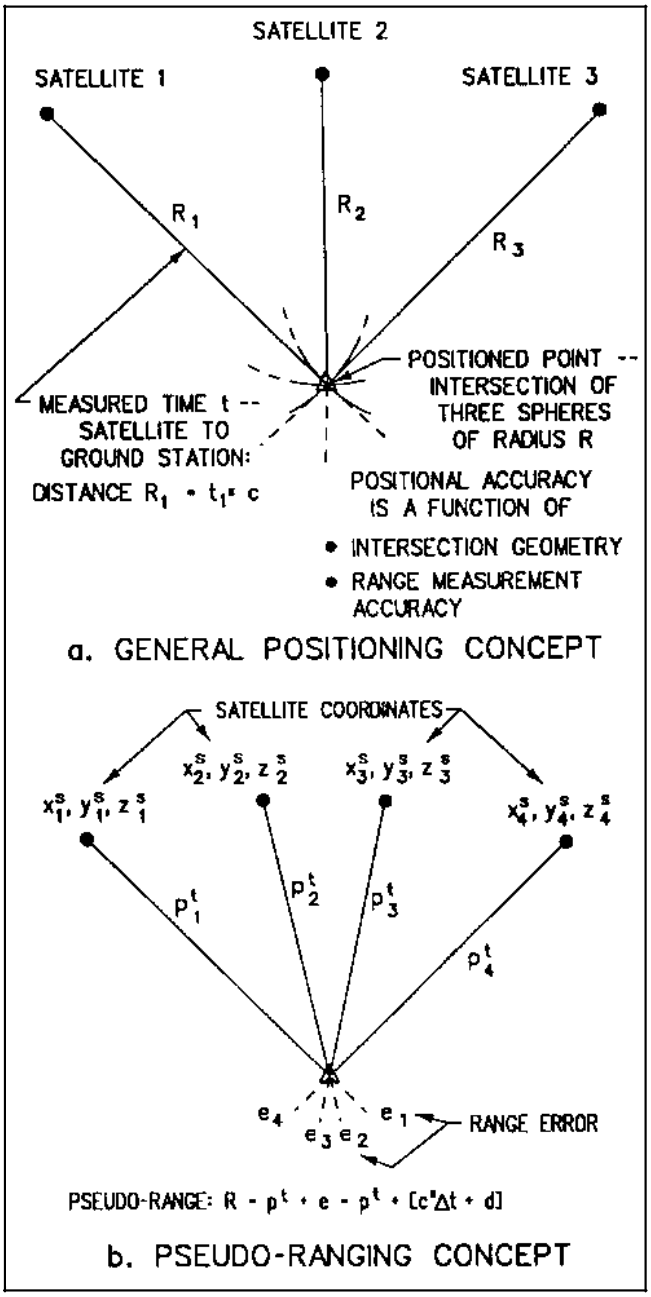

Figure 5-1. GPS satellite range measurement

resolve the clock biases t contained in both the satellite and ground-based receiver. Thus, in solving for the X-Y-Z coordinates of a point, a fourth unknown (i.e., clock bias) must also be included in the solution. The solution of the 3D position of a point is simply the solution of four pseudo-range observation equations containing four unknowns, i.e., X, Y, Z, and t.

c. A pseudo-range observation is equal to the true range from the satellite to the user ^{t} plus delays due to satellite/receiver clock biases and other effects, as was shown in Figure 5-1.

$$R = p^{t} + c(\ t) + d \tag{5-1}$$

where

R = observed pseudo-range

^{t} = true range to satellite (unknown)

c = velocity of propagation

t = clock biases (receiver and satellite)

d = propagation delays due to atmospheric conditions

These are usually estimated from models.

The true range ^{t} is equal to the 3D coordinate difference between the satellite and user.

$$^{t} = \left[(X^{s} - X^{u})^2 + (Y^{s} - Y^{u})^2 + (Z^{s} - Z^{u})^2\right]^{\frac{1}{2}} \tag{5-2}$$

where

X^s, Y^s, Z^s = known satellite coordinates from ephemeris data

X^u, Y^u, Z^u = unknown coordinates of user which are to be determined.

When four pseudo-ranges are observed, four equations are formed from Equations 5-1 and 5-2.

$$(R_1 - c\ \ t - d_1)^2 = \left(X_1^{s} - X^{u}\right)^2 + \left(Y_1^{s} - Y^{u}\right)^2 + \left(Z_1^{s} - Z^{u}\right)^2 \tag{5-3}$$

$$(R_2 - c\ \ t - d_2)^2 = \left(X_2^{s} - X^{u}\right)^2 + \left(Y_2^{s} - Y^{u}\right)^2 + \left(Z_2^{s} - Z^{u}\right)^2 \tag{5-4}$$

$$(R_3 - c \quad t - d_3)^2 = \left(X_3^s - X^u\right)^2 + \left(Y_3^s - Y^u\right)^2 + \left(Z_3^s - Z^u\right)^2 \tag{5-5}$$

$$(R_4 - c \quad t - d_4)^2 = \left(X_4^s - X^u\right)^2 + \left(Y_4^s - Y^u\right)^2 + \left(Z_4^s - Z^u\right)^2 \tag{5-6}$$

In these equations, the only unknowns are X^u, Y^u, Z^u, and t. Solving these equations at each GPS update yields the user's 3D position coordinates. Adding more pseudo-range observations provides redundancy to the solution. For instance, if seven satellites are simultaneously observed, seven equations are derived, and still only four unknowns result.

d. This solution is highly dependent on the accuracy of the known coordinates of each satellite (i.e., X^s, Y^s, and Z^s), the accuracy with which the atmospheric delays d can be estimated through modeling, and the accuracy of the resolution of the actual time measurement process performed in a GPS receiver (clock synchronization, signal processing, signal noise, etc.). As with any measurement process, repeated and long-term observations from a single point will enhance the overall positional reliability.

5-4. GPS Error Sources

There are numerous sources of measurement error that influence GPS performance. The sum of all systematic errors or biases contributing to the measurement error is referred to as range bias. The observed GPS range, without removal of biases, is referred to as a biased range or "pseudo-range." Principal contributors to the final range error that also contribute to overall GPS error are ephemeries error, satellite clock and electronics inaccuracies, tropospheric and ionospheric refraction, atmospheric absorption, receiver noise, and multipath effects. Other errors include those induced by DoD (Selective Availability (S/A) and Anti-Spoofing (A/S)). In addition to these major errors, GPS also contains random observation errors, such as unexplainable and unpredictable time variation. These errors are impossible to model and correct. The following paragraphs discuss errors associated with absolute GPS positioning modes. Many of these errors are either eliminated or significantly minimized when GPS is used in a differential mode. This is due to the same errors being common to both receivers during simultaneous observing sessions. For a more detailed analysis of these errors, consult one of the technical references listed in Appendix A.

a. Ephemeris errors and orbit perturbations. Satellite ephemeris errors are errors in the prediction of a satellite position which may then be transmitted to the user in the satellite data message. Ephemeris errors are satellite dependent and very difficult to completely correct and compensate for because the many forces acting on the predicted orbit of a satellite are difficult to measure directly. Because direct measurement of all forces acting on a satellite orbit is difficult, it is nearly impossible to accurately account or compensate for those error sources when modeling the orbit of a satellite. The previous accuracy levels stated are subject to performance of equipment and conditions. Ephemeris errors produce equal error shifts in calculated absolute point positions.

b. Clock stability. GPS relies very heavily on accurate time measurements. GPS satellites carry rubidium and cesium time standards that are usually accurate to 1 part in 10^{12} and 1 part in 10^{13}, respectively, while most receiver clocks are actuated by a quartz standard accurate to 1 part in 10^8. A time offset is the difference between the time as recorded by the satellite clock and that recorded by the receiver. Range error observed by the user as the result of time offsets between the satellite and receiver clock is a linear relationship and can be approximated by the following equation:

$$R = T_O * c \tag{5-7}$$

where

R_E = user equivalent range error

T_O = time offset

c = speed of light

(1) The following example shows the calculation of the user equivalent range error (UERE or UR).

T_O = 1 microsecond (μs) = 10^{-06} seconds (s)

c = 299,792,458 m/s

From Equation 5-7:

R_E = (10^{-06} seconds) * 299,792,458 m/s

= 299.79 m = 300 m user equivalent range error

(2) In general, unpredictable transient situations that produce high-order departures in clock time can be

ignored over short periods of time. Even though this may be the case, predictable time drift of the satellite clocks is closely monitored by the ground control stations. Through closely monitoring the time drift, the ground control stations are able to determine second-order polynomials which accurately model the time drift. The second-order polynomial determined by the ground control station to model the time drift is included in the broadcast message in an effort to keep this drift to within 1 millisecond (ms). The time synchronization between the GPS satellite clocks is kept to within 20 nsec (ns) through the broadcast clock corrections as determined by the ground control stations and the synchronization of GPS standard time to the Universal Time Coordinated (UTC) to within 100 ns. Random time drifts are unpredictable, thereby making them impossible to model.

(3) GPS receiver clock errors can be modeled in a manner similar to GPS satellite clock errors. In addition to modeling the satellite clock errors and in an effort to remove them, an additional satellite should be observed during operation to simply solve for an extra clock offset parameter along with the required coordinate parameters. This procedure is based on the assumption that the clock bias is independent at each measurement epoch. Rigorous estimation of the clock terms is more important for point positioning than for differential positioning. Many of the clock terms cancel when the position equations are formed from the observations during a differential survey session.

c. Ionospheric delays. GPS signals are electromagnetic signals and as such are nonlinearly dispersed and refracted when transmitted through a highly charged environment like the ionosphere. Dispersion and refraction of the GPS signal is referred to as an ionospheric range effect because dispersion and refraction of the signal result in an error in the GPS range value. Ionospheric range effects are frequency dependent.

(1) The error effect of ionosphere refraction on the GPS range values is dependent on sunspot activity, time of day, and satellite geometry. GPS operations conducted during periods of high sunspot activity or with satellites near the horizon produce range results with the most error. GPS operations conducted during periods of low sunspot activity, during the night, or with a satellite near the zenith produce range results with the least amount of ionospheric error.

(2) Resolution of ionospheric refraction can be accomplished by use of a dual-frequency receiver (a receiver that can simultaneously record both L1 and L2 frequency measurements). During a period of uninterrupted observation of the L1 and L2 signals, these signals can be continuously counted and differenced. The resultant difference reflects the variable effects of the ionosphere delay on the GPS signal. Single-frequency receivers used in an absolute and differential positioning mode typically rely on ionospheric models that model the effects of the ionosphere. Recent efforts have shown that significant ionospheric delay removal can be achieved using signal frequency receivers.

d. Tropospheric delays. GPS signals in the L-band level are not dispersed by the troposphere, but they are refracted. The tropospheric conditions causing refraction of the GPS signal can be modeled by measuring the dry and wet components. The dry component is best approximated by the following equation:

$$D_C = (2.27 * 0.001) * P_O \tag{5-8}$$

where

D_C = dry term range contribution in zenith direction in meters

P_O = surface pressure in millibar

(1) The following example shows the calculation of average atmospheric pressure P_O = 765 mb:

From Equation 5-8:

D_C = (2.27 * 0.001) * 765 mb

= 1.73655 m = 1.7 m, the dry term range error contribution in the zenith direction

(2) The wet component is considerably more difficult to approximate because its approximation is dependent not just on surface conditions, but also on the atmospheric conditions (water vapor content, temperature, altitude, and angle of the signal path above the horizon) along the entire GPS signal path. As this is the case, there has not been a well-correlated model that approximates the wet component.

e. Multipath. Multipath describes an error affecting positioning that occurs when the signal arrives at the receiver from more than one path. Multipath normally occurs near large reflective surfaces, such as a metal building or structure. GPS signals received as a result of

multipath give inaccurate GPS positions when processed. With the newer receiver and antenna designs and sound prior mission planning to eliminate possible causes of multipath, the effects of multipath as an error source can be minimized. Averaging of GPS signals over a period of time can also reduce the effects of multipath.

f. Receiver noise. Receiver noise includes a variety of errors associated with the ability of the GPS receiver to measure a finite time difference. These include signal processing, clock/signal synchronization and correlation methods, receiver resolution, signal noise, and others.

g. Selective Availability (S/A) and Anti-Spoofing (A/S). S/A purposely degrades the satellite signal to create position errors. This is done by dithering the satellite clock and offsetting the satellite orbits. The effects of S/A can be eliminated by using differential techniques discussed further in Chapter 6. A-S is implemented by interchanging the P-code with a classified Y-code. This denies users who do not possess an authorized decryption device. Manufacturers of civil GPS equipment have developed methods such as squaring or cross correlation in order to make use of the P-code when it is encrypted.

5-5. User Equivalent Range Error

The previous sources of errors or biases are principal contributors to overall GPS range error. This total error budget is often summarized as the UERE. As mentioned previously, they can be removed or at least effectively suppressed by developing models of their functional relationships in terms of various parameters that can be used as a corrective supplement for the basic GPS information. Differential techniques also eliminate many of these errors. Table 5-1 lists the more significant sources for errors and biases and correlates them to the segment source.

5-6. Absolute GPS Accuracies

The absolute range accuracies obtainable from GPS are largely dependent on which code (C/A or P) is used to determine positions. These range accuracies (i.e., UERE), when coupled with the geometrical relationships of the satellites during the position determination (i.e., DOP), result in a 3D confidence ellipsoid which depicts uncertainties in all three coordinates. Given the changing satellite geometry and other factors, GPS accuracy is time/location dependent. Error propagation techniques are used to define nominal accuracy statistics for a GPS user.

a. Root mean square error measures. Two-dimensional (2D) (horizontal) GPS positional accuracies are normally estimated using a root mean square (RMS) radial error statistic. A 1- RMS error equates to the radius of a circle in which the position has a 63 percent probability of falling. A circle of twice this radius (i.e., 2- RMS or 2DRMS) represents (approximately) a 97 percent positional probability circle. This 97 percent probability circle, or 2DRMS, is the most common positional accuracy statistic used in GPS surveying. In some instances, a 3DRMS or 99+ percent probability is used. This RMS error statistic is also related to the positional variance-covariance matrix. (Note that an RMS error statistic represents the radius of a circle and therefore is not preceded by a ± sign.)

Table 5-1
GPS Range Measurement Accuracy

		Absolute Positioning		
Segment Source	Error Source	C/A-code Pseudo-range, m	P-code Pseudo-range, m	Differential Positioning, m (P-code)
Space	Clock stability	3.0	3.0	Negligible
	Orbit perturbations	1.0	1.0	Negligible
	Other	0.5	0.5	Negligible
Control	Ephemeris predictions	4.2	4.2	Negligible
	Other	0.9	0.9	Negligible
User	Ionosphere	3.5	2.3	Negligible
	Troposphere	2.0	2.0	Negligible
	Receiver noise	1.5	1.5	1.5
	Multipath	1.2	1.2	1.2
	Other	0.5	0.5	0.5
1- UERE		12.1	6.5	2.0

[a] Without S/A.

b. Probable error measures. 3D GPS accuracy measurements are most commonly expressed by Spherical Error Probable, or SEP. This measure represents the radius of a sphere with a 50 percent confidence or probability level. This spheroid radial measure only approximates the actual 3D ellipsoid representing the uncertainties in the geocentric coordinate system. In 2D horizontal positioning, a Circular Error Probable (CEP) statistic is commonly used, particularly in military targeting. CEP represents the radius of a circle containing a 50 percent probability of position confidence.

c. Accuracy comparisons. It is important that GPS accuracy measures clearly identify the statistic from which they are derived. A "100-m" or "3-m" accuracy statistic is meaningless unless it is identified as being either 1D, 2D, or 3D, along with the applicable probability level. For example, a PPS-16 m 3D accuracy is, by definition, SEP (i.e. 50 percent). This 16-m SEP equates to 28-m 3D 95 percent confidence spheroid, or when transformed to 2D accuracy, roughly 10 m CEP, 12 m RMS, 24 m 2DRMS, and 36 m 3DRMS. See Table 5-2 for further information on GPS measurement statistics. In addition, absolute GPS point positioning accuracies are defined relative to an earth-centered coordinate system/datum. This coordinate system will differ significantly from local project or construction datums. Nominal GPS accuracies may also be published as design or tolerance limits and accuracies achieved can differ significantly from these values.

d. Dilution of Precision (DOP). The final positional accuracy of a point determined using absolute GPS survey techniques is directly related to the geometric strength of the configuration of satellites observed during the survey session. GPS errors resulting from satellite configuration geometry can be expressed in terms of DOP. In mathematical terms, DOP is a scaler quantity used in an expression of a ratio of the positioning accuracy. It is the ratio of the standard deviation of one coordinate to the measurement accuracy. DOP represents the geometrical contribution of a certain scaler factor to the uncertainty (i.e., standard deviation) of a GPS measurement. DOP values are a function of the diagonal elements of the covariance matrices of the adjusted parameters of the observed GPS signal and are used in the point formulations and determinations (Figure 5-2).

(1) General. In a more practical sense, DOP is a scaler quantity of the contribution of the configuration of satellite constellation geometry to the GPS accuracy, in other words, a measure of the "strength" of the geometry of the satellite configuration. In general, the more satellites that can be observed and used in the final solution, the better the solution. Since DOP can be used as a measure of the geometrical strength, it can also be used to selectively choose four satellites in a particular constellation that will provide the best solution.

(2) Geometric dilution of precision (GDOP). The main form of DOP used in absolute GPS positioning is the geometric DOP (GDOP), which is a measure of accuracy in a 3D position and time. The relationship between final positional accuracy, actual range error, and GDOP can be expressed as follows:

$$_{a} = {}_{R} * \text{GDOP} \tag{5-9}$$

where

$_{a}$ = final positional accuracy

$_{R}$ = actual range error (UERE)

$$\text{GDOP} = \frac{\left[{}_{E}2 + {}_{N}2 + {}_{u}2 + (c \cdot {}_{T})^2 \right]^{\frac{1}{2}}}{{}_{R}} \tag{5-10}$$

where

$_{E}$ = standard deviation in east value, m

$_{N}$ = standard deviation in north value, m

$_{u}$ = standard deviation in up direction, m

c = speed of light (299,792,458 m/s)

$_{T}$ = standard deviation in time, s

$_{R}$ = overall standard deviation in range, m, usually in the range of 6 m for P-code usage and 12 m for C/A-code usage

(3) Positional dilution of precision (PDOP). PDOP is a measure of the accuracy in 3D position, mathematically defined as:

$$\text{PDOP} = \frac{\left[{}_{E}2 + {}_{N}2 + {}_{U}2 \right]^{\frac{1}{2}}}{{}_{R}} \tag{5-11}$$

Table 5-2
Representative GPS Error Measurement Statistics for Absolute Point Positioning

Error Measure Statistic	**Probability %**	**Relative Distance ft( )** (1)	**GPS Precise Positioning Service m** (2)		**GPS Standard Positioning Service m** (2)	
Linear Measures			$_N$ or $_E$	$_U$	$_N$ or $_E$	$_U$
Probable error	50	0.6745	4 m	9 m	24 m	53 m
Average error	57.51	0.7979	5 m	11 m	28 m	62 m
1-sigma standard error/deviation (3)	68.27	1.00	6.3 m	13.8 m	35.3 m	78 m
90% probability (map accuracy standard)	90	1.645	10 m	23 m	58 m	128 m
95% probability/confidence	95	1.96	12 m	27 m	69 m	153 m
2-sigma standard error/deviation	95.45	2.00	**± 12.6 m**	**± 27.7 m**	**± 70.7 m**	**± 156 m**
99% probability/confidence	99	2.576	16 m	36 m	91 m	201 m
3-sigma standard error (near certainty)	99.73	3.00	19 m	42 m	106 m	234 m
Two-Dimensional Measures (4)			Circular Radius		Circular Radius	
1-sigma standard error circle ($_c$) (5)	39	1.00 $_c$	6 m		35 m	
Circular error probable (CEP) (6)	50	1.177 $_c$	7 m		42 m	
1-dev root mean square (1DRMS) (3)(7)	63	1.414 $_c$	9 m		50 m	
Circular map accuracy standard	90	2.146 $_c$	13 m		76 m	
95% 2D positional confidence circle	95	2.447 $_c$	15 m		86 m	
2-dev root mean square error (2DRMS) (8)	98$^+$	2.83 $_c$	**17.8 m**		**100 m**	
99% 2D positional confidence circle	99	3.035 $_c$	19 m		107 m	
3.5-sigma circular near-certainty error	99.78	3.5 $_c$	22 m		123 m	
3-dev root mean square error (3DRMS)	99.9$^+$	4.24 $_c$	27 m		150 m	
Three-Dimensional Measures			Spherical Radius		Spherical Radius	
1- spherical standard error ($_s$) (9)	19.9	1.00 $_s$	9 m		50 m	
Spherical error probable (SEP) (10)	50	1.54 $_s$	13.5 m		76.2 m	
Mean radial spherical error (MRSE) (11)	61	1.73 $_s$	16 m		93 m	
90% spherical accuracy standard	90	2.50 $_s$	22 m		124 m	
95% 3D confidence spheroid	95	2.70 $_s$	24 m		134 m	
99% 3D confidence spheroid	99	3.37 $_s$	30 m		167 m	
Spherical near-certainty error	99.89	4.00 $_s$	35 m		198 m	

Notes:

Most Commonly Used Statistics Shown in Bold Face Type.
Estimates not applicable to differential GPS positioning. Circular/Spherical error radii do not have signs.

Absolute positional accuracies are derived from GPS simulated user range errors/deviations and resultant geocentric coordinate (X-Y-Z) solution covariance matrix, as transformed to a local datum (N-E-U or - -h). GPS accuracy will vary with GDOP and other numerous factors at time(s) of observation. The 3D covariance matrix yields an error ellipsoid. Transformed ellipsoidal dimensions given (i.e., $_N$- $_E$- $_U$) are only average values observed under nominal GDOP conditions. Circular (2D) and spherical (3D) radial measures are only approximations to this ellipsoid, as are probability estimates.

(Continued)

Table 5-2
(Concluded)

(1) Valid for 2-D and 3-D only if $_N = {}_E = {}_U$. ($_{min}$/ $_{max}$) generally must be 0.2. Relative distance used unless otherwise indicated.
(2) Representative accuracy based on 1990 FRNP simulations for PPS and SPS (FRNP estimates shown in bold), and that $_N$ $_E$. SPS may have significant short-term variations from these nominal values.
(3) Statistic used to define USACE hydrographic survey depth and positioning criteria.
(4) 1990 FRNP also proposes SPS maintain, at minimum, a 2D confidence of 300 m @ 99.99% probability.
(5) $_c \approx 0.5$ ($_N$ + $_E$) -- approximates standard error ellipse.
(6) CEP ≈ 0.589 ($_N$ + $_E$) 1.18 $_c$.
(7) 1DRMS ≈ ($_N^2$ + $_E^2$)$^{1/2}$.
(8) 2DRMS ≈ 2 ($_N^2$ + $_E^2$)$^{1/2}$.
(9) $_s \approx 0.333$ ($_N$ + $_E$ + $_U$).
(10) SEP ≈ 0.513 ($_N$ + $_E$ + $_U$).
(11) MRSE ≈ ($_N^2$ + $_E^2$ + $_U^2$)$^{1/2}$.

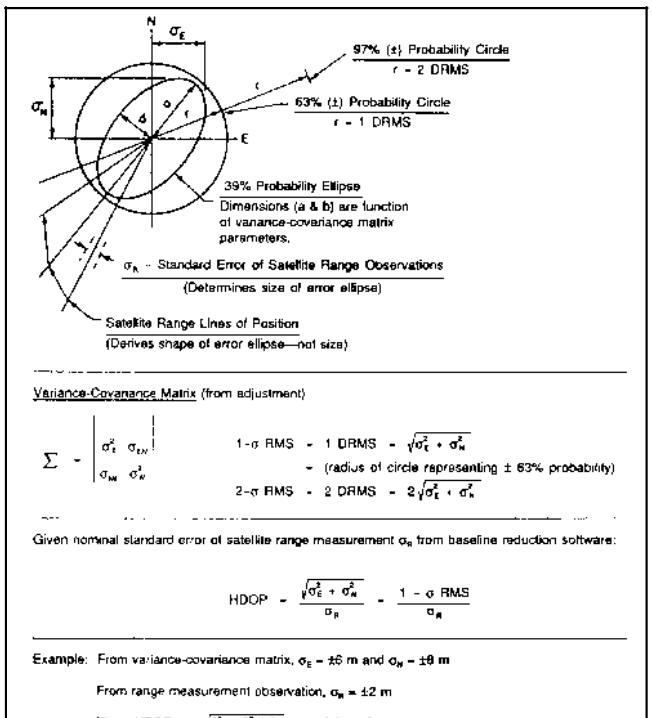

Figure 5-2. Dilution of Precision

where all variables are equivalent to those used in Equation 5-10.

(a) PDOP values are generally developed from satellite ephemerides prior to the conducting of a survey. When developed prior to a survey, PDOP can be used to determine the adequacy of a particular survey schedule. This is valid for rapid static or kinematic but is less valid for long duration static.

(b) The key to understanding PDOP is to remember that it represents position recovery at an instant in time and is not representative of a whole session of time. PDOP error is generally given in units of meters of error per 1-m error in the pseudo-range measurement (i.e., m/m). When using pseudo-range techniques, PDOP values in the range of 4-5 m/m are considered very good, while PDOP values greater than 10 m/m are considered very poor. For static surveys it is generally desirable to obtain GPS observations during a time of rapidly changing GDOP and/or PDOP.

(c) When the values of PDOP or GDOP are viewed over time, peak or high values (>10 m/m) can be associated with satellites in a constellation of poor geometry. The higher the PDOP or GDOP, the poorer the solution for that instant in time. This is critical in determining the acceptability of real-time navigation and photogrammetric solutions. Poor geometry can be the result of satellites being in the same plane, orbiting near each other, or at similar elevations.

(4) Horizontal dilution of precision (HDOP). HDOP is a measurement of the accuracy in 2D horizontal position, mathematically defined as:

$$\text{HDOP} = \frac{\left({}_E{}^2 + {}_N{}^2 \right)^{\frac{1}{2}}}{{}_R} \qquad (5\text{-}12)$$

This HDOP statistic is most important in evaluating GPS surveys intended for horizontal control. The HDOP is basically the RMS error determined from the final variance-covariance matrix divided by the standard error of the range measurements. HDOP roughly indicates the effects of satellite range geometry on a resultant position.

(5) Vertical dilution of precision (VDOP). VDOP is a measurement of the accuracy in standard deviation in vertical height, mathematically defined as:

$$\text{VDOP} = \frac{u}{R} \tag{5-13}$$

(6) Acceptable DOP values. Table 5-3 indicates generally accepted DOP values for a baseline solution.

(7) Additional material. Additional material regarding GPS positional accuracy may be found in the references listed in Appendix A.

Table 5-3
Acceptable DOP Values

GDOP and PDOP: Less than 10 m/m -- optimally 4-5 m/m.
In static GPS surveying, it is desirable to have a GDOP/PDOP that changes during the time of GPS survey session.
The lower the GDOP/PDOP, the better the instantaneous point position solution is.
HDOP and VDOP: 2 m/m for the best constellation of four satellites.

Chapter 6
GPS Relative Positioning Determination Concepts

6-1. General

Absolute positioning, as discussed earlier, will not provide the accuracies needed for most USACE control projects due to existing and induced errors. In order to eliminate these errors and obtain higher accuracies, GPS can be used in a relative positioning mode. The terms "relative" and "differential" used in this chapter and throughout this manual have similar meaning. "Relative" will be used when discussing one thing in relation to another. The term "differential" will be used when discussing the technique of positioning one thing in relation to another.

6-2. Differential (Relative) Positioning

Differential or relative positioning requires at least two receivers set up at two stations (usually one is known) to collect satellite data simultaneously in order to determine coordinate differences. This method will position the two stations relative to each other (hence the term "relative positioning") and can provide the accuracies required for basic land surveying and hydrographic surveying.

6-3. Differential Positioning (Code Pseudo-Range Tracking)

Differential positioning using code pseudo-ranges is performed similarly to that described in Chapter 5; however, some of the major uncertainties in Equations 5-1 through 5-6 are effectively eliminated or minimized. This pseudo-range process results in absolute coordinates of the user on the earth's surface. Errors in range are directly reflected in resultant coordinate errors. Differential positioning is not so concerned with the absolute position of the user but with the relative difference between two user positions, which are simultaneously observing the same satellites. Since errors in the satellite position (X^s, Y^s, and Z^s) and atmospheric delay estimates d are effectively the same (i.e., highly correlated) at both receiving stations, they cancel each other to a large extent.

a. For example, if the true pseudo-range distance from a "known" control point to a satellite is 100 m and the observed or measured pseudo-range distance was 92 m, then the pseudo-range error or correction is 8 m for that particular satellite. A pseudo-range correction or PRC can be generated for each satellite being observed. If a second receiver is observing at least four of the same satellites and is within a reasonable distance (300 km) it can use these PRCs to obtain a relative position to the "known" control point since the errors will be similar. Thus, the relative distance (i.e., coordinate difference) between the two stations is relatively accurate (i.e., within 0.5-5 m) regardless of the poor absolute coordinates. In effect, the GPS observed baseline vectors are no different from azimuth/distance observations. As with a total station, any type of initial coordinate reference can be input to start the survey.

b. The absolute GPS coordinates will not coincide with the user's local project datum coordinates (Figure 6-1). Since differential survey methods are concerned only with relative coordinate differences, disparities with a global reference system used by the NAVSTAR GPS are not significant for USACE purposes. Therefore, GPS coordinate differences can be applied to any type of local project reference datum (i.e., NAD 27, NAD 83, or any local project grid reference system).

c. Code pseudo-range tracking has primary application to real-time navigation systems where accuracies at the 0.5- to 5-m level are tolerable. Given these tolerances, engineering survey applications of code pseudo-range tracking GPS are limited, with two exceptions being hydrographic survey and dredge positioning. Specifications for real-time hydrographic code tracking systems are contained in EM 1110-2-1003. See Chapter 9 for further discussion on real-time code pseudo-range tracking applications.

6-4. Differential Positioning (Carrier Phase Tracking)

Differential positioning using carrier phase tracking uses a formulation of pseudo-ranges similar to those shown in Equations 5-1 through 5-6. The process becomes somewhat more complex when the carrier signals are tracked such that range changes are measured by phase resolution. In carrier phase tracking, an ambiguity factor is added to Equation 5-1 which must be resolved in order to obtain a derived range (see Figure 5-1). Methods for resolving this ambiguity (the number of unknown integer cycles) are described in Chapter 9. Carrier phase tracking provides for a more accurate range resolution due to the short wavelength (approximately 19 cm for L1 and 24 cm for L2) and the ability of a receiver to resolve the carrier phase down to about 2 mm. This method, therefore, has primary application to engineering, topographic, and geodetic surveying, and may be employed with either static

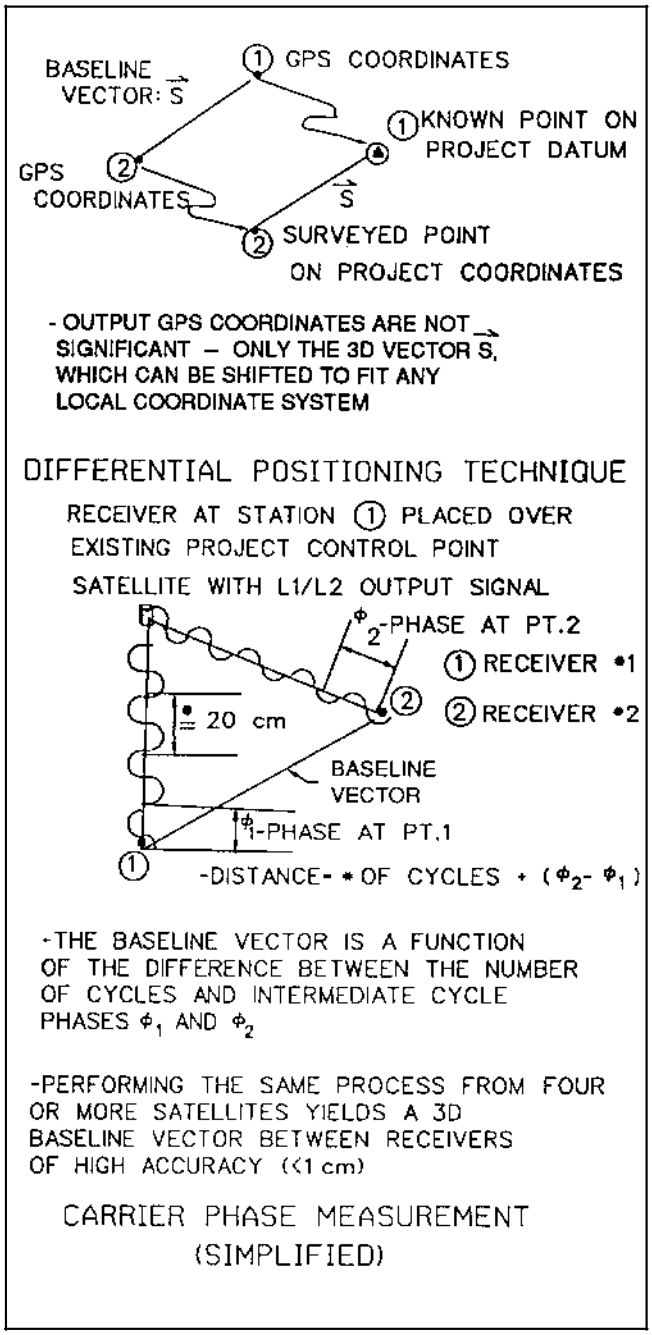

Figure 6-1. Differential positioning

or kinematic methods. There are several techniques which use the carrier phase in order to determine a station's position. These include static, rapid static, kinematic, stop and go kinematic, pseudo kinematic, and real-time kinematic (RTK) and on-the-fly (OTF) kinematic. The concepts of these techniques are explained below, but procedures can be found in Chapter 9. Table 6-1 lists these techniques, their associated accuracies, applications, and required components.

a. Static. Static surveying is the most widely used differential technique for control and geodetic surveying. It involves long observation times (1-2 hr, depending on number of visible satellites) in order to resolve the integer ambiguities between the satellite and the receiver. Accuracies in the subcentimeter range can be obtained from using the static method.

b. Rapid static. The concept of rapid static is to measure baselines and determine positions in the centimeter level with short observation times, 5-20 min. The observation time is dependent on the length of the baseline and number of visible satellites. Loss of lock, when moving from one station to the next, can also occur since each baseline is processed independent of each other.

c. Kinematic. Kinematic surveying, allows the user to rapidly and accurately measure baselines while moving from one point to the next. The data are collected and post-processed to obtain accurate positions to the centimeter level. This technique permits only partial loss of satellite lock during observation and requires a brief period of static initialization. The OTF technology, both real-time and post-processed, could eventually replace standard kinematic procedures at least for short baselines.

d. Stop and go kinematic. Stop and go kinematic involves collecting data for several minutes (1-2 min.) at each station after a period of initialization to gain the integers. This technique does not allow for loss of satellite lock during the survey. If loss of satellite lock does occur, a new period of initialization must take place. This method can be performed with two fixed or known stations in order to provide redundancy and improve accuracy.

e. Pseudo-kinematic. This technique is similar to standard kinematic procedures and static procedures combined. The differences are that there is no static initialization, longer period of time at each point (approximately 1-5 min), each point must be revisited after about an hour, and loss of satellite lock is acceptable. The positional accuracy is more than for kinematic or rapid static procedures, which makes it a less acceptable method for establishing baselines.

f. RTK and OTF carrier phase based positioning determination. The OTF/RTK positioning system uses

Table 6-1
Carrier Phase Tracking Techniques

Concept	Requirements	Applications	Accuracy
Static (Post-processing)	• L1 or L1/L2 GPS receiver • 386/486 computer for post-processing • 45 min to 1 hr minimum observation time[1]	• Control surveys (that require high accuracy)	• Subcentimeter level
Rapid Static (Post-processing)	• L1/L2 GPS receiver • 5-20 min observation time[1]	• Control surveys (that require medium to high accuracy)	• Subcentimeter level
Kinematic[2] (Post-processing)	• L1 GPS receiver with kinematic survey option • 386/486 computer for post-processing	• Continuous topo • Location surveys	• Centimeter level
Stop & Go Kinematic[2] (Post-processing)	• L1 GPS receiver • 386/486 computer for post-processing	• Medium accuracy control surveys	• Centimeter level
Pseudo Kinematic[2] (Post-processing)	• L1 GPS receiver • 386/486 computer for post-processing	• Medium accuracy control surveys	• Centimeter level
Real Time Kinematic/OTF Kinematic[3] (Real-time or post-processing)	For post-processing: • L1/L2 GPS receiver • 386/486 computer For real-time: • Internal or external processor (1- 386, 1- 486 computers w/dual com ports) • Min 4800 baud radio/modem data link set	• Real-time high accuracy hydro surveys • Location surveys • Medium accuracy control surveys • Photo control • Continuous topo	• Subdecimeter level

1. Dependent on satellite constellation and number of satellites in view.
2. Initialization period required and loss of satellite lock is not tolerated.
3. No static initialization necessary, integers gained while moving, and loss of satellite lock is tolerated.

GPS technology to allow the positioning to a subdecimeter in real time. This system determines the integer number of carrier wavelengths from the GPS antenna to the GPS satellite, transmitting them while in motion and without static initialization. The basic concept behind the OTF/RTK system is kinematic surveying without static initialization (integer initialization is performed while moving) and allows for loss of satellite lock. Other GPS techniques that can achieve this kind of accuracy require static initialization while the user is not moving and no loss of satellite lock while in motion.

6-5. Vertical Measurements with GPS

a. Elevation determination. **GPS is not recommended for Third-Order or higher vertical control surveys. It is recommended that it not be used as a substitute for standard differential leveling. It is, however, practical for small-scale topographic mapping or similar projects.**

b. Accuracy of GPS height differences. The height (h) component of GPS measurements is the weakest plane. This is due to the orbital geometry of the X-Y-Z position determination. Thus, GPS ellipsoidal height differences are usually less accurate than the horizontal components. Currently, GPS-derived elevation differences will not meet Third-Order standards as would be obtained using conventional spirit levels. Accordingly, GPS-derived elevations must be used with caution.

c. Topographic mapping with GPS. GPS positioning, whether operated in an absolute or differential positioning mode, can provide heights (or height differences) of surveyed points. The height h or height difference h obtained from GPS is in terms of height above or below

the WGS 84 ellipsoid. These ellipsoid heights are not the same as orthometric heights, or elevations, which would be obtained from conventional differential/spirit leveling. This distinction between ellipsoid heights and orthometric elevations is critical to many engineering and construction projects; thus, users of GPS must exercise extreme caution in applying GPS height determinations to USACE projects which are based on conventional orthometric elevations.

(1) GPS uses WGS 84 as the optimal mathematical model best describing the shape of the true earth at sea level based on an ellipsoid of revolution. The WGS 84 ellipsoid adheres very well to the shape of the earth in terms of horizontal coordinates but differs somewhat with the established mean sea level definition of orthometric height. The difference between ellipsoidal height, as derived by GPS, and conventional leveled (orthometric) heights is required over an entire project area to adjust GPS heights to orthometric elevations. NGS has developed geoid modeling software (GEOID90, GEOID91, and GEOID93) to be used to convert ellipsoidal heights to approximate orthometric elevations. These values should be used with extreme caution.

(2) Static or kinematic GPS survey techniques can be used effectively on a regional basis for the densification of low-accuracy vertical control for topographic mapping purposes. Existing benchmark data (orthometric heights) and corresponding GPS-derived ellipsoidal values for at least three stations in a small project area can be used in tandem in a minimally constrained adjustment program to reasonably model the geoid. More than three correlated stations are required for larger areas to ensure proper modeling of the geoidal undulations in the area. The model from the benchmark data and corresponding GPS data can then be used to derive the unknown orthometric heights of the remaining stations occupied during the GPS observation period.

(3) Procedures for constraining GPS observations to existing vertical control are detailed in Section 11 of Leick and Lambert (1990). Step-by-step vertical control planning, observation, and adjustment procedures employed by the NGS are described in some of the publications listed in Appendix A (see Zilkoski 1990a, 1990b; Zilkoski and Hothem 1989). These procedures are recommended should a USACE field activity utilize GPS to densify low-order vertical control relative to the orthometric datum.

6-6. Differential Error Sources

The error sources encountered in the position determination using differential GPS positioning techniques are the same as those outlined in Chapter 5. In addition to these error sources, the user must ensure that the receiver maintains lock on at least three satellites for 2D positioning and four satellites for 3D positioning. When loss of lock occurs, a cycle slip (a discontinuity of an integer number of cycles in the measured carrier beat phase as recorded by the receiver) may occur. In GPS absolute surveying, if lock is not maintained, positional results will not be formulated. In GPS static surveying, if lock is not maintained, positional results may be degraded, resulting in incorrect formulations. Sometimes, in GPS static surveying, if the observation period is long enough, post-processing software may be able to average out loss of lock and cycle slips over the duration of the observation period and formulate positional results that are adequate; if this is not the case, reoccupation of the stations may be required. In all differential surveying techniques, if loss of lock does occur on some of the satellites, data processing can continue easily if a minimum of four satellites have been tracked. Generally, the more satellites tracked by the receiver, the more insensitive the receiver is to loss of lock. In general, cycle slips can be repaired.

6-7. Differential GPS Accuracies

There are two levels of accuracies obtainable from GPS using differential techniques. The first level is based on pseudo-range formulations, while the other is based on carrier beat phase formulations.

a. Pseudo-range accuracies. Pseudo-range formulations can be developed from either the C/A-code or the more precise P-code. Pseudo-range accuracies are generally accepted to be 1 percent of the period between successive code epochs. Use of the P-code where successive epochs are 0.1 μs apart produces results that are around 1 percent of 0.1 μs or 1 ns. Multiplying this value by the speed of light gives a theoretical resultant range measurement of around 30 cm. If using pseudo-range formulations with the C/A-code, one can expect results 10 times less precise or a range measurement precision of around 3 m. Point positioning accuracy for a differential pseudo-range formulated solution is generally found to be in the range of 0.5-10 m. These accuracies are largely dependent on the type of GPS receiver being used.

b. Carrier beat phase formulations. Carrier beat phase formulations can be based on either the L1 or L2, or both carrier signals. Accuracies achievable using carrier beat phase measurement are generally accepted to be 1 percent of the wavelength. Using the L1 frequency where the wavelength is around 19 cm, one can expect a theoretical resultant range measurement that is 1 percent of 19 cm, or about 2 mm. The L2 carrier can only be used with receivers which employ a cross correlation, squaring, or some other technique to get around the effects of A/S.

(1) The final positional accuracy of a point determined using differential GPS survey techniques is directly related to the geometric strength of the configuration of satellites observed during the survey session. GPS errors resulting from satellite configuration geometry can be expressed in terms of DOP. Positional accuracy for a differential carrier beat phase formulated solution is generally found to be in the range of 1-10 mm.

(2) In addition to GDOP, PDOP, HDOP, and VDOP, the quality of the baselines produced by GPS differential techniques (static or kinematic) through carrier phase recovery can be defined by a quantity called relative DOP (RDOP). Multiplying the uncertainty of a double difference measurement by RDOP yields the relative position error for that solution. Values of RDOP are measured in meters of error in relative position per error of one cycle in the phase measurement (m/cycle). Knowledge of an RDOP or a value equivalent to it is extremely important to the confidence one assigns to a baseline recovery. Key to understanding RDOP is to remember that it represents position recovery over a whole session of time and is not representative of a position recovery at an instant in time. When carrier phase recovery techniques are used, RDOP values around 0.1 m/cycle are considered acceptable.

Chapter 7
GPS Survey Equipment

7-1. GPS Receiver Selection

Selection of the right GPS receiver for a particular project is critical to its success. To ensure success, selection must be based on a sound analysis of the following criteria: applications for which the receiver is to be used, accuracy requirements, power consumption requirements, operational environment, signal processing requirements, and cost. This chapter presents only a brief overview on GPS survey equipment and selection criteria. Prior to initiating procurement, USACE Commands are advised to consult the referenced guide specifications for procuring GPS equipment.

a. Receiver applications. Current USACE receiver applications include land-based, water-based, and airborne applications. Land applications include surveying, geodesy, resource mapping, navigation, survey control, boundary determination, deformation monitoring, and transportation. Water or marine applications include navigation and positioning of hydrographic surveys, dredges, and drill rigs. Airborne applications include navigation and positioning of photogrammetric-based mapping. Generally, the more applications a receiver must fulfill, the more it will cost. It is important for the receiver application to be defined in order to select the proper receiver and the necessary options.

b. Accuracy requirements. A firm definition of the accuracy requirements (e.g., point accuracy to 100 m, 50 m, 25 m, 5 m, 1 m, cm or mm) helps to further define procedure requirements (static or kinematic), signal reception requirements (whether use of C/A- or L1/L2 P-codes is appropriate), and type of measurement required (pseudo-range or carrier beat phase measurements). This is an important part in the receiver selection process.

c. Power requirements. The receiver power requirements are an important factor in the determination of receiver type. Receivers currently run on a variety of power sources from A/C to 12-volt car batteries or small camcorder batteries. A high end GPS receiver can operate 3 to 4 hr on a set of batteries, whereas a low end may operate 1 to 2 days on the same set.

d. Operational environment. The operational environment of the survey is also an important factor in the selection of antenna type and mount, receiver dimension and weight, and durability of design. For example, the harsher the environment (high temperature and humidity variability, dirty or muddy work area, etc.), the sturdier the receiver and mount must be. The operational environment will also affect the type of power source to be used.

e. Processing requirements. Operational procedures required before, during, and after an observation session are very manufacturer-dependent and should be thoughtfully considered before purchase of a receiver. Often, a receiver may be easy to operate in the field, requiring very little user interface, but a tremendous amount of time and effort may be required after the survey to download the data from the receiver and process it (i.e., post-processing software may be complicated, crude, or under-developed). Also, whether a post-processed or real-time solution is desired represents a variable that is critical in determining the type of receiver to use.

f. Cost. Cost is a major factor in determining the type of receiver the user can purchase. Receiver hardware and software costs are a function of development costs, competition among manufacturers, and product demand. Historically, costs for the acquisition of GPS equipment have steadily fallen to the current range of prices seen today. High end receivers are upwards of $35,000 down to a low end receiver of $500.

g. Data exchange formats. In receiver selection it is important to remember that there is currently no standard format for exchanging data from different types of GPS receivers. However, most GPS receiver data can be put into a common text format such as RINEX. Refer to paragraph 7-4 for further discussion on receiver formats.

h. USACE. For most USACE civil applications, continuous tracking, C/A-code, L1 tracking, multichannel (eight or more channels) receivers are adequate. Receivers with other features may be required for a particular application. For example, a dual frequency (L1/L2) receiver with the cross correlation, squaring, or some other technique during anti-spoofing is required for the OTF and rapid static surveying techniques.

7-2. Conventional GPS Receiver Types

There are two basic types of GPS receivers: code phase and carrier phase receivers. Within these types there are C/A- and P-code receivers, codeless receivers, single- and dual-frequency receivers, and receivers that use cross correlation or squaring or P-W techniques. Figure 7-1 shows common equipment required at a station.

Figure 7-1. Common GPS equipment required at each setup

a. Code phase receivers. A code receiver is also called a "code correlating" receiver because it requires access to the satellite navigation message of the P- or C/A-code signal to function. This type of receiver relies on the satellite navigation message to provide an almanac for operation and signal processing. Because it uses the satellite navigation message, this type of receiver can produce real-time navigation data. Code receivers have "anywhere-fix" capability and, consequently, a quicker start-up time at survey commencement. An anywhere-fix receiver has the unique capability to begin calculations without being given an approximate location and time. A code receiver has anywhere-fix capability because it can synchronize itself with GPS time at a point with unknown coordinates once lock on the signals of four satellites has been obtained.

b. Carrier phase receivers. A carrier phase receiver utilizes the actual GPS signal itself to calculate a position. There are two general types of carrier phase receivers: (1) single frequency and (2) dual frequency.

(1) Single-frequency receivers. A single-frequency receiver tracks the L1 frequency signal. The single-frequency receiver generally has a lower price than the dual-frequency receiver because it has fewer components and is in greater demand. A single-frequency receiver can be used effectively to develop relative positions that are accurate over baselines of less than 50 km or where ionosphere effects can generally be ignored.

(2) Dual-frequency receivers. The dual-frequency receiver tracks both the L1 and L2 frequency signal. A dual-frequency receiver is generally more expensive than a single-frequency receiver. A dual-frequency receiver will more effectively resolve longer baselines of more than 50 km where ionosphere effects have a larger impact on calculations. Dual-frequency receivers eliminate almost all ionosphere effects by combining L1 and L2 observations. Most manufacturers of dual-frequency receivers utilize codeless techniques which allow the use of the L2 during anti-spoofing. These codeless techniques are squaring, cross-correlation, and P-W correlation.

(a) Squaring. Receivers which utilize the squaring technique are only able to obtain one-half of the signal wavelength on the L2 during anti-spoofing and have a high 30-dB loss.

(b) Cross correlation. Receivers that use this technique have a high 27-dB loss but are able to obtain the full wavelength on the L2 during anti-spoofing.

(c) P-W correlation. This method allows for both a low 14-dB loss and full wavelength on the L2 during anti-spoofing.

c. Military grade GPS receivers. The current military GPS receiver is the precise lightweight GPS receiver (PLGR), AN/PSN-11, which uses the course/acquisition (C/A), precise (P), or encrypted P(Y) codes. PLGR is designed to operate as a stand-alone unit and provide navigation information: position, velocity, and time. PLGR requires a crypto key to operate as a PPS receiver. A PPS receiver corrects for errors introduced by selective availability (S/A) and cannot be spoofed by imitated or retransmitted GPS signals, anti-spoofing (A/S). The accuracy is 16-m SEP when keyed. PLGR does not record code data because it was designed to be a navigation device, and P-code data are classified at time of reception. This also limits PLGR's ability to be used in differential GPS. PLGR can only be used in differential GPS when using C/A code and as a rover unit. However, C/A code differential GPS is not authorized by DoD for tactical military operations. If high accuracy surveys are required during a military conflict, PPS geodetic GPS receivers are available through commercial manufacturers. PLGRs or PPS receivers are the only authorized receivers to be used in a conflict area.

(1) Non-military DoD organizations that need PLGR accuracy for their positioning requirements can purchase

PLGR from the existing DoD contract through a memorandum of agreement with DoD.

(2) Commercial GPS receiver manufacturers produce hand-held, low cost PPS GPS receivers capable of 16-m SEP accuracy when keyed. These receivers may or may not have anti-spoofing capability and require the same crypto keys as PLGR.

7-3. Receiver Manufacturers

Up-to-date listings of manufacturers are contained in various surveying trade publications. Contact should be made directly with representatives of each firm to obtain current specifications, price, availability, material, or other related data on their products.

7-4. Other Equipment

There are several other relative miscellaneous equipment items that should be considered when making a GPS receiver selection. This equipment is discussed below.

a. Data link equipment for real-time positioning. The type of data link needed for real-time positioning should be capable of transmitting digital data. The specific type of data link will depend on the user's work area and environment. Most manufacturers of GPS equipment can supply or suggest a data link that can be used for real-time positioning. Depending on the type and wattage of the data link, a frequency authorization may have to take place in order to transmit digital data. Some radio and GPS manufacturers produce 1 W or less radios for transmission of digital data which do not require frequency authorization.

b. U.S. Coast Guard (USCG) radiobeacon receivers. The USCG provides a real-time pseudo-range corrections broadcast over low frequency (270-320 kHz marine band) from a radiobeacon transmitter tower. These towers exist in most if not all coastal areas including the Mississippi River and the Great Lakes regions. The range from each tower is approximately 120 to 300 km. These corrections can be received by using a radiobeacon receiver and antenna tuned to the nearest tower site. For further information on this system contact the USCG office in your district or the number listed in Appendix C.

c. Computer equipment. Most manufacturers of GPS receivers include computer specifications needed to run their downloading and post-processing software. Most software can be run on a 386-type computer with a math co-processor or on a 486-type computer.

d. Antenna types. There are three basic types of GPS antennas: ground plane antennas, no ground plane, and choke ring antennas. Both the ground plane and the choke rings are designed to reduce the effects of multipath on the antenna.

e. Associated survey equipment. There are several accessories needed along with a GPS receiver and antenna. These include tripods, tribrachs, and tribrach adapters to name a few. Fixed height (usually 2 m) poles can be used to eliminate the need to measure antenna heights. Most of the other equipment needed is similar to what is used in a conventional survey.

7-5. GPS Common Exchange Data Format

a. RINEX. Receiver INdependent EXchange (RINEX) format is an ASCII-type format which allows a user to combine data from different manufacturer's GPS receivers. Most GPS receiver manufacturers supply programs to convert raw GPS data into a RINEX format. However, one must be careful since there are different types of RINEX conversions. Currently, the NGS distributes software which converts several receivers' raw GPS data to RINEX. NGS will distribute this software free of charge to any government agency.

b. Real-time data transmission formats. There are two types of common data formats used most often during real-time surveying: (1) RTCM SC-104 v. 2 and (2) NMEA.

(1) Transmission of data between GPS receivers. The Radio Technical Commission for Maritime Services (RTCM) is the governing body for transmissions used for maritime services. The RTCM Special Committee 104 (SC-104) has defined the format for transmission of GPS corrections. The RTCM SC-104 standard was specifically developed to address meter-level positioning requirements. This current standard transmission standard for meter-level DGPS is the RTCM SC-104 v. 2.0. This standard allows various manufacturers' equipment to work together if it is used at both the reference and remote stations. It should be noted that not all manufacturers fully support the RTCM SC-104 v. 2.0 format, and careful consideration should be made to choose one that does. A committee was formed to address the means of a transmission format for centimeter-level DGPS. This committee proposed the RTCM SC-104 v. 2.1 format, which supports raw carrier phase data, raw pseudo-range data, and corrections for both. This will allow for correction of ionosphere and troposphere errors, with dual frequency measurements, to be applied at the receiving station. It is

deemed to be downward compatible with RTCM SC-104 v. 2.0, and therefore no special transmission considerations need to be made to use it.

(2) Transmission of data between a GPS receiver and a device. The *National Maritime Electronics Association (NMEA)* governs the format of output records (i.e., the positions at the remote end). The standard concerning the corrected GPS output records at the remote receiver is referred to as the *NMEA 0183 Data Sentencing Format*. The NMEA 0183 output records can be used as input to whatever system the GPS remote receiver is interfaced. For example, GPS receivers with an NMEA 0183 output can be used to provide the positional input for a hydrographic survey system or an Electronic Chart Display and Information System (ECDIS).

Chapter 8
Planning GPS Control Surveys

8-1. General

Using differential carrier phase GPS surveying to establish control for USACE civil and military projects requires operational and procedural specifications that are a project-specific function of the control being established. To accomplish these surveys in the most efficient and cost-effective manner, and to ensure that the required accuracy criteria are obtained, a detailed survey planning phase is essential. This chapter defines GPS survey design criteria and related observing specifications required to establish control for USACE military construction and civil works projects. Information on cost for GPS surveys can be found in Chapter 12, and information on using GPS for hydrographic surveys can be found in EM 1110-2-1003.

8-2. Required Project Control Accuracy

The first step in planning GPS control surveys is to determine the ultimate accuracy requirements. Survey accuracy requirements are a direct function of specific project functional needs, that is, the basic requirements needed to support planning, engineering design, maintenance, operations, construction, or real estate. This is true regardless of whether GPS or conventional surveying methods are employed to establish project control. Most USACE military and civil works engineering/construction activities require relative accuracies (i.e., accuracies between adjacent control points) ranging from 1:1,000 to 1:50,000, depending on the nature and scope of the project. Few USACE projects demand relative positional accuracies higher than the 1:50,000 level (Second-Order, Class I). Since the advent of GPS survey technology, there has been a tendency to specify higher accuracies than necessary. Specifying higher accuracy levels than those minimally required for the project can unnecessarily increase project costs.

a. Project functional requirements. Project functional requirements must include planned and future design, construction, and mapping activities. Specific control density and accuracy are designed from these functional requirements.

(1) Density of control within a given project is determined from factors such as planned construction, site plan mapping scales, master plan mapping scale, and dredging and hydrographic survey positioning requirements.

(2) The relative accuracy for project control is also determined based on mapping scales, design/construction needs, type of project, etc. Most site plan mapping for design purposes is performed and evaluated relative to American Society of Photogrammetry and Remote Sensing (ASPRS) standards. These standards apply to photogrammetric mapping, plane table mapping, total station mapping, etc. Network control must be of sufficient relative accuracy to enable hired-labor or contracted survey forces to reliably connect their supplemental mapping work.

b. Minimum accuracy requirements. Project control surveys shall be planned, designed, and executed to achieve the minimum accuracy demanded by the project's functional requirements. In order to most efficiently utilize USACE resources, control surveys shall not be designed or performed to achieve accuracy levels that exceed the project requirements. For instance, if a Third-Order, Class I accuracy standard (1:10,000) is required for offshore dredge/survey control on a navigation project, field survey criteria shall be designed to meet this minimum standard.

c. Achievable GPS accuracy. As stated previously, GPS survey methods are capable of providing significantly higher relative positional accuracies with only minimal field observations, as compared with conventional triangulation, trilateration, or EDM traverse. Although a GPS survey may be designed and performed to support lower accuracy project control requirements, the actual results could generally be several magnitudes better than the requirement. Although higher accuracy levels are relatively easily achievable with GPS, it is important to consider the ultimate use of the control on the project in planning and designing GPS control networks. Thus, GPS survey adequacy evaluations should be based on the project accuracy standards, not those theoretically obtainable with GPS.

(1) For instance, an adjustment of a pair of GPS-established points may indicate a relative distance accuracy of 1:800,000 between them. These two points may be subsequently used to set a dredging baseline using 1:2,500 construction survey methods; and from 100-ft-spaced stations on this baseline, cross sections are projected using 1:500 to 1:1,000 relative accuracy methods (typical hydrographic surveys). Had the GPS-observed baseline been accurate only to 1:20,000, such a closure would still have easily met the project's functional requirements.

(2) Likewise, in plane table topographic (site plan) mapping or photogrammetric mapping work, the difference between 1:20,000 and 1:800,000 relative accuracies is not perceptible at typical USACE mapping/construction scales (1:240 to 1:6,000), or ensuring supplemental compliance with ASPRS standards. In all cases of planimetric and topographic mapping work, the primary control network shall be of sufficient accuracy such that ASPRS standards can be met when site plan mapping data are derived from such points. For most large-scale military and civil mapping work performed by USACE, Third-Order relative accuracies are adequate to control planimetric and topographic features within the extent of a given sheet/map or construction site. On some projects covering large geographical areas (e.g., reservoirs, levee systems, installations), this Third-Order mapping control may need to be connected to/with a Second-Order (Class I or II) network to minimize scale distortions over longer reaches of the project.

(3) In densifying control for GIS databases, the functional accuracy of the GIS database must be kept in perspective with the survey control requirements. Performing 1:100,000 accuracy surveys for a GIS level containing 1-acre cell definitions would not be cost-effective; sufficient accuracy could be obtained by scaling relative coordinates from a U.S. Geological Survey (USGS) quadrangle map.

8-3. General GPS Network Design Factors

Some, but not all, of the factors to be considered in designing a GPS network (and subsequent observing procedure) should include the following:

a. Project size. The extent of the project will affect the GPS survey network shape. Many civil works navigation and flood control projects are relatively narrow in lateral extent but may extend for many miles longitudinally. Alternatively, military installations or reservoir/recreation projects may project equally in length and breadth. The optimum GPS survey design will vary considerably for these different conditions.

b. Required density of control. The type of GPS survey scheme used will depend on the number and spacing of points to be established, which is a project-specific requirement. In addition, maximum baseline lengths between stations and/or existing control are also prescribed. Often, a combination of GPS and conventional survey densification will prove to be the most cost-effective approach.

c. Absolute GPS reference datums. Coordinate data for GPS baseline observations are referenced and reduced relative to WGS 84, an earth-centered (geocentric) coordinate system. This system is not directly referenced to but is closely related to, for all practical purposes, GRS 80 upon which North American Datum of 1983 (NAD 83) is related (for CONUS work). GPS data reduction and adjustment are normally performed using the WGS 84 earth-centered (geocentric) coordinate system (X-Y-Z), with baseline vector components (X, Y, Z) measured relative to this coordinate system. Although baseline vectors are measured relative to the WGS 84 system, for most USACE engineering and construction applications these data may be used in adjustments on NAD 27 (Clarke 1866). (See paragraphs 3-4 and 4-1.)

(1) If the external network being connected (and adjusted to) is the published NAD 83, the GPS baseline coordinates may be directly referenced on the GRS 80 ellipsoid since they are nearly equal. All supplemental control established is therefore referenced to the GRS 80/NAD 83 coordinate system.

(2) If a GPS survey is connected to NAD 27 (SPCS 27) stations which were not adjusted to the NAD 83 datum, then these fixed points may be transformed to NAD 83 coordinates using USACE program CORPSCON (see EM 1110-1-1004) and the baseline reductions and adjustment performed relative to the GRS 80 ellipsoid. This method is recommended for USACE projects, only if resurveying is not a viable option.

(3) Alternatively, GPS baseline connections to NAD 27 (SPCS 27) project control may be reduced and adjusted directly on that datum with resultant coordinates on the NAD 27. Geocentric coordinates on the NAD 27 datum may be computed using the transformation algorithms given in Chapter 11. Refer also to EM 1110-1-1004 regarding state plane coordinate transforms between SPCS 27 and SPCS 83 grids. Conversions of final adjusted points on the NAD 27 datum to NAD 83 may also be performed using CORPSCON.

(4) Ellipsoid heights h referenced to the GRS 80 ellipsoid differ significantly from the orthometric elevations H on NGVD 29, NAVD 88, or dynamic/hydraulic elevations on the IGLD 55, IGLD 85. This difference (geoid separation, or N) can usually be ignored for horizontal control. This implies N is assumed to be zero and $h = H$ where the elevation may be measured, estimated, or scaled at the fixed point(s). See Chapter 6 for using GPS for vertical surveys.

(5) Datum systems other than NAD 27/NAD 83 will be used in OCONUS locations. Selected military operational requirements in CONUS may also require non-NAD datum references. It is recommended that GPS baselines be directly adjusted on the specific project datum.

d. Connections to existing control. For most static and kinematic GPS horizontal control work, at least two existing control points should be connected for referencing and adjusting a new GPS survey (Table 8-1). Existing points may be part of the NGRS or in-place project control which has been adequately used for years. Additional points may be connected if practical. In some instances, a single existing point may be used to generate spurred baseline vectors for supplemental construction control.

(1) Connections with existing project control. The first choice for referencing new GPS surveys is the existing project control. This is true for most surveying, not just GPS, and has considerable legal basis. Unless a newly authorized project is involved, long-established project control reference points should be used. If the project is currently on a local datum, then a supplemental tie to the NGRS should be considered as part of the project.

(2) Connections with NGRS. Connections with the NGRS (i.e., National Ocean Service/National Geodetic Survey control on NAD 83) are preferred where prudent and practical. As with conventional USACE surveying, such connections to the NGRS are not mandatory. In many instances, connections with the NGRS are difficult and may add undue cost to a project with limited resources. When existing project control is known to be of poor accuracy, then ties (and total readjustment) to the NGRS may be warranted. Sufficient project funds should have been programmed to cover the additional costs of these connections, including data submittal and review efforts if such work is intended to be included in the NGRS. (See paragraph 1-8*c* regarding advance programming requirements.)

(3) Mixed NGRS and project control connections. On existing projects, NGRS-referenced points should not be mixed with existing project control. This is especially important if existing project control was poorly connected with the older (NAD 27) NGRS, or if the method of this original connection is uncertain. Since NGRS control has been readjusted to NAD 83 (including subsequent high-precision HARNS readjustments of NAD 83) and most USACE project control has not, problems may result if these schemes are mixed indiscriminately. If a decision is made to establish and/or update control on an existing project, and connections with the NGRS (NAD 83/86) are required, then all existing project control points must be resurveyed and readjusted. Mixing different reference systems can result in different datums, with obvious adverse impacts on subsequent construction or boundary reference. It is far preferable to use "weak" existing (long-established) project control (on NAD 27 or whatever datum) for reference than to end up with a mixture of different systems or datums. See EM 1110-1-1004 for further discussion.

(4) Accuracy of connected reference control. Ideally, connections should be made to control of a higher order of accuracy than that intended for the project. In cases where NGRS control is readily available, this is usually the case. However, when only existing project control is available, connection and adjustment will have to be performed using that reference system, regardless of its accuracy. GPS baseline measurements should be performed over existing control to assess its accuracy and adequacy for adjustment, or to configure partially constrained adjustments.

(5) Connection constraints. Although Table 8-1 requires only a minimum of two existing stations to reliably connect GPS static and kinematic surveys, it may often be prudent to include additional NGRS and/or project points, especially if the existing network is of poor reliability. Adding additional points provides redundant checks on the surrounding network. This allows for the elimination of these points should the final constrained adjustment indicate a problem with one or more of the fixed points.

(a) Table 8-1 indicates the maximum allowable distance from the existing network that GPS baselines should extend.

(b) Federal Geodetic Control Subcommittee (FGCS) GPS standards (FGCC 1988) require connections to be spread over different quadrants relative to the survey project. Other GPS standards suggest an equilateral distribution of fixed control about the proposed survey area. These requirements are unnecessary for USACE work. The value shown in Table 8-1 (for Second-Order, Class I) is only suggested and not mandatory.

e. Location feasibility and field reconnaissance. A good advance reconnaissance of all marks within the project is crucial to the expedient and successful

Table 8-1
GPS Survey Design, Geometry, Connection, and Observing Criteria

Criterion	Classification Order			
	2nd, **I**	2nd, **II**	3rd, **I**	3rd, **II**
Relative accuracy				
ppm	20	50	100	200
1 part in	50k	20k	10k	5k
Required connections to existing horizontal control				
NGRS network		W/F/P		
Local project network		Yes		
Baseline observation check required over existing control	Yes	W/F/P	W/F/P	No
Number of connections with existing network (NGRS or local project control)				
Minimum	2	2	2	2
Optimum	3	3	2	2
New point spacing, m, not less than	1,000	500	200	100
Maximum distance from network to nearest control point in project, km	50	50	50	50
Minimum network control quadrant location (relative to project center)	2	N/R	N/R	N/R
Multiple station occupations (static GPS surveys)				
% Occupied three times	N/R	N/R	N/R	N/R
% Occupied two times	N/R	N/R	N/R	N/R
Repeat baseline observations (% of total baselines)	0	0	0	0
Master or fiducial stations required	W/F/P	No	No	No
Loop closure requirements:				
Maximum number of baselines/loop	10	20	20	20
Maximum loop length, km, not to exceed	100	200	N/R	N/R
Loop misclosure, ppm, not less than	20	50	100	200
Single spur baseline observations				
Allowed per order/class	No	No	Yes	Yes
Number of sessions/baseline	-	-	2	2
Required tie to NGRS	-	-	No	No
Field observing criteria -- static GPS surveys				
Required antenna phase height measurement per session	2	2	2	2
Meteorological observations required	No	No	No	No
Two frequency L1/L2 observations required:				
< 50-km lines	No	No	No	No
> 50-km lines	Yes	Yes	Yes	Yes

(Continued)

Table 8-1
(Concluded)

Criterion	Classification Order			
	2nd, **I**	2nd, **II**	3rd, **I**	3rd, **II**
Recommended minimum observing time (per session), min	60	45	30	30
Minimum number of sessions per GPS baseline	1	1	1	1
Satellite quadrants observed (minimum number)	3 W/F/P	N/R	N/R	N/R
Minimum obstruction angle above horizon, deg	15	15	15	15
Maximum HDOP/VDOP during session	N/R	N/R	N/R	N/R
Photograph and/or pencil rubbing required	A/R	No	No	No
Kinematic GPS surveying				
Allowable per survey class	Yes	Yes	Yes	Yes
Required tie to NGRS	W/F/P	W/F/P	No	No
Measurement time/baseline, min	(follow manufacturer's specifications) A/R			
Minimum number of reference points:	2	2	1-2	1
Preferred references	2	2	2	1
Maximum PDOP	15			
Minimum number of observations from each reference station	2	2	2	2
Adjustment and data submittal requirements				
Approximate adjustments allowed	Yes	Yes	Yes	Yes
Contract acceptance criteria				
Type of adjustment	Free (unconstrained)			
Evaluation statistic	Relative distance accuracies			
Error ellipse sizes	(not used as criteria)			
Histograms	(not used as criteria)			
Reject criteria				
Statistic	Normalized residual			
Standard	3 * SEUW			
Optimum/nominal weighting				
Horizontal	5 + 2 ppm			
Vertical	10 + 2 ppm			
Optimum variance of unit weight	between 0.5 and 1.5			
GPS station/session data recording format	Bound field survey book or form			
Final station descriptions	Standard DA form			
FGCS/NGS Bluebook required	No			
Written project/adjustment report required	Yes			

Notes:

1. Abbreviations used in this table are explained as follows:
   W/F/P--Where feasible and practical.
   N/R--No requirement for this specification--usually indicates variance with provisional FGCC GPS specifications.
   A/R--As required in specific project instructions or manufacturer's operating manual.
   SEUW--Standard error of unit weight.
2. Classification orders refer to intended survey precision for USACE application, not necessarily FGCC standards designed to support national network densification.

completion of a GPS survey. The site reconnaissance should ideally be completed before the survey is started. The surveyor should also prepare a site sketch and brief description on how to reach the point since the individual performing the site reconnaissance may not be the surveyor that returns to occupy the known or unknown station.

(1) Project sketch. A project sketch should be developed before any site reconnaissance is performed. The sketch should be on a 7-1/2-min USGS quadrangle map or other suitable drawing. Drawing the sketch on the map will assist the planner in determination of site selections and travel distances between stations.

(2) Station descriptions and recovery notes. Station descriptions for all new monuments will be developed as the monumentation is performed. The format of these descriptions will follow that stated in EM 1110-1-1002. Recovery notes should be written for existing NGRS network stations and project control points, as detailed in EM 1110-1-1002. Estimated travel times to all stations should be included in the description. Include road travel time, walking time, and GPS receiver breakdown and setup time. These times can be estimated while performing the initial reconnaissance. A site sketch shall also be made on the description/recovery form. Examples of site reconnaissance reports are shown in Figures 8-1 and 8-2. A blank reconnaissance report form is included as Worksheet 8-1 (Figure 8-3), which may be used in lieu of a standard field survey book.

(3) Way point navigation. Way point navigation is an option on some receivers, allowing the user to enter geodetic position (usually latitude and longitude) of points of interest along a particular route the user may wish to follow. The GPS antenna, fastened to a vehicle or range pole, and receiver can then provide the user with navigational information. The navigational information may include the distance and bearing to the point of destination (stored in the receiver), the estimated time to destination, and the speed and course of the user. The resultant message produced can then be used to guide the user to the point of interest. Way point navigation is an option that, besides providing navigation information, may be helpful in the recovery of control stations which do not have descriptions. If the user has the capability of real-time code phase positioning, the way point navigational accuracy can be in the range of 0.5 - 10 m.

(4) Site obstruction/visibility sketches. The individual performing the site reconnaissance should record the azimuth and vertical angle of all obstructions. The azimuths and vertical angles should be determined with a compass and inclinometer. Because obstructions such as trees and buildings cause the GPS signal transmitted from the GPS satellite to be blocked, the type of obstruction is also an important item to be recorded, see Figure 8-2. The type of obstruction is also important to determine if multipath might cause a problem. Multipath is caused by the reflection of the GPS signal by a nearby object producing a false signal at the GPS antenna. Buildings with reflective surfaces, chain-link fences, and antenna arrays are objects that may cause multipath. The site obstruction data are needed to determine if the survey site is suitable for GPS surveying. Obstruction data should be plotted on a Station Visibility Diagram, as shown in Figure 8-4. (A blank copy of this form is provided as Worksheet 8-2 (Figure 8-5).) GPS surveying does require that all stations have an unobstructed view 15 deg above the horizon, and satellites below 10 deg should not be observed.

(5) Suitability for kinematic observations. Clear, obstruction-free projects may be suitable for kinematic GPS surveys as opposed to static. The use of kinematic observations will increase productivity by a factor of 5 to 10 over static methods, while still providing adequate accuracy levels. On many projects, a mixture between both static and kinematic GPS observations may prove to be most cost-effective.

(6) Monumentation. All monumentation should follow the guidelines of EM 1110-1-1002.

(7) On-site physical restrictions. The degree of difficulty in occupying points due to such factors as travel times, site access, multipath effects, and satellite visibility should be anticipated. The need for redundant observations, should reobservations be required, must also be considered.

(8) Checks for disturbed existing control. Additional GPS baselines may need to be observed between existing NGRS/project control to verify their accuracy and/or stability.

(9) Satellite visibility limitations. For most of the Continental United States, there are at least four to five satellites in view at all times. However, some areas may have less during times of satellite maintenance or unhealthy satellites. Satellite visibility charts of the GPS satellite constellation play a major part in optimizing network configurations and observation schedules.

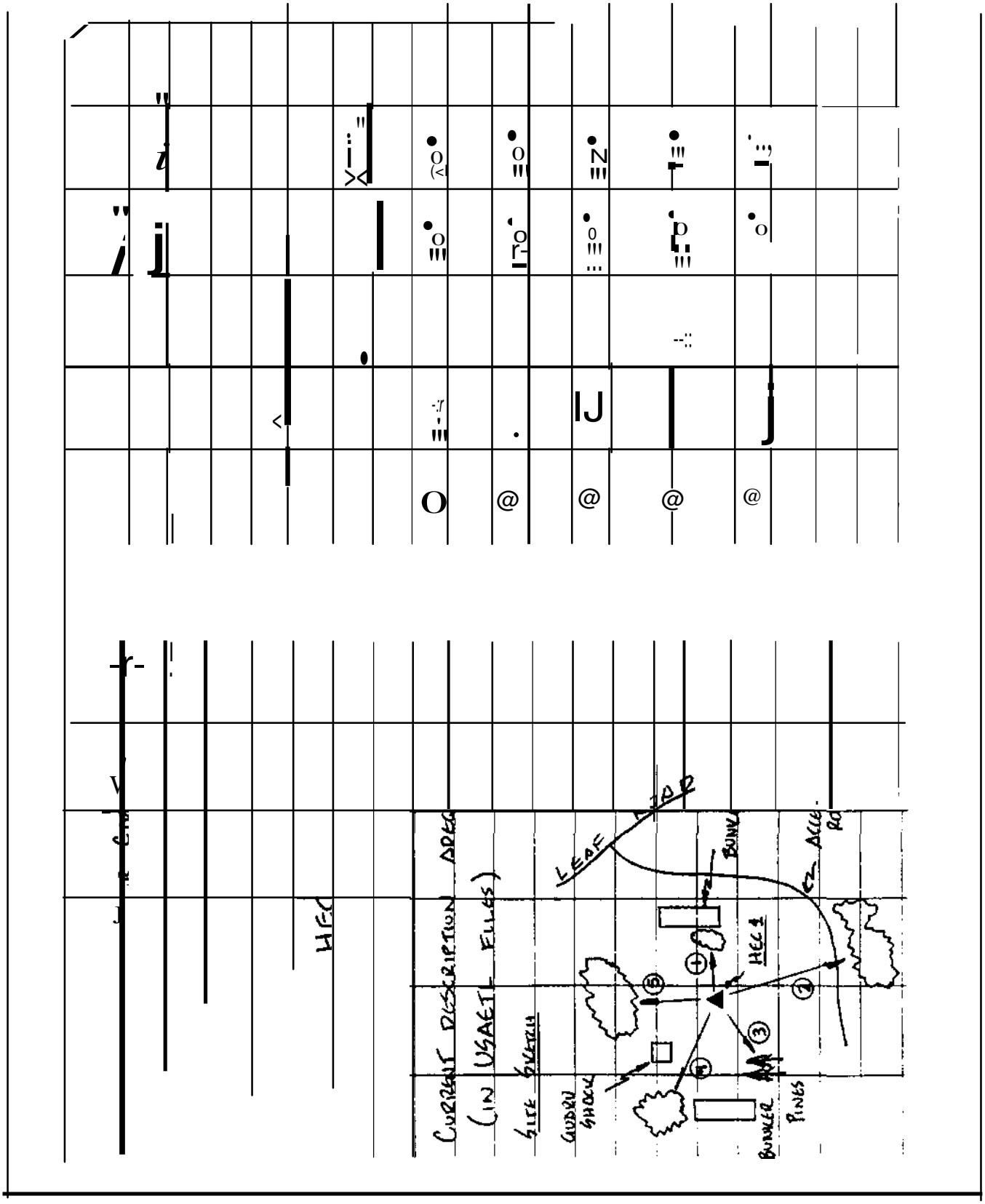

Figure 8-1. Sample site reconnaissance sketch

SITE RECONNAISSANCE/REPORT ON CONDITION OF SURVEY HARK

Project for Which Reconnaissance was Performed Dwo:e, HA.L<... "DA>-;

Station Harne OR..o!::"tNo Year Established I'\S"3

State Code ID County PoJIG'R. Map scale ': Z.'-l. oco

Organization's Mark C f'E,S Map Sheet CL. A.R.\o.JAT£'R.

Search Performed By K. .$""-IT' Date "1/12./Bj

Organization WALI.. A W,,, L..L..A. D, "'T'r.1,c...

Exact Stamping C>n..o INO 1'1"3"3 Condition 6OOC

Please report on the thoroughness of the search in case the mark was not recovered. Suggest changes in description, need for repairing or moving the mark, or other pertinent facts. Record letters and numbers found stamped in (not cast in)the mark.

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Figure 8-2. Reconnaissance report on condition of survey

SITE RECONNAISSANCE/REPORT ON CONDITION OF SURVEY MARK

Project for Which Reconnaissance was Performed _____

Station Name _____ Year Established ____

State Code __ __ County Map Scale ____

Organization's Mark Map Sheet ____

search Perfonmed By _____ Date _____

organization _____

Exact Stamp1ng Condition _____

Please report on the thoroughness of the search in case the mark was not recovered. Suggest changes in description, need for repairing or moving the mark, or other pertinent facts. Record letters and numbers found stamped in (not cast in)the mark.

****

SKETCH

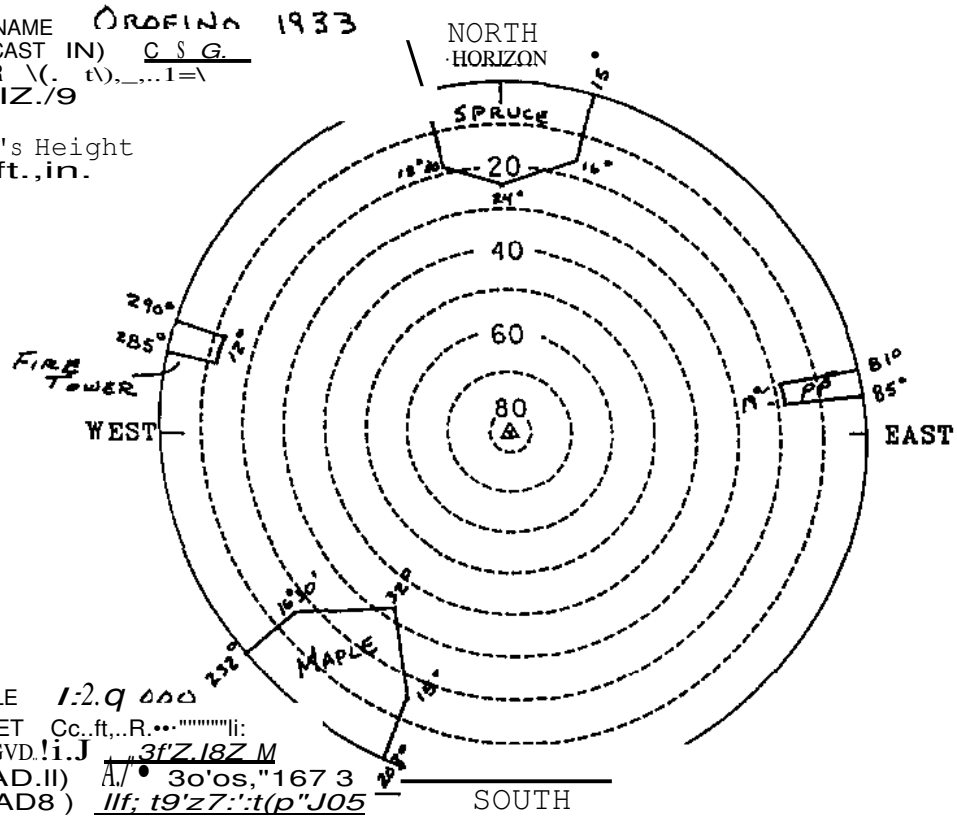
N

Figure 8-3. Worksheet 8-1, Site Reconnaissance Report fonn

STATION VISIBILITY DIAGRAM

STATION NAME ORDFINA 1933
AGENCY (CAST IN) C S G.
OBSERVER \(. t\),_,..1=\
DATE 'i/IZ./9

Observ?.r's Height
5' 10' ft.,in.



MAP SCALE 1:2.q ooo
MAP SHEET Cc..ft,..R.••·"""""li:
ELEV (NGVD.!i.J ,,3f'Z.I8Z M
LAT (NAD.II) A./• 3o'os,"167 3
LONG 0 AD8) IIf; t9'z7:':t(p"J05

Indicate the horizontal and vertical limits of all objects obstucting veiw of the sky exceeding 15 degrees above the horizon.

NO.	AZIHUTH	VEBT ANGLE	DESCRipTION	NO.	AZIMUIH	VERT ANGLE	QESCBip!ION
1	\J"17"b0'	:t•• 30'	:£-..r .:ll',...u.C!.	:11	:	:	
Z	:JsZ.'":so'!	2'1°oo'	!PeAlS. 5p.....,..-.	: 12			
3	! /S'"oo'!	!f.•Qo'	! E!>9!£. .5?&U(.(	\13			
6	:-z.o3•oc·:	15" oo'	\EDt>of. t:\P.p!.f.	: 16			
J	! Z.I5 9o' \	3'Z.• DO'	\'PAA!(tl Aj>L.§.	: : 17			
a	: Z.!>Z.6oo':	14"3o'	'!:pc..£. tJI/I.....E	\ : 1B			

Indicate distance, direction, freQuency and power of known RF sources. Indicate distance, horizontal and vertical limits of any object in the vicinity that max cause radio signals to be reflected (multipath).

,_ 3'2.0' z.ss'"-ro z.9o"' V;;LT" 1'2.° F"',R.c::: """fb....:aE. t_

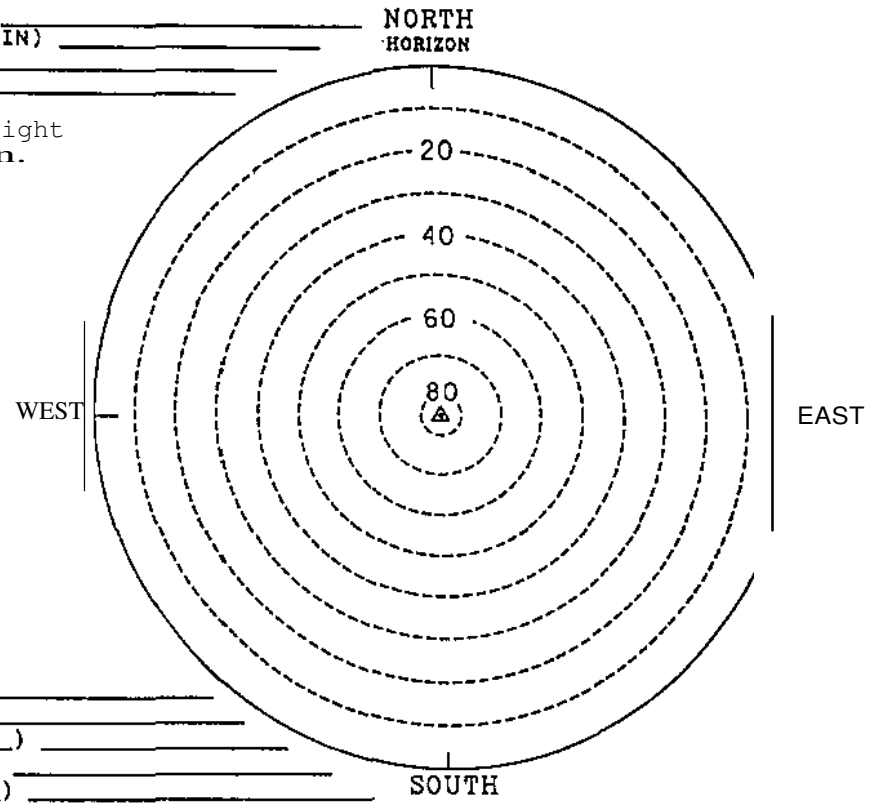
: % .:"S"%'5i .;z;;;.L .;;; fi;;;;;;.r.r.•,.z;.. "

Figure 8-4. Sample station visibility diagram

STATION VISIBILITY DIAGRAM

STATION NAME _____
AGENCY (CAST IN) _____
OBSERVER _____
DATE _____

Observer's Height
_____ ft.,in.



MAP SCALE _____
MAP SHEET _____
ELEV (NGVD___) _____
LAT (NAD___) _____
LONG (NAD___) _____

Indicate the horizontal and vertical limits of all objects obstucting veiw of the sky exceeding 15 degrees above the horizon,

NO,	AZIMUTH	VERT ANGLE	DESCRipTION	NO.	AZIMVTH	VERT ANGLE	DESCRIPTION
1				1			

Indicate distance, direction, frequency, and power of known RF sources. Indicate distance, horizontal and vertical limits of any object in the vicinity that mAY cause radio signals to be reflected (multipath).

1.
2.
3.

Figure 8-5. Worksheet 8-2, Station Visibility Diagram

(10) Station intervisibility requirements. Project specifications may dictate station intervisibility for azimuth reference. This may constrain minimum station spacing.

f. Multiple/repeat baseline connections. Table 8-1 lists recommended criteria for baseline connections between stations, repeat baseline observations, and multiple station occupations. Many of these standards were developed by FGCS for performing high-precision geodetic control surveys such that extensive redundancy will result from the collected data. Since the purpose of these geodetic densification surveys is markedly different from USACE control densification, the need for such high observational redundancy is also different. Adding redundant baseline/station occupations may prove prudent on some remote projects where accessibility is difficult.

g. Loop requirements. Loops (i.e., traverses) provide the mechanism for performing field data validation as well as final adjustment accuracy analysis. Since loops of GPS baselines are comparable to traditional EDM/taped traverse routes, misclosures and adjustments can be handled similarly. Most GPS survey nets (static or kinematic) end up with one or more interconnecting loops that are either internal from a single fixed point or external through two or more fixed network points. Loops should be closed off at the spacing indicated in Table 8-1. Loop closures should meet the criteria specified in Table 8-1, based on the total loop length. See also Chapter 10 for additional GPS loop closure checks.

(1) GPS control surveys may be conducted by forming loops between two or more existing points, with adequate cross-connections where feasible. Such alignment procedures are usually most practical on civil works navigation projects which typically require control to be established along a linear path, e.g., river or canal embankments, levees, beach renourishment projects, and jetties.

(2) Loops should be formed every 10 to 20 baselines, preferably closing on existing control.

(3) Connections to existing control should be made as opportunities exist and/or as often as practical.

(4) When establishing control over relatively large military installations, civil recreation projects, flood control projects, and the like, a series of redundant baselines forming interconnecting loops is usually recommended. When densifying Second- and Third-Order control for site plan design and construction, extensive cross-connecting loop and network configurations recommended by the FGCS for geodetic surveying are not necessary.

(5) On all projects, maximum use of combined static and kinematic GPS observations should be considered, both of which may be configured to form pseudo-traverse loops for subsequent field data validation and final adjustment.

8-4. GPS Network Design and Layout

A wide variety of survey configuration methods may be used to densify project control using GPS survey techniques. Unlike conventional triangulation, trilateration, and EDM traverse surveying, the shape, or geometry, of the GPS network design is not as significant. The following guidelines for planning and designing proposed GPS surveys are intended to support lower order (Second-Order, Class I, or 1:50,000 or less accuracy) control surveys applicable to USACE civil works and military construction activities. An exception to this would be GPS surveys supporting structural deformation monitoring projects where relative accuracies at the centimeter level or better are required over a small project area.

a. Newly established GPS control may or may not be incorporated into the NGRS, depending on the adequacy of the connection to the existing NGRS network, or whether it was tied only internally to existing project control.

b. Of paramount importance in developing a network design is to obtain the most economical coverage within the prescribed project accuracy requirements. The optimum network design, therefore, provides a minimum amount of baseline/loop redundancy without an unnecessary amount of "over-observation." Obtaining this optimum design (cost versus accuracy) is difficult and constantly changing due to evolving GPS technology and satellite coverage.

c. GPS survey layout schemes. The planning of a GPS survey scheme is similar to that for conventional triangulation or traversing. The type of survey design adopted is dependent on the GPS technique employed and the requirements of the user.

(1) GPS networking. A GPS network is proposed when established survey control is to be used in precise network densification (1:50,000-1:100,000). For lower order work (i.e., less than 1:50,000), elaborate network schemes are unnecessary and less work-intensive GPS

survey extension methods may be used. When the networking method is selected, the surveyor should devise a survey network that is geometrically sound. Triangles that are weak geometrically should be avoided. The networking method is practical only with static, pseudo-kinematic, and kinematic survey techniques. Figure 8-6 shows an example of a step-by-step method to build a GPS survey network.

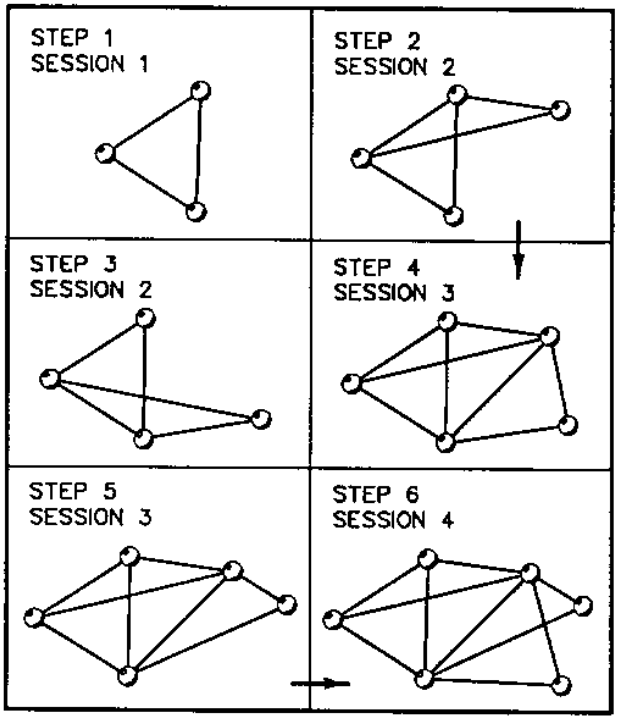


Figure 8-6. GPS network design

(2) GPS traversing. Traversing is the method of choice when the user has only two or three receivers and required accuracies are 1:5,000-1:50,000. Traversing with GPS is done similar to conventional methods. Open-end traverses are not recommended when 1:5,000 accuracies or greater are required. Since GPS does not provide sufficient point positioning accuracies, the surveyor must have a minimum of one fixed (or known) control point, although three are preferred. A fixed control point is a station with known latitude-longitude-height or easting-northing-height. This point may or may not be part of the NGRS. If only one control point is used and the station does not have a known height, the user will be unable to position the unknown stations. When performing a loop traverse, the surveyor should observe a check angle or check azimuth using conventional survey techniques to determine if the known station has been disturbed. If azimuth targets are not visible, and a check angle cannot be observed, a closed traverse involving one or more control points is recommended. Again, a check angle or check azimuth should be observed from the starting control station. If a check angle is not performed, the survey can still be completed. However, if the survey does not meet specified closure requirements, the surveyor will be unable to assess what control point may be in error. If a check angle or check azimuth cannot be observed, a third control point should be tied into the traverse (Figure 8-7). This will aid in determining the cause of misclosure.

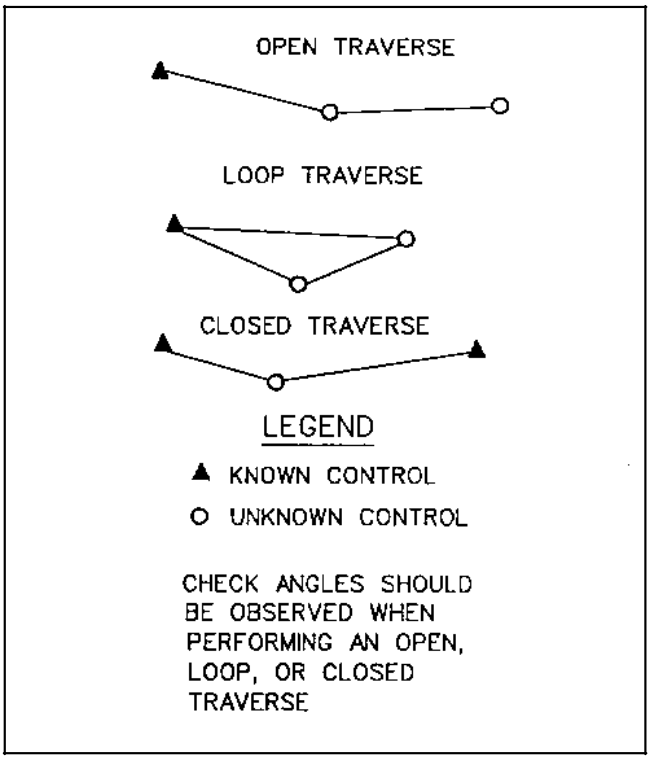


Figure 8-7. GPS traversing schemes

(3) GPS spur shots. Spurs are an acceptable method when the user has only two receivers or only a few control points are to be established. Spur lines should be observed twice during two independent observing sessions. Once the first session is completed, the receivers at each station should be turned off and the tripod elevations changed. This procedure is similar to performing a forward and backward level line. It is important that the tripods be moved in elevation and replumbed over the control station between sessions. If this step is not implemented, the two baselines cannot be considered independent. Figure 8-8 shows an example of a spur line. Spurs are most applicable to static survey and relative positioning (code phase) techniques.

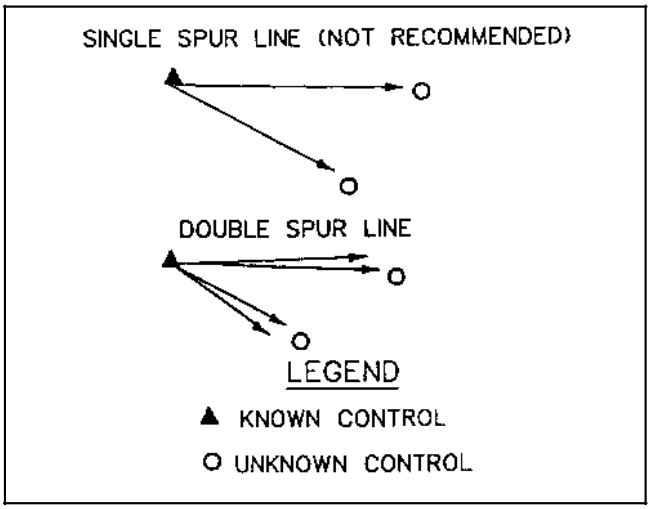


Figure 8-8. GPS spur line

8-5. GPS Techniques Needed for Survey

After a GPS network has been designed and laid out, a GPS survey method or technique needs to be considered. The concepts for each method were discussed in Chapter 6 and the procedures are discussed in Chapter 9. The most efficient method should be chosen in order to minimize time and cost while meeting the accuracy requirements of a given survey project. Once a technique is chosen, the following can be set up: equipment requirements, observation schedules, and sessions designations and planning functions.

a. General equipment requirements. The type of GPS instrumentation used on a project depends on the accuracy requirements of the project, GPS survey technique, project size, and economics. Most USACE projects can be completed using a single-frequency receiver. Dual-frequency receivers are recommended as baseline lengths approach or exceed 50 km. This length may also vary depending on the amount of solar activity during the observation period. Using a dual-frequency receiver permits the user to solve for possible ionospheric and tropospheric delays which can occur as the signal travels from the satellite to the receiver antenna.

(1) Number of GPS receivers. The minimum number of receivers required to perform a differential GPS survey is two. The actual number used on a project will depend on the project size and number of available instruments/operators. Using more than two receivers will often increase productivity and allow for more efficient field observations. For some kinematic applications, two reference (set at known points) receivers and at least one rover are recommended.

(2) Personnel. Personnel requirements are also project dependent. Most GPS equipment is compact and light weight and only requires one person per station setup. However, some cases where a station is not easily accessible or requires additional power for a data link, two individuals may be required.

(3) Transportation. One vehicle is normally required for each GPS receiver used on a project. This vehicle should be equipped to handle the physical conditions that may be encountered while performing the field observations. In most cases, a two-wheel-drive vehicle should be adequate for performing all field observations. If adverse site conditions exist, a four-wheel-drive vehicle may be required. Adequate and reliable transportation is important when the observation schedule requires moving from one station to another between observation sessions.

(4) Auxiliary equipment. Adequate power should be available for all equipment (receivers, computers, lights, etc.) that will be used during the observations. Computers (386-based recommended), software, and data storage devices (floppy disks and/or cassette tapes) should be available for onsite field data reduction use. Other equipment required for conduct of a GPS survey should include tripods, tribrachs, measuring tapes, flagging, flashlights, tools, equipment cables, compass, and inclinometer. If real-time positioning is required, then a data link is also needed.

b. Observation schedules. Planning a GPS survey requires that the surveyor determine when satellites will be visible for the given survey area; therefore, the first step in determining observation schedules is to plot a satellite visibility plot for the project area. Even when the GPS becomes fully operational, full 24-hr coverage of at least four satellites may not be available in all areas.

(1) Most GPS manufacturers have software packages which at least predict satellite rise and set times. An excellent satellite plot will have the following essential information: satellite azimuths, elevations, set and rise times, and satellite PDOPs for the desired survey area. Satellite ephemeris data are generally required as input for the prediction software.

(2) To obtain broadcast ephemeris information, a GPS receiver collects data during a satellite window. The receiver antenna does not have to be located over a

known point when collecting a broadcast ephemeris. The data are then downloaded to a personal computer where they are used as input into the software prediction program. Besides ephemeris data for the software, the user is generally required to enter approximate latitude and longitude (usually scaled from a topographic map) and time offset from UTC for the survey area.

(3) From the satellite plot, the user can determine the best time to perform a successful GPS survey by taking advantage of the best combination of satellite azimuths, elevations, and PDOPs as determined by the satellite visibility plot for the desired survey area (for further information on favorable PDOP values, refer to Chapter 5). The number of sessions and/or stations per day depends on satellite visibility, travel times between stations, and the final accuracy of the survey. Often, a receiver is required to occupy a station for more than one session per day.

(4) A satellite polar plot (Figure 8-9), a satellite azimuth and elevation table (Figure 8-10), and a PDOP versus time plot (Figure 8-11) may be run prior to site reconnaissance. The output files created by the satellite prediction software are used in determining if a site is suitable for GPS surveying.

(5) Determination of session times is based mainly on the satellite visibility plan with the following factors taken into consideration: time required to permit safe travel between survey sites; time to set up and take down the equipment before and after the survey; time of survey; and possible time loss due to unforeseeable problems or complications. Station occupation during each session should be designed to minimize travel time in order to maximize the overall efficiency of the survey.

c. Session designations and planning functions. A survey session in GPS terminology refers to a single period of observation. Sessions and station designations are usually denoted by alphanumeric characters (0, 1, 2, A, B, C, etc.), determined prior to survey commencement.

(1) When only eight numeric characters are permitted for station/session designations, the following convention may be followed:

<u>12345678</u>

where

1 = type of monument with the following convention being recommended:

1 = known horizontal control monument
2 = known benchmark
3 = known 3D monument
4 = new horizontal control monument
5 = new benchmark
6 = new 3D monument
7 = unplanned occupation
8 = temporary 2D point
9 = temporary 3D point

2, 3, 4 = actual station number given to each station

5, 6, 7 = Julian day of year

8 = session number

(a) Example: Station Identifier: 40011821
Position: 12345678

(b) The numeral 4 in the number 1 position indicates the monument being established is a new monument where only horizontal position is being established.

(c) The 001 in the number 2, 3, and 4 position is the station number that has been given to the monument for this project.

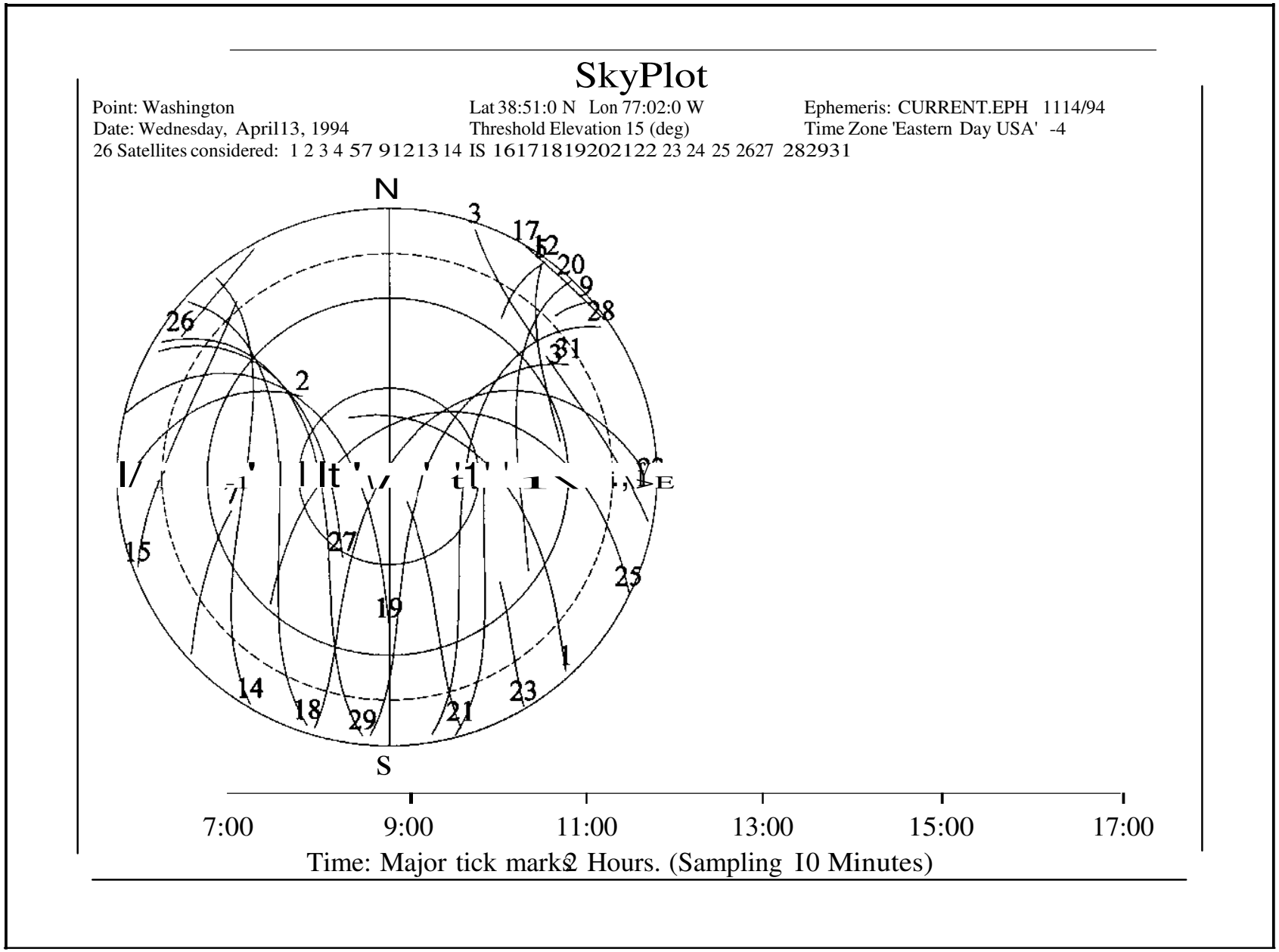
(d) The 182 in the number 5, 6, and 7 position is the Julian day of the year. This is the same day as 1 July.

(e) The numeral 1 in the number 8 position identifies the session number during which observations are being made. If the receiver performed observations during the second session on the same day on the same monument, the session number should be changed to 2 for the period of the second session (then the total station identifier would be 40011822).

(2) When alpha characters are permitted for station/session designation, then a more meaningful designation can be assigned to the designation. The date of each survey session should be recorded during the survey as calendar dates and Julian days and used in the station/session designation. Some GPS software programs will require Julian dates for correct software operation. In addition to determination of station/session designations before the survey begins, the user (usually the crew chief) must:

(a) Determine the occupant of each station.

(b) Determine satellite visibility for each station.



Ftgure 8-9. **Satellite polar plot**

SV Constellations

Point: Washingkxt Lat38:51:ON Loo 77:02:0 W Ephemeris: CURRENT.EPH 1114194
Date: Wednesday, Apri113, 1994 'Jbreshold EIC'r.lIioa 15 (deg} *Tunc:* Zooe 'Eastern Day USA' -4
26 Satellites considered: 12 3 4 57 9 12 13 14 IS 1617 \8 19 20 21 22 23 24 25 26 27 28 29 31
Sampling Rate: 10 Minutes

Constellation	T Rise	TSet	dT	PDOPRise	PDOPSet
4513162()2426	0:00	0·\0	0:10	▼▼	2S
41316202426	0:10	0:20	0:10	2.S	2.S
1 41316202426	0:20	0·Jo	0:10	1.8	1.8
3 416202426	0:30	0.40	0:10	1.9	>.9
316172426	0:40	I·40	1.00	29	32
31617232426	1:40	2:00	0:20	2.S	2.S
31617 2326	2:00	2.. ,	0.40	30	●●●
3 916172326	2:40	J'40	▮▮▮▮	2.7	32
J 9121617212326	3:40	3:50	0:10	1.8	>.8
) 9121721232{;	3:50	4:]{}	0.20	2>	22
3 9121721232628	4:J(l	4:20	0:10	2.0	2.0
I 3 9121721232628	4-:20	4·30	O·10	1.9	1.9
I 3 91217212326	4-:J(1	4:40	0:10	2.0	2.0
I 91217212326	4-:40	SOO	0:20	2.2	22
I 912172123	5:00	5:40	0:40	S.3	<.7
15912172123	5:40	000	0·2(1	33	32
59122123	6:00	6:10	0:10	3.3	D
15912202123	6:10	6.20	0.10	2.9	29
1 ſ 91220212325	6:20	700	0·40	2.'	2'
151220212325	7:00	7:20	0:20	2.<	▮.▮
15121520212325	7:20	7m	0:10	20	20
151520212325	7:30	800	0:30	2.>	▮.▮
I 515202125	S.:00	8·40	0:40	28	▼▼
11415202125	S:40	9.00	0:20	2.3	▼▼
114202125	9:00	9:10	0:10	2'	2S
11420212225	9:10	9:20	0:10	2.<	▮.▮
114202225	9:20	10.00	0:40	27	▼▼
11420222529	10.00	10:10	0:10	2.3	▼▼
114222529	10·10	10·50	0:40	28	20
314222529	10:50	11:10	0:20	3.'	3.,
31422252829	11:10	l\.20	0:10	▼▼	▼▼
3141822252829	11:20	12'()0	0:40	1.9	2.'
314182225282931	12.00	12.20	0:20	▮.▮	▼▼
3182225282931	12:20	12:40	0:20	2'	▼▼
3181922282931	12-40	12.50	0:10	,.0	20
181922282931	\2•50	13:50	1:00	3.0	U
18192227282931	I3.50	14.50	1:00	▼▼	▼▼
\819272831	14·50	15:00	0:10	3.>	3.'
151819272831	15.00	15.20	0:20	▼▼	27
2151819272831	15•20	\5·40	0:20	1.9	▼▼
21519272811	1 s-40	15-50	0:10	▼▼	2.'
215192731	15·50	16·00	0:10	'9	;.9
2715192731	16:00	17:20	1:20	;''	,.7
2 7151927	17.20	17;50	0:30	0.8	▼
2714151927	17_50	18_00	0:10	▼▼	SS
2 713141527	18:00	18:20	0:20	2.0	28
24713141527	18:20	18·40	0:20	▮.▮	▮.▮
247131415	18:40	18:50	0:10	;'	2.<
2479131415	18:50	19:00	0:10	2.0	▮.▮
247912131415	19:00	19:20	0:20	2.>	▮.▮
2479121314	19:20	19:30	0:10	2.8	▼▼
247912131424	]9:30	20:20	0:50	,.2	▼▼
2457912131424	20:20	20:50	0:30	>.9	1.7
2457121324	20:50	21:00	0:10	▼▼	▼▼
457121324	21:00	2UO	0:30	H	3.7
45712131824	21:30	21:40	0:10	2.9	▼▼
4 5 71213151824	21:40	21:50	0_10	2.7	2.7
4 5 7121315182024	21.50	22:00	0.10	>.7	>.7
4 5 71316182024	22:00	22:30	0.30	1.9	2.0
451315182024	22.30	23:20	0:50	▼▼	20
4 513152024	23:20	23:50	0:30	3.0	2.7
4 51315202426	23·50	24:00	0:10	▮.▮	2'

Figure 8-10. Satellite azimuth and elevation table

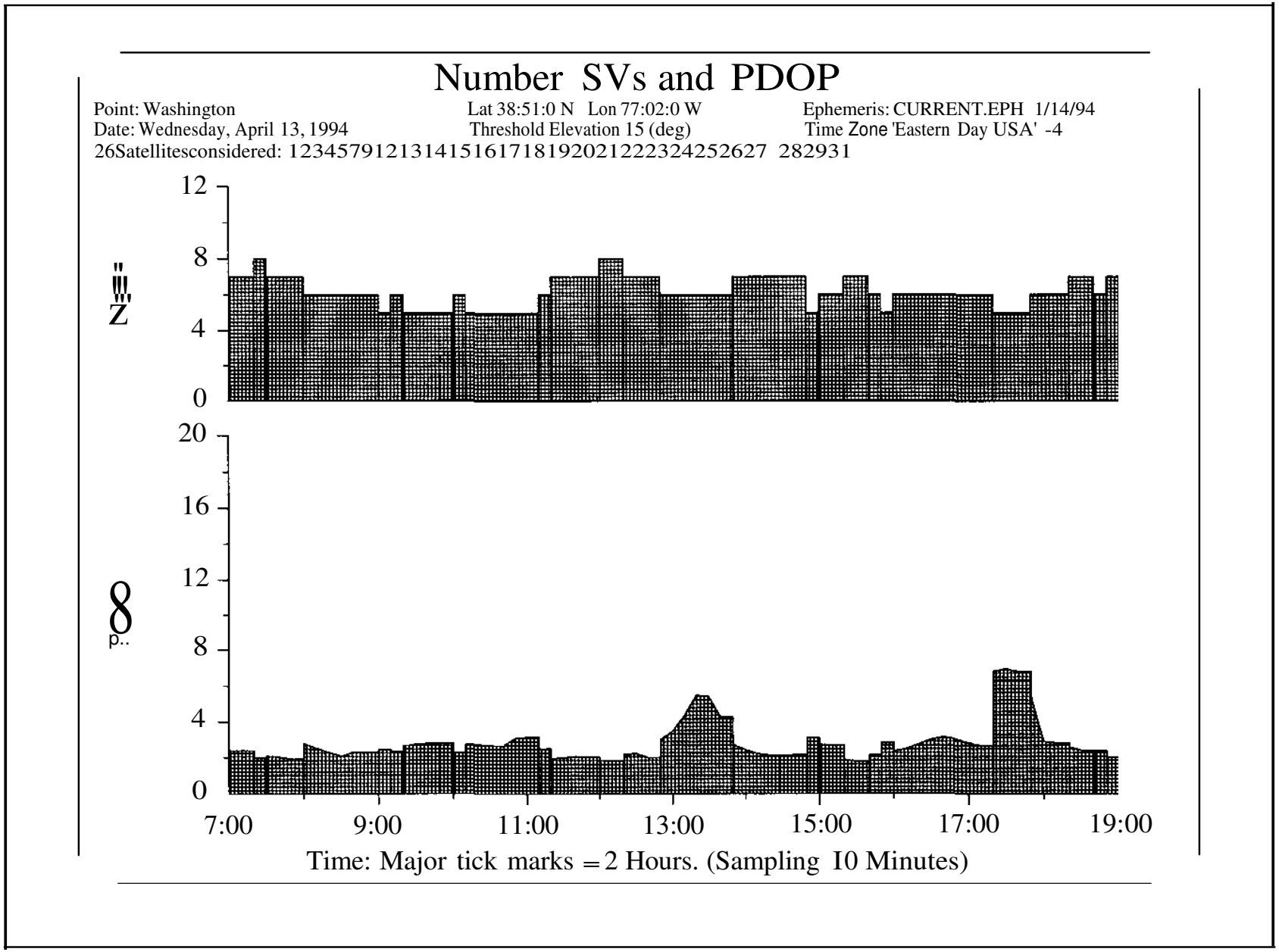


Figure B-11. POOP versus tim• plot

(c) Require site reconnaissance data for stations to be occupied. Remember the same person who performed the initial site reconnaissance may not be the individual performing the survey; therefore, prior determined site reconnaissance data may require clarification before survey commencement.

(d) Develop a project sketch.

(e) Issue explicit instructions on when each session is to begin and end.

(f) Require a station data logging sheet completed for each station. Figures 8-12 and 8-13 are examples of various station logs used in USACE, along with blank forms which may be used as worksheets. Standard bound field survey books may be used in lieu of separate log/work sheets.

U.S. ARMY CORPS OF ENGINEERS
GPS DATA LOGGING SHEET

PROJECT NAME CoYoTe. bl'iH LOCALITY U C..A-
OBSERVER baas LAM'6 AGENCY/FIR E!: C.Ol::
RECEIVER :CI3.u:l·J... 0 0.Sb S/N Z -Z.c c "_
ANTENNA In...\ .....!!>"I-E n..B.o 'Sb SIN 2 ''''
DATA RECORDING UNIT B t:...E.I VG" rot. SIN ezo --..-.
TRIBRACH Nu... D 6I:>F2"2. SIN I"")A LAST CALIBRATED: Z

	SESSION 1	SESSION 2	SESSION 3
STATION NAME	PIE.(<.. 'Z.	pl E.R.. 2.	p,·E.R -Z.
STATION NUMBER	Zooz._	200 z_	2002.
DAY OF YEAR	115	115	115
DATE MM DO yy	o-1 lz.s/B't	O¢/ZS/81	o't'lzs/fJ.9
UTC TIME OF OBSERVATION	START 0 ."5(, STOP 05:55	START - STOP QZ:.2: Ot..:Jo	START Q 1::2 STOP o9:z.o

ANTENNA HEIGHT MEASUREMENTS

	SESSION 1	SESSION 2	SESSION 3
SLOPE a BEGINNING	0.1 ZO o.JZ.O ()./IT IN :O-L'I.I M MN = O. 17.0 H	2 - 'J ', H IN = HN • Q. II(a H	0-1 Z3 .&2:..JEi. IN :O./Z</ H HN = 0- IZ.3S H
SLOPE a END	1-j"/u,. O·IZ.O M IN MN = 0.1'2.0 H	&t 'fJJ4 q/u:.. 'i 9/14 H IN HN • O· II&, M	— - ''he, ..Q..:..!.bi. M .!:f...!:I& IN HN • 0-IZ.:lo H
HN ADJ TO VERT	Q.IZO M	O. M	6· ''''''1 M

	PROGRAMMED REFPOS	FIELD POSITION	PROGRAMMED REFPOS	FIELD POSITION	PROGRAMMED REFPOS	FIELD POSITION
LAT	Jj -12-30	3j-J'Z·2 - i	j-IZ. 3o	J:j·IZ·Z:Z-'-lB	39-II-JD	1'9-It.-22Bl
LONG	uJ- a-JD	I:Z,3-16-3J.4I.	IZ3-to-3o	11J-/I::>-3J..W	/Z.3-{0·30	!Z -tb· ft.t..
HT	24- O	ZID-	24'/.0	I -a	Z Jf. 02Z.Z·B	POOP
	3..,		'l B		'(. O	
SVS TO TRACK	ozi. .,..,1 ot-1 a1, 1'2.1 13, 1<-/		oz' ()=.'''. 6'1', .;ft,'/3 ft'		"'!.j. ". ". a,J $/I'1' 1!9	
LOCAL TIME: START	SCHEDULED 2.1:55	ACTUAL 2.1:54,	SCHEDULED '2.0:3€\	ACTUAL -zJ:IG	SCHEDULED of:z.0	ACTUAL 00.·S S
STOP	n:s5	z'Z.:ss	oo:3s	oo:38	Dz.:eo	02.:2.0

PAGE 1

Figure 8-12. Sample GPS data logging sheet (Continued)

U.S. ARMY CORPS OF ENGINEERS
GPS DATA LOGGING SHEET

	SESSION 1	SESSION 2	SESSION 3
ANT CABLE LENGTH	100 ft	/OCJ f'r	3S -F-r
POWER SUPPLY	12... De	!Zv De.	IZ ... be.
WEATHER CONDITIONS	CLEAR, COOL 45°	CLEAR 40°	CLEAR, BREEZY 40°
MONUMENT TYPE	'C' (SET IN PIER)	:S ... -.Ilt	SAME
EXACT STAMPING	PIER 2 1953	"	"
AGENCY CAST IN DISK	c.oe:	"	"

SKETCH OF SITE

CN 0	-"S.<!ON 2	5E5"0N
SAME	SAME	

Describe any abnormalities and/or problems encountered during the survey, include session number, time c MOUNTED and duration.

THE A ...>T e. oJ .,J .._ J..J A !) USED. DIRECTLY oveR. PIER 2 WITH ,..J.c. -r''R-' "P e. b

ANTENNA HEIGHT I,.J,Io.!) K,;.,.. u R..C\) VERTICALLY FROM GROUND PLANE TO Bn.. b.k...

Figure 8-12. (Concluded)

U.S. ARMY CORPS OF ENGINEERS
GPS DATA LOGGING SHEET

****

PROJECT NAME LOCALITY
OBSERVER AGENCY/FIRM
RECEIVER S/N
ANTENNA S/N
DATA RECORDING UNIT S/N
TRIBRACH S/N LAST CALIBRATED:

****

	SESSION 1	SESSION 2	SESSION 3
STATION NAME			
STATION NUMBER			
DAY OF YEAR			
DATE MM DO YY			
UTC TIME OF OBSERVATION	START STOP	START STOP	START STOP

****

ANTENNA HEIGHT MEASUREMENTS

	SESSION 1	SESSION 2	SESSION 3
SLOPE a BEGINNING	IN = M MN = M	IN • M MN = M	IN = M MN = M
SLOPE • END	M = IN MN • MMN =	M = IN M MN = M	M = IN MN = M
MN ADJ TO VERT	M	M	M

****

	PROGRAMMED REFPOS	FIELD POSITION	PROGRAMMED REFPOS	FIELD POSITION	PROGRAMMED REFPOS	FIELD POSITION
LAT						
LONG						
HT						
POOP						
SVS TO TRACK						

LOCAL TIME:	SCHEDULED	ACTUAL	SCHEDULED	ACTUAL	SCHEDULED	ACTUAL
START						
STOP						

****

PAGE 1

Figure 8-13. Worksheet 8-3, GPS data logging sheet (Continued)

u.S. ARMY CORPS OF ENGINEERS
GPS DATA LOGGING SHEET

****

	SESSION 1	SESSION 2	SESSION 3
ANT CABLE LENGTH			
POWER SUPPLY			
WEATHER CONDITIONS			
MONUMENT TYPE			
EXACT STAMPING			
AGENCY CAST IN DISK			

****

SKE .s.,Ns;TE

N SOS<'o"

N; N:

****

Describe any abnormalities and/or problems encountered during the survey, include session number, time of occurance and duration.

****

PAGE 2

Figure 8-13. (Concluded)

Chapter 9
Conducting GPS Field Surveys

Section I
Introduction

9-1. General

This chapter presents guidance to field personnel performing GPS surveys for all types of USACE projects. The primary emphasis in this chapter is on static and kinematic carrier phase differential GPS measurements which is covered in Section IV. Absolute positioning is covered in Section II. Section III covers differential code phase GPS positioning techniques.

9-2. General GPS Field Survey Procedures

The following are some general GPS field survey procedures that should be performed at each station, observation, and/or session on a GPS survey.

a. Receiver setup. GPS receivers shall be set up in accordance with manufacturer's specifications prior to beginning any observations. To eliminate any possibility of missing the beginning of the observation session, all equipment should be set up with power supplied to the receivers at least 10 min prior to the beginning of the observation session. Most receivers will lock-on to satellites within 1-2 min of powering up.

b. Antenna setup. All tribrachs used on a project should be calibrated and adjusted prior to beginning each project. Dual use of both optical plummets and standard plumb bobs is strongly recommended since centering errors represent a major error source in all survey work, not just GPS surveying.

c. Height of instrument measurements. Height of instrument (HI) refers to the correct measurement of the distance of the GPS antenna above the reference monument over which it has been placed. HI measurements will be made both before and after each observation session. The HI will be made from the monument to a standard reference point on the antenna. (See Figure 9-1.) These standard reference points for each antenna will be established prior to the beginning of the observations so all observers will be measuring to the same point. All HI measurements will be made both in meters and feet for redundancy and blunder detection. HI measurements shall be determined to the nearest millimeter in metric units and to the nearest 0.01 ft (or 1/16 in.). It should be noted whether the HI is vertical or diagonal.

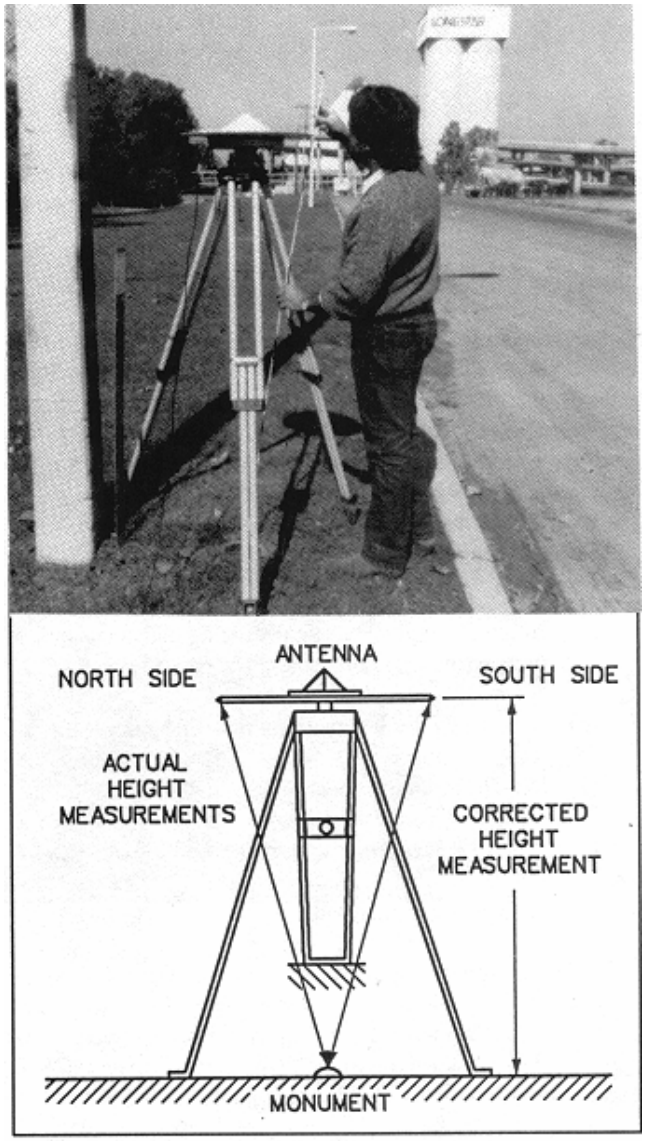


Figure 9-1. Height of instrument measurement setup

d. Field GPS observation recording procedures. Field recording books, log sheets, or log forms will be completed for each station and/or session. Any acceptable recording media may be used. For archiving purposes, standard bound field survey books are preferred; however, USACE Commands may require specific recording sheets/forms to be used in lieu of a survey book. The amount of record-keeping detail will be project-dependent; low-order

topographic mapping points need not have as much descriptive information as would permanently marked primary control points. The following typical data may be included on these field log records:

(1) Project, construction contract, observer(s) name(s), and/or contractor firm and contract number.

(2) Station designation.

(3) Station file number.

(4) Date, weather conditions, etc.

(5) Time start/stop session (local and UTC).

(6) Receiver, antenna, data recording unit, and tribrach make, model, and serial numbers.

(7) Antenna height: vertical or diagonal measures in inches (or feet) and meters (or centimeters).

(8) Space vehicle designations (satellite number).

(9) Sketch of station location.

(10) Approximate geodetic location and elevation.

(11) Problems encountered.

USACE Commands may require that additional data be recorded. These will be contained in individual project instructions or contract delivery order scopes. Samples of typical GPS recording forms are shown later in this chapter.

e. Field processing and verification. It is strongly recommended that GPS data processing and verification be performed in the field where applicable. This is to identify any problems that may exist which can be corrected before returning from the field. Processing and verification is covered in Chapters 10 and 11.

Section II
Absolute GPS Positioning Techniques

9-3. General

The accuracy obtained by GPS point positioning is dependent on the user's authorization. The SPS user can provide an accuracy of 80-100 m. SPS data are most often expressed in real time; however, the data can be post-processed if station occupation was over a period of time. The post-processing produces a best-fit point position. Although this will provide a better internal approximation, the effects of S/A when activated still degrade positional accuracy up to 80-100 m. The PPS user requires a decryption device within the receiver to decode the effects of S/A. The PPS provides an accuracy between 10 and 16 m when a single-frequency receiver is used for observation. Dual-frequency receivers using the precise ephemeris may produce an absolute positional accuracy on the order of 1 m or better. These positions are based on the absolute WGS 84 ellipsoid. The PPS that uses the precise ephemeris requires the data to be post-processed. At present, a commercial or military receiver capable of meter-level GPS point positioning without post-processing is not available.

9-4. Absolute (Point Positioning) Techniques

There are two techniques used for point positioning in the absolute mode. They are long-term averaging of positions and differencing between signals.

a. In long-term averaging, a receiver is set up to store positions over a period of observation time. The length of observation time varies based upon the accuracy required. The longer the period of data collection, the better average position. These observation times can range between 1 and 24 hr. This technique can also be used in real-time (i.e., the receiver averages the positions as they are calculated). For example, the precise lightweight GPS receiver (PLGR) GPS receiver uses this technique in calculating a position at a point.

b. The process of differencing between signals can only be performed in a post-processed mode. Currently, the Defense Mapping Agency has produced software that can perform this operation.

Section III
Differential Code Phase GPS Positioning Techniques

9-5. General

Differential (or relative) GPS surveying is the determination of one location with respect to another location. When using this technique with the C/A- or P-code it is called relative code phase positioning or surveying. Relative code phase positioning has limited application to detailed engineering surveying and topographic site plan mapping applications. Exceptions include general

reconnaissance surveys, hydrographic survey vessel or dredge positioning (see EM 1110-2-1003 for further information on these surveys), and some operational military or geodetic survey support functions. Additional applications for relative code phase positioning have been on the increase as positional accuracies have become better.

9-6. Relative Code Phase Positioning

The code phase tracking differential system is currently a functional GPS survey system for positioning hydrographic survey vessels and dredges. It also has application for topographic, small-scale mapping surveys and input to a GIS database. The basic concept is shown in Figure 9-2. Although greater positional accuracies can be obtained with use of the P-code, DoD's implementation of A/S will limit its use. A real-time dynamic DGPS positioning system includes a reference station, communication link, and user (remote) equipment. If results are not required in real-time, the communication link can be eliminated and the positional information is post-processed.

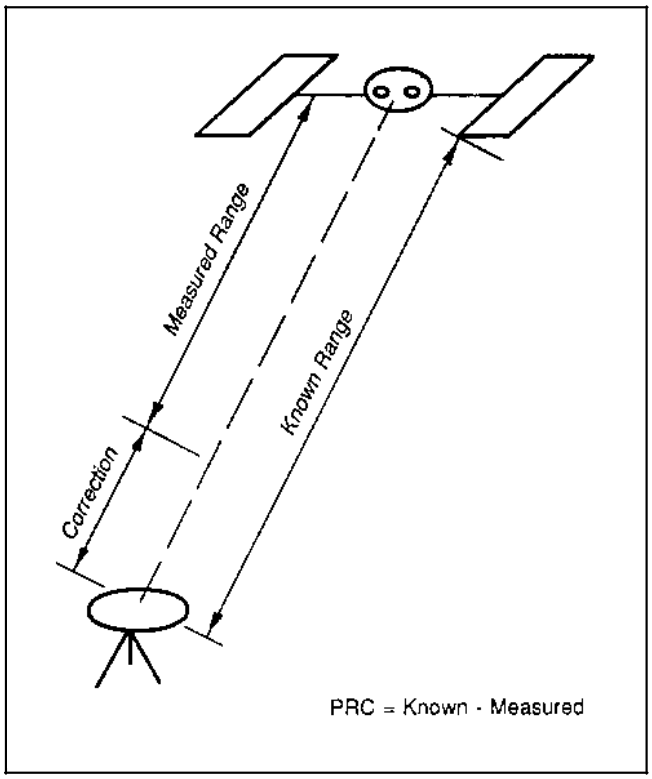


Figure 9-2. Code phase DGPS concept

a. Accuracy of relative code surveys. Relative code phase surveys can obtain accuracies of 0.5 to 10 m. These accuracies will meet Class 1 hydrographic survey standards as stated in EM 1110-2-1003. This type of survey could also be used for small-scale mapping or used as input to a GIS database.

b. Reference station. The reference station is placed on a known survey monument in an area having an unobstructed view of the sky of at least four satellites, 10 deg above the horizon. It consists of a GPS receiver, GPS antenna, processor, and a communication link (if real-time results are desired). The reference station measures the timing and ranging information broadcast by the satellites and computes and formats range corrections for broadcast to the user equipment. Using the technology of differential pseudo-ranging, the position of a survey vessel is found relative to the reference station. The pseudo-ranges are collected by the GPS receiver and transferred to the processor where PRCs are computed and formatted for data transmission. Many manufacturers have incorporated the processor within the GPS receiver, eliminating the need for an external processing device. The recommended data format is that proposed by the RTCM Special Committee (SC) 104 v. 2.0. The processor should be capable of computing and formatting PRCs every 1-3 sec. A longer time span could affect the user's positional solution due to effects of S/A.

c. Communication link. The communication link is used as a transfer media for differential corrections. The main requirement of the communication link is that transmission be at a minimum rate of 300 bits per second. The type of communication system is dependent on the user's requirements.

(1) Frequency authorization. All communication links necessitate a reserved frequency for operation to avoid interference with other activities in the area. No transmission can occur over a frequency until the frequency has been officially authorized for use in transmitting digital data. This applies to all government agencies. Allocating a frequency is handled by the FOA's Frequency Manager responsible for the area of application, the vendor supplying the equipment, and the user.

(2) Ultra High Frequency (UHF) and Very High Frequency (VHF). Communication links operating at UHF and VHF are viable systems for the broadcast of DGPS corrections. UHF and VHF can extend out some 20 to 50 km, depending on local conditions. The disadvantages of UHF and VHF links are their limited range to line of sight and the effects of signal shadowing (i.e. islands, structures, and buildings), multipath and licensing issues.

(3) Satellite communications. There are several companies that sell satellite communication systems which can be used for the transmission of PRCs. These systems can be efficient for wide areas, but are usually higher in price.

(4) License-free radio-modems. Several companies have developed low wattage (1 watt or less) radio-modems to transmit digital data. These radio-modems require no license and can be used to transmit DGPS corrections in a localized area (within 5-8 km or less depending on line of sight). The disadvantages are the short range and line-of-sight limitations.

d. User (remote station) equipment. The remote receiver should be a multichannel single frequency C/A-code GPS receiver. The receiver must be able to store the raw data to be post-processed. During post-processing, these PRCs are generated with the GPS data from the reference station and then applied to the remote station data to obtain a corrected position. If the results are desired in real time, the receiver must be able to accept the PRCs from the reference station (via data link) in the RTCM SC 104 v. 2.0 format and apply those corrections to the measured pseudo-range. The corrected position can then be input into a data collector, hydro package, or GIS database.

e. USCG DGPS Navigation Service. The USCG DGPS Navigation Service was developed to provide a nationwide (coastal regions, Great Lakes regions, and some inland waterways), all-weather, real-time, radio navigation service in support of commercial and recreational maritime interests. A 50+ station network will be operational by FY96. Its accuracy was originally designed to fulfill an 8- to 20-m maritime navigation accuracy. However, a reconfigured version of the USCG system will now yield 1.5-m 2DRMS at distances upward of 150 km from the reference beacon. The system operates on the USCG marine radio beacon frequencies (285-325 kHz). Each radio beacon has an effective range of 150 to 250 km at a 99.9 percent signal availability level. It is fully expected that the USCG system, once completed will be the primary marine navigation device used by commercial and recreational vessels requiring meter-level accuracy.

(a) Corps-wide implementation and use of the USCG system will eliminate need for maintaining existing USACE-operated microwave positioning systems. It will also significantly reduce or eliminate USACE requirements to develop independent UHF/VHF DGPS networks for meter-level vessel navigation and positioning.

(b) The USCG system has potential for supporting other nonmarine activities such as master planning, engineering, mapping, operations, and GIS development activities where meter-level accuracy is sufficient.

Section IV
Differential Carrier Phase GPS Horizontal Positioning Techniques

9-7. General

Differential (or relative) GPS carrier phase surveying is used to obtain the highest precision from GPS and has direct application to most USACE military construction and civil works topographic and engineering survey activities.

a. Differential survey techniques. There are basically six different GPS differential surveying techniques (paragraph 6-4) in use today:

(1) Static.

(2) Pseudo-kinematic.

(3) Stop and go kinematic.

(4) Kinematic.

(5) Rapid static.

(6) On-the-fly (OTF)/Real-time kinematic (RTK).

Procedures for performing each of these methods are described below. These procedures are guidelines for conducting a field survey. Manufacturers' procedures should be followed, when appropriate, for conducting a GPS field survey. Project horizontal control densification can be performed using any one of these methods. Procedurally, all six methods are similar in that each measures a 3D baseline vector between a receiver at one point (usually of known local project coordinates) and a second receiver at another point, resulting in a vector difference between the two points occupied. The major distinction between static and kinematic baseline measurements involves the method by which the carrier wave integer cycle ambiguities are resolved; otherwise they are functionally the same process.

b. Ambiguity resolution. Cycle ambiguity is the unknown number of whole carrier wavelengths between the satellite and receiver. It is also referred to as "Integer

Ambiguity." Figure 9-3 shows an example of an integer ambiguity measurement. Successful ambiguity resolution is required for successful baseline formulations. Generally, in static surveying, instrumental error and ambiguity resolution can be achieved through long-term averaging and simple geometrical principles, resulting in solutions to a linear equation that produces a resultant position. But ambiguity resolution can also be achieved through a combination of the pseudo-range and carrier beat measurements, made possible by a knowledge of the PRN modulation code.

c. Post-observation data reduction. Currently, all carrier phase relative surveying techniques, except OTF and RTK, require post-processing of the observed data to determine the relative baseline vector differences. OTF and RTK can be performed in real-time or in the post-processed mode. Post-processing of observed satellite data involves the differencing of signal phase measurements recorded by the receiver. The differencing process reduces biases in the receiver and satellite oscillators and is performed in a computer. When contemplating the purchase of a receiver, the user should keep in mind the computer requirements necessary to post-process the GPS data. Most manufacturers require, as a minimum, a 386-based IBM-compatible personal computer (PC) with a math co-processor. It is also strongly recommended that all baseline reductions be performed in the field, if possible, in order to allow an onsite assessment of the survey adequacy.

9-8. Static GPS Survey Techniques

Static GPS surveying is perhaps the most common method of densifying project network control. Two GPS receivers are used to measure a GPS baseline distance. The line between a pair of GPS receivers from which simultaneous GPS data have been collected and processed is a vector referred to as a baseline. The station coordinate differences are calculated in terms of a 3D, earth-centered coordinate system that utilizes X-, Y-, and Z-values based on the WGS 84 geocentric ellipsoid model. These coordinate differences are then subsequently shifted to fit the local project coordinate system.

a. General. GPS receiver pairs are set up over stations of either known or unknown location. Typically one of the receivers is positioned over a point whose coordinates are known (or have been carried forward as on a traverse), and the second is positioned over another point

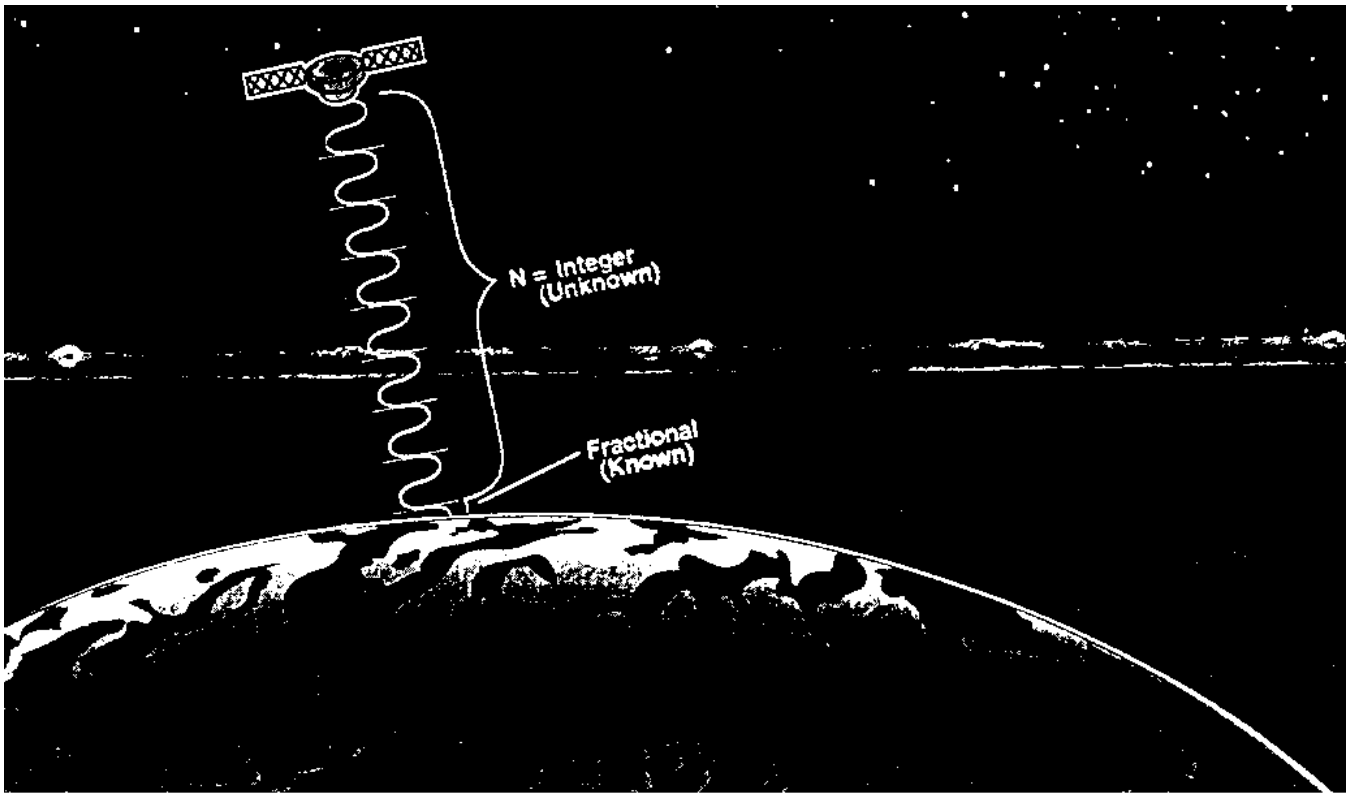


Figure 9-3. Integer Ambiguity

whose coordinates are unknown, but are desired. Both GPS receivers must receive signals from the same four (or more) satellites for a period of time that can range from a few minutes to several hours, depending on the conditions of observation and precision required.

b. Static baseline occupation time. Station occupation time is dependent on baseline length, number of satellites observed, and the GPS equipment used. In general, 30 min to 2 hr is a good approximation for baseline occupation time for shorter baselines of 1-30 km. A rough guideline developed by Trimble, Inc., for estimating occupation time is shown in Figure 9-4. Note that this guideline exceeds the recommended minimum observing times prescribed in Table 8-1.

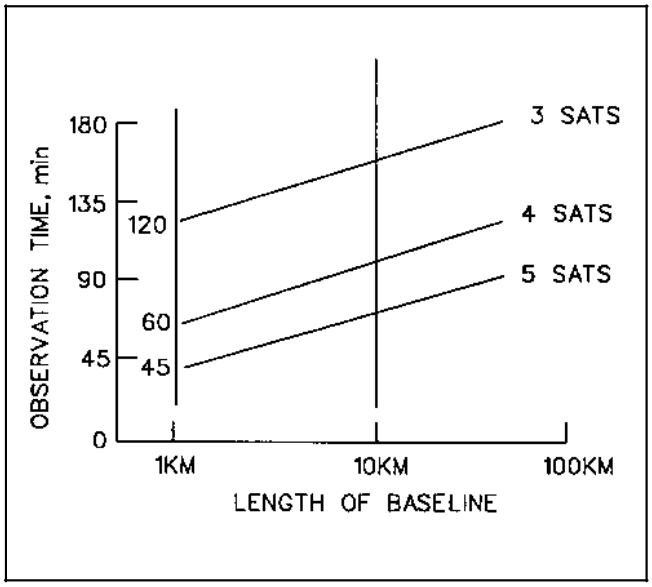


Figure 9-4. Station occupation time versus baseline distance

(1) Since there is no definitive guidance for determining the required baseline occupation time, the results from the baseline reduction (and subsequent adjustments) will govern the adequacy of the observation irrespective of the actual observation time. The most prudent policy is to exceed the minimum estimated times, especially for lines where reoccupation would be difficult or field data assessment capabilities are limited.

(2) For baselines greater than 50 km in length, the ionosphere may have an adverse effect on the solution. Adverse ionosphere effects for baselines of this length can be reduced by using a dual-frequency GPS receiver, as opposed to a single frequency as is normally used.

c. Satellite visibility requirements. The stations that are selected for survey must have an unobstructed view of the sky for at least 15 deg or greater above the horizon during the "observation window." An observation window is the period of time when observable satellites are in the sky and the survey can be successfully conducted.

d. Common satellite observations. It is critical for a static survey baseline reduction/solution that the receivers simultaneously observe the same satellites during the same time interval. For instance, if receiver No. 1 observes a satellite set during the time interval 1,000 to 1,200 and another receiver, receiver No. 2, observes that same satellite set during the time interval 1,100 to 1,300, only the period of common observation, 1,100 to 1,200, can be processed to formulate a correct vector difference between these receivers.

e. Data post-processing. After the observation session has been completed, the received GPS signals from both receivers are then processed (i.e., "post-processed") in a computer to calculate the 3D baseline vector components between the two observed points. From these vector distances, local or geodetic coordinates may be computed and/or adjusted.

f. Survey configuration. Static baselines may be extended from existing control using any of the control densification methods described in Chapter 8. These include networking, traverse, spur techniques, or combinations thereof. Specific requirements are normally contained in project instructions (or scope of work) provided by the District office.

g. Receiver operation and data reduction. Specific receiver operation and baseline data post-processing requirements are very manufacturer-dependent. The user is strongly advised to consult and study manufacturer's operations manuals thoroughly along with the baseline data reduction examples shown in this manual.

h. Accuracy of static surveys. Accuracy of GPS static surveys will usually exceed 1 ppm. Currently of all GPS processing methods, static is the most accurate and can be used for any order survey.

9-9. Stop-and-Go Kinematic GPS Survey Techniques

Stop-and-go surveying is similar to static surveying in that each method requires at least two receivers simultaneously

recording observations. A major difference between static and stop-and-go surveying is the amount of time required for a receiver to stay fixed over a point of unknown position. In stop-and-go surveying, the first receiver--the home or reference receiver--remains fixed on a known control point. The second receiver--the "rover" receiver--collects observations statically on a point of unknown position for a period of time (usually a few minutes), and then moves to subsequent unknown points to collect signals for a short period of time. During the survey, at least four common satellites (preferably five) need to be continuously tracked by both receivers. Once all required points have been occupied by the rover receiver, the observations are then post-processed by a computer to calculate baseline vector/coordinate differences between the known control point and points occupied by the rover receiver during the survey session. The main advantage of this form of GPS surveying over static surveying is the reduced occupation time required over the unknown points. Because stop-and-go surveying requires less occupation time over unknown points, time and cost for the conduct of a survey are significantly reduced. Achievable accuracies typically equal or exceed Third-Order, which is adequate for most USACE projects.

a. Survey procedure. A typical stop-and-go survey scheme is illustrated in Figure 9-5. Stop-and-go GPS surveying is performed similarly to a conventional EDM traverse or electronic total station radial survey. The system is initially calibrated by performing either an antenna swap (see *d* below) with one known point and one unknown point or by performing a static measurement over a known baseline. This calibration process is performed to resolve initial cycle ambiguities. This known baseline may be part of the existing network or can be established using static GPS survey procedures described above. The remote roving receiver then traverses between unknown points as if performing a radial topographic survey. Typically, the points are double-connected, or double-run, as in a level line. Optionally, two fixed receivers may be used to provide redundancy on the remote points. With only 1-1/2 min at a point, X-Y-Z coordinate production is high and limited only by satellite observing windows, travel time between points, and overhead obstructions.

b. Satellite lock. During a stop-and-go kinematic survey, the rover station must maintain lock on at least four satellites during the period of survey (the reference station must be observing at least the same four satellites). Loss of lock occurs when the receiver is unable to continuously record satellite signals or the transmitted satellite

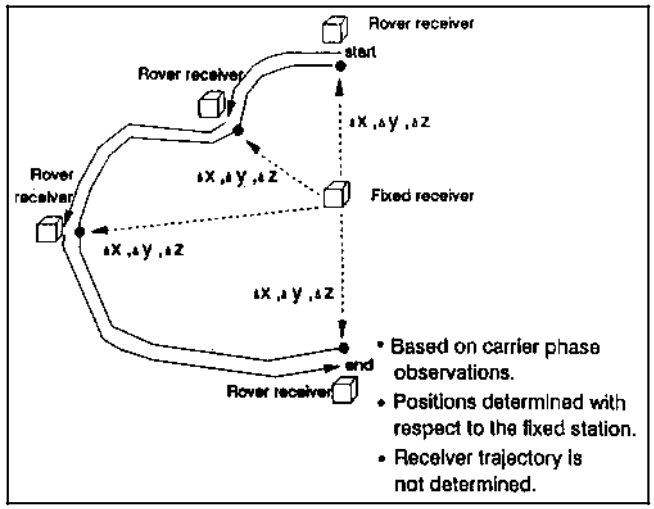


Figure 9-5. Typical stop-and-go survey scheme

signal is disrupted and the receiver is not able to record it. If satellite lock is lost, the roving receiver must reobserve the last control station surveyed before loss of lock. The receiver operator must monitor the GPS receiver when performing the stop-and-go survey to ensure loss of lock does not occur. Some manufacturers have now incorporated an alarm into their receiver that warns the user when loss of lock occurs, thus making the operator's job of monitoring the receiver easier.

c. Site constraints. Survey site selection and route between rover stations to be observed are critical. All sites must have a clear view of satellites having a vertical angle of 15 deg or greater. The routes between rover occupation stations must be clear of obstructions so that the satellite signal is not interrupted. Each unknown station to be occupied should be occupied for a minimum of at least 1-1/2 min. Stations should be occupied two or three times to provide redundancy between observations.

d. Antenna swap calibration procedure. Although the antenna swap procedure can be used to initialize a survey prior to a stop-and-go survey, an antenna swap can also be used to determine a precise baseline and azimuth between two points. The procedure requires that both stations occupied and the path between both stations maintain an unobstructed view of the horizon. A minimum of four satellites and maintainable lock are required to perform an antenna swap; however, more than four satellites are preferred. To perform an antenna swap, one receiver/antenna is placed over a point of known control and the second, a distance of 10 to 100 m away from the other receiver. Referring to Figure 9-6, the receivers at each

station collect data for approximately 2 to 4 min. The receivers/antennae sets then swap locations; the receiver/antenna at the known station is moved to the unknown site while the other receiver/antenna at the unknown site is moved to the known site. Satellite data are again collected for 2 to 4 min. The receivers are then swapped back to their original locations. This completes one antenna swap calibration. If satellite lock is lost during the procedure, the procedure must be repeated.

e. Accuracy of stop-and-go surveys. Accuracy of stop-and-go baseline measurements will usually well exceed 1 part in 5,000; thus, Third-Order classification project/mapping horizontal control can be effectively, efficiently, and accurately established using this technique. For many USACE projects, this order of horizontal accuracy will be more than adequate; however, field procedures should be designed to provide adequate redundancy for what are basically "open-ended" or "spur" points. Good satellite geometry and minimum multipath are also essential in performing acceptable stop-and-go surveys.

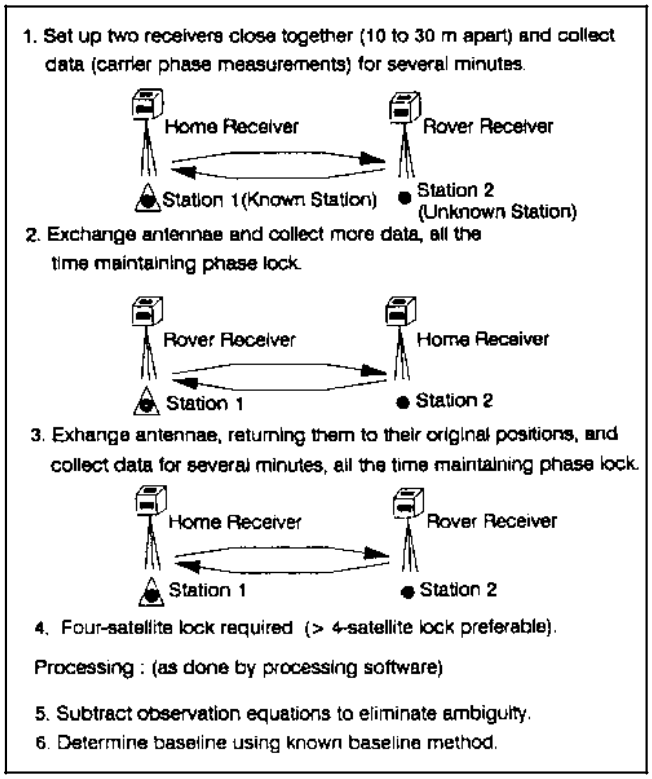


Figure 9-6. Stop-and-go ambiguity resolution (antenna swap method)

9-10. Kinematic GPS Survey Techniques

Kinematic surveying using differential carrier phase tracking is similar to the two previous types of differential carrier phase GPS surveying because it also requires two receivers recording observations simultaneously. Kinematic surveying is often referred to as dynamic surveying. As in stop-and-go surveying, the reference receiver remains fixed on a known control point while the roving receiver collects data on a constantly moving platform (vehicle, vessel, aircraft, manpack, etc.), as illustrated in Figure 9-7. Unlike stop-and-go surveying, kinematic surveying techniques do not require the rover receiver to remain motionless over the unknown point. The observation data are later post-processed with a computer to calculate relative vector/coordinate differences to the roving receiver.

a. Survey procedure. A kinematic survey requires two single frequency (L1) receivers. One receiver is set over a known point (reference station) and the other is used as a rover (i.e., moved from point to point or along a path). Before the rover receiver can rove, a period of static initialization or antenna swap (see paragraph 9-9*d*) must be performed. This period of static initialization is dependent on the number of satellites visible. Once this is done, the rover receiver can move from point to point as long as satellite lock is maintained on at least four common (with the reference station) satellites. If loss of satellite lock occurs, a new period of static initialization must take place. It is important to follow manufacturers' specifications when performing a kinematic survey.

b. Kinematic data processing techniques. In general, kinematic data processing techniques are similar to those used in static surveying (Chapter 10). When processing kinematic GPS data, the user must ensure that satellite lock was maintained on four or more satellites and that cycle slips are adequately resolved in the data recorded.

c. Accuracy of kinematic surveys. Differential (carrier phase) kinematic survey errors are correlated between observations received at the reference and rover receivers, as in differential static surveys. Experimental test results indicate kinematic surveys can produce results in centimeters. Test results from an experimental full kinematic GPS survey conducted by U.S. Army Engineer Topographic Laboratory (now TEC) personnel at White Sands Missile Range, Holloman Air Force Base, New Mexico, verified (under ideal test conditions) that kinematic GPS

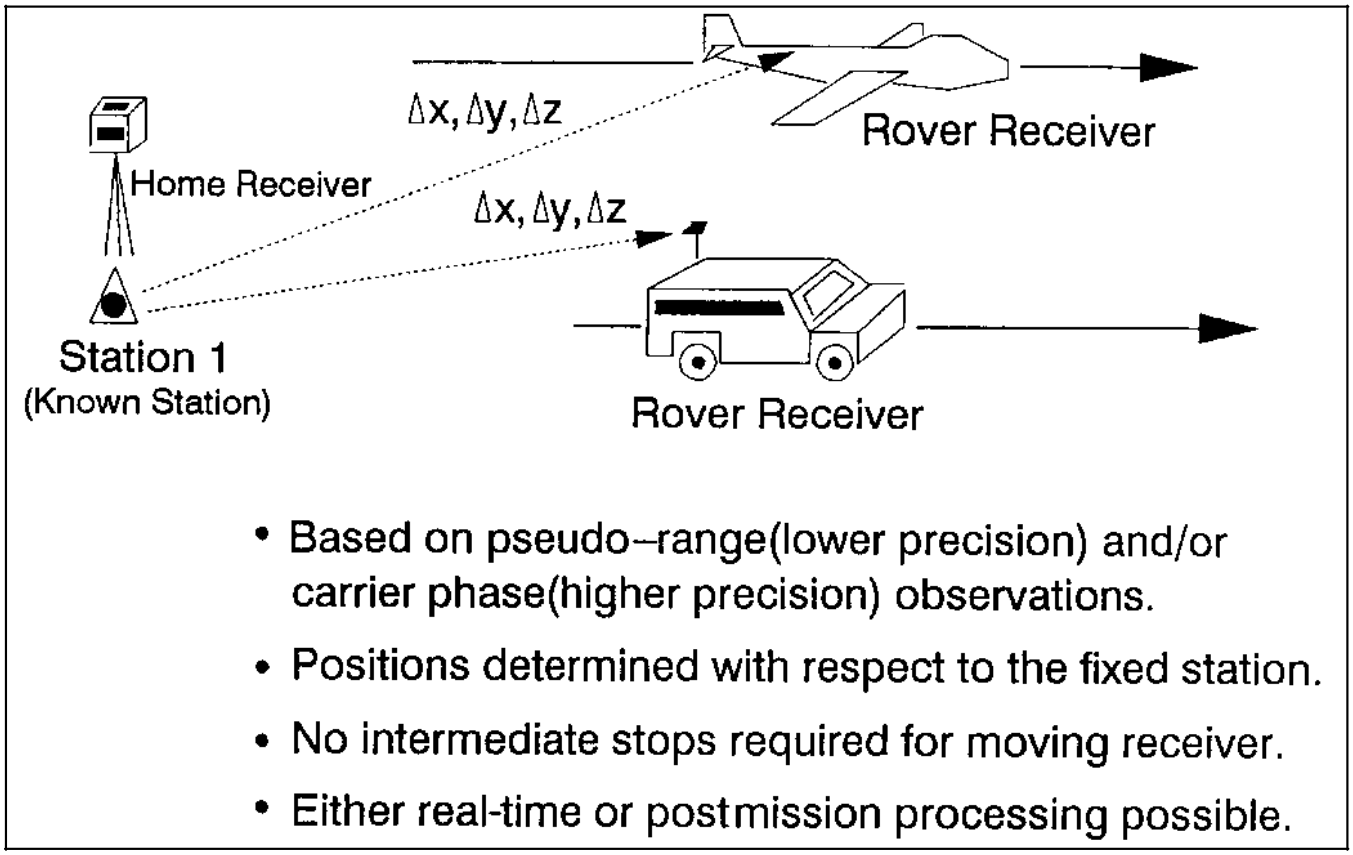


Figure 9-7. Kinematic survey techniques

surveying could achieve centimeter-level accuracy over distances up to 30 km.

9-11. Pseudo-Kinematic GPS Survey Techniques

Pseudo-kinematic GPS surveying is similar to stop-and-go techniques except that loss of satellite lock is tolerated when the receiver is transported between occupation sites (in fact, the roving receiver can be turned off during movement between occupation sites, although this is not recommended). This feature provides the surveyor with a more favorable positioning technique since obstructions such as bridge overpasses, tall buildings, and overhanging vegetation are common. Loss of lock that may result due to these obstructions is more tolerable when pseudo-kinematic techniques are employed.

a. General. The pseudo-kinematic techniques require that one receiver be placed over a known control station. A rover receiver occupies each unknown station for 5 min. Approximately 1 hr after the initial station occupation, the same rover receiver must reoccupy each unknown station.

b. Common satellite requirements. The pseudo-kinematic technique requires that at least four of the same satellites are observed between initial station occupations and the requisite reoccupation. For example, the rover receiver occupies Station A for the first 5 min and tracks satellites 6, 9, 11, 12, 13; then 1 hr later, during the second occupation of Station A, the rover receiver tracks satellites 2, 6, 8, 9, 19. In this example, only satellites 6 and 9 are common to the two sets, so the data cannot be processed because four common satellites were not tracked for the initial station occupation and the requisite reoccupation.

c. Planning. Prior mission planning is essential in conducting a successful pseudo-kinematic survey. Especially critical is the determination of whether or not common satellite coverage will be present for the desired period of the survey. Also, during the period of observation, one receiver, the base receiver, must continuously occupy a known control station.

d. Pseudo-kinematic data processing. Pseudo-kinematic survey satellite data records and resultant baseline

processing methods are similar to those performed for static GPS surveys. Since the pseudo-kinematic technique requires each station to be occupied for 5 min and then reoccupied for 5 min approximately an hour later, this technique is not suitable when control stations are widely spaced and transportation between stations within the allotted time is impractical.

e. Accuracy of pseudo-kinematic surveys. Pseudo-kinematic survey accuracies are similar to kinematic survey accuracies of a few centimeters.

9-12. Rapid Static Surveying Procedures

Rapid static surveying is a combination of the stop-and-go kinematic, pseudo-kinematic, and static surveying methods. The rover or remote receiver spends only a short time on each station, loss of lock is allowed between stations, and accuracies are similar to static. However, rapid static surveying does not require re-observation of remote stations like pseudo-kinematic. The rapid static technique does require the use of dual-frequency (L1/L2) GPS receivers with either cross correlation or squaring or any other technique used to compensate for A-S.

a. Survey procedure. Rapid static surveying requires that one receiver be placed over a known control point. A rover or remote receiver occupies each unknown station for 5-20 min, depending on the number of satellites and their geometry. Because most receiver operations are manufacturer-specific, following the manufacturers' guidelines and procedures for this type of survey is important.

b. Rapid static data processing. Data collected in the rapid static mode should be processed in accordance with the manufacturer's specifications. See Chapter 10 for more information on post-processing GPS data.

c. Accuracy of rapid static surveys. Accuracies of rapid static surveys are similar to static surveys of a centimeter or less. This method can be used for medium-to-high accuracy surveys up to 1/1,000,000.

9-13. OTF/RTK Surveying Techniques

OTF/RTK surveying is similar to kinematic differential GPS surveying because it requires two receivers recording observations simultaneously and allows the rover receiver to be moving. Unlike kinematic surveying, OTF/RTK surveying techniques use dual-frequency L1/L2 GPS observations and can handle loss of satellite lock. Since OTF/RTK uses the L2 frequency, the GPS receiver must be capable of tracking the L2 frequency during A-S. There are several techniques used to obtain L2 during A-S. These include the squaring and cross-correlation methods.

a. Ambiguity resolution. As explained before in paragraph 9-7*b*, successful ambiguity resolution is required for successful baseline formulations. The OTF/RTK technology allows the remote to initialize and resolve these integers without a period of static initialization. With OTF/RTK, if loss of satellite lock occurs, initialization can occur while in motion. The integers can be resolved at the rover within 10-30 sec, depending on the distance from the reference station. OTF/RTK uses the L2 frequency transmitted by the GPS satellites in the ambiguity resolution. After the integers are resolved, only the L1 C/A is used to compute the positions.

b. Survey procedure. OTF/RTK surveying requires dual frequency L1/L2 GPS receivers. One of the GPS receivers is set over a known point, and the other is placed on a moving or mobile platform. If the survey is performed in real time, a data link and a processor (external or internal) are needed. The data link is used to transfer the raw data from the reference station to the remote.

(1) Internal processor. If the OTF/RTK system is done with an internal processor (i.e., built into the receiver), follow manufacturer's guidelines.

(2) External processor. If OTF/RTK is performed with external processors (i.e., notebook computer), then computer at the reference (386-based PC) collects the raw GPS data and formats it to be sent via a data link to the remote. The notebook computer at the rover (486/33 based PC) processes the raw data from the reference and remote receivers to resolve the integers and obtain a position.

c. Accuracy of OTF/RTK surveys. OTF/RTK surveys are accurate to within 10 cm when the distance from the reference to the rover does not exceed 20 k. Results of testing by TEC produced results of less then 10 cm.

Chapter 10
Post-processing Differential GPS Observational Data

10-1. General

GPS baseline solutions are usually generated through an iterative process. From approximate values of the positions occupied and observation data, theoretical values for the observation period are developed. Observed values are compared to computed values, and an improved set of positions occupied is obtained using least squares minimization procedures and equations modeling potential error sources.

a. Processing time is dependent on the accuracy required, software development, computer hardware used, data quality, and amount of data. In general, high accuracy solutions, crude computer software and hardware, low-quality data, and high volumes of data will cause longer processing times.

b. The ability to determine positions using GPS is dependent on the effectiveness of the user to determine the range or distance of the satellite from the receiver located on the earth. There are two general techniques currently operational to determine this range: pseudo-ranging and carrier beat phase measurement. These techniques are discussed in further detail below.

c. The user must take special care when attempting a baseline formulation with observations from different GPS receiver manufacturers. It is important to ensure that observables being used for the formulation of the baseline are of a common format (i.e., RINEX). The common data exchange formats required for a baseline formulation exist only between receivers produced by the same manufacturer, but there are some exceptions.

d. This chapter will discuss general post-processing issues. Due to the increasing number and variety of software packages available, consult the manufacturer guidelines when appropriate.

10-2. Pseudo-Ranging

The pseudo-range observable is calculated from observations recorded during a GPS survey. The pseudo-range observable is the difference between the time of signal transmission from the satellite, measured in the satellite time scale, and the time of signal arrival at the receiver antenna, measured in the receiver time scale. When the differences between the satellite and the receiver clocks are reconciled and applied to the pseudo-range observables, the resulting values are corrected pseudo-range values. The value found by multiplying this time difference by the speed of light is an approximation of the true range between the satellite and the receiver, or a true pseudo-range. A more exact approximation of true range between the satellite and receiver can be determined if ionosphere and troposphere delays, ephemeris errors, measurement noise, and unmodeled influences are taken into account while pseudo-ranging calculations are performed. The pseudo-range can be obtained from either the C/A-code or the more precise P-code (if access is available).

10-3. Carrier Beat Phase Observables

The carrier beat phase observable is the phase of the signal remaining after the internal oscillated frequency generated in the receiver is differenced from the incoming carrier signal of the satellite. The carrier beat phase observable can be calculated from the incoming signal or from observations recorded during a GPS survey. By differencing the signal over a period or epoch of time, one can count the number of wavelengths that cycle through the receiver during any given specific duration of time. The unknown cycle count passing through the receiver over a specific duration of time is known as the cycle ambiguity. There is one cycle ambiguity value per satellite/receiver pair as long as the receiver maintains continuous phase lock during the observation period. The value found by measuring the number of cycles going through a receiver during a specific time, when given the definition of the transmitted signal in terms of cycles per second, can be used to develop a time measurement for transmission of the signal. Once again, the time of transmission of the signal can be multiplied by the speed of light to yield an approximation of the range between the satellite and receiver. The biases for carrier beat phase measurement are the same as for pseudo-ranges although a higher accuracy can be obtained using the carrier. A more exact range between the satellite and receiver can be formulated when the biases are taken into account during derivation of the approximate range between the satellite and receiver.

10-4. Baseline Solution by Linear Combination

The accuracy achievable by pseudo-ranging and carrier beat phase measurement in both absolute and relative positioning surveys can be improved through processing

that incorporates differencing of the mathematical models of the observables. Processing by differencing takes advantage of correlation of error (e.g., GPS signal, satellite ephemeris, receiver clock, and atmospheric propagation errors) between receivers, satellites, and epochs, or combinations thereof, in order to improve GPS processing. Through differencing, the effects of the errors that are common to the observations being processed are eliminated or at least greatly reduced. Basically, there are three broad processing techniques that incorporate differencing: single differencing, double differencing, and triple differencing. Differenced solutions generally proceed in the following order: differencing between receivers takes place first, between satellites second, and between epochs third.

a. Single differencing. There are three general single differencing processing techniques: between receivers, between satellites, and between epochs (see Figure 10-1).

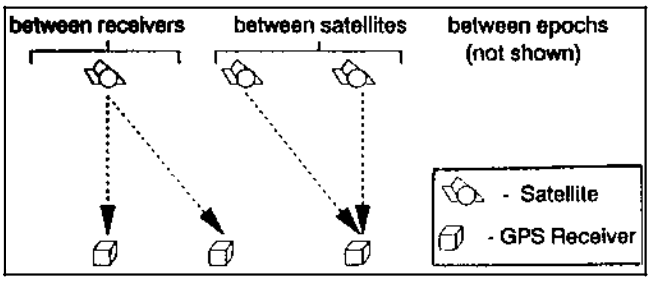


Figure 10-1. Single differencing

(1) Between receivers. Single differencing the mathematical models for a pseudo-range (P- or C/A-code) or carrier phase observable measurements between receivers will eliminate or greatly reduce satellite clock errors and a large amount of satellite orbit and atmospheric delays.

(2) Between satellites. Single differencing the mathematical models for pseudo-range or carrier phase observable measurements between satellites eliminates receiver clock errors. Single differencing between satellites can be done at each individual receiver during observations as a precursor to double differencing and in order to eliminate receiver clock errors.

(3) Between epochs. Single differencing the mathematical models between epochs takes advantage of the Doppler shift or apparent change in the frequency of the satellite signal by the relative motion of the transmitter and receiver. Single differencing between epochs is generally done in an effort to eliminate cycle ambiguities. There are three forms of single differencing techniques between epochs currently in use today: Intermittently Integrated Doppler (IID), Consecutive Doppler Counts (CDC), and Continuously Integrated Doppler (CID). IID uses a technique whereby Doppler count is recorded for a small portion of the observation period, the Doppler count is reset to zero, and then at a later time the Doppler count is restarted during the observation period. CDC uses a technique whereby Doppler count is recorded for a small portion of the observation period, reset to zero, and then restarted immediately and continued throughout the observation period.

b. Double differencing. Double differencing is actually a differencing of two single differences (as detailed in *a* above). There are two general double differencing processing techniques: receiver-time double and receiver-satellite (see Figure 10-2). Double difference processing techniques eliminate clock errors.

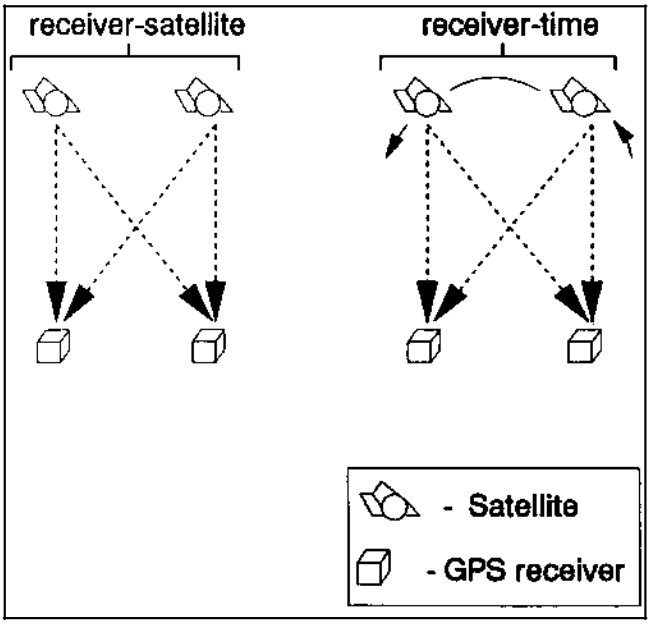


Figure 10-2. Double differencing

(1) Receiver-time double differencing. This technique uses a change from one epoch to the next, in the between-receiver single differences for the same satellite. Using this technique eliminates satellite-dependent integer cycle ambiguities and simplifies editing of cycle slips.

(2) Receiver-satellite double differencing. There are two different techniques that can be used to compute a receiver-satellite double difference. One technique involves using two between-receiver single differences.

This technique also uses a pair of receivers, recording different satellite observations during a survey session and then differencing the observations between two satellites. The second technique involves using two between-satellite single differences. This technique also uses a pair of satellites, but different receivers, and then differences the satellite observations between the two receivers.

c. Triple differencing. There is only one triple differencing processing technique: receiver-satellite-time (see Figure 10-3). All errors eliminated during single- and double-differencing processing are also eliminated during triple differencing. When used in conjunction with carrier beat phase measurements, triple differencing eliminates initial cycle ambiguity. During triple differencing, the data are also automatically edited by the software to delete any data that cannot be solved , so that the unresolved data are ignored during the triple difference solution. This feature is advantageous to the user because of the reduction in the editing of data required; however, degradation of the solution may occur if too much of the data are eliminated during triple differencing.

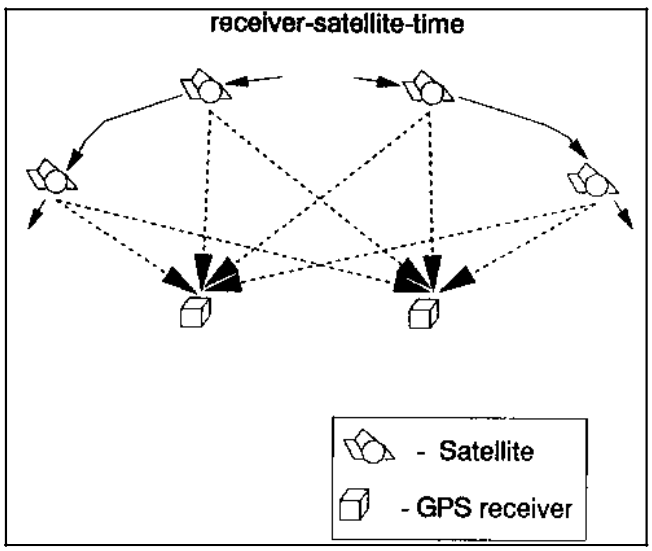


Figure 10-3. Triple differencing

10-5. Baseline Solution by Cycle Ambiguity Recovery

The resultant solution (baseline vector) produced from carrier beat phase observations when differencing resolves cycle ambiguity is called a "fixed" solution. The exact cycle ambiguity does not need to be known to produce a solution; if a range of cycle ambiguities is known, then a "float" solution can be formulated from the range of cycle ambiguities. It is desirable to formulate a fixed solution. However, when the cycle ambiguities cannot be resolved, which occurs when a baseline is between 20 and 65 km in length, a float solution may actually be the best solution. The fixed solution may be unable to determine the correct set of integers (i.e., "fix the integers") required for a solution. Double-differenced fixed techniques can generally be effectively used for positional solutions over short baselines less than 20 km in length. Double differenced float techniques normally can be effectively used for positional solutions for medium-length lines between 20 and 65 km in length.

10-6. Field/Office Data Processing and Verification

a. It is strongly recommended that baselines should be processed daily in the field. This allows the user to identify any problems that may exist. Once baselines are processed, the field surveyor should review each baseline output file. The procedures used in baseline processing are manufacturer-dependent. Certain computational items within the baseline output are common among manufacturers and may be used to evaluate the adequacy of the baseline observation in the field. A list of the triple difference, float double difference, and fixed double difference vectors (*dx-dy-dz*) are normally listed. The geodetic azimuth and distance between the two stations are also listed. The RMS is a quality factor that helps the user determine which vector solution (triple, float, or fixed) to use in an adjustment. The RMS is dependent on the baseline length and the length of time the baseline was observed. Table 10-1 provides guidelines for determining the baseline quality. If the fixed solution meets the criteria in this table, the fixed vector should be used in the adjustment. In some cases the vector passes the RMS test, but after adjustment the vector does not fit into the network. If this occurs, the surveyor should try using the float vector in the adjustments or check to make sure stations were occupied correctly.

b. The first step in data processing is transferring the observation data to a storage device for archiving and/or further processing. Examples of storage devices include a hard disc drive, 5.25-in. disc, 3.5-in. disc, magnetic tape, etc.

c. Once observation data have been downloaded, preprocessing of data can be completed. Pre-processing consists of smoothing/editing the data and ephemeris determination. Smoothing and editing are done to ensure

Table 10-1
Post-processing Criteria

Distance Between Receivers, km	RMS Criteria Formulation (d = distance between receivers)	Formulated RMS Range, cycles	Formulated RMS Range, m
0 - 10	(0.02 + (0.004*d))	0.02 - 0.06	0.004 - 0.012
10 - 20	(0.03 + (0.003*d))	0.06 - 0.09	0.012 - 0.018
20 - 30	(0.04 + (0.0025*d))	0.09 - 0.115	0.018 - 0.023
30 - 40	(0.04 + (0.0025*d))	0.115 - 0.14	0.023 - 0.027
40 - 60	(0.08 + (0.0015*d))	0.14 - 0.17	0.027 - 0.032
60 - 100	0.17	0.17	0.032
> 100	0.20	0.20	0.04

Note:

1. These are only general post-processing criteria that may be superseded by GPS receiver/software manufacturer guidelines; consult those guidelines when appropriate.
2. For lines longer than 50 km, dual frequency GPS receivers are recommended to meet these criteria.

data quantity and quality. Activities done during smoothing and editing include determination and elimination of cycle slips; editing gaps in information; and differencing between receivers, satellites, and epochs.

d. Retrieval of post-processed ephemerides may be required depending on the type of receiver used for the survey. Codeless receivers require a post-processed ephemerides file, either that recorded by another GPS receiver concurrent with conduct of the survey or post-processed ephemerides provided by an ephemeris service. Code receivers do not require post-processed ephemerides since they automatically record the broadcast ephemerides during conduct of the survey.

10-7. Post-processing Criteria

Generally, post-processing software will give three solutions: a triple difference, a double-difference fixed solution, and a double-difference float solution. In addition to RDOP as a measurement of the quality of data reduction, methods exist today to gauge the success of an observation session based on data processing done by a differencing process.

a. RMS. RMS is a measurement (in units of cycles or meters) of the quality of the observation data collected during a point in time. RMS is dependent on line length, observation strength, ionosphere, troposphere, and multipath. In general, the longer the line and the more signal interference by other electronic gear, ionosphere, troposphere, and multipath, the higher the RMS will be. A good RMS factor (one that is low, e.g., between 0.01 and 0.2 cycles) may not always indicate good results but is one indication to be taken into account. RMS can generally be used to judge the quality of the data used in the post-processing and the quality of the post-processed baseline vector.

b. Repeatability. Redundant lines should agree to the level of accuracy that GPS is capable of measuring to. For example, if GPS can measure a 10-km baseline to 1 cm $\pm$1 ppm, the expected ratio of misclosure would be

$$\frac{0.01\text{ m} + 0.01\text{m}}{10{,}000} = 1{:}500{,}000$$

Repeated baselines should be near the corresponding

$$\frac{1\text{cm} + 1\text{ppm}}{\text{baseline}}$$

ratio. See Table 10-2 for an example of repeatability of GPS baselines.

c. Other general information included in a baseline solution.

(1) The following information is typically output from a baseline solution:

(a) Listing of the filename.

(b) Types of solutions (single, double, or triple difference).

Table 10-2
Example of Repeatability of GPS Baselines

Baseline	X	Y	Z	Distance
Line 1	5,000.214	4,000.000	7,680.500	9,999.611
Line 2	5,000.215	4,000.005	7,680.491	9,999.607
Difference	0.001	0.005	0.009	
Ratio = 0.010 / 9,999.6	= 1:967,000			

(c) Satellite availability during the survey for each station occupied.

(d) Ephemeris file used for the solution formulation.

(e) Type of satellite selection (manual or automatic).

(f) Elevation mask.

(g) Minimum number of satellites used.

(h) Meteorological data (pressure, temperature, humidity).

(i) Session time (date, time).

(j) Data logging time (start, stop).

(k) Station information: location (latitude, longitude, height), receiver serial number used, antenna serial number used, ID numbers, antenna height.

(l) RMS.

(m) Solution files: *x*, *y*, *z* between stations, slope distance between stations, latitude, longitude between stations, distance between stations, and height.

(n) Epoch intervals.

(o) Number of epochs.

(2) Sample static baseline formulations from two equipment manufacturers, Ashtech, Inc., (GPPS) and Trimble Navigation (GPSurvey), are shown in Figures 10-4 and 10-5, respectively. The baseline formulations have been annotated with the conventions in (a)-(o) above as an aid in an explanation of the results.

10-8. Field/Office Loop Closure Checks

Post-processing criteria are aimed at an evaluation of a single baseline. In order to verify the adequacy of a group of connected baselines, one must perform a loop closure on the baselines formulated. When GPS baseline traverses or loops are formed, their linear (internal) closure should be determined in the field. If job requirements are less than Third-Order (1:10,000 or 1:5,000), and the internal loop/traverse closures are very small, a formal (external) adjustment may not be warranted.

a. Loop closure software packages. The internal closure determines the consistency of the GPS measurements. Internal closures are applicable for loop traverses and GPS networks. It is required that one baseline in the loop be independent. An independent baseline is observed during a different session or different day. Today, many of the better post-processing software packages come with a loop closure program. Refer to the individual manufacturer post-processing user manuals for a discussion on the particulars of the loop closure program included with the user hardware.

b. General loop closure procedure. If the user post-processing software package does not contain a loop closure program, the user can perform a loop closure as shown below.

(1) List the *x*, *y*, and *z* and length of the baseline being used in a table of the form shown in Table 10-3.

(2) Sum the *x*, *y*, *z*, and distance components for all baselines used in the loop closure. For instance, for the baselines in Table 10-3, the summation would be *x*, *y*, *z*, and *Distances* or *(x#1 + x#2 + x#3), (y#1 + y#2 + y#3), (z#1 + z#2 + z#3),* and *(Distance#1 + Distance#2 + Distance#3)*, respectively.

(3) Once summation of the *x*, *y*, *z*, and *Distance* components has been completed, the square of each of the summations should be added together and the square root of this sum then taken. This resultant value is the misclosure vector for the loop. This relationship can be expressed in the following manner:

```
Ashtech, Inc. GPPS-L          Program; LINECOMP          Version: 4.5.00
                            Tue Jan 25 10:16:25 1994
_____________________________________________________________________
Project information
GPS Survey                  25-character project name  [ The | is in column 26. ]
3203C                      |5-character session name
Project information

Known-station parameters
00                         |Receiver identifier used in "LOGTIMBS" file
000000                     |Project station number
MANT                       |4-character short name
FIXED STATION              |25-character long name
4270 DCO PIC               |25-character comment field
                           |Position extraction (O=below,l=U-file,2 proj. file)
N  40  2 18.36587          |Latitude deg-min-sec  (g=good;b bad)
E 285 56 49.57251          |E-Longitude deg-min-sec  (g=good;b=bad)
W  74  3 10.42749          |W-Longitude deg-min-sec  (g=good;b•bad)
   -12.0807                |Ellipsoidal height  (m)  (g=good;b=bad)
     0.0000                |North antenna offset{m)
     0.0000                |East antenna offset  (m)
  1.4300  0.0000  0.0000   |Vert antenna offset  (m): slant/radius/added offset
    20.0                   |Temperature  (degrees C)
    50.0                   |Humidity (percent)
  1010.0                   |Pressure {millibars)
UMANTC93.320               |Measurement filename {restricted to 24 characters)
Known-station parameters

Unknown-station parameters
00                         |Receiver identifier used in MLOGTIMESK file
000000                     |Project station number
FTM1                       |4-character short name
UNKNOWN STATION            |25-character long name
4270- DCO PIC              |25-character comment field
                           |Position extraction (O=below,l=U-file,2=p.roj. file)
N  40 18 45.82336          |Latitude deg-min-sec  (g=good;b•bad)
E 285 57 46.72853          |E-Longitude deg-min-sec (g=good;b=bad)
W  74  2 13.27147          |W-Longitude deg-min-sec (g=good;b=bad)
   -20.5991                |Ellipsoidal height  (m) (g=good;b=bad)
     0.0000                |North antenna offset(m)
     0.0000                |East antenna offset  (m)
  0.0000  0.0000  0.0000   |Vert antenna offset  (m): slant/radius/added offset
    20.0                   |Temperature  (degrees C)
    50.0                   |Humidity (percent)
  1010.0                   |Pressure (millibars)
UFTM1C93.320               |Measurement filename (restricted to 24 characters)
Unknown-station parameters

Run-time parameters
   10                      |First .epoch to process
   -I                      |Final epoch to process (-1 = last available)
15.0                       |Elevation cutoff angle (degrees)
 ▮                         |Data to process (O=Wdln;l=Ll;2•L2;3=Llc;6=RpdSt)
0.010000                   |Convergence criterion (meters)
00 00 00 00 00 00 00       |Omit these satellites (up to 7)
10                         |Maximum iterations for tlsq and dlsq
00 00 00 00 00 00 00       |Forbidden reference SVs (up to 7)
yes                        |Apply trope delay correction
Run-time parameters
```

Figure 10-4. Sample static baseline formulation (Ashtech, Inc., **GPPS-L)** (Sheet 1 of 5)

```
LINECOMP  4.5.00  12/11/92

FIXED  U-File  from  P-Code  receiver.
UNKWN U-File  from  P-Code  receiver.

FIXED  U-File  used  BROADCAST  orbits.
UNKWN U-File  used  BROADCAST orbits.

Common  start  of  two  UFILES:  1993/11/16  20:23:60.00
Common  end    of  two  UFILES:  1993/11/16  22:00:20.00
    Selected  first  epoch:  10
    Selected  last   epoch:  290
For  SV  1  there  are    280  triple-difference  measurements.
For  SV  5  there  are    181  triple-difference  measurements.
For  SV  12  there  are   136  triple-difference  measurements.
For  SV  15  there  are   152  triple-difference  measurements.
For  SV  20  there  are   181  triple-difference  measurements.
For  SV  21  there  are   181  triple-difference  measurements.
For  SV  23  there  are   181  triple-difference  measurements.
For  SV  25  there  are   181  triple-difference  measurements.
Epoch interval  (seconds) : 20.000000


THE  TRIPLE  DIFFERENCE  SOLUTION  {Ll)
Measure  of  geometry:  0.712832
num meas    1192        num used    1191         rms resid   0.002725(m)
Pos'f-Fit Chisq =  1403,765          NDF      =    1T.028


  Sigmax  {m):      0.347912
  Sigmay  (m):      0.646995
  Sigmaz  (m):      0.327369
  x     y
x  1.00
y0.17yl.OO
z 0.12z-0.50z  1.00

del  station:  -0.000007  -0.000001  0,000027
     Station1:  FIXED  STATION              Station2:  UNKNOWN  STATION
                (00000)     (MANTI                     {00000)     (FTM1)
 Latitude:  40.03843496   40  2 18.36587          40.31281330   40 18 46.12789
 E-Long    285.94710348  285 56 49.57251         285.96293196  285 57 46.55506
 W-Long     74.05289652   74  3 10.42749          74.03706804   74  2 13.44494
 E-Beight: -12.0807                                -2.fl7.36

 Baseline  vector:     -4104.5950      19261.5243      23284.3880

 Markl  xyz     1343513.8259  -4701767.9098   4081246.0717
 Az1  ETl  Dl          2.52867       -0.1200     30496.1759
 El  N1  Ul         1350.8948     .30465.6429         9.2071
 Mark2  xyz     1339409.2309  -4682506.3855   4104530.4598
 Az2  El'2  02        182.53888       -0.1546     30496.1759
 E2  N2  U2        -1345.4669    -30467.1353        -9.2071

Double-Difference  Epochs:
  Prn:   1  Start epoch:   11  End epoch:  290
  Prn:   5  Start epoch:  110  End epoch:  290
  Prn:  12  Start epoch:  110  End epoch:  249
  Prn:  15  Start epoch:  139  End epoch:  290
  Prn:  20  Start epoch:  110  End epoch:  290
```

Figure 10-4. (Sheet 2 of 5)

```
  Prn:  21  Start epoch:  110  End epoch:  290
  Prn:  23  Start epoch:  110  End epoch:  290
  Prn:  25  Start epoch:  110  End epoch:  290


THE FLOAT DOUBLE DIFFERENCE SOLUTION {Ll)
Measure of geometry: 0.195687     Wavelength = 0.190294  (m/cycle)
num rneas =  1200        num used =  1200        rms resid = 0.013991(m)
Post-Fit Chisq =   186.429 –        NDF          IT.111

Reference SV:  1
  SV     Ambiguity        FIT    Meas      SV     Ambiguity        FIT    Meas
   5        59386-483£   0.054   182      12      -1227312-585£   0.050   138
  15      2121069.816£   0.097   152      20        531426.734£   0.072   182
  21      -184904.908£   0.073   182      23      -1075927.194£   0.062   182
  25       646212.381£   0,093   182

  Sigrnax (m):      0.049793
  Sigmay (m):       0.056987
  Sigmaz (m):       0.026423
  SigmaN (cy) :     0.283527
  SigmaN (cy):      0.289386
  SigmaN (cy):      0.245180
  SigmaN (cy):      0.217266
  SigmaN {cy) :     0.134735
  SigmaN (cy):      0.204750
  SigmaN (cy):      0.196954
  x     y     ,     N     N     N     N     N     N     N
x 1.00
y 0.19y 1.00
z 0.08z-0.30z 1.00
N 0.77N Q.74N-0.23N 1.00
N 0.53N 0.90N-0.22N Q.92N 1.00
N-0.81N Q.35N-0.35N-0.27N O.OlN 1.00
N 0.87N 0.27N-0.35N O.BON 0.58N-0.57N 1.00
N 0.39N-0.52N-0.30N 0.04N-0,24N-0.51N O.SSN 1.00
N 0.70N 0.11N-0.56N 0.62N 0.39N-0.47N 0.91N Q,71N 1.00
N-0.68N-0.57N-0.38N-0.71N-0.70N 0.41N-0.40N 0.3SN-0.09N 1.00

del station: -0.000000 -0.000000 0.000000
   -Station!: FIXED STATION              Station2: UNKNOWN STATION
              100000I     (lIliNT)                    (00000)     (FTM1)
 Latitude:  40.03843496  40  2 18.36587          40.31281268   40 18 46.12563
 B-I,ong    285.94710348 285 56 49.57251         285.96293166  285 57 46.55396
 W-Long      74.05289652  74  3 10.42749          74.03106834  74  L 13.44604
 E-Height: -12.0807                               -2.8299

 Baseline vector:     -4104.5984      19261.4419      23284.3633

 Mark!  xyz     1343513.8259  -4701767.9098   4081246.0717
 Azl E'I1 D1          2.52863       -0.1199     30496.1054
 E1 N1 UI          1350.8687     30465.5734         9.2508
 Mark2 xyz     1339409.2275  -4682506.4679   4104530.4350
 Az2 E'I2 D2        182.53884       -0.1547     30496.1054
 E2 N2 U2        -1345.4410    -30467.0660        -9.2508


AMBIGUITY RESOLUTION
                        1          2          3          4
Abs Contrast        0.000      0.000      0.000      0.000
```

Figure 10-4. (Sheet 3 of 5)

```
Contrast                          99.999    100.000    100.000
Change  Chi2          318.829    907.189   1231.184   1556.459
Bias S 1' 5             59387      59385      59387      59387
Bias S 1:12          -1227312  -1227314  -1227312  -1227312
Bias S 1:15           2121070    2121070    2121069    2121071
Bias S 1:20            531427     531426     531427     531427
Bias S 1:21           -184905    -184905    -184905    -184905
Bias S 1:23         -1075927   -1075928   -1075927   -1075927

NDF"'l27.0000 Chi2•186,4289
                        1          2          3          4
Abs Contrast          0.000      0.000      0.000      0.000
Contrast                         99.999    100.000    100.000
Change  Chi2          298.148    843.456   1086.524   1100.925
Bias S 1:12          -1227312  -1227314  -1227313  -1227313
Bias S 1:15           2121070    2121070    2121069    2121071
Bias S 1:20            531427     531426     531427     531426
Bias S 1:21           -184905    -184905    -184905    -184905
Bias S 1:23         -1075927   -1075928   -1075927   -1075928
Bias S 1:25            646212     646213     646212     646213
NDF=127.0000  Chi2=186.4289

Abs Contrast          0.()4      0.000      0.000      0.000
Contrast                         99.986    100.000    100.000
Change  Chi2          190.078    526.018    746.284   1076.670
Bias S 1:15           2121070    2121069    2121070    2121069
Bias S 1:20            531427     531427     531426     531426
Bias S 1:21           -184905    -184905    -184905    -184905
Bias S 1:23         -1075927   -1075927   -1075928   -1075928
Bias S 1:25            646212     646212     646213     646212
NDF=127.0000  Chi2=186.4289
                        1          2          3          4
Abs Contrast            4.563      0.000      0.000      0.000
Contrast                        100.000    100.000    100.000
Change  Chi2          128.751   2529.042   3851.923   5153.774
Bias S 1' 5             59387      59388      59387      59387
Bias S 1:12          -1227312  -1227311  -1227311  -1227313
NDF=132.0000  Chi2=376.5065


THE FIXED DOUBLE DIFFERENCE SOLUTION {L1)
Measure of geometry: 0.038900     wavelength = 0.190294 (m/cycle)
num meas =  1200        num used    1188          rms resid g 0.021554(m)
Post-Fit Chisq     435.849           NDF            11.000

Reference SV:  1                    Integer Search Ratio =   99.986
  SV     Ambiguity        FIT    Meas       SV     Ambiguity        FIT    Meas
   5        59387.000X  0.066   182       12      -1227312.000X  0.070   138
  15      2121070.000X  0.195   140       20        531427.000X  0.065   182
  21      -184905.000X  0.067   182       23      -1075927.000X  0.080   182
  25       646212.000X  0.176   182

  Sigmax  (m):      0.009106
  Sigmay  (m):      0.015190
  Sigmaz  {m):      0.016909
  x      y      z
x 1.0()
y-0.37y  1.00
z 0.40z-0.7lz  1.00
```

Figure 10-4. (Sheet 4 of 5)

```
del station: 0.001087 -0.002400 0.000191
     Station!: FIXED STATION              Station2: UNKNOWN STATION
                (00000)     (MANT)                    (00000)     {FTMl)
 Latitude:  40.03843496  40  2 18.36587          40.31281315  40 18 46.12733
 E-Long    285.94710348 285 56 49.57251         285.96293257 285 57 46.55727
 W-Long     74.05289652  74  3 10.42749          74.03706743  74  2 13.44273
 E-Height: -12.0807                               -2.9282

 Baseline  vector:     -4104.5533     19261.5680     23284.3397

 Mark1xyz       1343513.8259  -4701767.9098   4081246.0717
 Azl Eil Dl          2.52877       -0.1201     30496.1610
 El  Nl  Ul        1350.9471     30465.6258        9.1525
 Mark2 xyz      1339409.2726  -4682506.3418   4104530.4115
 Az2  ET2  D2        182.53898       -0.1545     30496.1610
 E2  N2  U2       -1345.5190    -30467.1180        -9.1525
Tue Jan 25 10:18:17 1994
```

Figure 10-4. (Sheet 5 of 5)

Project Name:	ftml
Processed:	Tuesday, January 25, 1994 11:17
	WAVE Baseline Processor, versiOn 1.01
Summary Reference Index:	▮
Fixed Station:	MANT
Antenna Height (meters):	1.430 [True Vertical]
Data rile:	MANT320C.DAT
Floating Station:	FTMI
Antenna Height (meters):	0.000 [True Vertical]
Data file:	FTM1320C.DAT
Start Time: Stop	11/16/93 20:21:40 GPS (723 246100)
Time: Occupation	11/16/93 22:00:20 GPS (723 252020)
Time:	0 0Jo38,40
Measurement Epoch Interval (seconds):	20.00
Solution Type:	Receiver/satellite double difference
	Fixed integer phase ambiguity
	lono free carrier phase
Solution Acceptability:	Passed
Number of Observations / Number Rejected:	1838 / 0 (0.00% of Total Observations)
Baseline Slope Distance (meters):	30496.196

	Forward	Backward
Normal Section Azimuth:	28 31' 42.850578"	182. 32' 19.610607"
Vertical Angle:	-OR 07' 12.582816"	-O• 09' 16.140268"

Baseline Components (meters):	dn	30466.437	de	1345.414	du	-63.957
	dx	-4104.555	dy	19261.587	dz	23284.370

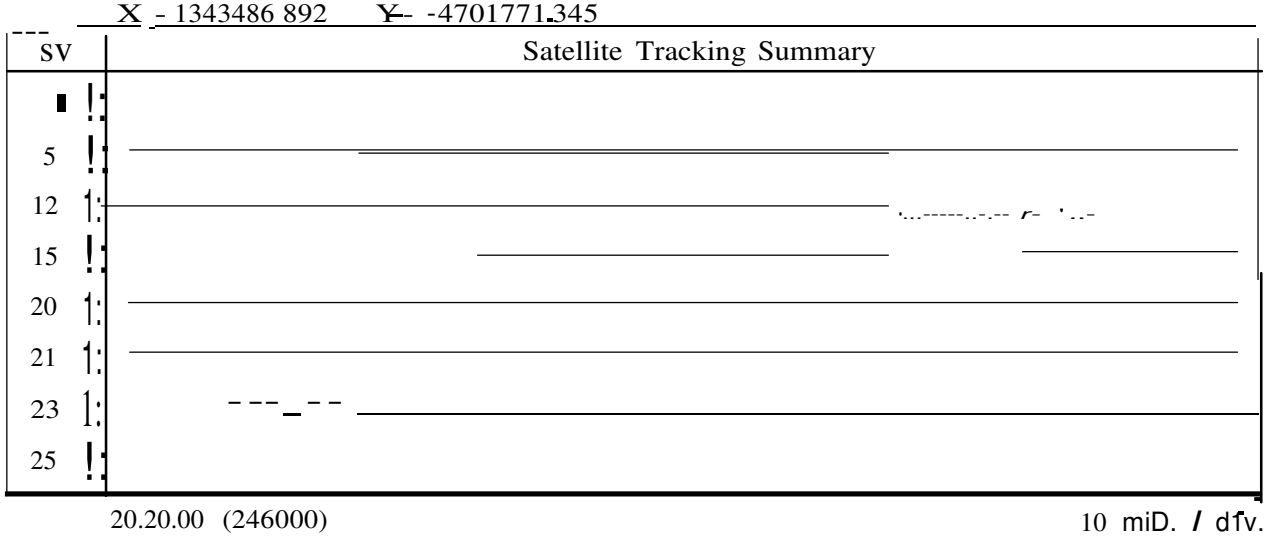
Standard Deviations:	5.303799E-004	9.044810E-004	8.225305E-004
Aposteriori Covariance Matrix:	2.813028E-007		
	-2.038846E-007	8.180858E-007	
	1.759316E-007	-4.827601E-007	6.765565E-007

Reference Variance:	0.633
Variance Ratio 2nd Best/Best Ambiguity Candidate:	28.0
RMS (meters):	0.014

Figure 10·5. Sample static baseline fonnulation (Trimble Navigation (GP Survey) (Sheet 1 of 3)

Project: ftml
Processed: Tuesday, January 25, 1994 11:17 WAVE 1.01

Fixed Sta
Position: 4011 02' 18.244439" N 74• 03' 11.
X - 1343486 892 Y- -4701771.345



Float Sta
Position: 4011 18' 46.008533" N 74• 02' 14.
X 1339382.336 Y-4682509.759

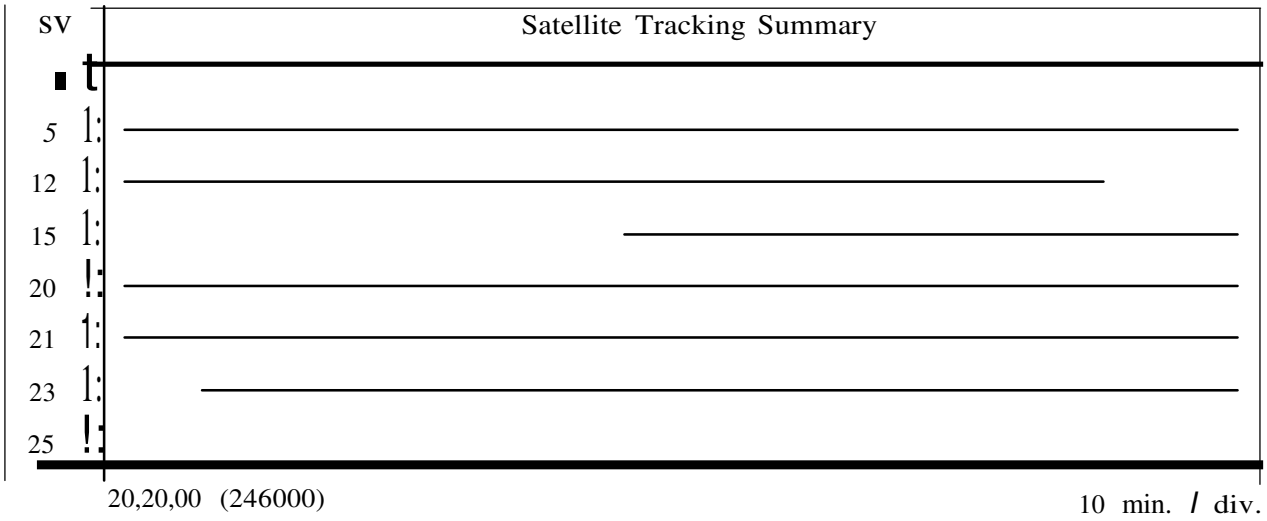


Figure 10-5. (Sheet 2 of 3)

Project ftml
Processed: Tuesday, January 25, 1994 ll:17 WAVE 1.01

Station si
Shading i

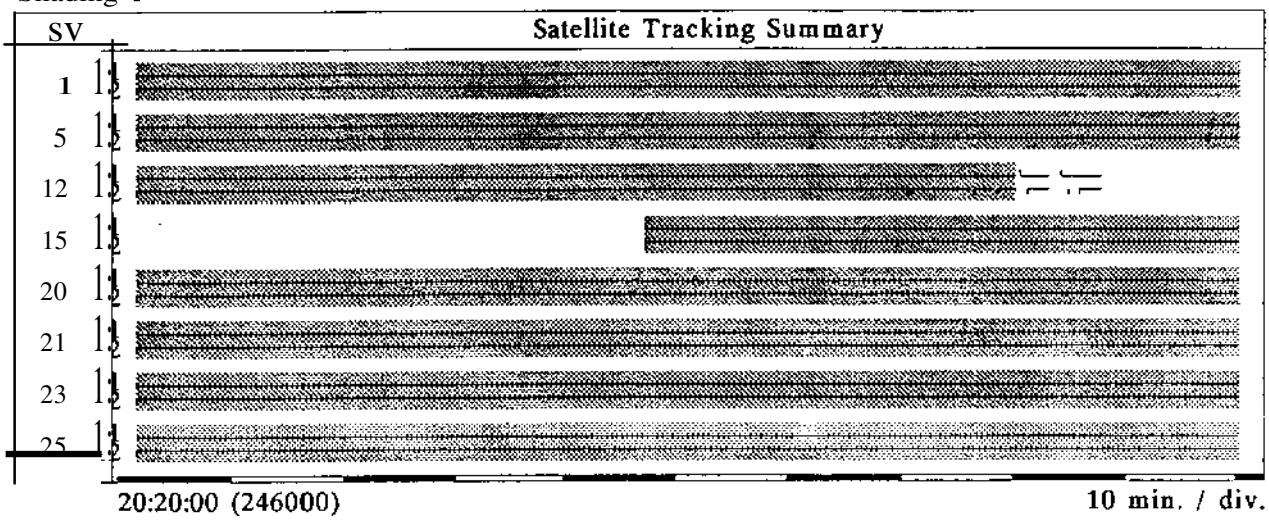


Figure 10-5. (Sheet 3 of 3)

Table 10-3
Loop Closure Procedure

Baseline	Julian Day	Session	x	y	z	Distance
#1	Day	#	x #1	y #1	z #1	Distance #1
#2	Day	#	x #2	y #2	z #2	Distance #2
#3	Day	#	x #3	y #3	z #3	Distance #3

$$m = \sqrt{(\quad x^2) + (\quad y^2) + (\quad z^2)} \tag{10-1}$$

where

m = misclosure for the loop

x = sum of all x vectors for baselines used

y = sum of all y vectors for baselines used

z = sum of all z vectors for baselines used

(4) The loop misclosure ratio may be calculated as follows:

$$\textit{Loop misclosure ratio} = \frac{m}{L} \tag{10-2}$$

where

L = total loop distance (perimeter distance)

(5) The resultant value can be expressed in the following form:

1: Loop Misclosure Ratio

with all units for the expressions being in terms of the units used in the baseline formulations (e.g., m, ft, mm, etc.).

c. Sample loop closure computation. Figure 10-6 shows two loops which consist of four stations. During session A on day 065, three GPS receivers observed the baselines between stations 01, 02, and 03 for approximately 1 hr. The receivers were then turned off and the receiver at station 01 was moved to station 04. The tripod heights at stations 02 and 03 were adjusted. The baselines between stations 02, 03, and 04 were then observed during session B, day 065. Stations 01 and 04 were known control stations. This provided an independent baseline for both loops.

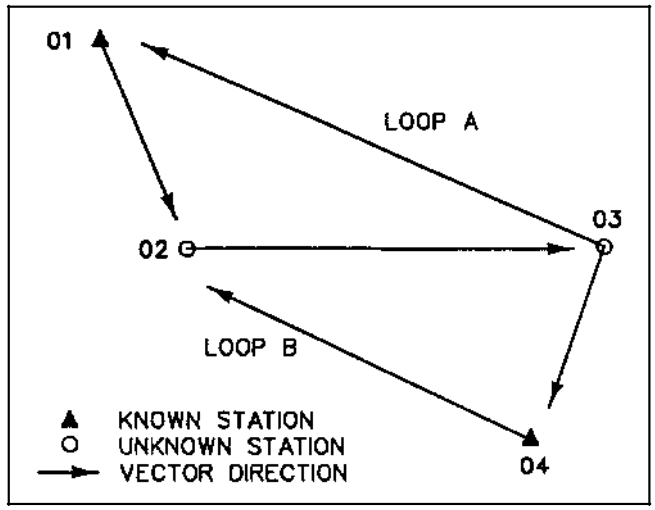


Figure 10-6. Internal loop closure diagram

(1) The closure for loop 01-02-03 is computed with the vectors 01-02 and 01-03, day 065, session A, and the vector 02-03, day 065, session B. The vector 02-03 from session B provides an independent baseline. The loop closure is determined by arbitrarily assigning coordinate values of zero to station 01 (X=0, Y=0, Z=0). The vector from 01-02 is added to the coordinates of station 01. The vector from 02-03, session B, is added to the derived coordinates of station 02. The vector from 03-01 is then added to the station coordinates of 02. Since the starting coordinates of station 01 were arbitrarily chosen as zero, the misclosure is then the computed coordinates of Station 04 (*dx, dy, dz*). The vector data are listed in Table 10-4.

(2) To determine the relative loop closure, the square root of the sum of the squares of the loop misclosures (*mx, my, mz*) is divided into the perimeter length of the loop:

Table 10-4
Vector Data for Stations 01, 02, and 03

Baseline	Julian Day	Session	X	Y	Z	Distance
01-02	065	A	-4077.865	-2877.121	-6919.829	8531.759
02-03	065	B	7855.762	-3129.673	688.280	8484.196
03-01	065	A	-3777.910	6006.820	6231.547	9443.869

$$\textit{Loop misclosure ratio} = \frac{(x^2 - y^2 - z^2)^{0.5}}{L} \qquad (10\text{-}3)$$

Where the PD = distance 01-02 + distance 02-03 + distance 03-01, or:

PD = 8531.759 + 8484.196 + 9443.869

= 26,459.82

And where distance 03-01 is computed from:

$(-3777.91^2 + 6006.820^2 + 6231.547^2)^{0.5}$

= 9443.869

(Other distances are similarly computed.)

Summing the misclosures in each coordinate:

x = -4077.865 + 7855.762 - 3777.910 = -0.0135

y = -2877.121 - 3129.673 + 6006.820 = +0.0264

z = -6919.829 + 688.280 + 6231.547 = -0.0021

then

$(x^2 + y^2 + z^2)^{0.5} = 0.029$

Loop misclosure ratio = 0.029/26,459.82

or (approximately) 1 part in 912,000 (1:912,000)

(3) This example is quite simplified; however, it illustrates the necessary mechanics in determining internal loop closures. The values *DX*, *DY*, and *DZ* are present in the baseline output files. The perimeter distance is computed by adding the distances between each point in the loop.

d. External closures. External closures are computed in a similar manner to internal loops. External closures provide information on how well the GPS measurements conform to the local coordinate system. Before the closure of each traverse is computed, the latitude, longitude, and ellipsoid height must be converted to geocentric coordinates (X,Y,Z), using the algorithms given in Chapter 11. If the ellipsoid height is not known, geoid modeling software can be used with the orthometric height to get an approximate ellipsoid height. The external closure will aid the surveyor in determining the quality of the known control and how well the GPS measurements conform to the local network. If the control stations are not of equal precision, the external closures will usually reflect the lower order station. If the internal closure meets the requirements of the job, but the external closure is poor, the surveyor should suspect that the known control is deficient and an additional known control point should be tied into the system.

10-9. Data Management (Archival)

The raw data are defined as data recorded during the observation period. Raw data shall be stored on an appropriate medium (floppy disk, portable hard drive, magnetic tape, etc.). The raw data and the hard copy of the baseline reduction (resultant baseline formulations) shall be stored at the discretion of each USACE Command.

10-10. Flow Diagram

When processing GPS observational data, the progress should generally follow the path shown in Figure 10-7.

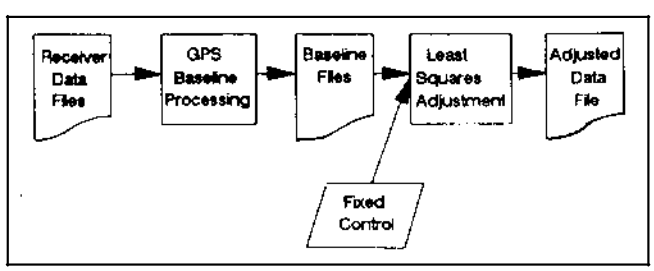


Figure 10-7. GPS data processing flowchart

Chapter 11
Adjustment of GPS Surveys

11-1. General

Differential carrier phase GPS survey observations are adjusted no differently from conventional surveys. Each three-dimensional GPS baseline vector is treated as a separate distance observation and adjusted as part of a trilateration network. A variety of techniques may be used to adjust the observed GPS baselines to fit existing control. Since GPS survey networks often contain redundant observations, they are usually (but not always) adjusted by some type of rigorous least squares minimization technique. This chapter describes some of the methods used to perform horizontal GPS survey adjustments and provides guidance in evaluating the adequacy and accuracy of the adjustment results.

11-2. GPS Error Measurement Statistics

In order to understand the adjustment results of a GPS survey, some simple statistical terms should be understood.

a. Accuracy. Accuracy is how close a measurement or a group of measurements are in relation to a "true" or "known" value.

b. Precision. Precision is how close a group or sample of measurements are to each other. For example, a low standard deviation indicates high precision. It is important to understand that a survey or group of measurements can have a high precision but a low accuracy (i.e., measurements are close together but not close to the known or true value).

c. Standard deviation. The standard deviation is a range of how close the measured values are from the arithmetic average. A low standard deviation indicates that the observations or measurements are close together.

11-3. Adjustment Considerations

a. This chapter deals primarily with the adjustment of horizontal control established using GPS observations. Although vertical elevations are necessarily carried through the baseline reduction and adjustment process, the relative accuracy of these elevations is normally inadequate for engineering and construction purposes. Special techniques and constraints are necessary to determine approximate orthometric elevations from relative GPS observations, as was covered in Chapter 6.

b. The baseline reduction process (described in Chapter 10) directly provides the raw relative position coordinates which are used in a 3D GPS network adjustment. In addition, and depending on the manufacturer's software, each reduced baseline will contain various orientation parameters, covariance matrices, and cofactor and/or correlation statistics which may be used in weighing the final network adjustment. Most least squares adjustments use the accuracy or correlation statistics from the baseline reductions; however, other weighing methods may be used in a least squares or approximate adjustment.

c. The adjustment technique employed (and time devoted to it) must be commensurate with the intended accuracy of the survey, as defined by the project requirements. Care must be taken to prevent the adjustment process from becoming a project in itself.

d. There is no specific requirement that a rigorous least squares type of adjustment be performed on USACE surveys, whether conventional, GPS, or mixed observations. Traditional approximate adjustment methods may be used in lieu of least squares and will provide comparable practical accuracy results.

e. Commercial software packages designed for higher order geodetic densification surveys often contain a degree of statistical sophistication which is unnecessary for engineering survey control densification (i.e., Second-Order or less). For example, performing repeated chi-square statistical testing on observed data intended for 1:20,000 base mapping photogrammetric control may be academically precise but, from a practical engineering standpoint, is inappropriate. The distinction between geodetic surveying and engineering surveying must be fully considered when performing GPS survey adjustments and analyzing the results thereof.

f. Connections and adjustments to existing control networks, such as the NGRS, must not become independent projects. It is far more important to establish dense and accurate local project control than to consume resources tying into First-Order NGRS points miles from the project. Engineering, construction, and property/boundary referencing requires consistent local control with high relative accuracies; accurate connections/references to distant geodetic datums are of secondary importance. (Exceptions might involve projects in support of military operations.) The advent of GPS surveying technology has

provided a cost-effective means of tying previously poorly connected USACE projects to the NGRS, and simultaneously transforming the project to the newly defined NAD 83. In performing (adjusting) these connections, care must be taken not to distort or warp long-established project construction/boundary reference points.

11-4. Survey Accuracy

a. General. The accuracy of a survey (whether performed using conventional or GPS methods) is a measure of the difference between observed values and the true values (coordinates, distance, angle, etc.). Since the true values are rarely known, only estimates of survey accuracy can be made. These estimates may be based on the internal observation closures, such as on a loop traverse, or connections with previously surveyed points assumed to have some degree of reliability. The latter case is typically a traverse (GPS or conventional) between two previously established points, either existing USACE project control or the published NGRS network.

(1) GPS internal accuracies are typically far superior to most previously established control networks (including the NAD 83 NGRS). Therefore, determining the accuracy of a GPS survey based on misclosures with external points is not always valid unless statistical accuracy estimates (i.e., station variance-covariance matrices, distance/azimuth relative accuracy estimates, etc.) from the external network's original adjustment are incorporated into the closure analysis for the new GPS work. Such refinements are usually unwarranted for most USACE work.

(2) Most survey specifications and standards (including USACE) classify accuracy as a function of the resultant relative accuracy between two usually adjacent points in a network. This resultant accuracy is estimated from the statistics in an adjustment, and is defined by the size of a 2D or 3D relative error ellipse formed between the two points. Relative distance, azimuth, or elevation accuracy specifications and classifications are derived from this model, and are expressed either in absolute values (e.g., ±1.2 cm or ±3.5 in.) or as ratios of the propagated standard errors to the overall length (e.g., 1:20,000).

b. Internal accuracy. A loop traverse originating and ending from a single point will have a misclosure when observations (i.e., EDM traverse angles/distances or GPS baseline vectors) are computed forward around the loop back to the starting point. The forward-computed misclosure provides an estimate of the relative or internal accuracy of the observations in the traverse loop, or more correctly, the internal precision of the survey. This is perhaps the simplest method of evaluating the adequacy of a survey. (These point misclosures, usually expressed as ratios, are not the same as relative distance accuracy measures.)

(1) Internal accuracy estimates made relative to a single fixed point are obtained when so-called free, unconstrained, or minimally constrained adjustments are performed. In the case of a single loop, no redundant observations (or alternate loops) back to the fixed point are available. When a series of GPS baseline loops (or network) are observed, then the various paths back to the single fixed point provide multiple position computations, allowing for a statistical analysis of the internal accuracy of not only the position closure but also the relative accuracies of the individual points in the network (including relative distance and azimuth accuracy estimates between these points). The magnitude of these internal relative accuracy estimates (on a free adjustment) determines the adequacy of the control for subsequent design, construction, and mapping work.

(2) Loop traverses are discouraged for most conventional surveys due to potential systematic distance or orientation errors which can be carried through the network undetected. FGCS classification standards for geodetic surveys do not allow traverses to start and terminate at a single point. Such procedures are unacceptable for incorporation into the NGRS network; however, due to many factors (primarily economic), loop traverses or open-ended spur lines are commonly employed in densifying project control for engineering and construction projects. Since such control is not intended for inclusion in the NGRS and usually covers limited project ranges, such practices have been acceptable. Such practices will also be acceptable for GPS surveys performed in support of similar engineering and construction activities.

c. External accuracy. The coordinates (and reference orientation) of the single fixed starting point will also have some degree of accuracy relative to the network in which it is located, such as the NGRS if it was established relative to that system/datum. This "external" accuracy (or inaccuracy) is carried forward in the traverse loop or network; however, any such external variance (if small) is generally not critical to engineering and construction. When a survey is conducted relative to two or more points on an existing reference network, such as USACE project control or the NGRS, misclosures with these fixed control points provide an estimate of the "absolute" accuracy of the survey. This analysis is usually obtained from a final adjustment, usually a fully constrained least squares minimization technique or by

other recognized traverse adjustment methods (Transit, Compass, Crandall, etc.).

(1) This absolute accuracy estimate assumes that the fixed (existing) control is superior to the survey being performed, and that any position misclosures at connecting points are due to internal observational errors and not the existing control. This has always been a long-established and practical assumption and has considerable legal basis in property/boundary surveying. New work is rigidly adjusted to existing control regardless of known or unknown deficiencies in the fixed network.

(2) Since the relative positional accuracies of points on the NGRS are known from the NAD 83 readjustment, and GPS baseline vector accuracy estimates are obtained from the individual reductions, variations in misclosures in GPS surveys are not always due totally to errors in the GPS work. Forcing a GPS traverse/network to rigidly fit the existing (fixed) network usually results in a degradation of the internal accuracy of the GPS survey, as compared with a free (unconstrained) adjustment.

11-5. Internal versus External Accuracy

Classical geodetic surveying is largely concerned with absolute accuracy, or the best-fitting of intermediate surveys between points on a national network, such as the NGRS. Alternatively, in engineering and construction surveying, and to a major extent in boundary surveying, relative, or local, accuracies are more critical to the project at hand. Thus, the absolute NAD 27 or NAD 83 coordinates (in latitude and longitude) relative to the NGRS datum reference are of less importance; however, accurate relative coordinates over a given project reach (channel, construction site, levee section, etc.) are critical to design and construction.

a. For example, in establishing basic mapping and construction layout control for a military installation, developing a dense and accurate internal (or relative) control network is far more important than the values of these coordinates relative to the NGRS.

b. On flood control and river and harbor navigation projects, defining channel points must be accurately referenced to nearby shore-based control points. These points, in turn, directly reference boundary/right-of-way points and are also used for dredge/construction control. Absolute coordinates (NGRS/NAD) of these construction and/or boundary reference points are of less importance.

c. Surveys performed with GPS, and final adjustments thereof, should be configured/designed to establish accurate relative (local) project control; of secondary importance is connection with NGRS networks.

d. Although reference connections with the NGRS are desirable and recommended, and should be made where feasible and practicable, it is critical that such connections (and subsequent adjustments thereto) do not distort the internal (relative) accuracy of intermediate points from which design, construction, and/or project boundaries are referenced.

e. Connections and adjustments to distant networks (i.e., NGRS) can result in mixed datums within a project area, especially if not all existing project control has been tied in. This in turn can lead to errors and contract disputes during both design and construction. On existing projects with long-established reference control, connections and adjustments to outside reference datums/networks should be performed with caution. The impacts on legal property and project alignment definitions must also be considered prior to such connections. (See also paragraph 8-3*d*.)

f. On newly authorized projects, or on projects where existing project control has been largely destroyed, reconnection with the NGRS is highly recommended. This will ensure that future work will be supported by a reliable and consistent basic network, while minimizing errors associated with mixed datums.

11-6. Internal and External Adjustments

GPS-performed surveys are usually adjusted and analyzed relative to their internal consistency and external fit with existing control. The internal consistency adjustment (i.e., free or minimally constrained adjustment) is important from a contract compliance standpoint. A contractor's performance should be evaluated relative to this adjustment. The final, or constrained, adjustment fits the GPS survey to the existing network. This is not always easily accomplished since existing networks often have lower relative accuracies than the GPS observations being fit. Evaluation of a survey's adequacy should not be based solely on the results of a constrained adjustment.

11-7. Internal or Geometric Adjustment

This adjustment is made to determine how well the baseline observations fit or internally close within themselves.

(Other EDM distances or angles may also be included in the adjustment.) It is referred to as a free adjustment. This adjustment provides a measure of the internal precision of the survey.

a. In a simplified example, a conventional EDM traverse which is looped back to the starting point will misclose in both azimuth and position, as shown in Figure 11-1. Classical "approximate" adjustment techniques (e.g., Transit, Compass, Bowditch, Crandall) will typically assess the azimuth misclosure, proportionately adjust the azimuth misclosure (usually evenly per station), recompute the traverse with the adjusted azimuths, and obtain a position misclosure. This position misclosure (in X and Y) is then distributed among all the points on the traverse using various weighing methods (distance, latitudes, departures, etc.). Final adjusted azimuths and distances are then computed from grid inverses between the adjusted points. The adequacy/accuracy of such a traverse is evaluated based on the azimuth misclosure and position misclosure after azimuth adjustment (usually expressed as a ratio to the overall length of the traverse).

b. A least squares adjustment of the same conventional loop traverse will end up adjusting the points similarly to the approximate methods traditionally employed. The only difference is that a least squares adjustment simultaneously adjusts both observed angles (or directions) and distance measurements. A least squares adjustment also allows variable weighting to be set for individual angle/distance observations, which is a somewhat more complex process when approximate adjustments are performed. In addition, a least squares adjustment will yield more definitive statistical results of the internal accuracies of each observation and/or point, rather than just the final closure. This includes estimates of the accuracies of individual station X-Y coordinates, relative azimuth accuracies, and relative distance accuracies.

c. A series of GPS baselines forming a loop off a single point can be adjusted and assessed similarly to a conventional EDM traverse loop described in *a* above (see Figure 11-1). The baseline vector components may be computed (accumulated) around the loop with a resultant 3D misclosure back at the starting point. These misclosures (in X, Y, and Z) may be adjusted using either approximate or least squares methods. The method by which the misclosure is distributed among the intermediate points in the traverse is a function of the adjustment weighting technique.

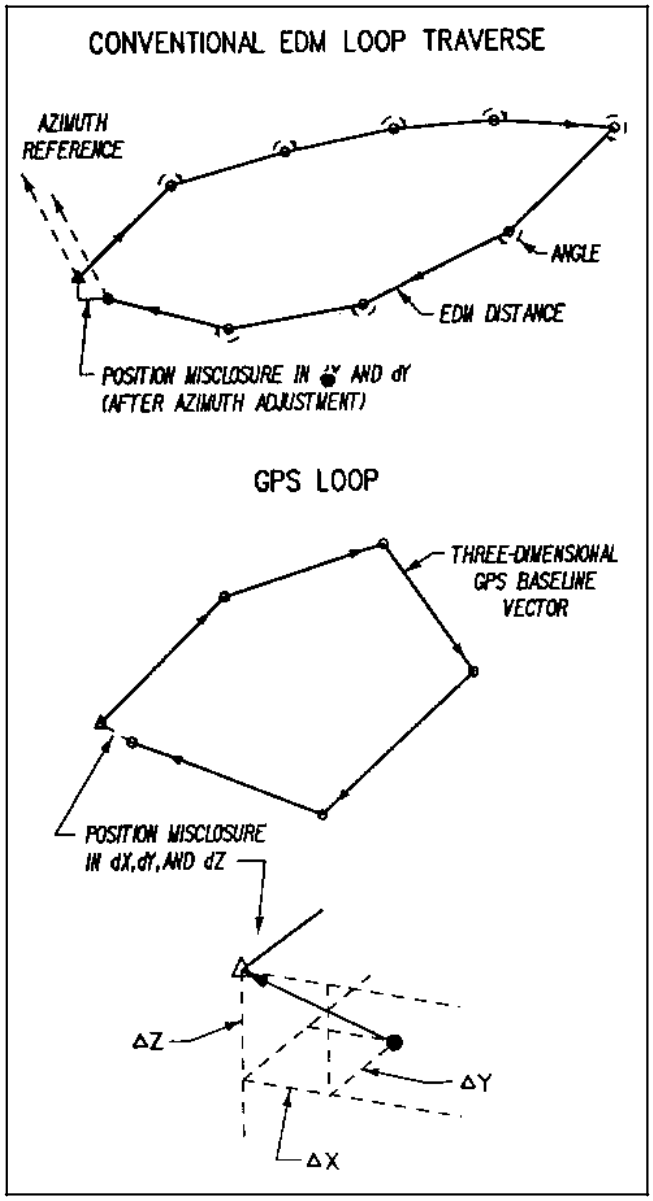


Figure 11-1. Conventional EDM and GPS traverse loops

(1) In the case of a simple EDM traverse adjustment, the observed distances (or position corrections) are weighted as a function of the segment length and the overall traverse length (Compass Rule), or to the overall sum of the latitudes/departures (Transit Rule). Two-dimensional EDM distance observations are not dependent on their direction; that is, a distance's X- and Y-components are uncorrelated.

(2) GPS baseline vector components (in X, Y, and Z) are correlated due to the geometry of the satellite solution; that is, the direction of the baseline vector is significant. Since the satellite geometry is continuously changing, remeasured baselines will have different correlations between the vector components. Such data are passed down from the baseline reduction software for use in the adjustment.

d. The magnitude of the misclosure (i.e., loop closure) of the GPS baseline vectors at the initial point provides an estimate of the internal precision or geometric consistency of the loop (survey). When this misclosure is divided by the overall length of the baselines, an internal relative accuracy estimate results. This misclosure ratio should not be less than the relative distance accuracy classification intended for the survey, per Table 8-1.

(1) For example, if the position misclosure of a GPS loop is 0.08 m and the length of the loop is 8,000 m, then the loop closure is 0.08/8,000 or 1 part in 100,000 (1:100,000).

(2) When an adjustment is performed, the individual corrections/adjustments made to each baseline (so-called residual errors) provide an accuracy assessment for each baseline segment. A least squares adjustment can additionally provide relative distance accuracy estimates for each line, based on standard error propagation between adjusted points. This relative distance accuracy estimate is most critical to USACE engineering and construction work and represents the primary basis for assessing the acceptability of a survey.

11-8. External or Fully Constrained Adjustment

The internal "free" geometric adjustment provides adjusted positions relative to a single, often arbitrary, fixed point. Most surveys (conventional or GPS) are connected between existing stations on some predefined reference network or datum. These fixed stations may be existing project control points (on NAD 27--SPCS 27) or stations on the NGRS (NAD 83). In OCONUS locales, other local or regional reference systems may be used. A constrained adjustment is the process used to best fit the survey observations to the established reference system.

a. A simple conventional EDM traverse (Figure 11-2) between two fixed stations best illustrates the process by which comparable GPS baseline vectors are adjusted. As with the loop traverse described in paragraph 10-8, the misclosure in azimuth and position between the two fixed end points may be adjusted by any type of approximate or least squares adjustment method. Unlike a loop traverse, however, the azimuth and position misclosures are not wholly dependent on the internal errors in the traverse--the fixed points and their azimuth references are not absolute, but contain relative inaccuracies with respect to one another.

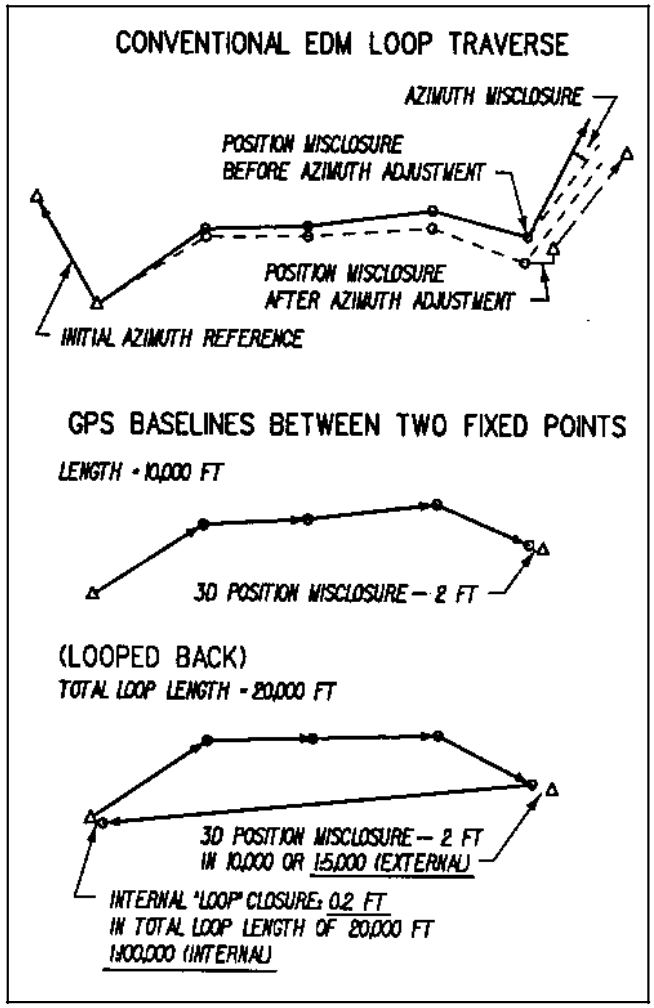


Figure 11-2. Constrained adjustment between two fixed points

b. A GPS survey between the same two fixed points also contains a 3D position misclosure. Due to positional uncertainties in the two fixed network points, this misclosure may (and usually does) far exceed the internal accuracy of the raw GPS observations. As with a conventional EDM traverse, the 3D misclosures may be approximately adjusted by proportionately distributing them over the intermediate points. A least squares adjustment will also accomplish the same thing.

c. If the GPS survey is looped back to the initial point, the free adjustment misclosure at the initial point may be compared with the apparent position misclosure with the other fixed point. In Figure 11-2, the free adjustment loop misclosure is 1:100,000 whereas the misclosure relative to the two network control points is only 1:5,000. Thus, the internal relative accuracy of the GPS survey is on the order of 1 part in 100,000 (based on the misclosure); if the GPS baseline observations are constrained to fit the existing control, the 0.6-m external misclosure must be distributed among the individual baselines to force a fit between the two end points.

(1) After a constrained adjustment, the absolute position misclosure of 0.6 m causes the relative distance accuracies between individual points to degrade. They will be somewhat better than 1:5,000 but far less than 1:100,000. The statistical results from a constrained least squares adjustment will provide estimates of the relative accuracies between individual points on the traverse.

(2) This example also illustrates the advantages of measuring the baseline between fixed network points when performing GPS surveys, especially when weak control is suspected (as in this example).

(3) Also illustrated is the need for making additional ties to the existing network. In this example, one of the two fixed network points may have been poorly controlled when it was originally established, or the two points may have been established from independent networks (i.e., were never connected). A third or even fourth fixed point would be beneficial in resolving such a case.

d. If the intent of the survey shown in Figure 11-2 was to establish 1:20,000 relative accuracy control, connecting between these two points obviously will not provide that accuracy given the amount of adjustment that must be applied to force a fit. For example, if one of the individual baseline vectors was measured at 600 m and the constrained adjustment applied a 0.09-m correction in this sector, the relative accuracy of this segment would be roughly 1:6,666. This distortion would not be acceptable for subsequent design/construction work performed in this area.

e. Most GPS survey networks are more complex than the simple traverse example in Figure 11-2. They may consist of multiple loops and may connect with any number of control points on the existing network. In addition, conventional EDM, angles, and differential leveling measurements may be included with the GPS baselines, resulting in a complex network with many adjustment conditions.

11-9. Partially Constrained Adjustments

In the previous example of the simple GPS traverse, holding the two network points rigidly fixed caused an adverse degradation in the GPS survey, based on the differences between the free (loop) adjustment and the fully constrained adjustment. Another alternative is to perform a semiconstrained (or partially constrained) adjustment of the net. In a partially constrained adjustment, the two network points are not rigidly fixed but only partially fixed in position. The degree to which the existing network points are constrained may be based on their estimated relative accuracies or, if available, their original adjustment positional accuracies (covariance matrices). Partially constrained adjustments are not practicable using approximate adjustment techniques; only least squares will suffice.

a. For example, if the relative distance accuracy between the two fixed network points in Figure 11-2 is approximately 1:10,000, this can be equated to a positional uncertainty between them. Depending on the type and capabilities of the least squares adjustment software, the higher accuracy GPS baseline observations can be best fit between the two end points such that the end points of the GPS network are not rigidly constrained to the original and two control points but will end up falling near them.

b. Adjustment software will allow relative weighting of the fixed points to provide a partially constrained adjustment. Any number of fixed points can be connected to, and these points may be given partial constraints in the adjustment.

c. Performing partially constrained adjustments (as opposed to a fully constrained adjustment) takes advantage of the inherent higher accuracy GPS data relative to the existing network control, which is traditionally weak on many USACE project areas. Less warping of the GPS data (due to poor existing networks) will then occur.

d. A partial constraint also lessens the need for performing numerous trial-and-error constrained adjustments in attempts to locate poor external control points causing high residuals. Fewer ties to the existing network need be made if the purpose of such ties was to find a best fit on a fully constrained adjustment.

e. When connections are made to the NAD 83, relative accuracy estimates of NGRS stations can be obtained from the NGS. Depending on the type of adjustment software used, these partial constraints may be in the form of variance-covariance matrices, error ellipses, or circular accuracy estimates.

11-10. Approximate Adjustments of GPS Networks

Simply constructed GPS networks used for establishing lower order (i.e., Second-Order and lower) USACE control can be effectively adjusted using approximate adjustment techniques, or adjustments which approximate the more rigorous least squares solution. Although least squares solutions may be theoretically superior to approximate methods, the resultant differences between the adjustments are generally not significant from a practical engineering standpoint.

a. Given the high cost of commercial geodetic adjustment software, coupled with the adjustment complexity of these packages, approximate adjustment methods are allowed for in-house and contracted surveys.

b. In practice, any complex GPS survey network may be adjusted by approximate methods. If the main loop/line closures are good, redundant ties to other fixed network points may be used as checks rather than being rigidly adjusted.

c. In some cases it is not cost-effective to perform detailed and time-consuming least squares adjustments on GPS project control surveys requiring only 1:5,000 or 1:10,000 engineering/construction/boundary location accuracy. If internal loop closures are averaging over 1:200,000, then selecting any simple series of connecting baselines for an approximate adjustment will yield adequate resultant positional and relative distance accuracies for the given project requirements. If a given loop/baseline series of say five points miscloses by 0.01 ft over 1,000 m (1:100,000), a case can be made for not even making any adjustment if a relative accuracy of only 1:5,000 is required between points.

d. Any recognized approximate adjustment method may be used to distribute baseline vector misclosures. The method used will depend on the magnitude of the misclosure to be adjusted and the desired accuracy of the survey. These include the following:

(1) Simple proportionate distribution of loop/line position misclosures among the new station coordinates.

(2) Compass Rule.

(3) Transit Rule.

(4) Crandall Method.

(5) No adjustment. Use raw observations if misclosures are negligible.

e. Approximate adjustments are performed using the 3D earth-centered X-Y-Z coordinates. The X-Y-Z coordinates for the fixed points are computed using the transform algorithms shown in *f* below or obtained from the baseline reduction software. Coordinates of intermediate stations are determined by using the baseline vector component differences (X, Y, Z) which are obtained directly from the baseline reductions. These differences are then accumulated (summed) forward around a loop or traverse connection, resulting in 3D position coordinate misclosures at the loop nodes and/or tie points. These misclosures are then adjusted by any of the methods in *d* above. GPS vector weighting is accomplished within the particular adjustment method used; there is no need to incorporate the standard errors from the baseline reductions into the adjustment. Internal survey adequacy and acceptance are performed based on the relative closure ratios, as in conventional traversing criteria (see FGCC 1984). Final local datum coordinates are then transformed back from the X-Y-Z coordinates.

f. Given a loop of baseline vectors between two fixed points (or one point looped back on itself), the following algorithms may be used to adjust the observed baseline vector components and compute the adjusted station geocentric coordinates.

(1) Given: Observed baseline vector components X_i, Y_i, Z_i for each baseline i (total of n baselines in the loop/traverse). The 3D length of each baseline is l_i, and the total length of the loop/traverse is L.

(2) The misclosures (dx, dy, and dz) in all three coordinates are computed from:

$$dx = X_F + \sum_{i=1}^{i=n} X_i - X_E$$

$$dy = Y_F + \sum_{i=1}^{i=n} Y_i - Y_E \qquad (11\text{-}1)$$

$$dz = Z_F + \sum_{i=1}^{i=n} Z_i - Z_E$$

Where X_F, Y_F, and Z_F are the fixed coordinates of the starting point and X_E, Y_E, and Z_E are the coordinates of the end point of the loop/traverse. (These misclosures would also be used to assess the internal accuracy of the work.)

(3) Adjustments (x_i, y_i, z_i) to each baseline vector component may be computed using either the Compass Rule:

$$x_i = - dx \frac{l_i}{L}$$

$$y_i = - dy \frac{l_i}{L} \qquad (11\text{-}2)$$

$$z_i = - dz \frac{l_i}{L}$$

or the Transit Rule:

$$x_i = - dx \frac{X_i}{\sum X_i}$$

$$y_i = - dy \frac{Y_i}{\sum Y_i} \qquad (11\text{-}3)$$

$$z_i = - dz \frac{Z_i}{\sum Z_i}$$

(4) The adjusted vector components are computed from:

$$\begin{aligned} X_i^a &= X_i + x_i \\ Y_i^a &= Y_i + y_i \\ Z_i^a &= Z_i + z_i \end{aligned} \qquad (11\text{-}4)$$

(5) The final geocentric coordinates are then computed by summing the adjusted vector components from Equation 11-4 above:

$$\begin{aligned} X_i^a &= X_F + X_i^a \\ Y_i^a &= Y_F + Y_i^a \\ Z_i^a &= Z_F + Z_i^a \end{aligned} \qquad (11\text{-}5)$$

g. Example of an approximate GPS survey adjustment:

(1) Fixed control points from the U.S. Army Yuma Proving Ground GPS Survey (May 1990) (see Figure 11-3):

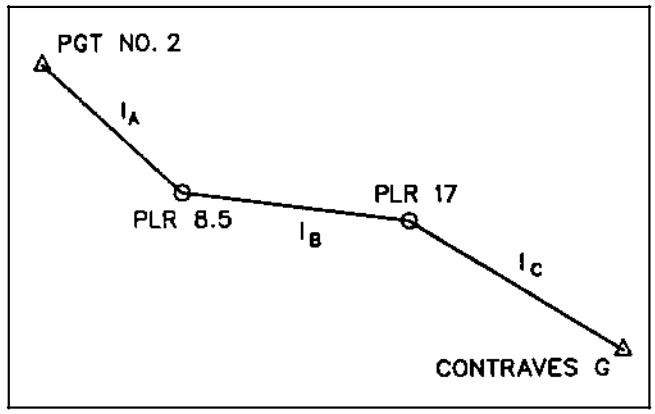


Figure 11-3. Yuma GPS traverse sketch

PGT NO 2:

X_F = (-) 2205 949.0762

Y_F = (-) 4884 126.7921

Z_F = + 3447 135.1550

CONTRAVES G:

X_E = (-) 2188 424.3707

Y_E = (-)4897 740.6844

Z_E = + 3438 952.8159

(XYZ geocentric coordinates were computed from GP-XYZ transform using Equations 11-6 and 11-7 below)

l_a, l_b, l_c = observed GPS baseline vectors (from baseline reductions)

and PLR 8.5 and PLR 17 are the points to be adjusted.

(2) Misclosures in X, Y, and Z (from Equation 11-1):

(-)2205	949.0762 X_F	(-)4884	126.7921 Y_F
+3	777.9104 ΔXa	(-)6	006.8201 ΔY_a
+7	859.4707 ΔX_b	(-)3	319.1092 ΔY_b
+5	886.8716 ΔXc	(-)4	288.9638 ΔY_c
-(-)2188	424.3707 X_E	-(-)4897	740.6844 Y_E

dx = (-) 0.4528 dy = (-) 1.0008

3447	135.1550 Z_F
(-)6	231.5468 ΔZ_a
+	400.1902 ΔZ_b
(-)2	350.2230 ΔZ_c
- 3438	952.8159 Z_E

dz = + 0.7595

(3) Linear 3D misclosure:

$$= (0.4528^2 + 1.0008^2 + 0.7595^2)^{1/2} = \underline{1.335 \text{ m}}$$

or 1 part in 25,638.2/1.335 = 1:19,200

(Note: This is a constrained misclosure check, not free)

(4) Compass Rule adjustment:

(a) Compass Rule misclosure distribution:

l_a	= 9,443.869	l_a/L	= 0.368
l_b	= 8,540.955	l_b/L	= 0.333
l_c	= 7,653.366	l_c/L	= 0.299
L	= 25,638.190		= 1.000

(b) Compass Rule adjustment to GPS vector components using Equation 11-2:

Vector	x	y	z
A	0.1666	0.3683	(-) 0.2795
B	0.1508	0.3333	(-) 0.2529
C	0.1354	0.2992	(-) 0.2271
	(+0.4528)	(+1.0008)	((-)0.7595) Check

(c) Adjusted baseline vectors (Equation 11-4):

Vector	X[a]	Y[a]	Z[a]
A	3778.0770	(-)6006.4518	(-)6231.8263
B	7859.6215	(-)3318.7759	399.9373
C	5887.0070	(-)4288.6646	(-)2350.4501

(d) Final adjusted coordinates (Equation 11-5):

	X[a]	Y[a]
PGT No. 2	(-)2205 949.0762	(-)4884 126.7921
PLR 8.5	(-)2202 170.9992	(-)4890 133.2439
PLR 17	(-)2194 311.3777	(-)4893 452.0198
Contraves G (Check)	(-)2188 424.3707	(-)4897 740.6844

	Z[a]	
PGT No. 2	+3447	135.1550
PLR 8.5	+3440	903.3287
PLR 17	+3441	303.2660
Contraves G (Check)	+3438	952.8159

(e) Adjusted geocentric coordinates are transformed to , , h, using Equations 11-9 through 11-13. Geographic coordinates may then be converted to local SPCS (either NAD 83 or NAD 27) project control using USACE program CORPSCON.

(5) Transit Rule adjustment.

(a) Distribution of GPS vector misclosures using Equation 11-3:

$$X_i = 3777.9104 + 7859.4707 + 5886.8716$$
$$= 17{,}524.2527$$

Similarly,

$$Y_i = 13{,}614.8931$$

$$Z_i = 8{,}981.9600$$

$$- \quad x_i = -dx^i \frac{X}{\sum X_i} = -(-)\frac{0.4528}{17{,}524.2527} X_i$$

$$= +2.584 \times 10^5 \quad X_i$$

Similarly,

$$y_i = +7.351 \times 10^5 \quad Y_i$$
$$z_i = (-)8.456 \times 10^5 \quad Z_i$$

(b) Adjustments to baseline vector components using Transit Rule (Equation 11-3):

Vector	x	y	z
A	0.0976	0.4415	(-)0.5269
B	0.2031	0.2440	(-)0.0338
C	0.1521	0.3153	(-)0.1987
(check)	(0.4528)	(1.0008)	(- 0.7595)

(c) Adjusted baseline vectors (Equation 11-4):

Vector	X^a	Y^a	Z^a
A	3 778.0080	(-)6 006.3786	(-)6 232.0737
B	7 859.6738	(-)3 318.8652	+ 400.1564
C	5 887.0237	(-)4 288.6485	(-)2 350.4217

(d) Final adjusted coordinates (Equation 11-5):

	X^a	Y^a
PGT No. 2	(-)2 205 949.0762	(-)4884 126.7921
PLR 8.5	(-)2 202 171.0682	(-)4890 133.1707
PLR 17	(-)2 194 311.3944	(-)4893 452.0359
Contraves G (Check)	(-)2 188 424.3707	(-)4897 740.6844

	Z^a
PGT No. 2	+3447 135.1550
PLR 8.5	+3440 903.0813
PLR 17	+3441 303.2377
Contraves G (Check)	+3438 952.8160

(6) Proportionate distribution adjustment method.

(a) Vector misclosures are simply distributed proportionately over each of the three GPS baselines in the traverse:

$$x = -(-)\frac{0.4528}{3} = +0.1509$$

$$y = -(-)\frac{1.0008}{3} = +0.3336$$

$$z = -(-)\frac{0.7595}{3} = (-)0.2532$$

Vector	X^a	Y^a	Z^a
A	3778.0613	(-) 6006.4865	(-) 6231.8000
B	7859.6216	(-) 3318.7756	+ 399.9370
C	5887.0225	(-) 4288.6302	(-) 2350.4762

(b) Final adjusted coordinates:

	X^a	Y^a
PLR 8.5	(-)2202 171.0149	(-)4890 133.2786
PLR 17	(-)2194 311.3933	(-)4893 452.0542

	Z^a
PLR 8.5	+3440 903.3550
PLR 17	+3441 303.2920

Note: Relatively large horizontal (2D) misclosure (1:23,340) may be due to existing control inadequacies, not poor GPS baseline observations.

(c) Variance between adjusted coordinates yields relative accuracies well in excess of 1:20,000; thus, if project control requirements are only 1:10,000, then any of the three adjustment methods may be used.

The recommended method is the Compass Rule.

Fixed coordinates of PGT No. 2 and CONTRAVES G can be on any reference ellipsoid -- NAD 27 or NAD 83.

11-11. Geocentric Coordinate Conversions

The following algorithms for transforming between geocentric and geographic coordinates can be performed in the field on a Hewlett-Packard-style hand-held calculator.

a. Geodetic to Cartesian coordinate conversion. Given geodetic coordinates on NAD 83 (in , , *H*) or NAD 27, the geocentric Cartesian coordinates (*X, Y,* and *Z*) on the WGS 84, GRS 80, or Clarke 1866 ellipsoid are converted directly by the following formulas.

$$X = (R_N + h) \cos \quad \cos$$
$$Y = (R_N + h) \cos \quad \sin \qquad (11\text{-}6)$$
$$Z = \frac{b^2}{a^2} R_N + h \quad \sin$$

where

= latitude

= 360° - $_W$ (for CONUS west longitudes)

h = the ellipsoidal elevation. If only the orthometric elevation H is known, then that value may be used.

The normal radius of curvature R_N can be computed from either of the following equations:

$$R_N = \frac{a^2}{\sqrt{a^2 \cos^2 \quad + b^2 \sin^2}} \qquad (11\text{-}7)$$

$$R_N = \frac{a}{\sqrt{1 - e^2 \sin^2}} \qquad (11\text{-}8)$$

and

a (GRS 80) = 6,378,137.0 m (semimajor axis)
a (WGS 84) = 6,378,137.0 m
a (NAD 27) = 6,378,206.4 m

b (GRS 80) = 6,356,752.314 1403 m (semiminor axis)
b (WGS 84) = 6,356,752.314 m
b (NAD 27) = 6,356,583.8 m

f (GRS 80) = 1/298.257 222 100 88 (flattening)
f (WGS 84) = 1/298.257 223 563
f (NAD 27) = 1/294.978 698

e^2 (GRS 80) = 0.006 694 380 222 90 (eccentricity squared)
e^2 (WGS 84) = 0.006 694 379 9910
e^2 (NAD 27) = 0.006 768 658

NAD 27 = Clarke Spheroid of 1866
GRS 80 = NAD 83 reference ellipsoid

also

$$b = a(1 - f)$$

$$e^2 = f(2 - f) = (a^2 - b^2) / a^2$$

$$e^2 = (a^2 - b^2) / b^2$$

b. Cartesian to geodetic coordinate conversion. In the reverse case, given GRS 80 X, Y, Z coordinates, the conversion to NAD 83 geodetic coordinates (, , H) is performed using the following noniterative method (Soler and Hothem 1988):

$$= \text{arc tan} \frac{Y}{X} \qquad (11\text{-}9)$$

The latitude and height h are computed using the following sequence. The initial reduced latitude $_o$ is first computed:

$$\tan \quad _0 = \frac{Z}{p} (1 - f) + \frac{e^2 a}{r} \qquad (11\text{-}10)$$

where

$$p = \sqrt{X^2 + Y^2}$$
$$e^2 = 2f - f^2$$
$$r = \sqrt{p^2 + Z^2}$$

Directly solving for and h:

$$\tan \quad = \frac{Z(1 - f) + e^2 a \sin^3 \quad _0}{(1 - f)(p - a e^2 \cos^3 \quad _0)} \qquad (11\text{-}11)$$

$$h^2 = (p - a \cos \quad)^2 + (Z - b \sin \quad)^2 \qquad (11\text{-}12)$$

where the final reduced latitude is computed from

$$\tan \quad = (1 - f) \tan \qquad (11\text{-}13)$$

c. Transforms between other OCONUS datums may be performed by changing the ellipsoidal parameters a, b, and f to that datum's reference ellipsoid.

d. Example geocentric-geographic coordinate transform.

Geographic to geocentric (, , h to X, Y, Z) transform:

(1) Given any point:

$_N$ = 35° 27' 15.217"

$_W$ = 94° 49' 38.107"

= 360° - $_W$ = 265.1727481°

h = 100 m (N = 0 assumed)

(2) Given constants (WGS 84):

a = 6,378,137 m b = a(1 - f) = 6,356,752.314

f = 1/298.257223563 e^2 = f(2 - f) = 6.694380 x 11^{-3}

$$R_N = - a/(1- e^2 \sin^2 \quad)^{1/2} = \underline{6,385,332,203}$$
$$X = (R_N + h) \cos \quad \cos \quad = \underline{(-)437,710.553}$$
$$Y = (R_N + h) \cos \quad \sin \quad = \underline{(-)5,182,990.319}$$
$$Z = \frac{b^2}{a^2} R_N + H \quad \sin \quad = \underline{+3,679,090.327}$$

e. Geocentric (X, Y, Z) to geographic (, , H) transform.

Inversing the above X, Y, Z geocentric coordinates:

p = $(X^2 + Y^2)^{1/2}$ = 5,201,440.106

r = $(p^2 + Z^2)^{1/2}$ = 6,371,081.918

$$_o = \tan^{-1} \frac{Z}{p} (1 - f) + \frac{e^2 a}{r} = 35.36295229°$$

$$\tan \quad = \frac{Z(1 - f) + e^2 a \sin^3 \quad _o}{(1 - f)\ (p - ae^2 \cos^3 \quad _o)}$$
= 0.712088398

= 35.45422693° = 35° 27' 15.217"

= $\tan^{-1}$(Y/X) = 85.17274810° (= 265.17274810°)

$_W$ = 360° - = 94° 49' 38.107"

= $\tan^{-1}$ [(1 - f) tan] = 35.36335663°

h^2 = $(p - a \cos \quad)^2 + (Z - b \sin \quad)^2$
= $(81.458)^2 + (58.004)^2$

h = 99.999 = 100 m

f. North American Datum of 1927 (Clarke Spheroid of 1866). Given a point with SPCS/Project coordinates on NAD 27, the point may be converted to X, Y, Z coordinates for use in subsequent adjustments.

$_N$ = 35° 27' 15.217"

$_W$ = 94° 49' 38.107" h or H = 100 m

(NAD 27 from SPCS X-Y , conversion using USACE program CORPSCON)

a = 6,378,206.4

b = 6,356,583.8

f = 1/294.978698

e^2 = 0.006768658
(NAD 27/Clarke 1866 Spheroid)

$$R_N = \frac{a}{(1 - e^2 \sin^2 \quad)^{1/2}} = \underline{6,392,765.205}$$

$$X - (R_N \quad h) \cos \quad \cos \quad = (-)\ 438,220.073 \text{ m}$$
$$Y - (R_N \quad h) \cos \quad \sin \quad = (-)\ 5,189,023.612 \text{ m}$$
$$Z = \frac{b^2}{a^2} R_N + H \quad \sin \quad = +3,733,466.852 \text{ m}$$

These geocentric coordinates (on NAD 27 reference) may be used to adjust subsequent GPS baseline vectors observed on WGS 84.

11-12. Rigorous Least Squares Adjustments of GPS Surveys

Adjustment of GPS networks on PC-based software is typically a trial-and-error process for both the free and constrained adjustments. When a least squares adjustment is performed on a network of GPS observations, the adjustment software will provide 2D or 3D coordinate accuracy estimates, variance-covariance matrix data for the adjusted coordinates, and related error ellipse data. Most software will provide relative accuracy estimates (length and azimuth) between points. Analyzing these

various statistics is not easy, and they are also easily misinterpreted. Arbitrary rejection and readjustment in order to obtain a best fit (or best statistics) must be avoided. The original data reject criteria must be established and justified in a final report document.

a. When a series of loops are formed relative to a fixed point or off another loop, different redundant conditions are formed. (This is comparable to loops formed in conventional differential level nets.) These different loops allow forward baseline vector position computations to be made over different paths. From the different routes (loops) formed, different positional closures at a single fixed point result. These variances in position misclosures from the different routes provide additional data for assessing the internal consistency of the network, in addition to checking for blunders in the individual baselines. The number of different paths, or conditions, is partially related to the number of degrees of freedom in the network.

(1) Multiple observed baseline observations also provide additional redundancy or strength to a line or network since they are observed at two distinct times of varying satellite geometry and conditions. The amount of redundancy required is a function of the accuracy requirements of a particular survey.

(2) Performing a free adjustment on a complex network containing many redundancies is best performed using least squares methods. An example of such a network is shown in Figure 11-4. Approximate adjustment methods are difficult to evaluate when complex interweaving networks are involved.

(3) Baseline reduction vector component error statistics are usually carried down into the least squares adjustment; however, their use is not mandatory for lower order engineering surveys. GPS network least squares adjustments can be performed without all the covariance and correlation statistics from the baseline reduction.

(4) In practice, any station on the network can be held fixed for the free adjustment. The selected point is held fixed in all three coordinates, along with the orientation of the three axes and a network scale parameter. Usually one of the higher order points on the existing network is used.

b. Least squares adjustment software will output various statistics from the free adjustment to assist in detecting blunders and residual outliers in the free adjustment. Most commercial packages will display the normalized residual for each observation (GPS, EDM, angle, elevation, etc.), which is useful in detecting and rejecting residual outliers. The variance of unit weight is also important in evaluating the overall adequacy of the observed network. Other statistics, such as tau, chi-square, confidence levels, histograms, etc., are usually not significant for lower order USACE engineering projects, and become totally insignificant if one is not well versed in statistics and adjustment theory. Use of these statistics to reject data (or in reporting results of an adjustment) without a full understanding of their derivation and source within the network adjustment is ill-advised; they should be "turned off" if they are not fully understood.

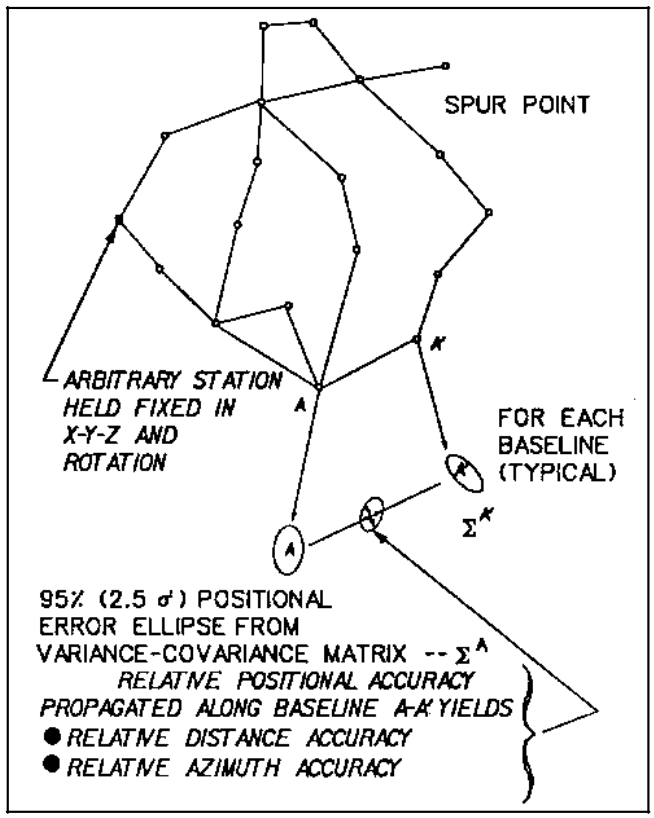


Figure 11-4. Free adjustment of a complex GPS network

c. Relative positional and distance accuracy estimates resulting from a free (unconstrained) geometric adjustment of a GPS network are usually excellent in comparison to conventional surveying methods. Loop misclosures and relative distance accuracies between points will commonly exceed 1:100,000.

d. Relative distance accuracy estimates between points in a network are determined by error propagation

of the relative positional standard errors at each end of the line, as shown in Figure 11-4. Relative accuracy estimates may be derived for resultant distances or azimuths between the points. The relative distance accuracy estimates are those typically employed to assess the free (geometric) and constrained accuracy classifications, expressed as a ratio, such as 1:80,000. Since each point in the network will have its particular position variances, the relative distance accuracy propagated between any two points will also vary throughout the network.

(1) The minimum value (i.e., largest ratio) will govern the relative accuracy of the overall project. This minimum value (from a free adjustment) is then compared with the intended relative accuracy classification of the project to evaluate compliance. However, relative distance accuracy estimates should not be rigidly evaluated over short lines (i.e., less than 500 m).

(2) Depending on the size and complexity of the project, large variances in the propagated relative distance accuracies can result.

(3) When a constrained adjustment is performed, the adequacy of the external fixed stations will have a major impact on the resultant propagated distance accuracies, especially when connections are made to weak control systems. Properly weighted partially constrained adjustments will usually improve the propagated distance accuracies.

e. The primary criteria for assessing the adequacy of a particular GPS survey shall be based on the relative distance accuracy results from a minimally constrained free adjustment, not the fully constrained adjustment. This is due to the difficulty in assessing the adequacy of the surrounding network. Should the propagated relative accuracies fall below the specified level, then reobservation would be warranted.

(1) If the relative distance accuracies significantly degrade on a constrained adjustment (due to the inadequacy of the surrounding network), any additional connections to the network would represent a change in contract scope. A large variance of unit weight usually results in such cases.

(2) If only approximate adjustments are performed, then the relative distance accuracies may be estimated as a function of the loop or position misclosures, or the residual corrections to each observed length. For example, if a particular loop or line miscloses by 1 part in 200,000, then individual baseline relative accuracies can be assumed adequate if only a 1:20,000 survey is required.

f. Most commercial and Government adjustment software will output the residual corrections to each observed baseline (or actually baseline vector components). These residuals indicate the amount by which each segment was corrected in the adjustment. A least squares adjustment minimizes the sum of the squares of these baseline residual corrections.

(1) A number of commercial least squares adjustment software packages are available which will adjust GPS networks using standard IBM PC or PC-compatible computers. Those commonly used by USACE Commands include the following:

(a) TURBO-NET™, Geo-Comp, Inc., distributed by Geodetic Enterprises, Inc., PO Box 837, Odessa, FL 33556, (813) 920-4045.

(b) Geo-Lab™, distributed by GEOsurv, Inc., The Baxter Centre, 6-1050 Baxter Road, Ottawa, Ontario, Canada K2C 3P1, (613) 820-4545.

(c) FILLNET™, distributed by Ashtech, Inc., 1156-C Aster Avenue, Sunnyvale, CA, 94086, (408) 249-1314.

(d) ADJUST™, an adjustment program distributed by the National Geodetic Survey Information Center, Rockville, MD 20852.

(e) TRIMNET™, distruibuted by Trimble Navigation, Inc., 645 North Mary Avenue, P.O. Box 3642, Sunnyvale, CA, 94088-3642, (1-800-TRIMBLE).

(f) STAR*NET™, distributed by STARPLUS SOFTWARE, INC., 460 Boulevard Way, Oakland, CA, 94610, (510) 653-4836).

Annotated sample adjustment outputs from two commercial packages are shown in Figures 11-5 and 11-6.

(2) Relative GPS baseline standard errors can be obtained from the baseline reduction output and, in some software (i.e., Geo-Lab), can be directly input into the adjustment. These standard errors, along with their correlations, are given for each vector component (in X, Y, and Z). They are converted to relative weights in the adjustment. FILLNET allows direct input of vector component standard errors in a ±x + y ppm form. Correlations are not used in FILLNET. The following typical input (a priori) weighting is commonly used in FILLNET:

```
ADJUSTMENT STATISTICS SUMMARY
NETWORK - FTMl
TIME  -Wed Dec 15 18:13:40 1993


                ADJUSTMENT  SUMMARY

  Network Reference Factor  - 9.09
  Chi-Square  Test  (a = 95\) =  FAIL
         Degrees  of  Freedo=   20.00


       GPS OBSERVATIONS
           Reference Factor = 9.09
                              r .. 20.00

GPS Solution   1 Reference Factor m    6.08   r =  2.38
GPS Solution   2 Reference Factor  =  14.38   r =  2.66
GPS Solution   3 Reference Factor =    9.91   r =  2.06
GPS Solution   4 Reference Factor  =   6.65   r =  2.21
GPS Solution   5 Reference Factor     11.46   r =  2.13
GPS Solution   6 Reference Factor ..   3.37   r "  1.96
GPS Solution   7 Reference Factor -    2.52   r =  2.05
GPS Solution   8 Reference Factor =    5.56   r =  2.10
GPS Solution   ● Reference Factor =   11.65   r =  2.45

                WEIGHTING STRATEGIES:

     GPS OBSERVATIONS:
          No scalar weighting strategy was used

          No summation weighting strategy was used

          Station Error Strategy:
H.I. error- 0.0010
Tribrach error  - 0.0010
```

Figure 11·5. TRIMNET sample adjustment output (Sheet 1 of 6)

COORDINATE ADJUSTMENT SUMJIARY
NETWORK • FTMI
TIME • Wed Dec 15 18:13:41 1993

Datum = NAD-83
Coordinate System • Geographic
Zone • Global

Network Adjustment Constraints:
3 fixed coordinates in y
3 fixed coordinates in x
3 fixed coordinates in H
3 fixed coordinates in h

POINT	NAME	OW COORDS	ADJUST	NEW COORI>S	1.960
1	C2PR				
	LAT=	40- 25' 35.433030"	+0.000000"	40" 25' 35.433030"	FIXED
	LON=	74" 20' 41.879000"	+0.000000"	74" .20 ' 41.879000"	FIXED
	ELL HT=	-29.8100m	+O.OOOOm	-29.8100m	FIXED
	ORTHO HT=	3.0400m	+O.OOOOm	3.040Dm	FIXED
	GEOID HT-	-32.8500m	+O.OOOOm	-32.BSOOm	FIXED
2	FTM1				
	LAT=	40- 18' 46.192066"	+0.000003"	40' 18' 46.192069"	O.Ol1390m
	LON=	74- 02' 14.692854"	+0.000000"	74" 02' 14.692854[8]	O.Ol1542m
	ELL HT=	-22.3923m	-0.5752m	-22.9675m	0.016921m
	ORTHO HT=	O.OOOOm	+0 .0000m	O.OOOOm	NOT KNOWN
3	KANT				
	LAT:	40- 02' 18.425950"	+0.000000"	40" 02' 18.425950"	FIXED
	LON•	74. 03' 11.673310"	+0.000000"	74' 03' 11.673310"	FIXED
	ELL HT=	-32.1600m	+O.OOOOm	-32.1600m	FIXED
	ORTHO HT=	1.1500m	+O.OOOOm	1.1500m	FIXED
	GEOID HT=	-33.3100m	+O.OOOOm	-JJ.J1OOm	FIXED
4	SIMJ				
	LA"'	40. 28' 06.064930"	+0.000000"	40" 28' 06.064930"	FIXED
	LON=	74- OO' 28.941590"	+0.000000"	74" OO' 28.941590"	FIXED
	ELL HT=	-Jo.ssoom	+O.OOOOm	-30.5800m	FIXED
	ORTHO HT=	2.1000m	+O.OOOOm	2.1ooom	FIXED
	GEOID HT=	-32.6BOOm	+O.OOOOm	-J2.6800m	FIXED

Fr...,_ "
u..,-- 40 18 4G.•H>-8
tm.! H• .:z_ lt.112-18"
>H -1.'2.- BS'"'

Figure 11-5. (Sheet 2 of 6)

OBSERVATION'ADJUSTMENT SUMMARY
NETWORK • FTMI
TIME • Wed Dec 15 18:13:43 1993

OBSERVATION ADJUSTMENT (Tau • 2.85)

GPS Parameter Group 1 GPS Observations

Azimuth rotation • -0.2339 seconds	1.960	• 0.0587 seconds
Deflection in latitude • +0.0470 seconds	1.960'	• 0.1005 seconds
Deflection in longitude • +0.5992 seconds	1.960	• 0.1960 seconds
Network scale • 0.999995521210	1.960	– 0.000000288587

OBSI	BLKf/ REF#	TYPE	BACKSIGBT/ INSTRUMENT/ FORESIGHT	UDVC/ UDPG/ SBNT	OBSERVED/ ADJUSTED/ RESIDUAL	1.960'/ 1.960'/ 1.960'	TAU
1	1	gpsaz	-**-	▪'▪	8'12'30.7755"	0.3399"	0.04
	1		FTM1	▪'▪	8'12'30.7931"	0.1507"	
			SI:M3	1	+0.017599"	0.3046"	
2	1	qpsht	-**-	▪'▪	-7.6308m	0.0495m	0.23
	1		FTMI	▪"▪	-7.6160m	0.0219m	
			SIM3		+0.014794m	o.0444m	
3	1	qpsds	▪'▪	▪'▪	17448.3884m	0.0279m	0.34
	1		FTM1	▪'▪	17448.4006m	0.0126m	
			51M3	1	+0.012253m	0.0249m	
4	2	gpsaz	–**–	–**–	260.52'34.5985"	0.2105"	0.02
	1		SIM3	–**–	260'52'34.5939"	0.0587"	
			C2PR	1	-o.004628"	0.2022"	
5	2	gpsht	–**–	–**–	+0.8693m	0.0696m	0.19
	1		SIMI	–**–	+0.8516m	0.0282m	
			C2PR	1	-O.O17753m	0.0636m	
6	2	gpsds	–**–	–**–	28957.8274m	0.0312m	0.84
	1		81M3	-**–	28957.8638m	0.0084m	
			C2PR	1	+0.036478m	0.0300m	
7	3	gpsaz	–**–	–**–	8'12'30.5976"	0.3100"	0.50
	1		FTMI	–**–	8'12'30.7931"	0.1507"	
			81M3	1	+0.195536"	0.2710"	
8	3	gpsht	–**–	–**–	-7.6089m	0.0316m	0.21
	1		FTM1	▪'▪	-7.6160m	o.0219m	
			SIMJ	1	-o.007130m	0.0228m	
9	3	gpsds	▪'▪	–**–	17448.4119m	0.0265m	0.33
	1		FTM1	▪"▪	17448.4006m	O.O126m	
			81M3		-O.O11284m	0.0233m	
10	●	gpsaz	-**-	-**-	182'32'19.4314"	0.1863"	0..-29
	1		FTM1	-**-	182'32'19.3636"	0.0963"	
			MANT	1	-0.067829"	O..1595"	

Figure 11·5. (Sheet 3 of 6)

11	4 gpsht	-'-'	-'-'	-9.1984JD	O.OJBBil	0.05
	1	FTM1	-'-'	-9.196Dm	0.019811	
		KANT	1	+0.002485m	0.033311	
12	4 gpsds	-'-'	-'-'	30496.2387m	0.0281•	0.33
	1	FTM1	-'-'	J0496.2272m	0.014111	
		KANT	1	-O.O11512m	0.024211	
13	5 gpsaz	-'-'	-'-'	184'37'13.9839"	0.1196⁸	0.17
	1	SIMJ	-'-'	184'37¹14.0097"	0.0586"	
		KANT	1	+0.025802"	0.1043"	
14	5 gpsht	-'-'	-'-'	-1.590lm	0.0399•	0.21
	1	SIMJ	-'-'	-1.5B06m	0.0250m	
		KANT	1	+0.00952lm	Q,O11111	
15	5 gpsds	-'-'	-'-'	47890.3245m	0.0284m	0.68
	1	SIM3	-'-'	47890.3000m	O.Ol38m	
		KANT	1	-0.024483m	O.024811.	
16	6 gpsaz	-'-'	-'-'	330'08'41.8933"	0.1115"	0.05
	1	MANT	-'-'	330'08'41.8865"	0.0587	
		C2PR	1	-0.006765¹¹	0.0947⁸	
17	6 gpsht	-'-'	-'-'	+2.4222m	0.0348111.	0.23
	1	KANT	-'-'	+2.4307m	0.0242111	
		C2PR	1	+O.OOB509m	0.0250111	
18	6 gpsds	-'-'	-'-'	49729.7388m	o.0273m	0.07
	1	KANT	-'-'	49729.7364m	0.0144m	
		C2PR	1	-0.002441111	0.0232m	
19	7 gpsaz	-'-'	-'-'	2.31¹42.5754"	0.1792"	0.14
	1	KANT	-'-'	2'31'42.6064"	0.0960"	
		FTM1	1	+0.031010"	0.1513¹¹	
20	7 gpsht	-'-'	-'-'	+9.1917111	0.0324111	0.09
	1	KANT	-'-'	+9.1951111	o.Ol9Bm	
		FTM1	1	+0.003409111	o.0256m	
21	7 gpsds	-'-'	-'-'	30496.2264111	o.026Bm	0.02
	1	KANT	-'-'	30496.2272111	o.Ol43m	
		FTM1	1	+0.000753m	0.0226m	
22	8 gpsaz	-'-'	-'-'	295'53'30.6165"	0.1904"	0.21
	1	FTM1	-'-'	295'53'30.5663"	0.0923"	
		C2PR	1	-0.050255"	0.1665"	
23	8 gpsht	-'-'	-'-'	-6.7766m	o.0341m	0.33
	1	FTM1	-**-	-6.7642m	0.0224m	
		·C2PR	1	+0.012405m	o.0257m	
24	8 gpsds	-**-	-'-'	29010.8695m	o.0272m	0.05
	1	FTM1	-'-'	29010.867Bm	o.Ol29m	
		C2PR	1	-0.001702m	o.0239m	
25	● gpsaz	-'-'	-'-'	295'53'30.6764"	0.2227"	0.37
	1	FTM1	-'-'	295'53'30.5663"	0.0923"	
		C2PR	1	-0.110138¹¹	0.2026•	

Figure 11·5. (Sheet 4 of 6)

26	9 gpsht	[illegible]	[illegible]	-6.7600m	0.0564m	0.06
	1	FTMl	[illegible]	-6.76421D	o.0224m	
		C2PR	1	-0.004171m	0.051Sm	
27	9 qpsds	[illegible]	[illegible]	29010.8399m	0.0319m	0.66
	1	FTMl	[illegible]	29010.8678m	o.Ol29m	
		C2PR		+0.027863m	o.0291m	

Figure 11-5. (Sheet 5 of 6)

SUMMARY OF COVARIANCES
NETWORK - FTMl
TIME - Wed Dec 15 18:13:45 1993

FROM/ TO	AZIMU'l'll/ DELTA H	1.96a 1.960'	DISTANCE/ DELTA h	1.96a 1.960'	HOR PREC
FTMl	+6.8425m	o.Ol69m	-'-'		
	-'-	-'-		-'-'	-'-'
				O.01l4m	
				-'-'	
C2PR	115"41'34"	0.08"	29010.998m		1: 2536313
				-'-'	
C2PR !<ANT					
				-'-'	
C2PR	-'-'	-'-'	-'-'		-'-'
SIM3	-'-'	-'-'	-'-'	O.Ol l4m	
				-'-'	
FTMl	182'32'20"	0.08"	30496.364m		1: 2675331
!<ANT	-9.1925m	0.0169m	-'-'		
FTMl	8'12'31"	0.14"	17448.479m	O.Ol l4m	1: 1527827
SIM3	-7.6125m	O.Ol69m	-'-'		
!<ANT					-'-'
SIM3	-'-'	-'-'	-'-'	-'-'	

Figure 11-5. (Sheet 6 of 6)

```
PROGRAM FILLNET, Version 3.0.00
LICENSED TO: ASHTECH INC.


Fillnet Input File acts                    40.3    74.1

a .. 6378137.000    1/f .. 298.2572221    W      Longitude positive WEST

PRELIMINARY COORDINATES:
                        LAT.                LON-          ELEV.     G.B.   CONSTR.

  1        F'I'M2 40  18  46.25804   74  2  14.14056    47.648    0.000
  2  FFF   MANT 40   2  18.42595   74  3  11.67331   -32.160    0.000
  3  FFF   C2PR 40  25  35.43303   74 20  41.87900   -29.810    0.000
  4  FFF   SIMJ 40  28   6.06493   74  0  28.94159   -30.580    0.000
  5        FTM1 40  18  46.19156   74  2  14.69409   -24.152    0.000

GROUP 1' NO. OF VECTORS AND BIAS CONSTRAINTS:

 11      0.000  0.000    0.000  0.000    0.000  0.000    0.000   0.000

VECTORS:
                    DX          OY          DZ       LENGTH   ERROR CODES

FTM1   FTM2      -1.061      -3.124      -3.223      4.612   3 51.0  51.0  2
FTM1   FTM2      -1.059      -3.126      -3.223      4.613   3 51.0  51.0  2
C2PR   MANT   31466.066 -20017.367 -32897.190  49729.603   3 51.0  51.0  3
C2PR   FTM1   27361.521   -755.791  -9612.798  29010.859   3 51.0  51.0  3
MANT   SIM3   -4788.603  30711.771  36432.475  47890.175   3 51.0  51.0  3
MANT   FTM1   -4104.542  19261.593  23284.378  30496.204   3 51.0  51.0  3
51M3   FTM1     684.063 -11450.182 -13148.091  17448.407   3 51.0  51.0  3
MANT   FTM1   -4104.553  19261.590  23284.377  30496.203   3 51.0  51.0  3
C2PR   51M3   26677.446  10694.407   3535.282  28957.809   3 51.0  51.0  3
C2PR   FTM1   27361.503   -755.790  -9612.797  29010.842   3 51.0  51.0  3
SIM3   FTM1     684.055 -11450.181 -13148.088  17448.404   3 51.0  51.0  3

 SHIFTS:
   1  -6.254 -14.914 -70.647
   2   0.000   0.000   0.000
   3   0.000   0.000   0.000
   4   0.000   0.000   0.000
   5   0.009   0.035   1.170

ADJTJSTED VECTORS, GROUP ''
                            DX,DY,DZ    V        DN,DE,DU    v       v'

FTM1   FTM2     3213B       -1.060  0.001      -4.214 -0.001  -0.3
                            -3.125 -0.001      -1.876  0.001   0-1
                            -3.223 -0.000      -0.014  0.001   0-2

FTM1   FTM2     3213A       -1.060 -0.001      -4.214  0.001   0.3
                            -3.125  0.001      -1.876 -0.001  -0.1
                            -3.223 -0.000      -0.014 -0.001  -0.2

C2PR   MANT     3203C    31466.069 -0.002  -43116.924  0.019   0.3
                        -20017.389  0.005   24778.270 -0.000  -0.0
                        -32897.156  0.021     -20.476  0.009   0- 2-

C2PR   FTM1     3203C    27361.531  0.000  -12649.806  0.009   0-2
                          -755.810  0.013   26107.654  0.004   0.1
```

Figure 11·6. **FILLNET** sample adjustment output (Sheet 1 of 3)

			-9612.775	0.001	53.853	-0.009	-0.2
MANT	SIM3	32038	-4788.587	0.006	47738.483	-0.015	-0.2
			30711.758	-0.003	3808.387	0.005	0.1
			36432.476	-0.015	36.869	-0.006	-0.1
MANT	FTM1	32038	-4104.538	-0.001	30467.118	-0.010	-0.3
			19261.579	-0.009	1329.384	-0.003	-0.1
			23284.381	-0.006	74.329	0,003	0.1
51M3	FTM1	32038	684.050	-0.009	-17271.365	0.003	0.1
			-11450.179	-0.002	-2479.003	-0.009	-0.4
			-13148.095	0.003	37.460	0.001	0.1
MANT	FTM1	3203C	-4104.538	0.010	30467.118	-0.009	-0.2
			19261.579	-0.006	1329.384	0.008	0-2
			23284.381	-0.005	74.329	0.003	0.1
C2PR	51M3	3203A	26677.482	0.021	4621.559	0.002	0.1
			10694.369	-0.001	28586.657	0.020	0.6
			3535.320	0.009	16.393	0.011	0.3
C2PR	FTM1	3203A	27361.531	0.018	-12649.806	0.004	0.1
			-755.810	0.012	26107.654	0.021	0.6
			-9612.775	-0.000	53.853	-0.005	-0.1
SIM3	FTM1	3203A	684.050	-0.001	-17271.365	-0.001	-0.1
			-11450.179	-0.003	-2479.003	-0.002	-0.1
			-13148.095	0.000	37.460	0.002	0.1

S.E. OF UNIT WEIGHT = 0.278

NUMBER OF –

OBS. EQUATIONS	33
UNKNOWNS	10
DEGREES OF FREEDOM	23
ITERATIONS	0

GROUP 1 ROT. ANGLES (sec.) AND SCALE DIFF. (ppm):

HOR. SYSTEM	0.342	-0.057	0.026	0.101
STD. ERRORS	0.044	0.030	0.025	0.120
XYZ SYSTEM	-0.110	0.178	0.277	

ADJUSTED POSITIONS:

		LAT.	LON.	ELEV.	STD. ERRORS (m)		
1	FTM2	40 18 46.05528	74 2 14.77217	-22.999	0.003	0.004	0.004
2	MANT	40 2 18.42595	74 3 11.67331	-32.160	0.000	0.000	0.000
3	C2PR	40 25 35.43303	74 20 41.87900	-29.810	0.000	0.000	0.000
4	51M3	40 28 6.06493	74 0 28.94159	-30.580	0.000	0.000	0.000
5	FTM1	40 18 46.19186	74 2 14.69262	-22.982	0.003	0.003	0.004

ACCURACIES (m) :

		D. LAT.	D. LON.	VERT.
FTM1	FTM2	0.001	0.001	0.001
FTM1	nM2	0.001	0.001	0.001

Figure 11-6. (Sheet 2 of 3)

C2PR	MANT	0.000	0.000	0.000
C2PR	FTM1	0.003	0.003	0.004
MANT	SIM3	0.000	0.000	0.000
MANT	FTM1	0.003	0.003	0.004
51M3	FTM1	0.003	0.003	0.004
MANT	FTM1	0.003	0.003	0.004
C2PR	SIM3	0.000	0.000	0.000
C2PR	FTM1	0.003	0.003	0.004
51M3	FTM1	0.003	0.003	0.004

```
*****************************************************************
*"'**                                                        ****
****                ESTIMATES OF PRECISION                   ****
****                                                        ****
****        Based on the VECTOR ACCURACIES produced by      ****
****                       FILLNET                          ****
****                                                        ****
****      This is a reasonable estimate of the accuracies   ****
"'***       of the vectors in the network at 1 SIGMA.       ****
****                                                        ****
*****************************************************************
```

VECTOR		LENGTH	PPM{h)	RATIO{h)	PPM{v)	RATIO{\>)
FTM1	FTM2	4.613	306.6	1: 3262	216.8	1: 4613
FTM1	FTM2	4.613	306.6	1: 3262	216.8	1: 4613
C2PR	MANT	49729.591	0.0	1: 0	0.0	1: 0
C2PR	FTM1	29010.862	0-1	1: 6837914	0-1	1: 7252715
MANT	SIM3	47890.165	0.0	1: 0	0.0	1: 0
MANT	FTM1	30496.198	0-1	1: 7188001	0.1	1: 7624049
51M3	FTM1	17448.407	0-2	1: 4112620	0.2	1: 4362102
MANT	FTMI	30496.198	0-1	1: 7188001	0.1	1: 7624049
C2PR	SIM3	28957.832	0.0	1: 0	0.0	1: 0
C2PR	FTM1	29010.862	0-1	1: 6837914	0.1	1: 7252715
51M3	FTM1	17448.407	0.2	1: 4112620	0.2	1: 4362102
51M3	FTM1	17448.407	0.2	1: 4112620	0.2	1: 4362102

Figure 11-6. (Sheet 3 of 3)

(a) Fixed: ±3 mm (Lat) ± 5 mm (Long) + 1 ppm ±5 mm (Height) + 1 ppm

(b) Float: ± 6 mm (Lat) ± 10 mm (Long) + 2 ppm ± 10 mm (Height) + 2 ppm

The optimum standard errors shown have been found to be reasonable in standard USACE work where extremely long baselines are not involved. Use of these optimum values is recommended for the first adjustment iteration.

(3) The adequacy of the initial network weighting described in (2) above is indicated by the variance of unit weight (or variance factor in Geo-Lab) which equals the square of the standard error of unit weight (FILLNET). The variance of unit weight should range between 0.5 and 1.5 (or the standard error of unit weight should range between 0.7 and 1.2), with an optimum value of 1.0 signifying realistic weighting of the GPS input observations. A large unit variance (say 5.0) indicates the initial GPS standard errors were too optimistic (low). A low unit variance (say 0.1) indicates the results from the adjustment were better than the assumed GPS baseline precisions used. This unit variance test, however, is generally valid only when a statistically significant number of observations are involved. This is a function of the number of degrees of freedom shown on the adjustment. To evaluate the adequacy of the unit weight, a test such as chi-square in Geo-Lab is performed. Failure of such a test indicates the variance factor statistic may not be statistically valid, including any rejections made using this value.

(4) The input standard errors can easily be juggled in order to obtain a variance of unit weight near 1.0. This trial-and-error method is generally not a good practice. If the input weights are changed, they should not be modified beyond reasonable levels (e.g., do not input a GPS standard error of ±50 + 50 ppm in order to get a good unit variance). If input standard errors are modified, these modifications should be the same for all lines, not just selected ones. Any such modifications of a priori standard errors must be justified in the adjustment report.

(5) Changing the magnitude of the input standard errors/weights will not change the adjusted position or residual results in a free adjustment provided all weight changes are made equally. Although the reference variance will change, the resultant precisions (relative line accuracies) will not change. (This is not true in a constrained adjustment.) Therefore, the internal accuracy of a survey can be assessed based on the free adjustment line accuracies regardless of the initial weighting or variance of unit weight.

(6) The magnitude of the residual corrections shown in the sample adjustments may be assessed by looking for blunders or outliers; however, this assessment should be performed in conjunction with the related normalized residual (FILLNET) or standardized residual (Geo-Lab) statistic. This statistic is obtained by multiplying the residual by the square root of the input weight (the inverse of the square of the standard error). If the observations are properly weighted, the normalized residuals should be around 1.0. Most adjustment software will flag normalized residuals which exceed selected statistical outlier tests. Such flagged normalized residuals are candidates for rejection. A rule-of-thumb reject criterion should be set at three times the standard error of unit weight, again provided that the standard error of unit weight is within the acceptable range given in (3) above. All rejected GPS observations must be justified in the adjustment report clearly describing the test used to remove the observation from the file.

(7) Error ellipses, or 3D error ellipsoids, generated from the adjustment variance-covariance matrices for each adjusted point in Geo-Lab are also useful in depicting the relative positional accuracy. The scale of the ellipse may be varied as a function of the 2D deviation. Usually a 2.45- , or 95 percent, probability ellipse is selected for output. The size of the error ellipse will give an indication of positional reliability, and the critical relative distance/azimuth accuracy estimate between two adjacent points is a direct function of the size of these positional ellipses.

(8) The relative distance accuracy estimates (i.e., relative station confidence limits in Geo-Lab and estimates of precision in FILLNET) are used to evaluate acceptability of a survey. This is done using a free adjustment. The output is shown as a ratio (FILLNET) or in parts per million (Geo-Lab). Note that FILLNET uses a 1- line accuracy. The resultant ratios must be divided by 2 in order to equate them to FGCS 95 percent criteria. Geo-Lab is set to default to the 95 percent level.

(9) Further details on these statistical evaluations are beyond the scope of this manual. Technical references listed under paragraph A-1 should be consulted.

g. The following is a summary of a network adjustment sequence recommended by the NGS for surveys which are connected with the NGRS:

(1) A minimally constrained 3D adjustment is done initially as a tool to validate the data, check for blunders and systematic errors, and to look at the internal consistency of the network.

(2) A 3D horizontal constrained adjustment is performed holding all previously published horizontal control points fixed and one height constraint. If the fit is poor, then a readjustment is considered. All previous observations determining the readjusted stations are considered in the adjustment.

(3) A fully constrained vertical adjustment is made to determine the orthometric heights. All previously published benchmark elevations are held fixed along with one horizontal position in a 3D adjustment. Geoid heights are predicted using the latest model.

(4) A final free adjustment is performed in which relative accuracy estimates are computed.

11-13. Evaluation of Adjustment Results

A survey shall be classified based on its horizontal point closure ratio, as indicated in Table 11-1 or the vertical elevation difference closure standard given in Table 11-2.

Table 11-1
USACE Point Closure Standards for Horizontal Control Surveys

USACE Classification	Point Closure Standard (Ratio)
Second Order Class I	1:50,000
Second Order Class II	1:20,000
Third Order Class I	1:10,000
Third Order Class II	1: 5,000
4th Order - Construction Layout	1: 2,500 - 1:20:000

Table 11-2
USACE Point Closure Standards for Vertical Control Surveys

USACE Classification	Point Closure Standard (mm)
Second Order Class I	6mm$\sqrt{K}$
Second Order Class II	8mm$\sqrt{K}$
Third Order	12mm$\sqrt{K}$
4th Order - Construction Layout	24mm$\sqrt{K}$

($\sqrt{K}$ is square root of distance K in kilometers)

a. Horizontal control standards. The horizontal point closure is determined by dividing the linear distance misclosure of the survey into the overall circuit length of a traverse, loop, or network line/circuit. When independent directions or angles are observed, as on a conventional survey (i.e., traverse, trilateration, or triangulation), these angular misclosures may optionally be distributed before assessing positional misclosure. In cases where GPS vectors are measured in geocentric coordinates, then the 3D positional misclosure is assessed.

(1) Approximate surveying. Approximate surveying work should be classified based on the survey's estimated or observed positional errors. This would include absolute GPS and some differential GPS techniques with positional accuracies ranging from 10 to 150 ft (2DRMS). There is no order classification for such approximate work.

(2) Higher order surveys. Requirements for relative line accuracies exceeding 1:50,000 are rare for most USACE applications. Surveys requiring accuracies of First-Order (1:100,000) or better should be performed using FGCS standards and specifications, and must be adjusted by the NGS.

(3) Construction layout or grade control (Fourth-Order). This classification is intended to cover temporary control used for alignment, grading, and measurement of various types of construction, and some local site plan topographic mapping or photo mapping control work. Accuracy standards will vary with the type of construction. Lower accuracies (1:2,500 - 1:5,000) are acceptable for earthwork, dredging, embankment, beach fill, and levee alignment stakeout and grading, and some site plan, curb and gutter, utility building foundation, sidewalk, and small roadway stakeout. Moderate accuracies (1:5,000) are used in most pipeline, sewer, culvert, catch basin, and manhole stakeout, and for general residential building foundation and footing construction, major highway pavement, and concrete runway stakeout work. Somewhat higher accuracies (1:10,000 - 1:20,000) are used for aligning longer bridge spans, tunnels, and large commercial structures. For extensive bridge or tunnel projects, 1:50,000 or even 1:100,000 relative accuracy alignment work may be required. Vertical grade is usually observed to the nearest 0.005 m for most construction work, although 0.04-m accuracy is sufficient for riprap placement, grading, and small-diameter-pipe placement. Construction control points are typically marked by semi-permanent or temporary monuments (e.g., plastic hubs, P-K nails, wooden grade stakes). Control may be established by short, nonredundant spur shots, using total stations or GPS, or by single traverse runs between two existing permanent control points. Positional accuracy

will be commensurate with, and relative to, that of the existing point(s) from which the new point is established.

b. Vertical control standards. The vertical accuracy of a survey is determined by the elevation misclosure within a level section or level loop. For conventional differential or trigonometric leveling, section or loop misclosures (in millimeters) shall not exceed the limits shown in Table 11-2, where the line or circuit length (K) is measured in kilometers. Fourth-Order accuracies are intended for construction layout grading work. Procedural specifications or restrictions pertaining to vertical control surveying methods or equipment should not be over-restrictive.

11-14. Final Adjustment Reports and Submittals

a. A variety of free and/or constrained adjustment combinations may be specified for a contracted GPS survey. Specific stations to be held fixed may be indicated or a contractor may be instructed to determine the optimum adjustment, including appropriate weighting for constrained points. When fixed stations are to be partially constrained, then appropriate statistical information must be provided--either variance-covariance matrices or relative positional accuracy estimates which may be converted into approximate variance-covariance matrices in the constrained adjustment. All rejected observations will be clearly indicated, along with the criteria/reason used in the rejection.

b. When different combinations of constrained adjustments are performed due to indications of one or more fixed stations causing undue biasing of the data, an analysis shall be made as to a recommended solution which provides the best fit for the network. Any fixed control points which should be readjusted to anomalies from the adjustment(s) should be clearly indicated in a final analysis recommendation.

c. The final adjusted horizontal and/or vertical coordinate values shall be assigned an accuracy classification based on the adjustment statistical results. This classification shall include both the resultant geodetic/Cartesian coordinates and the baseline differential results. The final adjusted coordinates shall state the 95 percent confidence region of each point and the accuracy in parts per million between all points in the network. The datum and/or SPCS will be clearly identified for all coordinate listings.

d. Final report coordinate listings may be required on hard copy as well as on a specified computer media.

e. It is recommended that a scaled plot be submitted with the adjustment report showing the proper locations and designations of all stations established.

Chapter 12
Estimating Costs for Contracted GPS Surveys

12-1. General

Developing cost estimates for GPS surveys is not markedly different from estimating conventional traverse or topographic mapping surveys. Similar production factors directly affect the ultimate cost: number of available GPS receiver units, daily productivity rates, survey accuracy criteria, network redundancy requirements, and required observation time per station. These factors are discussed in detail in previous chapters of this manual. Once the number of GPS observations for a given project has been determined, then the total field survey time and subsequent costs can be computed. Office data reduction and adjustment functions are performed and cost estimated identically to that of conventional survey work. The explanations herein regarding procurement policies and practices describe only the framework within which cost estimates are used. For detailed guidance on procurement policies and practices, refer to the appropriate procurement regulations.

12-2. Hired Labor Surveys

Developing cost estimates for USACE field forces engaged in GPS surveys is performed similarly to that of conventional topographic survey work. Normally, an average daily rate of personnel, travel, per diem, and equipment is established. The GPS instrumentation rental rate is established at the time of purchase and is periodically updated based on actual utilization rates as charged against projects. Fringes, technical indirect, and direct overhead costs are added to a field crew's direct labor. The GPS survey crew rate should be recomputed at least annually, or more often if GPS instrumentation and other plant rental rates change significantly.

12-3. Contracted GPS Survey Services

In accordance with current laws and regulations, GPS surveying services must be procured using qualification-based selection procedures in accordance with PL 92-582 (Brooks Act). GPS services may be included as part of a fixed-price (single project scope) A-E design contract or included as a line item on an indefinite delivery type (IDT) surveying and mapping A-E contract. In some instances, a fixed-scope GPS service contract may be issued. In all cases, GPS surveying services will be negotiated as part of the A-E selection process; therefore, a Government cost estimate for these services must be prepared in advance of formal negotiations with the contractor.

a. Contract types. Fixed-scope GPS service contracts are not common; in most cases, USACE Commands obtain GPS services via the IDT contracting methods. One or more delivery orders may be placed against the IDT contract for specific projects. An overall contract threshold is established--currently $750,000 per year/contract; thus, the accumulation of individual orders cannot exceed this limit. Individual orders placed against the basic contract are normally limited to $150,000. The term of an IDT contract is usually set at 1 year; however, an option for year extensions may be authorized. Separate project scopes are written and negotiated for each order. The unit prices established in the basic IDT contract are used as a basis for estimating and negotiating each delivery order. The basic unit prices (U/P) in an IDT contract are established as part of the A-E acquisition and negotiation process; therefore, a Government cost estimate for these services must be prepared in advance of formal negotiations with the contractor. These basic unit prices must adequately represent the anticipated work over the course of the IDT contract--typically a 1-year period. (Separate rates are negotiated for additional option years.) Deficiencies in these unit rates will impact subsequent delivery order negotiations.

b. Unit price basis. A number of methods are used for scheduling GPS services in a fixed-price or IDT contract. The daily rate basis is the cost for a GPS field crew (including all instrumentation, transport, travel, and overhead) over a nominal 8-hr day. This rate method is normally used only on IDT contracts. This pricing method has advantages and drawbacks which need to be considered prior to determining.

(1) A daily crew rate estimating basis is the preferred unit price basis in estimating contracted GPS services for both fixed-price and IDT contracts. It provides the most flexibility for IDT contracts, especially when individual project scopes are expected to vary widely. It is, therefore, considered a more accurate method of determining costs for individual delivery orders. One disadvantage is that a detailed independent government estimate (IGE) must be developed for each delivery order placed against an IDT contract.

(2) The daily rate for a GPS surveying crew must be estimated using the following USACE-directed detailed

analysis method. The crew personnel size, number of GPS receivers deployed, vehicles, etc., must be explicitly indicated in the contract specifications, with differences resolved during negotiations. Options to add additional GPS receiver units (along with personnel and/or transport) must be accounted for in the estimate and unit price schedule. The seven-item breakdown for estimating costs is listed in Table 12-1.

Table 12-1
Factors for Estimating Costs

Item	Description
I	Direct labor or salary costs of GPS survey technicians: includes applicable overtime or other differentials necessitated by the observing schedule.
II	Overhead on Direct Labor.
III	G&A Overhead Costs (on Direct Labor).
IV	Material Costs.[1]
V	Travel and Transportation Costs: crew travel, per diem, etc. Includes all associated costs of vehicles used to transport GPS receivers.[1]
VI	Other Costs: includes survey equipment and instrumentation, such as GPS receivers. GPS receiver costs should be amortized down to a daily rate, based on average utilization rates, expected life, etc. Exclude all instrumentation and plant costs covered under G&A, such as interest.[1]
VII	Profit (To be computed/negotiated on individual delivery orders per EFARS Part 15).

1. Government audit must confirm if any of these direct costs are included in overhead.

(3) A typical contract price schedule using the daily rate basis is shown in Table 12-2. This schedule may be modified as necessary to reflect larger GPS receiver and personnel inventories.

(4) Another advantage of a daily rate basis unit of measure (U/M) is that it is not dependent on the type or order of accuracy of the GPS survey being performed. Either static or kinematic GPS surveys can be estimated and negotiated using this cost basis.

12-4. Verification of Contractor Cost or Pricing Data

Regardless of the cost rate method used, it is essential (but not always required) that a cost analysis, price analysis, and field pricing support audit be employed to verify all cost or pricing data submitted by a contractor, in particular, actual GPS instrumentation utilization rates and reduced costs per day. GPS equipment and instrumentation costs represent a major portion of a field crew's costs, and these cost rates are currently extremely variable. Some GPS operation and maintenance costs may be direct, or portions may be indirectly included in a firm's General and Administrative (G&A) overhead account. In some instances, a firm may lease/rent GPS equipment in lieu of purchase. Rental rates average 10 to 15 percent per month of the purchase cost, or $4,000 to $6,000 per month (1994). Rental would be economically justified only on limited scope projects and if the equipment is deployed on a full-time basis. Whether the GPS equipment is rented or purchased, the primary (and most variable) factor is the GPS equipment's actual utilization rate, or number of actual billing days to clients over a year. Only a detailed audit and cost analysis can establish such rates and justify modifications to the usually rough assumptions used in the IGE. In addition, an audit will establish any nonproductive labor/costs which are transferred to a contractor's G&A. Given the highly changing equipment costs and utilization rates in this new technology, failure to perform a detailed cost analysis and field pricing support audit on contracted GPS services will make the IGE difficult to substantiate.

12-5. Sample Cost Estimate for Contracted GPS Survey Services

The following cost computation is representative of the procedure used in preparing the IGE for an A-E contract. It is developed for a two-receiver, two-man, two-vehicle GPS field survey crew and based on a standard 8-hr workday. Larger crew/receiver size estimates would be performed similarly. Costs and overhead percentages are shown for illustration only--they are subject to considerable geographic-, project-, and contractor-dependent variation (e.g., audited G&A rates could range from 50 to 200 percent). GPS instrumentation rates are approximate (1994) costs. Associated costs for GPS receivers, such as insurance, maintenance contracts, interest, etc., are presumed to be indirectly factored into a firm's G&A overhead account. If not, then such costs must be directly added to the basic equipment depreciation rates shown. Other equally acceptable accounting methods for developing daily costs of equipment may be used. Equipment utilization estimates in an IGE must be subsequently revised (during negotiations) based on actual rates as determined from a detailed cost analysis and field price support audits.

Table 12-2
Daily Rate Basis Contract Schedule

Item	Description	Quan	U/M	U/P	Amount
0001	Registered/Licensed Land Surveyor -- Office	[1]	Day		
0002	Registered/Licensed Land Surveyor	[1]	Day		
0003	Civil Engineering Technician -- Field Party Supervisor (Multiple Crews)	[1]	Day		
0004	Engineering Technician (Draftsman) -- Office	[1]	Day		
0005	Supervisory GPS Survey Technician (Field)	[1]	Day		
0006	Surveying Technician -- GPS Instrumentman/Recorder	[1]	Day		
0007	Surveying Aid -- Rodman/Chainman {Conventional Surveys}	[1]	Day		
0008	[Two][Three][Four][___]- Man GPS Survey Party				
	[___] GPS Receiver(s)				
	[___] Vehicle(s)				
	[___] Computer(s)				
0009	Additional GPS Receiver	[1]	Day		
	{Add Item 0006 Observers as Necessary}	[1]	Day		
0010	Station Monuments [Disk Type] [Construction Materials]	[1]	EA		
0011	Professional Geodesist Computer (office)	[1]	Day		
0012					
0013					

a. *Basic daily crew rate cost estimate.*

(1) Direct Labor.

Supervisory Survey Technician (GPS Observer) @ $20,000/year or $77/day
Survey Technician @ $16,000/year or $62/day

Total direct labor: $139/day

(2) Overhead on direct labor:

@ 30% of direct labor $42/day

(3) G&A overhead:

@ 100% of direct labor $139/day

(4) Materials and supplies: $20/day

(5) Travel and transportation expenses:

Vehicle depreciation:
$17K base @ 5 years @ 220 days/year $15/day

Operation and maintenance (fuel, oil, etc.) $15/day

Total: Two vehicles @ $30/day ea $60/day

Per Diem: average assumed for IDT locale; rate not to exceed published General Services Administration (GSA)/Joint Travel Regulation (JTR) levels

Total: Two men @ $50/day each $100/day

(6) Other costs:

(Miscellaneous survey instrumentation/equipment, tools and equipment (T&E), etc., normally included in G&A overhead.)

GPS receivers (2 each) plus 386-based field computer

Receivers: 2 @ $20K ea $40,000
Computer + software: $10,000
Total: $50,000

5-year depreciation base --
assumed average utilization
of 200 days per year with
maintenance included in G&A rate

Total: $50K @ 5 years @ $200/day) $50/day

(7) Profit: Profit is not computed on the basic contract but is determined for each separate order based on the guidance contained in Part 15 of the EFARS.

Total Estimated Rate:	$550/day

b. Additional GPS receiver.

Direct Labor (Survey Technician)	$62/day
Overhead on direct labor @ 30%	$19/day
G&A @ 100%	$62/day
Material and supplies	$5/day
Travel and transportation:	
Vehicle	$30/day
Per diem	$50/day
Other costs: GPS Receiver	
One receiver $20K @ 5 years @ 200 days/year	$20/day
Total:	$248/day

c. Travel and per diem. The contract schedule must equitably account for actual travel and per diem expenses if a constant temporary duty locale is not involved, or if the per diem rate varies considerably from that estimated for an IDT contract. Some USACE Commands include crew per diem as a separate line item on the schedule or develop a schedule containing local and travel crew rates.

d. Delivery orders. Since unit prices (either daily rates or work unit rates) have been established in the basic contract, each such delivery order is negotiated strictly for effort. The negotiated fee on a delivery order is then a straight mathematical procedure of multiplying the agreed-upon effort (time or unit of measure quantity) against the unit prices, plus an allowance for profit. Thus, an IGE is required for each order placed, along with a detailed profit computation, documented records of negotiations, etc. The scope is attached to a DD 1155 order placed against the basic contract. The process for estimating the time to perform any particular survey function, in a given project, is totally dependent upon the knowledge and personal field experience of the Government estimator.

Appendix A
References

A-1. Required Publications

Public Law 92-582
Public Law 92-582 (86 STAT. 1278), Public Buildings-Selection of Architects and Engineers

EP 25-1-1
Index of Publications, Forms, and Reports

EM 1110-1-1000
Photogrammetric Mapping

EM 1110-1-1002
Survey Markers and Monumentation

EM 1110-1-1004
Deformation Monitoring and Control Surveying

EM 1110-2-1003
Hydrographic Surveying

[1]CW 01332
Civil Works Construction Guide Specifications for Survey Markers and Monumentation

[1]CW 16701
Civil Works Construction Guide Specifications for Procurement of NAVSTAR Global Positioning System (GPS) and Related Instrumentation/Equipment

[1]CW 16702
Civil Works Construction Guide Specifications for Procurement of Real-Time Differential NAVSTAR Global Positioning System (DGPS)

American Society for Photogrammetry and Remote Sensing 1989
American Society for Photogrammetry and Remote Sensing. 1989. "ASPRS Accuracy Standards for Large-Scale Maps," *Photogrammetric Engineering and Remote Sensing*, 1068 and 1070.

[1]Reference published by Department of Army and available through USACE Command Information Management Office sources.

A-2. Related Publications

Section I
Documents Available from NGS

The National Geodetic Survey (NGS) performs research and development into precise positioning using GPS. NGS publishes the following publications and papers which discuss GPS and may be of help to the surveyor. The surveyor can inquire about the availability of these documents by contacting NOAA, National Geodetic Information Center, 1315 East West Highway, Silver Spring, MD, 20910.

Bossler and Challstrom 1985
Bossler, J. D., and Challstrom, C. W. 1985. *GPS instrumentation and federal policy*.

Bureau of the Budget 1947
Bureau of the Budget. 1947 (17 June). *United States national map accuracy standards*.

Department of Defense 1987
Department of Defense. 1987. "Department of Defense World Geodetic System 1984 - its definition and relationships with local geodetic systems," DMA Technical Report 8350.2.

Federal Geodetic Control Committee 1984
Federal Geodetic Control Committee. 1984. *Standards and specifications for geodetic control networks*. Rockville, MD.

Federal Geodetic Control Committee 1988
Federal Geodetic Control Committee. 1988 (Reprinted with Corrections: 1 Aug 1989). *Geometric geodetic accuracy standards and specifications for using GPS relative positioning techniques (Preliminary)*. Rockville, MD.

Global Positioning System Subcommission 1989
Global Positioning System Subcommission. 1989 (January-February). *GPS Bulletin*, Commission VIII, International Association of Geodesy/International Union of Geodesy and Geophysics, 2.(1).

Goad 1985
Goad, C. C. 1985. *Precise relative position determination using global positioning system carrier phase measurements in a nondifference mode*.

Hein 1985
Hein, G. W. 1985. "Orthometric height determination using GPS observations and the integrated adjustment model," NOAA Technical Report NOS 110 NGS-32, National Oceanic and Atmospheric Administration.

Hothem and Fronczek 1983
Hothem, L. D., and Fronczek, C. J. 1983. "Report on test and demonstration of macrometer model V-1000 interferometric surveyor," Federal Geodetic Control Committee.

Hothem and Williams 1985
Hothem, L. D., and Williams, G. E. 1985. *Factors to be considered in development of specifications for geodetic surveys using relative positioning GPS techniques.*

Hothem, Goad, and Remondi 1984
Hothem, L. D., Goad, C. C., and Remondi, B. W. 1984. *GPS satellite surveying - practical aspects.*

Kass and Dulaney 1986
Kass, W. G., and Dulaney, R. 1986. *Procedures for processing GPS phase observations at the National Geodetic Survey.*

Lucas and Mader 1988
Lucas, J. R., and Mader, G. L. 1988. *Recent advances in kinematic GPS photogrammetry.*

Mader 1986
Mader, G. L. 1986. *Decimeter precision aircraft positioning using GPS carrier phase.*

Mader and Abell 1985
Mader, G. L., and Abell, M. D. 1985. *A comparison between global positioning system and very long baseline interferometry surveys in Alaska and Canada.*

Milbert 1985a
Milbert, D. G. 1985a. *Application of the variance factor test to a global positioning system survey.*

Milbert 1985b
Milbert, D. G. 1985b. *Preliminary analysis of an operational global position system control survey.*

Milbert 1988
Milbert, D. G. 1988. *Network adjustment of correlated coordinate difference observations.*

Minke 1988
Minke, D. H. 1988. *Kinematic GPS land survey--description of operational test and results.*

National Geodetic Information Center 1989
National Geodetic Information Center. 1989 (revised). "Documents available on GPS," Information Flyer 86-1, National Oceanic and Atmospheric Administration.

National Geodetic Survey 1986
National Geodetic Survey. 1986. *Geodetic glossary.*

National Geodetic Survey 1988
National Geodetic Survey. 1988. *Guidelines for submitting GPS relative positioning data to the national geodetic survey*, Rockville, MD.

National Oceanic and Atmospheric Administration 1988
National Oceanic and Atmospheric Administration. 1988. National Geodetic Survey state plane coordinate manual NAD 1983.

Remondi 1984
Remondi, B. W. 1984. "Using the global positioning system (GPS) phase observable for relative geodesy: modeling, processing, and results," Ph.D diss., University of Texas.

Remondi 1985a
Remondi, B. W. 1985a. *Global positioning system carrier phase: description and use.*

Remondi 1985b
Remondi, B. W. 1985b. *Modeling the GPS carrier phase for geodetic applications.*

Remondi 1985c
Remondi, B. W. 1985c. "Performing centimeter-level surveys in seconds with GPS carrier phase: initial results," NOAA Technical Memorandum NOS NGS-43, National Oceanic and Atmospheric Administration.

Remondi 1986
Remondi, B. W. 1986. "Distribution of global positioning system ephemerides by the National Geodetic Survey." ACSM spring meeting, March 1986.

Remondi 1991
Remondi, B. W. 1991. "Kinematic GPS results without static initialization," NOAA Technical Memorandum NOS NGS-55.

Remondi 1992a
Remondi, B. W. 1992a. "Real-time centimeter-accuracy without static initialization." *Sixth International Geodetic Symposium on Satellite Positioning, Columbus, Ohio*.

Remondi 1992b
Remondi, B. W. 1992b. "Real-time centimeter-accuracy while in motion (warm start versus cold start)." *5th International Technical Meeting ION GPS-92, Albuquerque, New Mexico*.

Remondi and Hofmann-Wellenhof 1989
Remondi, B. W., and Hofmann-Wellenhof, B. 1989. *Accuracy of global positioning system broadcast orbits from relative surveys*.

Snay 1986
Snay R. A. 1986. *Network design strategies applicable to GPS surveys using three or four receivers*.

Soler and Hothem 1988
Soler, T., and Hothem, L. 1988. "Coordinate systems used in geodesy - basic definitions and concepts," *Journal on Surveying and Engineering, American Society of Civil Engineers.*

Soler, Hothem, and Fury 1986
Soler, T., Hothem, L. D., and Fury, R. J. 1986. *Precise geodetic surveying with code and carrier phase tracking GPS receivers*.

Stenn 1989
Stenn, James E. 1989. "The State Plane Coordinate System of 1983," NOAA Manual NOS NGS 5, National Oceanic and Atmospheric Administration.

Strange 1985
Strange, W. E. 1985. *High-precision three-dimensional differential positioning using GPS*.

Zilkoski 1990a
Zilkoski, David B. 1990a. "Establishing vertical control using GPS satellite surveys." *Proceedings of the 19th International Federation of Surveying Congress*. National Geodetic Survey.

Zilkoski 1990b
Zilkoski, David B. 1990b. "Minimum steps required when estimating GPS-derived orthometric heights." *Proceedings of the Fall GIS/LIS 1990 Convention*.

Zilkoski and Hothem 1989
Zilkoski, David B., and Hothem, Larry D. 1989. "GPS satellite surveys and vertical control," *Journal of Surveying Engineering*.

Section II
Other Sources

There are also several books and relatively inexpensive publications published by companies and agencies other than NOAA that may be used as general reference sources on GPS:

Burkhard, Richard K., et al. 1983. "Geodesy for the Layman," Defense Mapping Agency (DMA). Available from DMA, Aerospace Center, St. Louis AFS, MO 63118. This text presents the basic principles of geodesy in an elementary form. The formation of geodetic datums is introduced, and the necessity of connecting or joining datums is discussed. Methods used to connect independent geodetic systems to a single world reference system are discussed including the role of gravity data. There is also a discussion of satellite and related technological applications to geodesy and the World Geodetic System.

Canadian GPS Associates. 1987. "Guide to GPS Positioning," Fredericton, New Brunswick, Canada. Available from L. Hothem, 7563 Spring Lake Drive, Bethesda, MD 20817, U.S. $35.00 each (includes ONLY 4th class postage to U.S. addresses). This text is primarily an introduction of the basic concepts of GPS, rather than an explanation of the details of the latest research results. Subjects covered include a simplified description of GPS, GPS data collection and processing, applications, as well as GPS receivers.

Leick and Lambert 1990
Leick, Alfred, and Lambert, Steven. 1990. *GPS satellite surveying*. John Wiley, New York.

Mikhail and Ackermann 1976
Mikhail, Edward M., and Ackermann, Friedrich E. 1976. *Observations and least-squares*. IEP Series in Civil Engineering, New York.

Photogrammetry for Highways Committee 1968
Photogrammetry for Highways Committee. 1968. "Reference guide outline: specifications for aerial surveys and mapping by photogrammetric methods for highways," U.S. Department of Transportation, Washington, DC.

Scherrer, Rene 1985. "The WM GPS primer." Available from Geodesy Marketing, Wild Heerbrugg Instruments, Inc., 40 Technology Park/Atlanta, Norcross, GA 30092. Telephone: 800-FOR-WILD. Single copy cost: Free. This text details basic information on GPS satellite surveying, highlighting the WM101 receiver and its post-processing software, PoPS.

Trimble Navigation, Ltd., 1989, 1991, 1992
"GPS: A guide to the next utility," 1989, "GPS: field surveyor's guide, a field guidebook to static surveying," 1991, and "GPS: field surveyor's guide, a field guidebook for dynamic surveying," 1992. Available from Trimble Navigation, Ltd., 645 North Mary Avenue, Sunnyvale, CA 94088-3642. Telephone: (408) 730-2900. A fine basic overview of GPS, its operation, and processing detail.

Appendix B
Glossary

B-1. Abbreviations

A-E . . . . . Architect-Engineer
A-S . . . . . Anti-Spoofing
ASPRS . . . . . American Society for Photogrammetry and Remote Sensing
BIH . . . . . Bureau International Heure
C/A-code . . . . . Coarse Acquisition Code (for additional information, see paragraph B-2)
CDC . . . . . Consecutive Doppler Counts
CDMS . . . . . Continuous Deformation Monitoring System
CEP . . . . . circular error probable
CID . . . . . Continuously Integrated Doppler
CONUS . . . . . Continental United States
CTP . . . . . Conventional Terrestrial Pole
CW . . . . . Civil Works
DGPS . . . . . Differential GPS
DoD . . . . . Department of Defense
DOP . . . . . Dilution of Precision (for additional information, see paragraph B-2)
E&D . . . . . engineering and design
ECC . . . . . estimated construction cost
ECDIS . . . . . Electronic Chart Display Information System
ECEF . . . . . earth centered earth fixed
EDM . . . . . electronic distance measurement
EFARS . . . . . Engineer Federal Acquisition Regulation Supplement
FGCC . . . . . Federal Geodetic Control Committee
FGCS . . . . . Federal Geodetic Control Subcommittee
FRNP . . . . . Federal Radio Navigation Plan
FY . . . . . Fiscal Year
G&A . . . . . General & Administrative (overhead)
GCP . . . . . GPS Controlled Photogrammetry
GDOP . . . . . Geometric dilution of precision (for additional information, see *Dilution of Precision* in paragraph B-2)
GIS . . . . . Geographic Information System
GPS . . . . . Global Positioning System (for additional information, see paragraph B-2)
GRS 80 . . . . . Geodetic Reference System of 1980 reference ellipsoid (for additional information, see *Ellipsoid* in paragraph B-2)
HARNS . . . . . High Accuracy Reference Networks
HDOP . . . . . Horizontal dilution of precision (for additional information, see *Dilution of Precision* in paragraph B-2)
HI . . . . . height of instrument
IDT . . . . . indefinite delivery type
IGE . . . . . independent government estimate
IGLD 55 . . . . . International Great Lakes Datum of 1955 (for additional information, see *Datum* in paragraph B-2)
IGLD 85 . . . . . International Great Lakes Datum of 1985
IID . . . . . Intermittently Integrated Doppler (for additional information, see *Integrated Doppler* in paragraph B-2)
JPO . . . . . Joint Program Office MRSE
. . . . . mean radial spherical error MSC . . .
. . . . . Major Subordinate Command
NAD 27 . . . . . North American Datum of 1927 (for additional information, see *Datum* in paragraph B-2)
NAD 83 . . . . . North American Datum of 1983 (for additional information, see *Datum* in paragraph B-2)
NATO . . . . . North Atlantic Treaty Organization
NAVD 88 . . . . . North American Vertical Datum of 1988
NAVSTAR . . . . . NAVigation Satellite Timing and Ranging
NGRS . . . . . National Geodetic Reference System
NGS . . . . . National Geodetic Survey
NGVD 29 . . . . . National Geodetic Vertical Datum of 1929 (for additional information, see *Datum* in paragraph B-2)
NMEA . . . . . National Maritime Electronics Association
NOAA . . . . . National Oceanic and Atmospheric Administration
NOS . . . . . National Ocean Service
OCONUS . . . . . Outside the Continental United States
OTF . . . . . On-The-Fly
PC . . . . . personal computer
P-code . . . . . Precise Code (for additional information, see paragraph B-2)

PDOP . . . . . Positional Dilution of Precision (for additional information, see *Dilution of Precision* in paragraph B-2)
PLGR . . . . . precise lightweight GPS receiver
PPS . . . . . Precise Positioning Service (for additional information, see paragraph B-2)
PRC . . . . . pseudo-range correction
PRN . . . . . Pseudo-random noise
RINEX . . . . . Receiver INdependent EXchange
RDOP . . . . . Relative Dilution of Precision (for additional information, see *Dilution of Precision* in paragraph B-2)
RMS . . . . . root mean square
RTCM . . . . . Radio Technical Commission for Maritime Services
RTK . . . . . Real-Time Kinematic
S/A . . . . . selective availability (for additional information, see paragraph B-2)
SEP . . . . . spherical error probable
SPCS . . . . . State Plane Coordinate System (for additional information, see *Datum* in paragraph B-2)
SPCS 27 . . . . . State Plane Coordinate System of 1927 (for additional information, see *Datum* in paragraph B-2)
SPS . . . . . Standard Positioning Service (for additional information, see paragraph B-2)
TBM . . . . . temporary benchmark
3D . . . . . three-dimensional
2D . . . . . two-dimensional
2DRMS . . . . . two standard deviation root mean square
U/M . . . . . unit of measure
U/P . . . . . unit price
UERE . . . . . user equivalent range error (for additional information, see paragraph B-2)
USACE . . . . . U.S. Army Corps of Engineers
USATEC . . . . . U.S. Army Topographic Engineering Center
USCG . . . . . U.S. Coast Guard
USGS . . . . . U.S. Geological Survey
UTC . . . . . Universal Time Coordinated
VDOP . . . . . Vertical dilution of precision (for additional information, see *Dilution of Precision* in paragraph B-2)
WGS 84 . . . . . World Geodetic System of 1984 reference ellipsoid (for additional information, see *Ellipsoid* in paragraph B-2)

B-2. Terms

Absolute Positioning
The unique ability of a GPS receiver to produce positional values without another receiver for reference.

Ambiguity
The unknown number of whole carrier wavelengths between the satellite and the receiver. Also called **cycle ambiguity**.

Anti-spoofing (A-S)
An encryption technique developed by the U.S. Department of Defense (DoD) that when implemented, denies access to the P-code by any unauthorized users. With anti-spoofing on, the user will need a DoD-issued "key" in order to gain access to the P-code.

Anywhere Fix
Receiver with unique ability to calculate positions without being given an approximate location and time.

Apogee
The point in the orbit of a satellite about the earth that is the greatest distance from the center of the earth.

Auto-correlation
In reference to code, a plot of the scaler product of the noise sequence with a delayed copy of itself.

Bandwidth
A measure of the width of the frequency spectrum of a signal expressed in Hertz.

Baseline
The resultant three-dimensional vector V between any two stations from which simultaneous GPS data have been collected and processed. Generally given in earth-centered Cartesian coordinates where:

$$V = (x, \quad y, \quad z)$$

Beat Frequency
Either of the two additional frequencies obtained when two signals of two frequencies are mixed, equal to the sum or difference of the original frequencies.

Binary Biphase Modulation
Phase changes on a constant frequency carrier of either 0 or 180 deg. These represent the binary digits 0 and 1, respectively.

Binary Code
A system used in communication where selected strings of 0's and 1's are assigned definite meanings.

Binary Pulse Code Modulation
A two-state pulse modulation using a string of binary numbers or codes. The coding is generally represented by 1 and 0 with definite meanings attached to each.

Broadcast Ephemeris
The ephemeris broadcast by the GPS satellites.

C/A-Code
The standard Coarse/Acquisition GPS code, sometimes referred to as the Clear Access Code, also known as the S- or Standard Code. This code contains a sequence of 1,023 pseudo-random binary biphase modulations on the GPS carrier at a chipping rate of 1.023 MHz, thus having a period of 1 ms.

Carrier
A high-frequency radio wave having at least one characteristic (frequency, amplitude, or phase) which may be varied by modulation from an accepted value. In general, the carrier wavelength is much shorter than the wavelength of the codes.

Carrier Beat Phase
The difference between the phase of the incoming Doppler shifted satellite carrier signal and the phase of the nominally constant reference frequency generated in the receiver.

Carrier Frequency
The frequency of the unmodulated fundamental output of a radio transmitter.

Carrier Phase
The phase measurement of the carrier wave. The percentage value is usually converted to millimeters.

Cartesian/Geocentric Coordinates
A system of defining position which has its origin at the center of the earth with the x- and y-axes in the plane of the equator. Typically, the x-axis passes through the meridian of Greenwich, and the z-axis coincides with the earth's axis of rotation. The three axes are mutually orthogonal and form a right-handed system.

Channel
A channel of a GPS receiver consists of the hardware and the software to track the signal from one satellite at one of the two carrier frequencies.

Chip
a. The minimum transition time interval for individual bits of either a 0 or a 1 in a binary pulse code, usually transmitted in a pseudo-random sequence. b. A tiny square piece of thin semiconductor material on which an integrated circuit is formed or to be formed.

Clock Bias
Difference between clock's indicated time and true universal time.

Code
A system for representing information, together with rules for using the system.

Codeless Receiver
An instrument that does not require a knowledge of the P- or C/A-codes to perform measurements. This type of receiver does not record any ephemeris data. Therefore, before a baseline solution is computed, an ephemeris file must be obtained from another source.

Code Receiver
An instrument that requires a knowledge of the P- or C/A-code to complete its measurements. This type of receiver will also record the broadcast ephemeris.

Collimate
To physically align a survey target or antenna over a mark.

Complete Instantaneous Phase Measurement
A measurement of carrier beat phase which includes the integer number of cycles of phase since the initial measurement. See *Fractional Instantaneous Phase Measurement; Integer-cycle Ambiguity*.

Control Points
A point to which coordinates have been assigned. These coordinates can then be held fixed and are used in other dependent surveys.

Control Segment
A worldwide network of GPS monitoring and control stations that ensure the accuracy of the GPS satellite orbits and operations of their atomic clocks. The original control segment consists of control facilities in Diego Garcia, Ascension Island, Kwajalein, and Hawaii, with a master control station at the Consolidated Space Operations Center (CSPOC) at Colorado Springs, Colorado.

Correlation Type Channel
A channel which uses a correlator to maintain alignment between a receiver generated code and/or carrier frequency and the incoming satellite code and/or carrier frequency.

Cycle Ambiguity
See **Ambiguity**.

Cycle Slip
A discontinuity in measured carrier beat phase resulting from a temporary loss of lock in the carrier tracking loop of a GPS receiver.

Datum
A horizontal or vertical reference system for making survey measurements and computations. Horizontal datums are typically referred to ellipsoids, the State Plane Coordinate System, or the Universal Transverse Mercator Grid System. Vertical datums are typically referred to the geoid. The vertical datum used in the United States is the National Geodetic Vertical Datum of 1929 (NGVD 29), formerly referred to as the Sea Level Datum of 1929. This datum will soon be upgraded to the North American Vertical Datum of 1988 (NAVD 88).

D-code (Data Message)
A 1,500-bit message included in the GPS signal which reports the satellite's location, clock corrections, and health. Included is rough information on the other satellites in the constellation.

Deflection of the Vertical
The angle between the perpendicular to the geoid (plumb line) and the perpendicular to an ellipsoid.

Delay Lock
A code correlation technique where the code received from a satellite is compared with "early" and "late" versions of the reference code generated by the receiver to obtain a bi-polar discrimination function.

Delta Pseudo-range
See *Reconstructed Carrier Phase.*

Differencing
A technique used in baseline processing to resolve the integer cycle ambiguity and to reduce a number of error sources including oscillator variations and atmospheric and orbital modeling errors. This technique "differences" the measurement of the carrier beat phase across time, frequency, receivers, satellites, or any combination of these. The most popular differences are described below:

A **single difference** between receivers is the instantaneous difference in the complete carrier beat phase measurements made at two receivers simultaneously observing the same signal.

A **double difference** between receivers and between satellites is found by differencing the single difference for one satellite with the single difference for another satellite where both single differences are from the same epoch.

A **triple difference** between receivers, between satellites, and between epochs (time) is the difference between a double difference at one epoch and the same double difference at the following epoch.

Differential Positioning
The determination of the position of an object station relative to a reference station when receivers at each station are simultaneously tracking the same signals.

Dilution of Precision (DOP)
A measure of the geometric contribution to the uncertainty of a position fix. The more popular terms are given below:

GDOP - Geometric Dilution of Precision - measurement accuracy in 3D position and time.

PDOP - Position Dilution of Precision (PDOP) - measurement accuracy in 3D position.

HDOP - Horizontal Dilution of Precision (HDOP) - measurement accuracy in 2D horizontal position.

VDOP - Vertical Dilution of Precision (VDOP) - measurement accuracy as standard deviation of vertical height.

RDOP - Relative Dilution of Precision (RDOP) - measurement of the quality of baseline reductions.

Doppler-aiding
Signal processing strategy that uses a measured Doppler shift to help the receiver smoothly track the GPS signal, allowing more precise velocity and position measurement.

Doppler Shift
The apparent change in frequency of a received signal due to the rate of change of the distance between the transmitter and receiver.

DSARC
Defense System Acquisition Review Council, the DoD body which must authorize any major defense system acquisition.

Dynamic Positioning
Determination of the position of a moving receiver such as one mounted in a boat. Generally, each set of coordinates are computed from a single data sample. The GPS was originally conceived for dynamic positioning of a single receiver; however, it may be used in a differential mode to increase relative accuracy. Also, referred to as **kinematic positioning**.

Eccentricity
The ratio of the distance from the center of an ellipse to its focus on the semimajor axis.

Elevation
The height of an object above some reference datum.

Ellipsoid
A geometric shape formed by revolving an ellipse about its minor axis. The term is used interchangeably with spheroid. An ellipsoid is defined by the length of its semimajor axis a and its flattening f, where:

$$f = (a - b)/a$$

and b = length of the semiminor axis.

The most commonly used ellipsoids in North America are:

Clarke 1866
Geodetic Reference System of 1980 (GRS 80)
World Geodetic System of 1972 (WGS 72)
World Geodetic System of 1984 (WGS 84)

Prior to January 1987, the GPS operated with reference to WGS 72. Since January 1987, it has been referenced to WGS 84. For most purposes, the GRS 80 and WGS 84 can be considered identical.

Ellipsoid Height
The elevation h of a point above or below the ellipsoid.

Ephemeris
A tabular statement of the positions of a celestial body (satellite) at regular intervals.

Epoch
A period of time or a date selected as a point of reference.

Fast Switching Channel
A switching channel with a time sequence short enough to recover the integer part of the carrier beat phase. The switching time is generally between 2 to 5 ms.

Flattening
See **Ellipsoid**.

Fractional Instantaneous Phase Measurement
A measurement of the carrier beat phase that does not include any integer cycle count.

Frequency Band
A range of frequencies in a region of the electromagnetic spectrum.

Frequency Spectrum
The distribution of signal amplitudes as a function of frequency of the constituent signal waves.

Fundamental Frequency
The GPS fundamental frequency F is 10.23 MHz. The carrier frequencies are:

L1 = 154 * F = 1575.42 MHz
L2 = 120 * F = 1227.60 MHz

Geoid
An equipotential surface approximating the earth's surface and corresponding with mean sea level in the oceans and its extension through the continents. In other words, the geoid would coincide with the surface to which the oceans would conform over the entire earth if the oceans were set free to adjust to the combined effect of the

earth's mass attraction and the centrifugal force of the earth's rotation.

Geodetic Leveling Network
A network of vertical control or benchmarks whose heights are known as accurately as possible, and whose horizontal positions are known only approximately.

Geoid Height
The elevation *N* of the geoid above or below the reference ellipsoid.

GPS
Global Positioning System. The GPS consists of the NAVSTAR satellites in six different orbits, five monitor stations, and the user community.

GPS Time
The broadcast GPS time signals are synchronized with atomic clocks at the GPS Master Control Station. These clocks are in turn periodically synchronized with Coordinated Universal Time (UTC). However, UTC is incremented by "leap seconds" to correct for the slowing of the earth's rotation with respect to the sun; GPS time is not. As of July 1990:

GPS time = UTC + 4 seconds

The fundamental time scale for all the earth's timekeeping is International Atomic Time (TAI). It is a continuous time scale not corrected by "leap seconds." There is a constant offset of 10 sec between GPS time and TAI such that:

GPS time = TAI - 10 sec

Handover Word
The word in the GPS message that contains time synchronization information for the transfer from the C/A-code to the P-code.

Horizontal Geodetic Network
A network for which the horizontal coordinate, latitude, and longitude of the control points in the network are determined as accurately as possible, and heights are known only approximately.

Independent Baseline
Those baselines that provide a unique position solution for a given station.

INS
Inertial Navigation System, which contains an Inertial Measurement Unit (IMU).

Integer-cycle Ambiguity
The unknown integer number of whole carrier cycles between the satellite and receiver.

Integrated Doppler
The accumulation of measured Doppler frequency multiplied by the time interval of measurement, so as to approximate the integral over time of the Doppler frequency.

Interferometry
See **Differential Positioning**.

Ionosphere
Region of the earth's atmosphere between the stratosphere and the exosphere approximately 50 to 250 miles above the surface of the earth.

Ionospheric Refraction Delay
A delay in the propagation of the GPS signal caused by the signal traveling through the ionosphere.

IRON
Inter Range Operation Number. A random number assigned to various orbiting objects assigned by the joint US/Canadian North American Air Defense Command (NORAD). Each of the GPS satellites has an individual IRON.

JPO
GPS Joint Program Office, originally located at the U.S. Air Force Space Division at El Segundo, California. The JPO consists of the US Air Force Program Manager and Deputy Program Managers representing the Army, Navy, Marine Corps, Coast Guard, Defense Mapping Agency, and NATO.

Kinematic Positioning
Often used to describe **dynamic positioning**. A GPS differential surveying technique, whereby one GPS unit, the fixed receiver, stays fixed on a known control point, while another GPS unit, the rover, collects data on a constantly moving vehicle, all the time continually tracking four or more satellites during the observation period. This process is done in an effort to ascertain the location or position of the rover receiver.

L-band
The radio frequency band from 390 MHz to 1550 MHz. The primary L-band signal radiated by each NAVSTAR satellite is L1 at 1575.42 MHz. The L1 beacon is modulated with the C/A- and P-codes, and with the NAV message. L2 is centered at 1227.50 MHz.

L1
See **L-band**.

L2
See **L-band**.

Lock
The state of noninterruption in the reception of a radio signal.

Monitor Station
One of five worldwide stations maintained by the DoD and used in the GPS control segment to monitor and control satellite clock and orbital parameters. Corrections are calculated and uploaded to each satellite at least once per day. See **Control Segment**.

Multichannel Receiver
A receiver containing multiple channels.

Multipath
A phenomenon similar to "ghosts" on a television screen whereby GPS signals from a satellite arrive at an antenna having traversed different paths. The signal traversing the longer path may have been reflected off one or more objects--the ground, a vehicle, boat, building or some other surface--and once received by the antenna, will yield a larger pseudo-range estimate and increase the error. Multipath usually results in **multipath error**.

Multipath Error
A positioning error resulting from radio signals travelling from the transmitter to the receiver by two paths of different electrical lengths.

Multiplexing Channel
A receiver channel that is sequenced through a number of satellite signals, each from a specific satellite.

NAV Data
The 1,500-bit NAVigation message broadcast by each satellite at 50 bps on both L1 and L2 beacons. This message contains system time, clock correction parameters, ionospheric delay model parameters, and the vehicle's ephemeris and health. This information is used to process GPS signals to obtain user position and velocity. Sometimes referred to as the **Navigation message**.

Navigation Message
See **NAV data**.

NAVSTAR
NAVigation Satellite Timing and Ranging. NAVSTAR is the name give to GPS satellites, originally manufactured by Rockwell International.

Observing Session
The period of time over which data are collected.

Orthometric Height
The elevation H of a point above or below the geoid. A relationship between ellipsoid heights and orthometric heights is obtained from the following equation:

$$h = H + N$$

where

h = ellipsoidal height

H = orthometric height

N = geoidal height

Outage
The period of time when a Dilution of Precision exceeds a specified maximum.

Perigee
The point in the orbit of a satellite about the earth that is the least distant from the center of the earth.

Phase Lock
The technique where the phase of a signal is set to replicate the phase of a reference signal by comparing the phase of the two signals and then using the resultant phase difference to adjust the reference oscillator to eliminate the difference.

Phase Measurement
A measurement, expressed as a percentage of a portion of a wave (e.g., a sine wave). For example, a complete wavelength is 100 percent; one-half is 50 percent; etc.

Phase Observable
See **Reconstructed Carrier Phase**.

Polar Plot
A circular plot in which elevation and azimuth as a function of time for each satellite, with respect to a specified location, are predicted and plotted.

Positioning
Determination of a position (usually a GPS antenna) with respect to a coordinate system (WGS 84, UTM, State Plane, etc.).

Precise Ephemeris
The ephemeris computed after the transmission of the satellite signal and based on satellite tracking information.

Precise or Protected Code (P-Code)
A sequence of pseudo-random binary biphase modulations on the GPS carrier at a chip rate of 10.23 MHz which repeats once every 267 days. Each 1-week segment of code is unique to a particular GPS satellite and is generally reset each week.

Precise Positioning Service (PPS)
Dynamic positioning of a single receiver based on the P-code. Currently, the PPS is the most accurate dynamic positioning service offered with GPS.

Pseudolite
A ground-based GPS station that can be used in a ranging solution. The station transmits a signal with a structure similar to that of an actual GPS satellite.

Pseudo-random Noise (PRN)
When used as a description of code, it indicates that the code has some random noise-like properties. Each GPS satellite has a unique PRN number assigned to it.

Pseudo-range
The time shift required to align a replica of the GPS code generated in the receiver with the code received from the satellite, scaled into distance by the speed of light. The time shift is the difference between the time of signal of reception and the time of signal transmission where the reception is measured in the receiver time reference and the transmission is measured in the satellite time reference. Therefore, the pseudo-range contains several errors including satellite/receiver time offset, and satellite ephemeris error.

Pseudo-range Difference
See **Reconstructed Carrier Phase**.

Pseudo-range Observable
The difference between the time of transmission and the time of arrival of a particular signal transmitted by the satellite.

Reconstructed Carrier Phase
The difference between the incoming Doppler-shifted carrier phase and the phase of a nominally constant reference frequency generated in the receiver. In dynamic applications, the reconstructed carrier phase is sampled at epochs of the received message code, and the difference in reconstructed carrier phase between consecutive code epochs is a measure of the change in satellite-to-receiver range between epochs. This is referred to as the pseudo-range difference, or the delta pseudo-range. In static positioning, the reconstructed carrier phase is sampled at epochs determined by the receiver clock. The reconstructed carrier phase changes according to the continuously integrated Doppler shift of the incoming signal, biased by the integral of the frequency offset between the satellite and receiver oscillators. The reconstructed carrier phase can be referred to the range between satellite and receiver once the phase ambiguity has been resolved. One cycle change in the reconstructed carrier phase is one wavelength of the carrier signal change in the range from satellite to receiver.

Relative Positioning
See **Differential Positioning**.

Satellite Constellation
The arrangement of a set of satellites in space.

Satellite Message
Sometimes, referred to as the Data (D) code. A low-frequency (50 Hz) stream of data on both carriers (L1 and L2) of the satellite signal. The stream of data is designed to inform the user about the health and position of the satellite. The satellite message can be decoded by the receiver and used for positioning in real time.

S-Code
Another name for the C/A-Code.

Selective Availability (S/A)
The policy of the DoD to intentionally degrade the accuracy obtainable from GPS by civilian users.

Simultaneous Measurements
A measurement or set of measurements referred to the same epoch.

Slow Switching Channel
A channel that switches with a period too long to recover the integer part of the carrier phase.

Space Segment
The portion of the GPS system with major components in space (e.g., GPS satellites).

Spheroid
Used interchangeably with **ellipsoid**.

Squaring-type channel
A receiver channel that multiplies the received signal by itself to obtain a second harmonic of the carrier which does not contain the code modulation.

Standard Positioning Service (SPS)
Positioning of a single receiver based on the C/A-Code. Also see **PPS**.

Static Positioning
Determination of the position of a stationary receiver.

Stop-and-Go Kinematic Surveying
A GPS differential survey technique whereby one GPS unit, the fixed receiver, remains fixed on a known control point, while the other, a rover receiver, collects signals on a point of unknown position for a short period of time, usually minutes, and then moves to subsequent points to collect signals for a few more minutes, all the time continually tracking four or more satellites during the observation period. This process is done in an effort to ascertain the position of the object stations occupied by the rover receiver.

Switching Channel
A channel that is sequenced through a number of satellite signals at a rate that is slower than and asynchronous with the message data rate.

Time Tag
The time appended to an actual measurement.

Translocation
See **Differential Positioning**.

Troposphere
Inner layer of the atmosphere, located between 6 and 12 miles above the earth's surface.

User Equivalent Range Error (UERE)
A term for GPS measurement accuracy which represents the combined effects of ephemeris uncertainties, propagation errors, clock and timing errors, and receiver noise. A high UERE may indicate that S/A has been imposed on the satellite used.

User Segment
The portion of the GPS with major components that can be directly interfaced by the user (e.g., GPS receivers).

Visibility Plot
A plot against time of day of the number of satellites which are visible from a specified location.

Y-code
The P-code after encryption.

Z-count Word
The GPS satellite clock time at the leading edge of the data subframe of the transmitted GPS message.

Appendix C
Sources of GPS Information

Listed below are other sources of GPS information:

a. Civil GPS Service GPS Information Center. The GPS Information Center (GPSIC) of the U.S. Coast Guard operates under the Civil GPS service Steering Committee. The GPSIC will receive GPS status messages from the U.S. Air Force's 2nd Satellite Control Squadron (2SCS), located in Colorado Springs, and disseminate the information via a bulletin board. Current services include current constellation status, future schedule outages, and an almanac suitable for making GPS coverage and satellite visibility predictions. This bulletin board, a voice recording, and live information is accessible 24 hr a day, 7 days a week.

GPSIC voice recording	(703) 313-5907
GPSIC live information	(703) 313-5900

For Bulletin Board Information:

Comm. Parameters: 8 data bits, 1 stop bit, no parity
Modem access # (703) 313-5910

b. GPS satellite clock behavior and related information. Information on satellite clock behavior and related GPS information can be obtained from:

U.S. Naval Observatory
Washington, DC 20392-5100

Telephone Lines:	(202) 653-0068, 0155, 1079
Baud Rates:	1200, 2400, or 9600
Comm. parameters:	8 data bits, 1 stop bit, no parity terminate lines with CR/LF]
Internet access:	Telnet to tycho.usno.navy.mil (192.5.41.239) Log in as ads
Comments to:	adsmgr@tycho.navy.mil

USNO Series 4 Weekly Bulletins: Received by mail, they contain information on the status of GPS including GPS time steering and satellite clock behavior.

For operational comments, contact the Time Service Department of the National Observatory at (202) 653-1525 for further assistance.

c. General GPS bulletin boards. There are several bulletin board services (BBS) that list general GPS information.

(1) Holloman AFB. Provides daily almanac, observed range errors, comments on the satellites, and the OCS Advisories. Requires fill duplex, 8 data bits, 1 stop bit, no parity, or full duplex, 7 data bits, 1 stop bit, odd or even parity.

300 to 2400 baud:	(505) 679-1525
Live system operator:	(505) 679-1657

(2) Free hourly almanac:

Global Satellite Software, Inc.
5339 Prospect Road, Suite 239
San Jose, CA 95129
Telephone: (408) 252-7358
Baud Rate: 300 to 9,600
Contact: (408) 252-7490 for further information.

(3) Post-broadcast ephemeris data:

Associated Consulting Inc.
2245 N. Decatur Blvd.
Las Vegas, NV 89108
Telephone: (702) 647-9266
Baud: 300 to 14,400
System operator: (702) 647-9265

d. Precise GPS orbit information. There are various agencies or firms that provide GPS orbit information:

(1) Government. Precise orbital positions and velocities based on post-computations of tracking data are available from NGS. Satellite orbital data are scheduled to be available two weeks after the tracking data are collected. For further descriptions on formats, fee schedule, or to order data, contact:

NOAA, National Geodetic Survey, N/CG174
1315 East-West Highway
Silver Spring, MD 20910-3282
Telephone: (301) 713-3242
Fax: (301) 713-4172

(2) Commercial. Precise orbit data are available from the Aero Service Division, Western Atlas International, using data obtained from its tracking network

stations. For description of format, fee schedule, or to order data, contact:

Western Geophysical Division
A Division of Western Atlas Int'l
3600 Briarpark Drive
Houston, TX 77042-4299
Telephone: (713) 964-6345
Fax: (713) 964-6555

e. Performance evaluation of GPS survey equipment. For information on equipment tested or to comment on the GPS satellite survey system, contact:

GPS Test Coordinator
National Geodetic Survey Division, N/CG14
1315 East-West Highway
Silver Spring, MD 20910-3282
Telephone: (301) 713-3242
Fax: (301) 713-4172

f. General Information on GPS for USACE Personnel can be obtained from:

U.S. Army Topo Engrg Center
ATTN: CETEC-TD-AG
7701 Telegraph Road
Alexandria, VA 22315-3864

Phone: (703) 428-6766
Fax: (703) 428-8176

Appendix D
Static GPS Survey Examples

Section I
Survey No. 1: HORIZONTAL CONTROL GPS SURVEY (Ukiah Airport, California)

D-1. Planning Phase

The GPS survey was planned for 25 April 1989 in the vicinity of Ukiah Airport, Ukiah, California.

a. A diagram of the project area is shown in Figure D-1.

b. Four SPS (C/A-code) GPS carrier phase tracking receivers were used for the survey, one person per receiver. In actuality, because the personnel were inexperienced in conducting a GPS survey, a fifth person was also used. The fifth person was used as a "runner" who can be called upon during the survey to aid in smoothing out any complications (e.g., aiding in overall communication and coordination, parts retrieval in case of breakdown, bad power source, blown fuse, misplaced equipment, forgotten measurement device or power cord, as well as any other possible complication). Communication between personnel was by two-way radio. Care was taken in choosing and operating the two-way radio near the GPS survey so that the radio transmitter and receiver chosen, when in operation, would not interfere with the GPS receiver.

c. Prior to data collection, the stations were inspected and found to be acceptable (easy accessibility, no obstruction or possible multipath sources, and at least 20° satellite visibility above the horizon).

d. The date 25 April 1989 corresponds to Julian calendar day 115. Calpella, Perry, and Ukiah Airport were stations with established horizontal control. Pier 1 and Pier 2 were stations requiring horizontal coordinates accurate to 1:10,000 (refer to Figure D-2). Therefore, the following station conventions for Session 1 of the survey were:

Pier 1 - Station 20011151
Pier 2 - Station 20021151
Calpella - Station 20131151
Ukiah Airport - Station 20141151

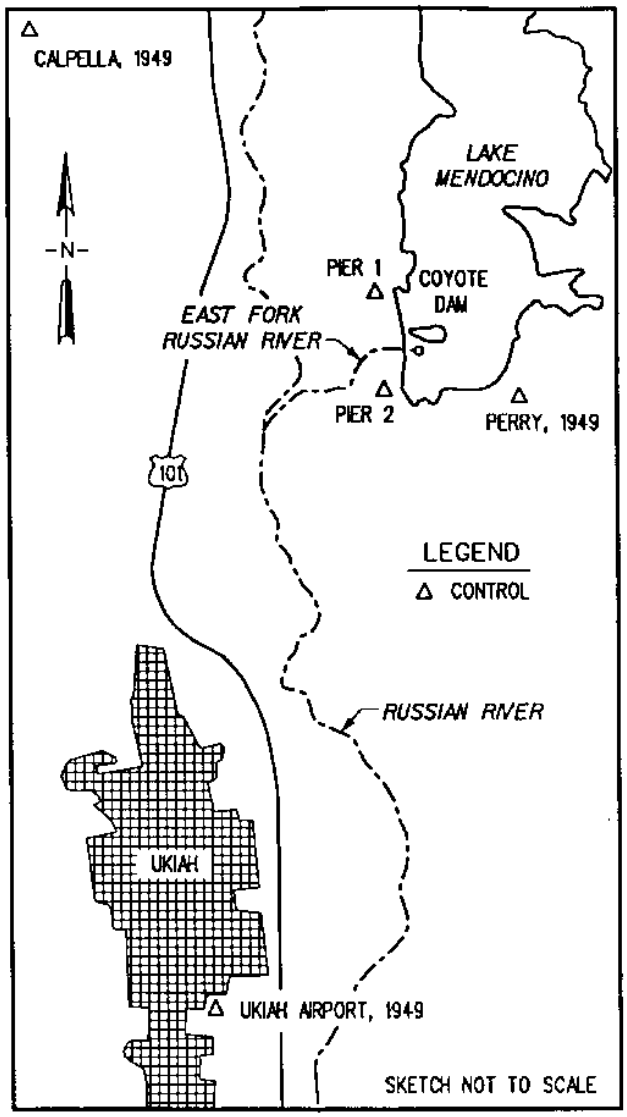


Figure D-1. Ukiah project area

It is important to note that this station convention was used for this survey because the receiver used only allowed numeric input of station names. Most newer receivers allow alphanumeric inputs for station names which provides more flexibility in station naming. (Consult the GPS manufacturer literature for further explanation and guidance on the receiver's station naming convention.)

e. A satellite visibility plan (a software package that produces a hard copy listing of satellite constellations and

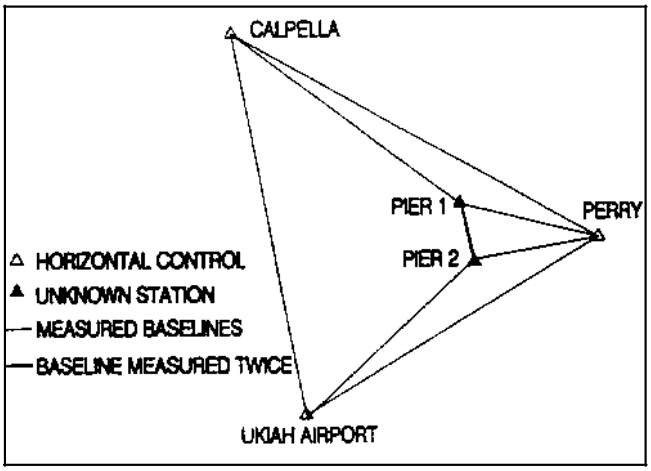


Figure D-2. GPS project diagram (Ukiah)

time availability based on ephemerides) was run for the project location. The satellite visibility was run with the most up-to-date ephemeris for the period of observation, using four-satellite visibility, and with a cutoff elevation angle of 20°. An up-to-date ephemeris was used to ensure the satellite visibility formulated was the most accurate. Four-satellite visibility was run in order to formulate accurate 3D solutions. A cutoff elevation of 20° was chosen in order to minimize any diffusion or dispersion of the signal by the atmosphere which in turn may cause errors in the solution as the satellites pass near the horizon. The satellite visibility plan produced for the Ukiah project is shown below.

All-In-View PDOP for Ukiah

Date: 25 Feb 1990 Latitude: 39° 12' 30" N
Time: 4:00 -> 4:00 Longitude: 123° 10' 30" W
Cutoff Elevation: 20 Zone: - 7:00

Satellite Constellation	Time Rise	Time Set	dT	PDOP Rise	PDOP Set
6 9 11 13	21:55	22:03	0:08	4.9	5.0
6 9 11 12 13	22:02	22:33	0:30	3.8	3.6
6 9 11 12 13 19	22:32	23:18	0:45	3.2	3.3
3 6 9 11 12 13 19	23:17	23:48	0:30	2.9	3.0
3 9 11 12 13 19	23:47	1:08	1:20	4.2	4.2
3 11 12 13 19	1:07	1:22	0:15	4.9	5.0
3 12 13 19	1:22	2:20	0:58	22.7	31.6

The portion of the satellite visibility where the PDOP is near 5.0 m/m or below are times when the satellite geometry is conducive for conduct of a survey. A PDOP near or below 5.0 m/m does not guarantee a successful survey but it does indicate good satellite geometry during that moment of the survey (see Chapter 5 for further information on PDOP).

f. From the satellite visibility plan, it was decided to conduct three sessions during the survey. Travel between survey sites, time to set up and take down the equipment before and after the survey, receiver warm-up time, time of survey (at least an hour allotment for survey data collection, but more than an hour if at all possible), and possible time loss due to unforeseeable problems or complications were taken into account before deciding on a specific session schedule. The final survey session schedule is shown in Table D-2.

Table D-2
Final Survey Session Schedule

Session	Start Time	Stop Time
1	21:55	22:55
2	23:38	00:38
3	01:23	02:20

It was further decided which stations would be occupied during each session. Station occupation was designed to minimize travel time and to add to the overall efficiency of the survey. The station occupation schedule was planned as shown in Table D-3.

Table D-3
Station Occupation Schedule

Session	Station	Station	Station	Station
1	Calpella	Ukiah Airport	Pier 1	Pier 2
2	Calpella	Perry	Pier 1	Pier 2
3	Ukiah Airport	Perry	Pier 1	Pier 2

g. A GPS station observation log is generally filled out prior to conduct of the survey. An example of a GPS log is shown in Figure D-3. The log must be filled out for each of the stations occupied in order to have a written record of the actual survey and as an aid for the personnel occupying each of the stations.

h. Portions of the GPS station observation log were filled out prior to data collection. These portions included the station name, start date, GPS 8-character ID for each session, project name, project location, observer name, approximate receiver position (latitude, longitude, and elevation), session scheduled start and stop times, and requisite tracking equipment information. In this case, six GPS station observation logs were filled out, one each

U.S. ARMY CORPS OF ENGINEERS
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****

PROJECT NAME LOCALITY_____

OBSERVER AGENCY/FIRM:----------
RECEIVER S/N:----------
ANTENNA S/N
DATA RECORDING UNIT S/N:----------
TRIBRACH S/N LAST CALIBRATED:

****

	SESSION 1		SESSION 2		SESSION 3	
STATION: NAME	_____		_____		_____	
NUMBER	_____		_____		_____	
DAY OF YEAR	_____		_____		_____	
DATE MM DO YY	_____		_____		_____	
UTC TIME OF OBSERVATION	START	STOP	START	STOP	START	STOP

****

ANTENNA HEIGHT MEASUREMENTS

	SESSION 1	SESSION 2	SESSION 3
SLOPE @ BEGINNING	IN M MN _____M	IN= ----r;; M MN _____ M	IN M MN _____M
SLOPE @ END	IN= M MN _____ M	IN= ----r;; M MN _____ M	IN M MN _____ M
MN ADJ TO VERT:	_____M	_____ M	M

****

	PROGRAMMED REFPOS	FIELD POSITION	PROGRAMMED REFPOS	FIELD POSITION	PROGRAMMED REFPOS	FIELD POSITION
LAT	_____	_____	_____	_____	_____	_____
LONG	_____	_____	_____	_____	_____	_____
HT	_____	_____	_____	_____	_____	_____
POOP------		_____	_____	_____	_____	_____

SVS TO TRACK ---------- _____ _____ _____

LOCAL TIME:	SCHEDULED	ACTUAL	SCHEDULED	ACTUAL	SCHEDULED	ACTUAL
START	_____	_____	_____	_____	_____	_____
STOP						

****

PAGE 1

a. Front

Figure D-3. Example GPS station observation log (front and back) (Continued)

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GPS DATA LOGGING SHEET

	SESSION 1	SESSION 2	SESSION 3
ANT CABLE LENGTH	_____	_____	_____
POWER SUPPLY	_____	_____	_____
WEATHER CONDITIONS	_____	_____	_____
MONUMENT TYPE	_____	_____	_____
EXACT STAMl'ING	_____	_____	_____
AGENCY CAST IN DISK	_____	_____	_____

SKETCH OF SITE

SESSION 1 SESSSION 2 SESSION 3

Describe any abnormalities andjor problems encountered during the survey, include session number, time of occurence and duration.

!'AGE 2

b. Back

Figure D-3. (Concluded)

for: Calpella (Sessions 1 and 2), Ukiah Airport (Session 3), Ukiah Airport (Session 1), Perry (Sessions 1 and 2), Pier 1 (Sessions 1, 2, and 3), and Pier 2 (Sessions 1, 2, and 3). An example of a GPS station observation log for Pier 2 is shown in Figure D-4.

D-2. Actual Survey Operation

These portions of the GPS station observation log which were not filled out during the planning phase of the survey were filled out during data collection. An example of the GPS station observation log for Pier 2, filled out after data collection, is shown in Figure D-5.

a. The key to proper data collection is the correct setup of the equipment (tripod, receiver, and power source) and correct antenna height measurements (height of the antenna above the mark).

b. Figure D-6 shows personnel correctly taking an antenna height measurement over a temporary monument. Figure D-7 illustrates a typical antenna setup with the following equation detailing the antenna height correction.

$$v = \sqrt{(s)^2 - (r)^2} \qquad \text{(D-1)}$$

where

v = corrected vertical height distance of the antenna center above the mark

s = slope distance measurement derived from the average of several antenna height measurements made

r = antenna radius

c. When measuring the antenna height during this survey, the procedure below was followed in order to ensure an accurate reading:

(1) The slope distance from the north point of the antenna to the center of the monument was measured to the nearest millimeter (0.001 m). Measurement was also done in non-SI units (inches) to the nearest 1/32 of an inch. This value then was compared to the metric value measured earlier in order to detect blunders.

(2) Similar measurements were also taken from the south point of the antenna to the center of the monument.

(3) The resultant north and south slope distances were averaged.

(4) *Example*: (Refer to Figure D-5.)

(a) Tripod set up flat on a dock.

(b) The north side measure up for session 1 = 0.120 m.

(c) The south side measure up for session 1 = 0.120 m.

(d) An extra "Check Measurement" was also taken for the measure up for Session 1 and was found to be 0.394 ft.

(e) As a check: (0.394 ft.) x (1 m/3.281 ft.) = 0.120 m.

(f) This value was recorded in the GPS station observation log.

d. Each GPS receiver was operated in direct accordance with the manufacturer's instructions, procedures, and/or guidance.

e. No problems were encountered during the survey sessions.

D-3. Post-Processing Observation Data

All observation data recorded were downloaded from the receivers to a 5.25-in. floppy disc. The downloading procedures detailed in the manufacturer's operating manuals were strictly adhered to.

a. Once the observation data were downloaded, preprocessing of data was performed. Preprocessing of data included checking the station names, antenna heights, latitude, longitude, and elevation of the points, as well as applying any required corrections. In general, most GPS processing software requires the antenna slope height be corrected to vertical at some point in the survey, usually during the pre-processing phase. (Consult receiver/software manufacturer guidelines for specifics.)

b. The data for the Ukiah project were post-processed using TRIMBLE software, but in general, all post-processing software produces similar results. The

U.S. ARMY CORPS OF ENGINEERS
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PROJECT NAME COYOTe /)1//1 LOCALITY (
OBSERVER l.f98Ry J.,At18 AGENCY/FIRMCof:. If N 1>JS12i'IGT
RECEIVER T&M!UG I/6DO SL SJN Zf oAc>o%2..3
ANTENNA T/IJH8LE IJ,/Up St.- S/N 2,Pif,lf<>O:zz.<{
DATA RECOIUJING UNIT &€cG!vE/< S/N :Lo o<>
TRIBRACH W/LD ftDE ZZ, S/N AI/A LAST CALIBRATED:

	SESSION 1	SESSION 2	SESSION 3
STATION: NAME	PIER 2	PtG8 2..	PIER .2.
NUMBER	1:<>0-Z.	.-ZOO 2.,	?"OZ..
DAY OF YEAR	1(5"	/15	/IS"
DATE MM DO YY	4/25/89	4/25/89	4/25/89
UTC TIME OF OBSERVATION START	01/:S",	(>£:	** *:(o
UTC TIME OF OBSERVATION STOP			""{:3f
UTC TIME OF OBSERVATION START			O'l:H'
UTC TIME OF OBSERVATION STOP			()f:

ANTENNA HEIGHT MEASUREMENTS

	SESSION 1	SESSION 2	SESSION 3
SLOPE @ BEGINNING	IN- M MN— M	— — IN= M MN— M	IN- ----.. MN— M
SLOPE @ END	IN- M MN— M	IN- M MN— M	IN= M MN— M
MN ADJ TO VERT:	M	M	M

	PROGRAMMED REFPOS	FIELD POSITION	PROGRAMMED REFPOS	FIELD POSITION	PROGRAMMED REFPOS	FIELD POSITION
LAT	31-!2-3o		31-12.-30		'11-12-30	
LONG	/Zi-(0-30		1 -rO-Jo		12"3-Jt>•Jo	
HT	Z'('{.0		Z<flf,0		244.0	
POOP	J.G,		4.8		4.0	
SVS TO TRACK	OZ,O""..>9 I/;IZ.,.13, 14!		02,03,06,09 11,12,13,14		D3. : .,09. 11 rZ t3/- '.	
LOCAL TIME:	SCHEDULED	ACTUAL	SCHEDULED	ACTUAL	SCHEDULED	ACTUAL
START	t.f:rr		Z-3!3'		** Z.o	
STOP	Z-2.:S5'		60:3 t		o:z: 2.o	

PAGE 1

a. Front

Figure D-4. GPS station observation log, presurvey (Continued)

U.S. ARMY CORPS OF ENGINEERS
GPS DATA LOGGING SHEET

****

	SESSION 2	SESSION 2	SESSION 3
ANT CABLE LENGTH	/00 f.t	too Ec	3£&
POWER SUPPLY	/1. v PC	12-v []c	/7- v Oc.
WEATHER CONDITIONS			
EXACT STAMPING	Pier< z. 110	"	"
MONUMENT TYPE	"C- "{sUIINPri/1)-SAME:		S'AM E
AGENCY CAST IN DISK	CoG	"	"

****

SKETCH OF SITE

SESSION 1 SESSION 2 SESSION" 3

****

Describe any abnormalities andjor problems encountered during the survey, include session number, time of occurence and duration.

****

PAGE 2

b. Back

Figure D-4. (Concluded)

U.S. ARMY CORPS OF ENGINEERS
GPS DATA LOGGING SHEET

OBSERVER
RECEIVER
AN NNA
DATA
PROJECT
TRIBRACH

STATION: NAME

	SESSION 1	SESSION 2	SESSION 3
NUMBER	2. GJOZ..	2.¢02.	zao2..
DAY OF YEAR	//£:"	/IS"	wr
DATE MM DD YY	'f/'2-6"/ f	lff z. ; "-	't/zsje-
UTC TIME OF OBSERVATION START	o'f:' oS'\f>	06 :fo	o'f:$"5'
STOP		01•,Y	<l9-'ZO

ANTENNA HEIGHT MEASUREMENTS

	SESSION 1	SESSION 2	SESSION 3
SLOPE @ BEGINNING	lJ.nt2. ./ZO O.tZD lf 1 &IN tY..Zi M O.lLtJ M	P. ' ' ' O-t/6 O.!Jj f u.IN P,/1 M MN = 0.116 M	0.123 4 1 4/16 O tz'f I-N MN = <>•lZ.'f M
SLOPE @ END	'f'V J'Y' ▷..JM?.._IN= M MN =),f'Z.6 M	'f r:tJt 1{. D...!..l"_IN= M MN = t?.tiW M	I'J.lZ.iiJi' M 'f/1f- t2Z: O..LZZ_IN :fJf._ M MN 0./21<> M
MN ADJ TO VERT:	0./2-0 M	6./f' M	0·/Z-3'f M

	PROGRAMMED REFPOS	FIELD POSITION	PROGRAMMED REFPOS	FIELD POSITION	PROGRAMMED REFPOS	FIELD POSITION
LAT	'37-/t-30	3'1·JL·ZZ·'	3'1·/Z.•:Jo	3'l-U.•Q.,'f8	1'f•it•30	31·/Z.·z.t.'/1/
LONG	/Z.3•/0·3()	/Z.J·LO·H. t.	/?.J•/0•30	IZJ-t0·1J,UJI2-'3•f0•3o		/Z-3-I"·n,,z
HT	1.-'ff.O	z_/O.f.	?..t</-0	l'l?·'	Pf'f•d	Z,Z-2.8'
POOP	'3, C..					
SYS TO TRACK	oz.oz,otp oy liJ2.. l-. t'f		QZ,.,3. o&,o1 u; tz.(t3,'51		ll1,()6.o!. II a:.t3.'t't.' 16	

LOCAL

TIME:	SCHEDULED	ACTUAL	SCHEDULED	ACTUAL	SCHEDULED	ACTUAL
START	2.(:-	'Z./15"	Z. :,9	2-3:/0	01'2-0	OOIS'S
STOP	Z.z:ff	7-z:sr;"	1JO/38	00:31	t>z.:z.a	Oi?,>Z.O

PAGE 1

a. Front

Figure D-5. GPS station observation log, postsurvey (Continued)

u.s. ARMY CORPS OF ENGINEERS
GPS DATA LOGGING SHEET

****

	SESSION 1	SESSION 2	SESSION 3
ANT CABLE LENGTH	lt2D Ft	tOO£+ —	35"f"+
POWER SUPPLY	IZV VC	1?-V pc_	/2. V ()C-
WEATHER	ci-{:/IB, Ce>DL.	Ct-C/IR ,. ,	eLEi'l.R, OI)t..
MONUMENT TYPE	"c"ISn ttrPtoU		-sAttE
CONDITIONS	If5•	O.·'	+'.<;)•
		£/I.He	
EXACT STAMPING	f.le-R 2. 11£3	,,,,. ,,	"
AGENCY CAST IN DISK	(!O£	"	"

****

SKETCH OF SITE

SESSION 1 SESSION 2 SESSION 3

LM:ib
ME"NDI

N

111v£R. PJE"RZ. $AME 5AI'1€

****

Describe any abnormalities andjor problems encountered during the survey, include session number, time of occurance and duration.

C AL'.I'TeNIJA W....5 M.OOIJTeP DIRE<OTL'(oveR.. PI€:12. z_ WITH NO ""C"Rt ?Cil> uScP.

A r.IT€:N/JA tiE:: IG HT f...J/'5 EA-SOR,E;-J) VE:RTICALL R<af--\ –

<:,Ro<>NI> PL.A- E. 1:0 BR,.. s 'J)\S /<.

****

b. Back

Figure D-5. (Concluded)

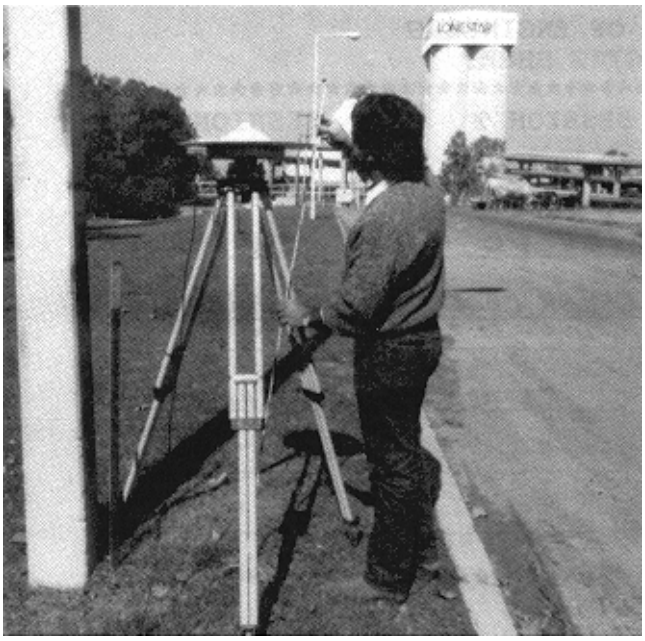


Figure D-6. Antenna height measurement

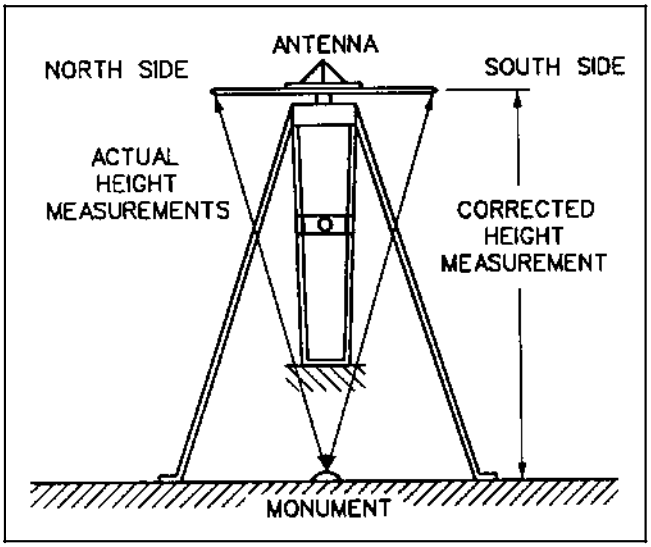


Figure D-7. Diagram of antenna setup

observation data were processed in accordance with manufacturer's guidelines. (See Chapter 10 for further discussion on post-processing.)

(1) An examination of the results reveals the following, which are produced in one form or another in other manufacturer's solution file formats:

(a) Listing of the file name.

(b) Types of solutions (single, double, or triple difference).

(c) Satellite availability during the survey for each station occupied.

(d) Ephemeris file used for solution formulation.

(e) Type of satellite selection (manual or automatic).

(f) Elevation mask.

(g) Minimum number of satellites used.

(h) Meteorological data (pressure, temperature, humidity).

(i) Session time (date, time).

(j) Data logging time (start, stop).

(k) Station information:

- Location (latitude, longitude)
- Receiver serial number used
- Antenna serial number used
- ID number
- Antenna height

(l) RMS.

(m) Solution files:

- Δx, Δy, Δz between stations
- Slope distance between stations
- Δlatitude, Δlongitude between stations
- Distance between stations
- Δheight

(n) Epoch intervals.

(o) Number of epochs.

(2) The triple difference, double difference float, and double difference fix TRIMBLE solutions of the baseline reductions for 2014->2002 are shown annotated with the above conventions (a - o) provided as an explanation.

c. In general, all GPS manufacturer data reduction software programs produce a summary of results once data have been reduced and a baseline formulated.

d. The listing of the baseline formulations for line 2014 to 2002 follows in Figure D-8, as reproduced from the TRIMBLE Navigation TRIMVEC solution file.

e. Although the TRIMBLE summary solution file does specify that the integers were found, the RMS is OK, and FIXED solution is recommended, an analysis of the output prior to this conclusion in accordance with Chapter 10 would have revealed the following:

(1) With a baseline distance of 7,000 m for the formulated baseline (baseline 1402) and from Table 10-1, the RMS must be less than [(0.02 + (0.004*d))]. Using the equation [(0.02 + (0.004/d))] from Table 10-1 with a d (distance) equal to 7 km, the equation is [(0.02 + (0.004*7))] and the RMS is approximately equal to 0.048. Therefore, the RMS is acceptable.

(2) With a baseline distance of 7,000 m for the formulated baseline (baseline 1,402) and from Table 10-1, the quality factor ratio must be more than 3. The fixed solution factor from the summary solution file is 18.9. Therefore, the fixed solution quality factor is acceptable.

(3) From Table 10-1, with a baseline length of 7 km for baseline 1402 (between 0 and 20 km), an acceptable RMS (small), an acceptable quality factor ratio (large), and an integer solution, the fixed solution should be acceptable.

f. All other formulated baselines for this survey were found to be acceptable.

D-4. Loop Closure

An approximate loop closure was done by following the procedures detailed in Chapter 10. The resulting calculations would proceed as shown in the following computation:

a. Follow Figure D-9, holding 2013 as the starting point.

b. Formulate a table similar to Table 10-3 (see page D-25), where all values are taken from the GPS post-processed baseline formulations:

c. Sum up the Δx, Δy, Δz, and distance components:

Δx components = Δx(2013->2014) + Δx(2014->2002)
+ Δx(2002->2006) + Δx(2006->2001)
+ Δx(2001->2013)
= -3,367.429 + 3,799.005 + 953.294
+ (-666.617) + (-718.244)

= <u>0.009</u>

Δy components = Δy(2013->2014) + Δy(2014->2002)
+ Δy(2002->2006) + Δy(2006->2001)
+ Δy(2001->2013)
= -7,891.019 + 2,554.018
+ (-748.319) + 1,441.548 + 4,643.775

= <u>0.003</u>

Δz components = Δz(2013->2014) + Δz(2014->2002)
+ Δz(2002->2006) + Δz(2006->2001)
+ Δz(2001->2013)
= -10,410.673 + 5,296.798
+ (-16.709) + 908.280 + 4,222.288

= <u>-0.016</u>

Distances = (2013->2014) + (2014->2002)
+ (2002-2006) + (2006->2001)
+ (2001->2013)
= 13,490.362 + 7,000.823 + 1,212.035
+ 1,829.593 + 6,317.297

= <u>29,850.110</u>

d. From Equation 10-1:

$$M = \sqrt{(0.009)^2 + (0.003)^2 + (-0.016)^2} \quad \text{(D-2)}$$

$$= \sqrt{(0.000081) + (0.000009) + (0.000256)} \quad \text{(D-3)}$$

= 0.018601075 or 0.0186

Therefore, misclosure is approximately 0.0186 in., 29,850.110 m, or 1 part in 1,600,000.

D-5. Final Adjustment

The program used for final adjustment of the Ukiah survey was the GEOLAB program. For an in-depth technical discussion on GEOLAB, refer to the literature accompanying the GEOLAB software package. The following discussion on the GEOLAB adjustment of the Ukiah survey highlights some of the criteria used in the adjustment of a horizontal survey.

```
                    TRIMBLE NAVIGATION, LTD.
                    585 NORTH MARY AVENUE
                    SUNNYVALE, CALIFORNIA 94086
                              u.s.A.

                    PROGRAM TRIMVEC
                GPS RELATIVE POSITIONING SOLUTION

                                          -la - listing of the filename!
 File name: 14022059.trp=
coordinate system - WGS-84 :::::::::VE::R:S:I:O:N::8:8:-0:88 - type of solution!!!!; i'""

Type solution:  Triple difference.-          li- session time

start date/time:  1988/ 2/29  7:26:30  day of year 60  tow 113190.-
stop  date/time:  1988/ 2/29  9:32:30  day of year 60  tow 120750.

Data available                                  c - satellite availability

station:  1
sat: 6 :-----------.-.-------
sat: 8
sat: 9 :.......................................................:
sat:11 :.............................................
sat:12 :.......................................................:
sat:13 :.......................................................:
sat: 3                  ......................................:

station:  2
sat:6:........
sat: 8:....
sat:  9 ...................................
sat:11 :.............................................
sat:12 :.......................................................:
sat:13 !...-.-.-.
```

Message file for station 1

```
station ID: 2014  Session #: 059-2   Feb. 29, 1988 07:24
Reference Position - HIGH ACCURACY:
Lat.= 39:07'57.401"N  Long.=123:12'14.788"W  Height=190.2 (meters]
Antenna height = 1.4387 (meters} (entered in the field in feet)
Receiver serial # = 4604
Antenna serial # = 110 (enterein the office)

Survey schedule mode    = AUTOMATIC;
Data-logging start time = 07:26
Data-logging stop time = 09:33

        ChO   Ch1   Ch2   Ch3   Ch4   ChS   Ch6   Chg   Chg   Chg
SVs      3     6     8     9    11    12    13
# meas  379   170    28   506   445   506   506
# cant  379   170    28   506   445   S06   506    O     O     O

sv Selection mode = MANUAL SELECTION

4 SV Position      Best POOP Position   3.1]     Mean Pos1.t1.on [4'.:1:1
Latitude:          39:07'57.17388" N            39:07'57.14899" N
Longitude:         123:12'14.47260" W           123:12'14,64029" W
Height (m):                169.0                        170.3

3 SV Position      Best PDOP Position ( 2.SJ    Mean Position [9)
Latitude:          39:07'57.62620" N            39:07'57.51783" N
Longitude:         123:12'14.95426" N           123:12'14.88427" N

Origin of station 1 coordinates: Best C/A code tracking solution

   STATION (mark) 1
input data file 1 : 20140592.dat
 antenna height (m)   1.378

met   values   used:          pressure(mb)                    1010.0
                   temperature(deg C)      20.0
                   relative humidity(%)    50.0

  x (m)  -2713023.277    lat (dms) N   39   7  S7.13720
  y (m)  -4145293.358    elan (dms) E 236  47  45.39187
  z (m)   4003847.775    wlon (dms) W 123  12  14.60813
                         ht (m)          168.8847
```

Message file for station 2

```
Station ID: 2002  session #: 059-2   Feb 29, 1988 07:21
Reference Position - LOW ACCURACY:
Lat.= 39:12'30.000"N  Long.=123:10'30.000"W  Height=244.0 [meters]
Antenna height= 0.1201 (meters) (entered in the field in feet)
Receiver serial # = 4604
Antenna serial # = 108 (entered in the office)

survey schedule mode
Data-logging start time  AUTOMATIC
Data-logging stop time = 09:32
```

Figure D-8. (Sheet 2 of 13)

```
         Ch0   Ch1   Ch2   Ch3   Ch4   Ch5   Ch6   Ch7   Ch8   Ch9
SVS        3     6     8     9    11    12    13     0     0     0
# meas   356    78    41   392   457   515   515     0     0     0
# cent   356    65    41   381   457   515   515     0     0     0

SV Selection mode = MANUAL SELECTION          e - type of satellite
Elevation mask    = 20      [degrees]  Minimum # of SVs = 4   selection
                  f - elevation mask   g - minimum # of satellite
4 SV Position     Best PDOP Position [ 3.5]    Mean Position [358] used
Latitude:          39:11'36.62852" N            39:11'36.67782" N
Longitude:        123:11'00.34360" W           123:11'00.44659" W
                            251.8                        247.9

3 SV Position     Best POOP Position ( 2.5]    Mean Position [157)
Latitude:          39:11'36.93995" N            39:11'36.76322"  N
Longitude:        123:11'00.75300" N           123:11'00.69634" W
```

```
STATION (mark) 1: 200392.dat                    -station informaronl
antenna height (m)      .120-
met values used:   pressure(mb)          1010.0
                   temperature(deg C)      20.0   h - meteorol ical dat
                   relative humidity(\)    50.0

  x (m)   -2709224.288     lat  (drns) N   39     7  36.66538
  y (m)   -4142739.316     elan (dms)  E  236    48  59.56686
  z (m)    4009144.597     wlon (dms)  W  123    11    .43314
                           ht   (m)          244.2261

slope distance (m)      7000.8406    sigma (m)     .032
normal section azimuth (dma) 14 43 50.71
vertical angle (dmo)          O 35  6.35

 east(m)   north(m}   up(m)    1780.060   6770.280   71.490  m - solution fil
Delta lat(dms)    0   3   39.52817
Delta lon(dms)    0   1   14.17498
Delta ht(m)     75.3413

Vector covariance matrix (m**2) :
                      dx                  dy                  dz
    dx  .2938675644770-02
    dy -.2413483646030-02   .4638584491910-02
    dz -.6694288660950-03  -.2524582611440-03   .689895896357D-03
 correlations
          dx     dy     dz
    dx  1.000
    dy  -.654  1.000
    dz  -.470  -.141  1.000
                     Solution        Sigma.
    dx (m)           3798.989         .054
    dy (m)           2554.042         .068
    dz (m)           5296.822         .026

Epoch increment      5
Interval between epo h s  (o e c:i)  1 5 0  :=  ;;;:fi          [J
Number of measurements used in solution  168
Number of measurements rejected            1
```

Figure 0·8. (Sheet 3 of 13)

```
 RMS  (cycles)          .033------------------{11 - RM ijij

 Elevation mask  (deg)       15.0
 Edit multiplier        3.5
 Modified Hopfield troposphere model used

Best tracking  C/A code positions
Station  1                                                  m   solution files
Pdop        3.1
  x  (m)    -2713023.862    lat   (dms)  N   39  7  57.13720
  y  (m)    -4145294.253    elan  (elms) E  236 47  45.39187
  z  (m)     4003848.645    wlon  (dms)  W  123 12  14.60813
                            ht  (m)          170.2629
clock  offset(s)       .432668080-03
freq  offset(s/s)     -.110423480-08

 Code  calibration(m)  Carrier  calibration(m)
1    2          .2520                  .0012
1 -  3          •0552                 -.0006
1 -  4         -.0249                 -.0007
1 -  5          .9292                 -.0008
1 -  6         -.2124                 -.0010
1 -  7         -.0181                 -.0005
1 -  8         -.1875                 -.0009
1 -  9         -.1875                 -.0012
1 - 10         1.0630                 -.0014
Station 2                                                   m   solution  file
Pdop        2.5
  x  (m)    -2709227.033    lat   (dms)  N   39 11  37.11338
  y  (m)    -4142726.880    elan  (dms)  E  236 48  59.18749
  z  (m)     4009155.162    wlon  (dms)  W  123 11    .81251
                            ht  (m)          244.0000
clock  offset(s)       .885849660-03
freq  offset{s/s)      .588277840-09


1 -  2          .2021                  .0007

 Code  calibration(rn)  carrier  calibration(m)
1 -  3         -.3682                 -.0011
1 -  4         -.4199                 -.0010
1 -  5         -.5342                 -.0013
1 -  6         -.5234                 -.0011
1 -  7         -.2754                 -.0002
1 -  8         -.6040                 -.0014
1 -  9         -.8003                 -.0020
1 - 10         -.6953                 -.0017
```

Figure 0·8. (Sheet 4 of 13)

TRIMBLE NAVIGATION, LTD.
585 NORTH MARY AVENUE
SUNNYVALE, CALIFORNIA 94086
u.s.A.

PROGRAM TRIMVEC
GPS RELATIVE POSITIONING SOLUTION

-Ia - listing of filename!

File name: 14022059.flt
Coordinate system - WGS-84 :::::::VE R:S:I:O:N::8:8:-:0 b - type of solution

Type solution: Triple difference 1 - sess1on 1me

Start date/time: 1988/ 2/29 7:26:30 day of year 60 tow 113190.-
Stop date/time: 1988/ 2/29 9:32:30 day of year 60 tow 120750.-

Data available (c— satellite availability

station: 1
sat:6:
sat: 8
sat: 9
sat:11
sat:12
sat:13
sat: 3

station: 2
sat:6
sat: 8
sat:9
sat:11
sat:13
sat:12
sat: 3

Ephemeris file used: 20140592.eph lct- ephemeris file used

SATELLITE	AOOE(hr.)	HEALTH	WEEK NO.	TOW(sec)	URA(m)
6	3.41	0	425	113040.00	5.7
8	4.55	0	425	113040.00	999.0
9	7.96	0	425	112770.00	4.0
11	3.98	0	425	112770.00	2.8
12	6.26	0	425	112770.00	5.7
13	4.55	0	425	112770.00	16.0
3	7.40	0	425	114570.00	2.o -

Broadcast satellite clock correction values c - satellite availability

prn	afO	af1	ar:2	toe
6	-.86983712390-03	-.17848833520-10	-.27755575620-16	.11880+06
8	.44125365090-03	-.74987838160-09	-.27755575620-16	.11880+06
9	.21295296300-03	.13542420530-11	-.27755575620-16	.11880+06
11	-.99658500400-04	-.48885340220-11	.00000000000+00	.11880+06
12	.63570542260-03	•53432813730-11	.00000000000+00	.11880+06
13	.32387301330-03	.22737367540-11	.00000000000+00	.11880+06
3	.40117371830-03	-.68212102630-12	.00000000000+00	.11880+06

Figure D-8. (Sheet 5 of 13)

```
 Message file for station 1
 ----------------------------------------------------------------
Station ID: 2014  session #: 059-2   F b. 29, 1988 07:24
Reference Position - HIGH ACCURACY:
Lat.= 39:07'57.401"N   Long.=123:12'14.788"W Height=190.2  (meters)
Antenna height c 1.4387 (meters] (entered in the field in feet)
Receiver serial # = 4604

Antenna serial # = 110 (entered in the office)
Survey schedule mode = AUTOMATIC                k - station information!"J
Data-logging start time = 07:26
Data-logging stop time = 09:33j   -data logging time( c - satel te 1
                                                  'r-- a v a:-i-l a b i=l=i .t yJ
        ChO   Ch1   Ch2   Ch3   Ch4   Ch5   Ch6   Ch7
SVS       3     6     8     9    11    12    13     0    Chg
# meas  379   170    28   506   445   506   506     0
# cant  379   170    28   506   445   506   506     0     0     0

SV Selection mode = MANUAL SELECTION              e  t  e of satellite!
Elevation mas.!£_    e 20     [degrees] Minimu.!!!_ # o  SVs - 4   selection!
                     -If - elevation maskl         g - m1.n  urn   o  sateu1.tel
4 SV Position     Best POOP Position [ 3.1]    Mean Posl.tl.on_!.q,  J       usedl
Latitude:          39:07'57.17388h N            39:07'57.14899" N
Longitude:        123:12'14.47260"  W          123:12'14.64029"  W
Height [m]:                169.0                        170.3

3 SV Position     Best PDOP Position [ 2.5]    Mean Position (9)
Latitude:          39:07'57.62620" N            39:07'57.51783" N
Longitude:        123tl2'14  5426" N           123"12'14  8427" N
 ----------------------------------------------------------------
Origin of station 1 coordinates Best  C/A code tracking solution
                 1                 |_ _._._._..-.--[h...!!          !}
   STATION (mark)                                  k - station information
input data file 1 : 20140592.dat
 antenna height (m)   1.378

met values used:   pressure(mb) J
                   temperature(deg C)     20.0   e€eorolog1.cal datal
                   relative humidity(\)   50.0

 x (m)   -2713023.277    lat  (dms) N    39     7  57.13720
 Y (m)   -4145293.358    elon (dms) E   236    47  45.39187
 z (m)    4003847.775    wlon (dms) W   123    12  14.60813
                         ht  (m)          168.8847
 Message file for station 2
 ----------------------------------------------------------------
Station ID: 2002  Session #: 059-2   Feb 29, 1988 07:21
Reference Position - LOW ACCURACY:
Lat.= 39:12'30.000"N Long.=123:10'30.000"W Height=244.0 [meters]
Antenna height= 0.1201 (meters) (entered in the field in feet\          .J
Receiver serial # = 4606                          k - station information
Antenna serial # = lOB (entered in the office)

survey schedule mode     AUTOMA=T IC ::::=====-!-1J    :I 2
Data-logging start time = 07:23          .j - data logging timel
Data-logging stop time  = 09:32--
```

Figure D-8. (Sheet 6 of 13)

```
         ChO   Ch1   Ch2   Ch3   Ch4   ChS   Ch6   Ch7   Ch8   Ch9
SVs        3     6     8     9    11    12    13     0     0     0
# meas  356    78    41   392   457   515   515     0     0     0
# cent  356    65    41   381   457   515   515     0     0     0

SV Selection mode "' MANUAL SELECTION--ie - tye! of satellite selectionl
Elevation mask__  "' 20     [degrees) Minimumof svs • 4
                  --f f - eieva€1.on mask |     - m1.n1.mum  o  sate ll.teJ
4 SV Position     Best PDOP Position [ 3.5)     Mean Position [,358] lused)
Latitude:          39:11'36.62852" N            39:11'36.67782" N
Longitude:        123:11'00.34360"  W          123:11'00.44659"  W
Height (m):                251.8                        247.9
                       k - station information
3 SV Position     Best POOP Position ( 2.5]     Mean Position [157]
Latitude:          39:11'36.93995" N            39:11'36.76322"  N
Longitude:        123:11'00  5300" W           123:11'00  9634" W
 ..........................................................
 STATION(mark)2 : 0 ;          ==========: (k : station informatioilJ  ]!
input data file 1 : 2002592.dat
 antenna height (m)      .120-                  ""
met values used:   pressure(mb)        1010.0
                   temperature(deg  C)     20.0    lh - m=e=t=e o ro lo all ·c a l d a t a l
                   relative humidity(\)  50.0)
  x (m)  -2709224.255    lat   (dms)  N   39    11   36.66472
  y (m)  -4142739.375    elan  (dms)  E  236    48   59.56932
  z (m)   4009144.596    wlon  (dms)  W  123    11     .43068
                         ht   (m)          244.2494

slope distance  (m)     7000.8363    sigma (m)     .036
normal section azimuth (elms) 14 43 52.54
vertical angle (elms)          0 35  7.03

 east(m)    north(m)    up(m)    1780.120   6770.360    71.514 m  solution file
Delta lat(dms)      0  3   39.52751
Delta lon(dms)      0  1   14.17745
Delta ht(m)      ´5.3647

vector covariance matrix (m**2) :
                        dx                  dy
    dx   .4410350642080-02
    dy -.4509019196400-02   .5750649737390-02
    dz -.1186864766470-02   ,7873012060000-03   .6898467551470-03
correlations:
           dx    dy   dz trop bias1 bias2 bias3 bias4 bias5 bias6
bias7
    dx 1.000
    dy -.895 1.000
    d• -.680  .395 1.000
  trop  .000  .000  .000 1.000
 biasl  .000  .000  .000  .000 1.000
 bias2  .587 -.667  -.394  .000  .000 1.000
 bias3  .925 -.836  -.683  .000  .000  .000 1.000
 bias4  .884 -.865 -.679  .000  .000  .000  .000 1.000
 biasS  •972 -.919 -.675  .000  .000  .000  .000  .000 1.000
 bias6  .969 -.912 -.687  .000  .000  .000  .000  .000  .000 1.000
 bias?  .000  .000  .000  .000  .000  ,000  .000  -000  .000  .000
1.000
```

Figure D-8. (Sheet 7 of 13)

	Solution	Sigma	Sensitivity to 10 meter error in station 1 coordinates		
dx (m)	3799.022	.066	9.996	.001	.002
dy (m)	2553.984	.076	•003	9.998	–.006
dz (m)	5296.821	.026	.004	.002	9.999
trap (\)	.000	.000	.000	.C00	.000
bias 1 (cycle)	.000	.000	.000	.C00	.C00
bias 2 (cycle)	.098	•272	-.025	.005	.015
bias 3 (cycle)	-.000	.271	-.020	.004	.017
bias 4 (cycle)	.025	.294	-.028	.008	.019
bias 5 (cycle)	.112	.572	-.039	.012	.038
bias 6 (cycle)	.086	.537	-.038	.012	.035
bias 7 (cycle)	.000	•212	.000	.000	.C00

Interval between epochs (sec) 120
Epoch increment 4
Number of measurements used in solution 167
Number of measurements r j e c t e:d ----------5 0;:-[[:;]
RMS (cycles) .020 (1 – RMS!
Elevation mask (deg) 15.0
Edit multiplier 3.5
Modified Hopfield troposphere model used
Best tracking C/A code positions

Station 1 m solution files
Pdop 3.1

x (m)	-2713023.862	lat (dms)	N	39	7	57.13720.
y (m)	-4145294.253	elon (dms)	E	236	47	45.39187
z (m)	4003848.645	wlon (dma)	W	123	12	14.60813
		ht (m)		170.2629		

clock offset(a) .432668080-03
freq offset(s/s) -.110423480-08

Code calibration(m)		Carrier calibration(m)
1 - 2	•2520	.0012
1 - 3	.0552	-.0006
1 - 4	-.0249	-.0007
1 - 5	•9292	-.0008
1 - 6	-.2124	-.0010
1 - 7	-.0181	.0005
1 - 8	-.1875	-.0009
1 - 9	-.1875	-.0012
1 - 10	1.0630	-.0014

Station 2 m colut on files
Pdop 2.5

x (m)	-2709227.033	lat (dms)	N	39	11	37.11338
Y (m)	-4142726.880	elon (dms)	E	236	48	59.18749
z (m)	4009155.162	wlon (dms)	W	123	11	.81251
		ht (m)		244.0000		

clock offset(s) .885849660-03
freq offset(s/s) .588277840-09

Code calibration(m)		carrier calibration(m)
1 - 2	.2021	.0007
1 - 3	-.3682	-.0011
1 - 4	-.4199	-.0010
1 - 5	-.5342	-.0013
1 - 6	-.5234	-.0011
1 - 7	-.2754	-.0002
1 - a	-.6040	-.0014
1 - 9	-.8003	-.0020
1 - 10	-.6953	-.0017

Figure D-8. (Sheet 8 of 13)

TRIMBLE NAVIGATION, LTD.
585 NORTH MARY AVENUE
SUNNYVALE, CALIFORNIA 94086
U.S.A.

PROGRAM TRIMVEC
GPS RELATIVE POSITIONING SOLUTION

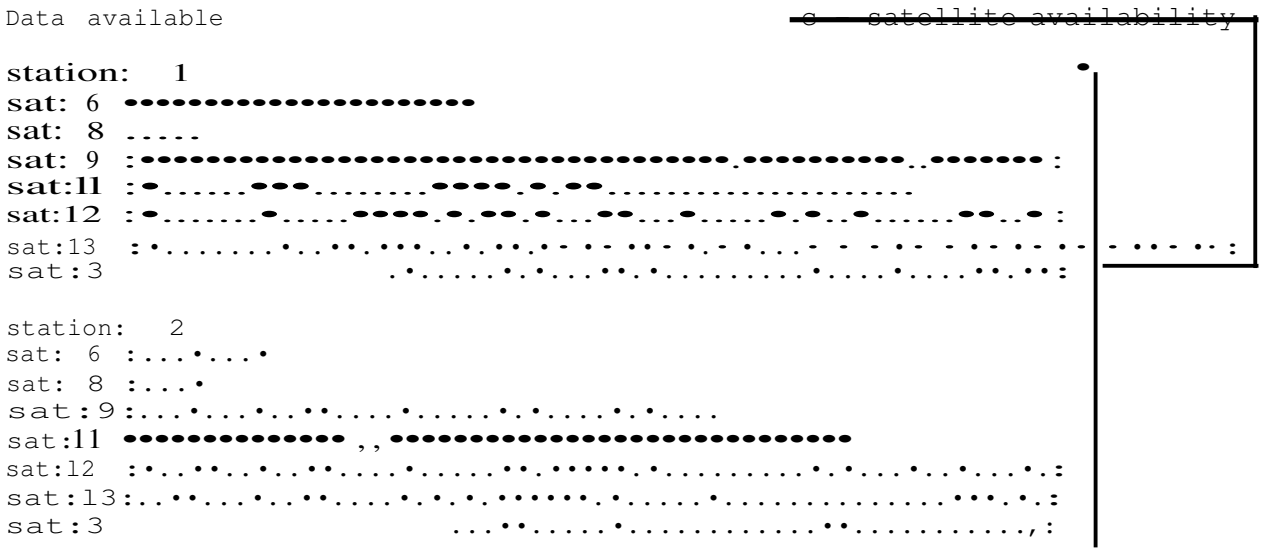
a - listing of the filenamel

File name: 14022059.fix
Coordinate system - WGS-84 ----VE::R:S I O N 8 8 - 0 2:8:: b - t of solution i)

Type solution: Double difference_. ■ - sessiontim

Start date/time: 1988/ 2/29 7:26:30 day of year 60 tow 113190.
Stop date/time: 1988/ 2/29 9:32:30 day of year 60 tow 120750.

Data available c satellite availability



Ephemeris file used: 20140592.eph !d— ephemeris file usedl

SATELLITE	AODE(hr.)	HEALTH	WEEK NO.	TOW(SEC)	URA(M)
6	3.41	0	425	113040.00	5.7
8	4.55	0	425	113040.00	999.0
9	7.96	0	425	112770.00	4.0
11	3.98	0	425	112770.00	2.8
12	6.26	0	425	112770.00	5.7
13	4.55	0	425	112770.00	16.0
3	7.40	0	425	114570,00	2.0

Broadcast satellite clock correction values

prn	af0	afl	af2	toe
6	-.86983712390-03	-.17848833520-10	-.27755575620-16	.11880+06
8	.44125365090-03	-.74987838160-09	-.27755575620-16	.11880+06
9	.21295296300-03	.13542420530-11	-.27755575620-16	.11880+06
11	-.99658500400-04	-.48885340220-11	.00000000000+00	.11880+06
12	.63570542260-03	.53432813730-11	.00000000000+00	.11880+06
13	.32387301330-03	•22737367540-11	.00000000000+00	.11880+06
3	.40117371830-03	-.68212102630-12	.OOOOOOOOOOD+OO	.11880+06

Figure D-8. (Sheet 9 of 13)

```
Message file for station 1
.....................................................
Station ID: 2014  Session #: 059-2   Feb. 29, 1988 07:24
Reference Position - HIGH ACCURACY:
Lat.= 39:07'57.401"N   Long.=123:12'14.788"W  Height=190.2  (meters]
Antenna height • 1.4387 [meters] (entered in the field of feet)
Receiver serial # • 4604
Antenna serial # • 110  (entered in the office)

Survey schedule mode    "' AUTOMATIC                  k - station information
Data-logging start time   07&26
Data-logging stop  time • 09:33  ii - data logging time!  c - satellite tv!
                                                          availailabilt
        ChD   Ch1   Ch2   Ch3   Ch4   Ch5   Ch6   Ch7   Ch8   Ch 7
svs       3     6     8     9    11    12    13     0     0
# meas  379   170    28   506   445   506   506     0     0     0
# cent  379   170    28   506   445   506   506     0     0     0

SV Selection mode • MANUAL SELECTIO          e - t    of satellit
Elevation ma_sk __- 20   rdeareesl _Minimum # of SVs • 4   selection
                        — elevation mask          — minimum # of satelli ,
4 SV Position     Best   DPo    on    1 3.11    Mean Position  [497]     used
Latitude:          39:07'57.17388"  N            39:07'57,14899"  N
Longitude:        123:12'14.47260"W             123:12'14.64029"  W
Height  lmJ'                169.0                          170.3

3 sv Position     Best  POOP Position  2- 51    Mean Position  19]
Latitude:          39:07'57.62620"  N            39:07'57.51783"  N
Longitude:        123:12'14 95426" N            123"12"14-88427"
.....................................................
N
 Origin of station 1 coordinates:  8 st C/A code tracking
solution
   STATION  (mark) 1
                                                 - station informationj
input data file 1 ' 20140592.dat
 antenna height  (m)   1.378

met values used:    pressure(mb)          1010.0
                    temperature(deg  C)     20.0  ""h  — meteorolOalcal  datal
                    relative  humidity(\)   50.0

x  (m)     -2713023.277     1at   (dms)  N    39     7    57.13720
y  (m)     -4145293.358     elon  (d.ms)  E   236    47    45.39187
z  (m)      4003847.775     wlon  (dms)  W   123    12    14.60813
                            ht  (m)            168.8847

st ti  .iD;.2002..    i.;;.059:;...  b.29:.i988.07;2i.......  ""
Reference Position - LOW ACCURACY:
Lat.= 39:12'30.000"N  Long.=123:10'30.000"W  Height•244.0  (mat  s
Antenna height • 0.1201  (meters] (entered in the field in feet
Receiver serial # • 4606                          -     on  n ormat on'
Antenna serial # • 108  (entered in the office)/

Survey schedule mode    "' AUTOMATIC
Data-logging  start time - 07:23                  ii - data loggi-ng time
Data-logging   stop time • 09:32-
```

Figure 0·8. (Sheet 10 of 13)

```
          ChO   Ch1   Ch2   Ch3   Ch4   Ch5   Ch6   Ch7   Ch8   Ch9
SVB         3     6     8     9    11    12    13     0     0     0
# meas    356    78    41   392   457   515   515     0     0     0
# cent    356    65    41   381   457   515   515     0     0     0

SV Selection mode  • MANUAL SELECTIDN--ie - type of satellite selection!
Elevation mask     • 20     [degreesl  Minimum # of SVs • 4
                        4f - elevatiOn maaJd        - m n  urn   o  satellite]
4 SV Position    Best PDOP Position ( 3.5]     Mean Position [358]  Lusedl
Latitude:          39:11'36.62852" N             39:11'36.67782" N
Longitude:       123:11'00.34360" W            123:11'00.44659" W
Height (m):                251.8                         247.9
                       k - station information
3 SV Position    Best PDOP Position ( 2.5]     Mean Position [157]
Latitude:          39:11'36.93995" N             39:11'36.76322"  N
Longitude:       123z11'00.75300"  W           123"11'00,69634H  W
 ----------------------------------------------------------------------
                  2 -  ;:========  lk-1F:;  D
input data (mark) 1 : 20020592.dat                  station information!
 antenna height (m)      .120                 —
                                                 l_...[Ei:::Jiil  l:§; §!:!J W
met values used:   pressure{mb)          1010.0 } h - meteorolo ical data
                   temperature(deg C)     20.0
                   relative humidity(\)   50.0.
  x (m)  -2709224.271     lat  (dms)  N   39 ""   11    36.66495
  y (m)  -4142739.345     elan (dms)  E  236    48    59.56810
  z (m)   4009144.592     wlon (dms)  W  123    11      .43190
                          ht  (m)          244.2339

slope distance  (m)     7000.8355    sigma (m)     .015
normal section azimuth (dms) 14 43 51.65
vertical angle  (dms)          O 35  6.58

 east(m)   north(m)   up(m)    1780.090   6770.367   71.498 m   solution file
Delta lat(dms)      O  3   39.52775
Delta lon(dms)      O  1   14.17622
Delta ht(m)      75.3491

Vector covariance matrix  (m**2) :
                      dx                   dy
    dx   .7856578360340-04
    dy   .6738394490770-04    .7235108729270-03
    dz -.8430657529120-04  -.5045461569000-03   .4649588133050-03
correlations:
           dx     dy   dz trap biasl bias2 biasJ biae4 bias5  bias6
bias?
    dx  1.000
    dy   .283  1.000
    dz  -.680  -.870  1.000
  trap   .000   .COO   .COO 1.000
 biasl   .000   .COO   .000   .COO 1.000
 bias2   .000   .COO   .COO   .000   .000 1.000
 bias3   .000   .000   .000   .COO   .000   .000 1.000
 bias4   .000   .000   .000   .COO   .000   .000   .000 1.000
 bias5   .000   .000   .000   .COO   .000   .000   .000   .000 1.000
 bias6   .000   .000   .000   .COO   .000   .000   .000   .000 .000 1.000
 bias7   .COO   .COO   .000   .000   .000   .000   .COO   .000 .000   .000
1.000
```

Figure D-8. (Sheet 11 of 13)

```
                    Solution      Sigma  Sensitivity to 10 meter error
                                            in station 1 coordinates
     dx  (m)        3799.006       .009      9.999      .COO     -.002
     dy  (m)        2554.013       .027      -.001    10.000     -.001
     dz  (m)            •000       ,000       .COO      .COO    10.000
   trap  (%)            .000       .000       .COO      .COO      .COO
bias 1 (cycle)          .000       .000       .000      .000      .COO
bias 2 (cycle)          .000       .000       .COO      .COO      .COO
bias 3 (cycle)          .000       .000       .000      .000      .000
bias 4 (cycle)          .000       .000       .COO      .000      .000
bias 5 (cycle)          .000       .000       .COO      .COO      .000
bias 6 (cycle)          .000       .000       .COO      .000      •000
bias 7 (cycle)          .000       .000       .000      .000      .COO
 Results of integer bias search:
            •0549                 1.06578                    1.36295
                0                       1                          0
                0                       0                          0
                0                       0                          0
                0                       0                          0
                0                       0                          0
                0                       0                          0
Ratio sum-of-squares(2) to sum-of-squares(!)        18.87
 Interval between epochs (sec}  120
 Epoch increment      4
 Number of measurements used in solution    161
 Number of measurements re··J e c t e d:_____s 6 Ul
 RMS (cycles)        .020.                  ! 1—RMSI
 Elevation mask (deg)    15.0
 Edit multiplier          3,5
 Modified Hopfield troposh re model used
Beet tracking C/A code pos1tions
station 1                                          m  so ut on
Pdop        3.1
  x {m)     -2713023.862   lat   (dms) N   39  7  57.13720
  y (m)     -4145294.253   elon  (dms) E  236 47  45.39187
  z (m)      4003848.645   wlon  (dms) W  123 12  14.60813
                           ht (m)          170.2629
clock offset(s)        .432668080-03
freq offset(e/s)      -.110423480-08
 Code calibration(m)  carrier calibration(m)
1 -  2          •2520                  -0012
1 -  3          .0552                 -.0006
1 -  4         -.0249                 -.0007
1 -  5          •9292                 -.0008
1 -  6         -.2124                 -.0010
1 -  7         -.0181                  .0005
1 —  8         -.1875                 -.0009
1 —  9         -.1875                 -.0012
1 - 10         1.0630                 -.0014
station 2                                          lm - solution file r-
Pdop       2.5
 x (m)     -2709227.033    lat   (dms) N    39  11  37.11338
 y (m)     -4142726.880    elon  (dms) E   236  48  59.18749
 z (m)      4009155.162    wlon  (dms) W   123  11   •81251
                           ht (m)          244.0000
clock offset(s) freq  .885849660-03
      offset(s/s)     .588277840-09
Code calibration(m)  carrier ca1ibration(m)
1 -  2          .2021                   .0007
1 -  3         -.3682                  -.0011
1 -  4         -.4199                  -.0010
1 -  5         -.5342                  -.0013
1 -  6         -.5234                  -.0011
1 -  7         -.2754                  -.0002
1 -  8         -.6040                  -.0014
1 -  9         -.8003                  -.0020
1 - 1O         -.6953                  --0017
```

Figure 0·8. (Sheet 12 of 13)

TRIMVEC GPS RELATIVE POSITIONING SOLUTION SUMMARY: VERSION 88.028

SOLUTION OUTPUT FILE: a:14022059.fix

STATION 1: Station ID: 2014 Session No.: 059-2 Feb 2"9,.1988 07:24
Data-iogging start time = 07:26 Data-logging stop time = 09:33

STATION 2: Station ID: 2002 Session #: 059-2 Feb 29,1988 07:21
Data-logging start time = 07:23 Data-logging stop time = 09:32

STATION COORDINATES:

Sta	Ant (m)	Latitude	Longitude	Hgt (m)
1	1-378	39:07'57.13720" N	12J!12 ▮14。60813" W	168.885
2 [TRPJ	0.120	39:11'36.66538" N	123:11'00.43314" W	244.226
2 [FLTJ	0.120	39:11'36.66472" N	123:11'00.43068" W	244.249
2 [FIX]	0.120	39:11'36.66495" N	123:11'00.43190" W	244.234

Origin of station 1 coordinates : Best C/A code tracking solution

SOLUTION SUMMARY:

Solution	dx (m)	dy (m)	dz (m)	dh (m)	RDOP
TRIPLE	3798.989	2554.042	5296.822	75-341	nfa
FLOAT	3799.022	2553.984	5296.821	75.365	nfa
FIXED	3799.006	2554.013	5296.817	75.349	nfa
FLT-FIX	0.016	-0.029	0.004	0.016	

Solution	Slope (m)	sig	Epochs/Rejected	Epoch int	Epo.ch inc
TRIPLE	7000.8406	[0.032]	168/ 1	150 (sees)	5 (epochs)
FLOAT	7000.8363	[0.036]	167/ 50	120 (sees)	4 (epochs)
FIXED	7000.8355	[0.015]	161/ 56	120 (sees)	4 (epochs)

Fixed solution quality factor: 18.9
Fixed solution rms: 0.020 (cycles)
Maximum float - fixed delta: 2.0 (em)

Integers found, RMS is OK, FIXED solution recommended.

Figure D-8. (Sheet 13 of 13)

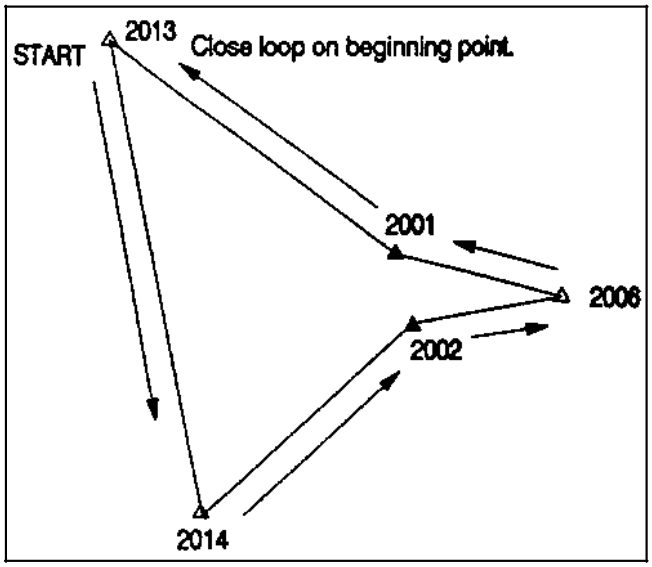


Figure D-9. Loop closure (Ukiah)

a. The input data file for a GEOLAB adjustment is called an "IOB" file. An IOB file can be created using a text editor program or with a GEOLAB option called "GPS Environment." An IOB file is specific to the GEOLAB adjustment software and may or may not be required by other least-square adjustment software (refer to Chapter 11 or the owner's manual). The GEOLAB Environment option takes GPS baseline solution files developed by most GPS manufacturers and automatically sets up an IOB file for adjustment.

b. The IOB input file generally consists of the following information:

(1) *Top line*. Title Record - usually a project name and an adjustment number.

(2) *Second line*. Options Record - this record specifies which GEOLAB options are to be activated for processing.

(3) *Third line*. Ellipsoid Specification Record - Prints ellipsoid parameters chosen in the Options Record or as chosen by the user.

(4) *Station information section*. All stations must have their coordinates defined here. The coordinates must be given as ellipsoidal latitude, longitude, and orthometric height, or as Cartesian coordinates. In this section, stations are either held fixed or are to be adjusted. If stations are not held fixed, estimated coordinates are input.

(5) *Auxiliary parameter definition record*. The auxiliary parameter group definition record is optional, but can be used if GEOLAB is to solve for various scale, orientation, translation, or constant parameters. In the sample GEOLAB input, enough vertical and horizontal control is held fixed to solve for SCALE and ROTATION. Rotation is about the Cartesian X-axis, Y-axis, and Z-axis.

(6) *Observation records section*. In the example GEOLAB input file, only GPS observations are entered. Each baseline is entered separately with the station name and Cartesian coordinate differences between the stations, which is the computed baseline. These can also be entered as $\Delta x=0$, $\Delta y=0$, $\Delta z=0$, for station 1 and the 3D

Baseline	Δx, m	Δy, m	Δz, m	Distance, m
13142059.FIX 2013 -> 2014	-3,367.429	-7,891.019	-10,410.673	13,490.362
14021059.FIX 2014 -> 2002	3,799.005	2,554.018	5,296.798	7,000.823
02053056.FIX 2002 -> 2006	953.294	-748.319	-16.709	1,212.035
06013056.FIX 2006 -> 2001	-666.617	1,441.548	908.280	1,829.593
01132059.FIX 2001 -> 2013	-718.244	4,643.775	4,222.288	6,317.297

baseline for station 2. For example, baseline 1 would be entered as:

STATION		Δx	Δy	Δz
92	2001	0.000	0.000	0.000
92	2006	-666.617	1,441.548	908.280

The correlation matrix elements from the baseline solution are also entered and the last line of the observation record is the standard deviation for Δx, Δy, and Δz.

c. The following figure (Figure D-10) taken from a GEOLAB input is annotated with the convention above.

d. Once an IOB file containing parameters necessary to perform an adjustment has been completed, the adjustment can begin. The first step is to select the baselines needed for the adjustment. The baselines chosen must have been processed adequately, as detailed in Chapter 10, or as recommended by the GPS manufacturer.

e. The example IOB file shown in Figure D-10 was adjusted as shown in Figure D-11. Figure D-11 has been annotated for a general discussion of the results.

f. For the first adjustment (Figure D-11), one point was held fixed in 3D, producing a free adjustment (refer to Chapter 10 for further detail). A free adjustment checks the internal consistency of a GPS survey.

g. A second adjustment (not shown) can be made to check the existing network if these control points are directly tied together with GPS baselines. To do this with GEOLAB, the user must set up an IOB file with only the fixed control and the respective baselines connecting them. Hold fixed all control except one point, then adjust. Next, fix that control point and free one of the others, and keep repeating this procedure until all control points have been allowed to be checked against their true position. If the position of one control point is "bad," that point can generally be omitted from the subsequent constrained adjustment or allowed to adjust with the other points.

h. A final constrained adjustment (Figure D-12) should hold fixed all good horizontal and vertical control. Adjust and check the output as detailed in Chapter 11.

D-6. Check of the Final Adjustment

After each adjustment was run, the 2D and 1D station (absolute) error ellipse for each adjusted point was reviewed (for further discussion on error ellipses and adjustments, refer to Chapter 11). These are listed as major semi-axis, minor semi-axis, major azimuth, and vertical (as shown on page 15 of the free adjustment and page 16 of the constrained adjustment).[1] The size of the error ellipses listed in this portion of the GEOLAB adjustment are an indication of the internal consistency of the GPS survey. The smaller the size of the ellipse, the better the survey. The size of the ellipse will also generally become larger as the project size increases. In the constrained adjustment shown, the major semi-axis and minor semi-axis are of the millimeter level (0.0066 and 0.0048 mm for 2001 and 0.0062 and 0.0044 mm for 2002, respectively) - which is acceptable.

a. The 2D and 1D relative error ellipses and line accuracies (i.e., precision) between survey points were checked. These are listed as major semi-axis, minor semi-axis, major azimuth, and vertical, spatial distance, and precision (as shown on page 16 of the free adjustment and page 17 of the constrained adjustment). When checking these values, one should remember they are relative values. The relativity of points used in the adjustment can sometimes produce deceptive values, higher major semi-axis and minor semi-axis values: this may occur between points that are close together, but have not been tied together by a baseline. Because of the possibility of the production of deceptive results, the user must take special care when reviewing these values. In the constrained adjustment shown, the major semi-axis and minor semi-axis are of the millimeter level (0.0045 and 0.0036 for the baseline 2001->2002). The project precision in parts per million (PPM) is also listed in this portion of the adjustment and should be checked.

b. The histograms in the GEOLAB adjustments were reviewed. The histogram is a visual representation of the standardized (normalized) residuals. The histogram shows whether the residuals are symmetrical about the mean residual, the total spread of values of the residuals, the frequencies of the different values, and how peaked or how flat the distribution of the residuals may be. A generally good looking histogram has data that, when graphed, is in the shape of a bell curve.

c. The free adjustment line accuracy precessions shown on page 16 of Figure D-11 are the primary criteria used to evaluate the survey adequacy. The worst precision (4.182 ppm between 2001 and 2013) equates to 1:239,000. This far exceeds the required project accuracy

[1] Note the page numbers listed on the right side of the sheets of Figures D-11 and D-12. Each sheet contains several pages of the GEOLAB adjustments.

```
COYOTE DAM CONTROL
0  0 21          001 0 1 O              00 010100    0.001  95.000-4ID
 80    6378137.000   298.2572221011  0.000       0.000          O.OOO

 24   2001                -2708942.23500  -4142043.83100   4010047.0300
 14   2006                  N39 11 34.37462W123  10 10.28988  366.0850
 24   2002                 °09230.74000 -4142726.83300  4009152.53400
 14   2014                  N39   7 57.41258W123  12 14.77684  190.1700
 14   2015                  N39 15 12.11624W123  13 17.48Ji87 222.8350
 94300WGSXX            SCAL ROTX ROTY ROTZ
      baseline#   1       day   57      01063056.FIX          type  10

 91300
 92   2001                -2708942.235   -4142043.831  @_010047.030
 92   2006                -2708275.618   -4143485.379   lloo9138.750
 94300WGSXX
 97POCUPPER
 98      1              0.5690      -0.6230
 98      1             -0.6310
 98      0.005000    0.006000     0.004000
      basel·ne#   2       day   57      02063056.FIX     ®.....type  10

 91300
 92   2002                -2709230. 74_0     4_1_4 2_7_2_6 .8-3_3__ 1 4009152.534
 92   2006                -2709227.764    -4143475.151    4009135.824
 94300WGSXX
 97POCUPPER
 98      1              0.3900      -0.6720
 98      1             -0.4460
 98      1
 98      0.003000    0.005000     0.004000
        6aseline#   3    day   59      01022058.FIX     ®._.type   10

 91300
 92   2001                -2708941.-0-9-5---.-_-4-14_2_o s=o=.=6 3·2  @4010039.950
 92   2002                -2709227.764    -4142743.851    4009149.248
 94300WGSXX
 97POCUPPER
 98      1              0.5190      -0.5760
 98      1             -0.7560
 98      1
 98      0.003000    0.004000     0.004000
         aseline#   4    day   59      01023058.FIX     0-....._type 10

 91300
 92   2001                -2708946 . 1 0 8 ---- 4 1 4 2 0 4  =- 2=-1 8-- 039.950
 92   2002                -2709232.787     -4142741.441    4009148.372
 94300WGSXX
 97POCUPPER
 98      1              0.6130      -0.7240
 98      1             -0.6180
 98      1
 98      0.004000    0.004000     0.004000
        6aseline#   5    day   60      14021059.FIX     ®--..type  10
 91300
```

Figure D-10. GEOLAB input (Ukiah) (Continued)

```
92   2014                -2713050- 5 1 7------ 4 1 4 5 2 8 6-.-- 8 3 1-- 3867.585
92   2002                -2709251.512     -4142732.813     4009164.383
94300WGSXX
97POCUPPER
98      1                 0.5930     -0.2650
98      1               -0-7720
98      1
98      0.018000  0.016000    0.020000
```

ba eline# 6 day 60 13142059- FIX type10

```
91300
92   2013                -2709663 .6oo    -4137421.45o    14263.662
92   2014                -2713031.029     -4145312.7[illegible]    4003852.989
94300WGSXX
97POCUPPER
98      1                 0.1480     -0-2650
98      1               -0.8850
98      1
98      o. 15000  0.046000    0.033000
```

ba eline# 7 day 60 13012059— type 10

```
91300
92   2013                -2709663.600     -4137421-450    4014263.662
92   2001                -2708945.356     -414206 ..225   4010041.375
94300WGSXX
97POCUPPER
98      1                 0.4380     -0.5290
98      1               -0.9090
98      1
98      0.007000  0.020000    0.015000
        )
99
```

Figure D-10. (Concluded)

U.S. ARMY ENGINEER TOPOGRAPHIC LABORATORIES
COYOTE DAM FREE ADJUSTMENT NAD-83

A= 6378137.000 B= 6356752.314 XO: 0.000 YO= 0.000 ZO: 0.000

PREPARE ASCII I"f)Ut file: <coyote 2.iob>
PREPARE successfully conpleted.

Geolab • V1.82S, (C) 1985/86/87 BitWise Ideas Inc. (1032076961 Page 0

GETUP:

PARAMETERS		OBSERVATIONS	
Description	NUDer	Description	Nurber
All Stations	5	Directions	0
Fixed Stations	1	Distances	0
Free 3-D Stations	4	AzinJJths	0
Free 2-D Stations!	0	Vertical Angles	0
Free 1·0Statfons	0	Zenithal Angles	0
Coord. Parameters!	12	Angles	0
Aatro.latitudes	0	Heights	0
Aatro.longitudes	0	Height Differences	0
Geoid Records	0	Auxiliary Params.	0
All Aux.Pars.	0	2·0coords.	0
Direction Pars.	0	2·DCoord.Diffs.	0
Scale Parameters	0	3·DCoords.	0
Constant Pars.	0	3-D Cool'(!.Diffs.	21
Rotation Pars.	0		
Translation Pars.	0		
Total Parameters	12	Total Observations!	21

Degrees of Freedom • 9

Geolab- V1.82S, (C)1985/86/87 BIU.Iise Ideas Inc. [1032076961 Page

SI.IIU:Y OF SELECTm IPTIONS

OPTION	SELECTION
Computation Mode	Adjustment
Linear Unit	Metre
Maximum Iterations	2
Confidence Regions Selected	All
Confidence Region Dimensions	1·0, 2-0, and 3·0
Print lnpJt Station Data	On
Variance Factor Knowledge	Known
Confidence Level for Statistics	95.000
Dual-Height Mode	Off
Print Solution Vector	on All Iterations
Printed Ellipsoidal Coordinates	5 Decimal Places
Print Adjusted X, Y, Z	|||
Print Histograms	On
Print Misclosures	On All Iterations
Print Residuals	All
Variance Factor Usage	Scale Confidence Regions
Residual Rejection Criterion	Tau Ma;o;
Angular Misclosure Limit Factor	10
Linear Misclosure Limit Factor	10
Convergence Criterion	0.001000

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Figure D-11. GEOLAB adjustment output (free) (Sheet 1 of 7)

U.S. ARMY ENGINEER
COYOTE DAM FREE ADJUSTMENT

CODE	!DENT.	DESCRIPTOII.	INITIAL VALUES		
14	2006				
		ELLIPSOIDAL	39 11 34.37462	-123 10 10.28988	336.0850
		ASTRONOMIC	39 11 34.37462	-123 10 10.28988	336.0850
		GEOIDAL	0 0 0.00000	0 0 0.00000	0.0000
		CARTESIAN	·2708280.4788	-4143494.m1	4009147.8933
24	2001				
		ELLIPSOIDAL	39 12 14.43422	·123 11 6.45941	243.6658
		ASTRONOMIC	39 12 14.43422	-123 11 6.45941	243.8658
		GEOIDAL	0 0 0.00000	0 0 0.00000	0.0000
		CARTESIAN	-2708942.2350	-4142043.8310	4010047.0300
24	2002				
		ELLIPSOIDAL	39 11 37.00656	-123 ¬ 0.94286	243.8815
		ASTRONOMIC	39 11 37.00656	-123 11 0.94286	243.8815
		GEOIDAL	0 0 0.00000	0 0 0.00000	0.0000
		CARTESIAN	·2709230.7400	-4142726.!330	4009152.5340
24	2014				
		ELLIPSOIDAL	39 7 57.44196	-123 12 15.70589	188.7219
		ASTRONOMIC	39 7 57.44196	-123 12 15.70589	188.7219
		GEOIOAL	0 0 0.00000	0 0 0.00000	0.0000
		CARTESIAN	·2713050.5170	-4145286.8310	4003867.5850
"	2013				
		ELLIPSOIDAL	39 15 11.55819	-123 13 17.15396	220.5009
		ASTRONOMIC	39 15 11.55819	-123 13 17.15396	220.5009
		GEOIOAL	0 0 0.00000	0 0 0.00000	0.0000
		CARTESIAN	-2709663.6000	·4137421.4500	4014263.6620

GETUP successfully c leted.

Geolab- V1.82S, (C) 1985/86/87 BitWise Ideas Inc. I103207!S96J Page 3

FORMEO: NOTE 6: Reordering was done.

2001	2006	3·D X·Coord Diff	666.6170	0.0037	·4.8608
2001	2006	3-D Y·Coord Diff	·1441 .5480	0.0045	·9.3931
2001	2006	3-D Z·Coord Diff	·908.2800	0.0028	9.1433
2002	2006	3-D X·Coord Diff	953.2950	0.0022	-3.0338
2002	2006	3-D Y·Coord Oiff	.748.3180	0.0044	·19.6211
2002	2006	3-D Z·Coord Diff	·16.7100	0.0029	12.0693
2001	2002	3·D X·Coord Diff	·286.6690	0.0024	·1.8360
2001	2002	3-D Y·Coord Oiff	·693.2190	0.0026	10.2170
2001	2002	3-D Z·Coord Diff	·891.5890	0.0025	·2.9070
2001	2002	3-D X·Coord Oiff	·286.6790	0.0026	·1.8260
2001	2002	3-D Y·Coord Diff	·693.2230	0.0030	10.2210
2001	2002	3-D z·coord Oiff	·891.5780	0.0026	·2.9180
2014	2002	3·0 X·Coord Oiff	3799.0050	0.0129	2o.mo
2014	2002	3-0 Y·Coord Diff	2554.0180	0.0101	5.9800
2014	2002	3-D 2-Coord Oiff	5296.7980	0.0113	·11.8490
2013	2014	3-D X·Coord Diff	·3367.4290	0.0142	·19.4880
2013	2014	3-D Y·Coord Diff	-7891.0200	0.0210	25.6390
2013	2014	3-D Z·Coord Diff	·10410.6730	0.0147	14.5960
2013	2001	3·0 X·Coord Diff	718.2440	0.0059	3.1210
2013	2001	3-0 Y·Coord Diff	-4643.mo	0.0083	21.3940
2013	2001	3-0 Z·Coord Diff	·4222.2870	0.0059	5.6550

FORMEQ successfully c leted.

GeoLab- V1.82S, (C) 1985/86/87 BitWise Ideas Inc. (103207696] Page 4

Figure D-11. (Sheet 2 of 7)

U.S. ARMY ENGINEER TOPOGRAPHIC LABORATORIES
COYOTE DAM FREE ADJUSTMENT
A• 6378137.000 B= 6356752.314 XOz 0.000 YO• 0.000 ZO= 0.000

SOLVE: solution (Iteration CcM!t • 1):

CODE	IDENT.	TYPE	INITIAL	DX	UPDATED
24	2001	LATITLIIE	39 12 14.43422	0.01413	39 12 14.44836
24	2001	LONGITUDE	-123 ⅋ 6.45941	0.04476	-123 ⅋ 6.41465
24	2001	HEIGHT	243.86577	13.93969	257.80546
24	2002	LATIT\liE	39 ⅋ 37.00656	·0.06729	39 ⅋ 36.93927
24	2002	LONiliTOOE	-123 ⅋ 0.94286	0.34171	-123 ⅋ 0.60115
24	2002	HEIGHT	243.88154	21.63376	265.51530
24	2014	LATITUOE	39 7 57.44196	·0.02938	39 7 57.41258
24	2014	LONGITIIIE	·123 12 15.70589	0.92905	·1Z3 12 14.77684
24	2014	HEIGHT	188.72193	1.44519	190.16712
24	2013	LATITLOE	39 ⅋ 11.55819	0.55805	39 ⅋ 12.11624
24	2013	LONGITIIIE	·123 13 17.15396	-0.33491	-123 13 17.48887
24	2013	HEIGHT	220.50094	2.33476	222.83570

SOLVE successfully c leted.

Geolab- V1.82S, (C) 1985/86/87 BitWise Ideas Inc. [103207696] Page 5

FORMEQ: FORMEQ suceessfutty earpleted.

GeoLeb • V1,82S, (C) 1985/86/87 BitWise Ideas Inc. (103207696] Page (

SOLVE: Adjusted Values (Iteration COUit '" 2);

COOE	!DENT.	TYPE	INITIAL	DX	ADJUSTED
14	2006	LATITIIIE	39 ⅋ 34.37462	FIXED	
14	2006	LONGITUDE	-123 10 10.28988	FIXED	
14	2006	HEIGHT	336.08500	FIXED	
24	2001	LATITIIIE	39 12 14.44836	-0.00000	39 12 14.44836
24	2001	LONGITUDE	-123 \1 6.41465	·O.DOOOO	-123 ⅋ 6.41465
24	2001	HEIGHT	257.80546	-0.00000	257.80546
24	2002	LATITUDE	39 \1 36.93927	0.00000	39 ⅋ 36.93927
24	2002	LONGITUDE	-123 \1 0.60115	·0.00000	-123 ⅋ 0.60115
24	2002	HEIGHT	265.51530	0.00001	265.51530
24	2014	LATITLDE	39 7 57.41258	-0.00000	39 7 57.41258
24	2014	LONGITUOE	·123 12 14.77684	-0.00000	-123 12 14.77664
24	2014	HEIGHT	190.16712	0.00004	190.16716
24	2013	LATITUDE	39 ⅋ 12.11624	-0.00000	39 ⅋ 12.11624
24	2013	LOHGITUOE	-123 13 17.48887	-0.00000	·123 13 17.48887
24	2013	HEIGHT	222.83570	0.00003	222.83573

GeoLab- V1.82S, (C) 1985/86/87 BitWise Ideas Inc. [1032076961 Page 1

Adjusted cartesf.,Coordinates:

COOE	IDENT,	X·COOROINATE	Y·COORDINATE	Z·COOROINATE
24	2001	-2708947.0978	·4142053.2284	4010056.1788
24	2002	-2709233.7714	·4142746.4510	4009164.5970
24	2014	-2713D32.mo	·4145300.4675	4003867.7943
24	2013	·2709665.3421	·4137409.4529	4014278.4662

SOLVE successfully earpteted.

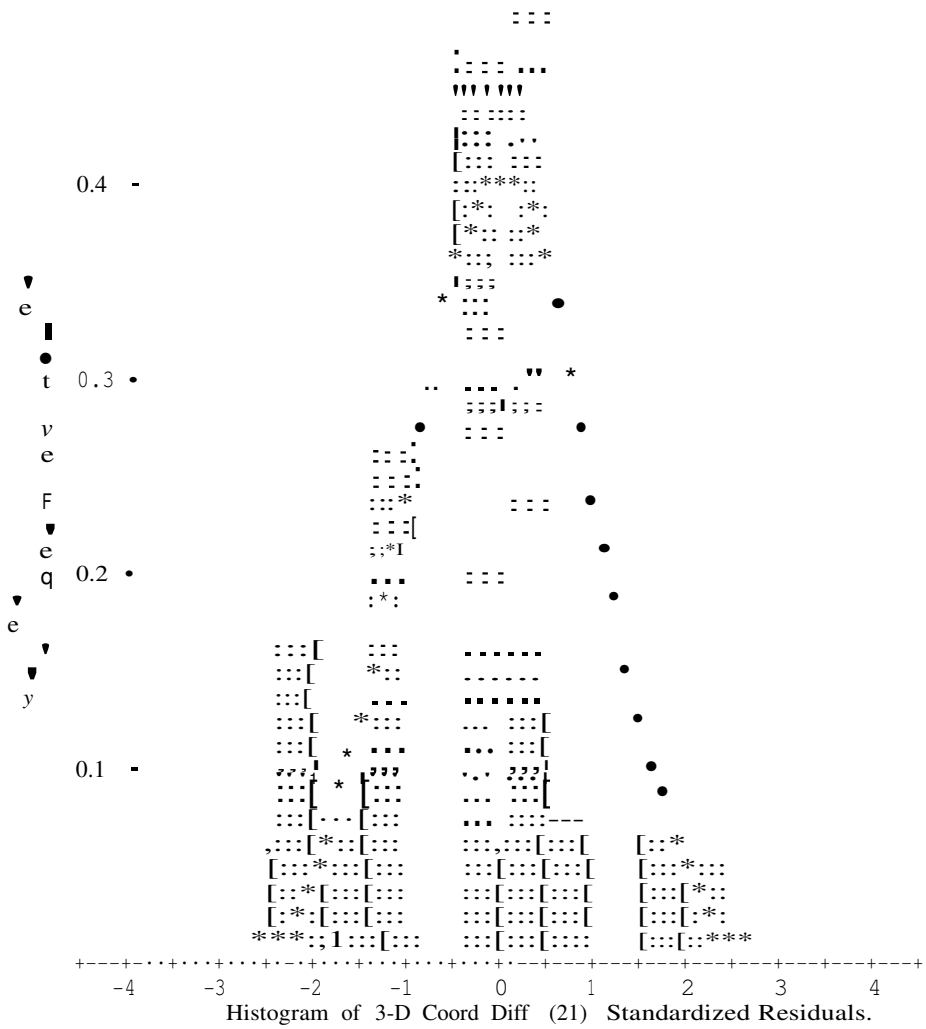
GeoLab- V1.82S, (C) 1985/86/87 BitWise Ideas Inc. [103207696] Page

Figure D-11. (Sheet 3 of 7)

```
-----------------------------------------------------------------------
                U.S. ARMY ENGINEER TOPOGRAPHIC LABORATORIES
                      COYOTE DAM        FREE ADJUSTMENT
A=  6378137.000 B=  635675<!.314 XO•        0.000  YO"        0.000  ZO=        0.000
-----------------------------------------------------------------------.
INVERT:          INVERT successfuLLy completed.
-----------------------------------------------------------------------
Geolab • V1.SZS, (C) 1985/86/87 BitWise Ideas Inc. [103207696]        Page      9
-----------------------------------------------------------------------
RESIO:
 STATION     3·O COORD OIFFS      STO.OEV.    RESIDUAL     STD.DEV.    STAH.RES.
 -------     -------------        ----------  ----------   ----------  ----------
2001         ·2708942.2350
             ·4142043.8310
              4010047.0300
2006         ·2708275.6180        0.0050      0.0020       0.0040      0.4913
             ·4143485.3790        0.0060      0.0043       0.0044      0.9722
              4009138.7500        0.0040     ·0.0055       0.0026     ·2.1131
--   = ===   =••--•••   =• End of Observation Set •••• •=c•••••••• ==•=s••===
2002         -2709230.7400
             ·4142726.8330
              4009152.5340
2006         ·2708277.4450        0.0030     -0.0024       0.0015     -1 .S684
             ·4143475.1510        0.0050     -0.0031       0.0031     -1.0050
              4009135.8240        0.0040      0.0063       0.0026      2.4021
  =•••••••••===•=••••••••== End of Observation set •========•••===========•••=
2001         ·2708941.0950
             -4142050.6320
              4010040.8370
2002         ·2709227.7640        0.0030     -0.0046       0.0020     -2.2695
             ·4142743.8510        0.0040     ·0.0036       0.0031     · 1.1723
              4009149.2480        0.0040      0.oon        0.0032      2.2790
====••••==========•••••==== End of Observation Set· ==========••===========•=
2001         -2708946.1080
             -4142048.2180
              4010039.9500
2002          - 2709232.7870      0.0040      0.0054       0.0033      1.6114
             -4142741.4410        0.0040      0.0004       0.0031      D.1290
              4009148.3720        0.0040     -0.0038       0.0032     -1.1996
========•• ========••• ==== End of Observation Set ==========================
2014         ·2713050.5170
             -4145286.8310
              4003867.5850
2002         -2709251.5120        0.0180     ·0.0034       0.0132     ·0.2586
             ·4142732.8130        0.0160     ·0.0015       0.0077     -0.1983
              4009164.3830        0.0200      0.0047       0.0129      0.3661
=======•=•================= End of Observation Set ==========================
2013         ·2709663.6000
             ·4137421 .4500
              4014263.6620
2014         ·2713031.0290        0.0150     ·0.0019       0.0092     -0.2019
             ·4145312.4700        0.0460      0.0054       0.0407      0.1332
              4003852•9890        0.0330      0.0011       0.0275      0.0389
-----------------------------------------------------------------------.
Geolab • Y1.82S, (C) 1985/86/87 BitWise Ideas Inc. [103207696]        Page      10
-----------------------------------------------------------------------
RESIO:
STATION     3-0 COORD DIFFS      STO.DEV.    RESIDUAL     STO.OEV.    STAN.RES.
••••----    ----•----------      ----------  ----------   ----------  ----------
=========••===========••=== End of Observation Set ==========================
2013         -2709663.6000
             -4137421.4500
              4014263.6620
2001         -2708945.3560        0.0070      O.Q003       0.0021      0.1596
             -4142065.2250        0.0200     ·0.0005       0.0076     ·0.0670
              4010041.3750        0.0150     -0.0004       0.0055     -0.0743
========================== End of Observation Set ==========================
•-••----------•-••----------•-••----••••••••••••••••••••••••••••••••••••••-----
GeoLab • V1.82S, (C) 1985/86/87 BitWise Ideas Inc. [103207696]        Page      11
```

Figure D-11. (Sheet 4 of 7)

U.S.ARMY ENGINEER TOPOGRAPHIC LABORATORIES
COYOTE DAM FREE ADJUSTMENT
A= 6378137.000 B= 635675 .314 XO= 0.000 YO= 0,000 ZD= 0.000



Histogram of 3-D Coord Diff (21) Standardized Residuals.

GeoLab- V1.82S, (C) 1985/86/87 BitWise Ideas Int. [1032076961 Page 12

Figure D-11. (Sheet 5 of 7)

U.S. ARMY ENGINEER TOPOGRAPHILA UKAIUKit
COYOTE DAM FREE ADJUSTMENT
A= 6378137.000 95 6356752.314 XO= 0.000 YO= 0.000 ZO= 0.000

STATISTICS SUMMARY

Residual Critical Value Type	Tau Max
Residual CriticaL Value	2.5985
Convergence Criterion	0.001000
Final Iteration COU"'ter Value	2
Confidence Level Used	95.0000
MUlDer of Flagged Residuals	0
Estimated Variance Factor	1.3376
Nurber of Degrees of Freedom	9

Chi-Square Test on the Variance Factor:

6.3283e-001 < 1.0000 < 4.4579e+OOO 7

THE TEST PASSES.

RESID successfully completed.

GeoLab - V1.82S, (C) 1985/86/87 Bit\llse Ideas Inc. (1032076961 Page 13

ELLIPSE:

NOTE: All confidence regions were computed using the following factors:

Variance factor used	•	1.33757
Estimated variance factor	"	1.33757
1·0 expansion factor	•	1.960
2-D expansion factor	•	2.448
3-D expansion factor	•	2.795

Note that, for relative confidence regions, prec1S1ons are computed from the ratio of the major semi-axis and the spatial distance between the two stations.

Error ellipses for which all covariance matrix elements were not c ted by INVERT, are marked with an asterisk(*).

GeoLab - V1.82S, CC) 1985/86/87 Bitlolise Ideas Inc. [1032076961 Page 14

ELLIPSE: 2-D AND 1·0 STATIC. CQIFIDENCE REGI(»>S (95.000 X):

!DENT.	MAJOR SEMI-AXIS	MINOR SEMI-AXIS	AZ(MAJ)	VERTICAL
2001	0.0073	0.0054	124.77	0.0112
2002	0.0074	0.0047	130.94	0.0106
2014	0.0277	0.0211	86.20	0.0483
2013	0.0273	0.0138	95.77	0.0505

GeoLab - V1.825, (C) 1985/86/87 Bitlolise Ideas Inc. I1032076961 Page 15

Figure D-11. (Sheet 6 of 7)

U.S. ARMY ENGINEER TOPOGRAPHIC LABORATORIES
COYOTE DAM FREE ADJUSTMENT
A= 6378137.000 B 6356752.314 XO• 0.000 YO= 0.000 ZO= 0.000

ELLIPSE: Z·D All) 1-D RELATIVE STATIOIII D:IIFIDEICE REiiiCIIS (95.000 S):

FROM	TO	MAJSEM	MIN.SEMI	AZ(MAJ)	VERTICAL	SPATIAL DIST.	PRECISION
2001	2002	0.0045	0.0038	105.27	0.0082	1165.1856	3.881 PPM
2001	2014	O.OZn	0.0204	84.07	0.0475	8095.2706	3.363 PPM
2001	2013	0.0264	0.0125	94.67	0.0494	6317.2966	4.182 PPM
2002	2014	0.0271	0.0203	83.67	0.0473	7000.8237	3.871 PPM
2002	2013	0.0267	0.0130	94.73	0.0499	7404.1516	3,612 PPM
2014	2013	0.0359	0.0216	91.44	0.0607	13490.3592	2.665 PPM

Geolab • V1.82S, (C) 1985/86/87 BitWise Ideas Inc. [1032076961 Page ▼▼

ELLIPSE: 3-D STATIOI COIFIDEICE REGIOIS (95.000 X):

IOEHT.	KAJOR SEMI·AXIS	MEDilll SEMI·AXIS	MINOR SEMI-AXIS
2001	0.0161 A=180.0 V= 80.4	0.0082 A=298.9V= 4.7	0.0059 A= 29.6 V: 8.3
2002	0.0152 A=161.8 V= 79.9	0.0082 A=307.9 V= 8.4	0.0054 A38.7 V= 5.6
2014	0.0690 A=345.0 V= 86.1	0.0316 A= 85.7 V: 0.7	0.0237 A=175.8 V= 3.8
2013	0.0 4 A= 94.5 V72.1	0.0219 A=279.0 V17.9	0.0157 A=188.6 V= 1.3

GeoLab • V1.82S, (C) 1985/86/87 Bit ise Ideas Inc. [103207696] Page 17

ELLIPSE: 3-D RELATIVE STATIC* COIFIDEIICE REGIONS (95.000 1):

FROM	TO	MAJOR-SEMI	MED.·SEMI	MINOR-SEMI	SPATIAL DIST.	PRECISION
2001	2002	0.0117	0.0051	0.0044	1165.1856	10.011 PPM
		A: 0 V:90 A= 90 V= 0 A= 0 V0				
2001	2014	0.0679	0.0311	0.0228	8095.2706	8.392 PPM
		A=347 V=86 A= 84 V= 1 A:174 V= 4				
2001	2013	0.0739	0.0201	0.0142	6317.2966	11.704 PPM
		A= 93 V=72 A=279 V=18 A:188 V2				
2002	2014	0.0677	0.0309	0.0226	7000.8237	9.666 PPM
		A=342 V=85 A= 83 V= 1 A=173 V= 4				
2002	2013	0.0745	0.0210	0.0148	7404.1516	10.064 PPM
		A= 93 V=72 A=278 V:18 A=188 V= 1				
2014	2013	0.0887	0.0363	0.0245	13490.3592	6.577 PPM
		A= 85 V=76 A:275 V=14 A=185 V2				

ELLIPSE successfully completed.

Geolab • V1.82S, (C) 1985/86/87 Bit ise Ideas Inc.[1032076961 Page 18

Figure D-11. (Sheet 7 of 7)

U.S. ARMY ENGINEER TOPOGRAPHIC LABORATORIES
COYOTE DAM CONSTRAINED ADJUSTMENT NAD-83

A= 6378137.000 B= 6356752.314 XO= 0.000 YO= 0.000 ZO: 0.000

PREPARE: ASCII input file: <c:oyote_1.iob:>.
PREPARE successfully completed.

Geolab • V1.82S, (C) 1985/86/87 Bit\lise Ideas Inc. [103207696] Page 0

GETUP:

PARAMETERS		OBSERVATIONS	
Description	h'llltbr	Description	N!ltbr
All Stations	5	Directions	0
Fixed Stations	3	Dfstanc:es	0
Free 3·0 Stationsi		Aziruths	
Free 2·0 Statfons		Vertical Angles	
Free 1·0 Statfonsj	0	Zenithal Angles	0
Coord, Parameters[	6	Angles	0
Astro. Latitudes [	0	Heights	0
Astro. Longitudes	0	Height Differences	0
Geoid Records	0	Auxiliary Params.	0
All Aux. Pars.	4	2·D Coords.	0
Direction Pars.	0	2-D Coord. Diffs.	D
Scale Parl!llllll!ters	1	3-D Coords.	0
Constant Pars.	0	3·0 Coord. Dfffs.	21
Rotation Pars.	3		
Translation Pars.	0		
Total Parameters	10	Total Observations!	21

Degrees of Freedom • 11

GeoLab • V1.82S, (C) 1985/86/87 BitWise Ideas Inc. [103207696] Page

GETUP: SIIIW:Y OF SELECTED OPTIONS

OPTIOH	SELECTION
Computation Mode	Adjustment
Linear Unit	Metre
Maximum Iterations	2
Confidence Regions selected	All
Confidence Region Dimensions	1·0, 2-D, and 3·0
Print Input Station Data	00
Variance Factor Knowledge	Known
Confidence Level for Statistics	95.000
Dual-Height Mode	Off
Print Solution Vector	On All Iterations
Printed Ellipsoidal Coordinates	5 Decimal Places
Print Adjusted X, Y, Z	Oo
Print Histograms	IIII
Print Misclosures	On All Iterations
Print Residuels	Alt
Variance Factor Usage	Scale Confidence Regions
Residual Rejection Criterion	Tau Max
Angular Mfsclosure Limit Factor	to
Linear Hisclosure Lfmlt· Factor	to
Convergence Criterion	0.00100

Geolab - V1.82S, (C) 1985/86/87 BitWise Ideas Inc. [103207696] 2

Figure D-12. GEOLAB adjustment output (constrained) (Sheet 1 of 7)

U.S. ARMY ENGINEER TOPOGRAPHIC LABORATORIES
COYOTE DAM ADJUSTMENT NAD·83
A= 6378137.000 B= 6356752.314 XO= 0.000 YO= 0.000 ZO= 0.000

CODE	!DENT.	DESCRIPTOR	INITIAL VALUES		
14	2006				
		ELLIPSOIDAL	39 ,, 34.37462	-123 10 10.28988	336.0850
		ASTRONOMIC	39 11 34.37462	·123 10 10.28988	336.0850
		GEOIDAL	0 0 0.00000	0 0 0.00000	0.0000
		CARTESIAN	·2708280.4788	-4143494.m1	4009147.8933
14	2013				
		ELLIPSOIDAL	39 15 12.11624	-123 13 17.48887	222.8350
		ASTRONCIUC	39 15 12.11624	-123 13 17.48887	222.8350
		GEOIDAL	0 0 0.00000	0 0 0.00000	0.0000
		CARTESIAN	-2709665.3418	-4137409.4525	4014278.4657
14	2014				
		ELLIPSOIDAL	39 7 57.41258	-123 12 14.77684	190.1700
		ASTRONCMIC	39 7 57.41258	-123 12 14.77684	190.1700
		GEOIOAL	0 0 0.00000	0 0 0.00000	0.0000
		CARTESIAN	-2713032.7142	-4145300.4693	4003867.7960
24	2001				
		ELLIPSOIDAL	39 12 14.43422	·123 11 6.45941	243.8658
		ASTRONQUC	39 12 14.43422	·1Z3 11 6.45941	243.8658
		GEOIDAL	0 0 0.00000	0 0 0.00000	0.0000
		CARTESIAN	·2708942.2350	-4142043.8310	4010047.0300
24	2002				
		ELLIPSOIDAL	39 11 37.00656	·123 11 0.94286	243.8815
		ASTRONOMIC	39 11 37.00656	-123 11 0.94286	243.8815
		GEDIDAL	0 0 0.00000	0 0 0.00000	0.0000
		CARTESIAN	-2709230.7400	-4142n6.B33o	4009152.5340
94	WGSXX				
		300 SCAL	0.00000		
		300 ROTX	0.00000		
		300 ROTY	0.00000		
		300 ROTZ	0.00000		

GETUP successfully conpleted.

Geolab • V1.82S, (C) 1985/86/87 Blt\o'iae Ideas Inc. [103207696] Page 3
FOII:MEQ: NOTE 6: Reordering was done.

AT	TO	OBS TYPE	OBSERVATION	APPROX.SIG.	MISCLOSURE
2001	2006	3·D X·Coord Diff	666.6170	0.0037	-4.8608
2001	2006	3-D Y-Coord Diff	-1441.5480	0.0045	·9.3931
2001	2006	3-D z-coord Diff	-908.2800	0.0028	9.1433
2002	21>06	3-o x-coord Oiff	953.2950	0.0022	·3.0338
2002	2006	3·0 Y·Coord Oiff	·748.3180	0.0044	-19.6211
2002	2006	3-D z-coord Diff	·16.7100	0.0029	12.0693
2001	2002	3·D x-coord Diff	·286.6690	0.0024	-1.8360
2001	2002	3·D Y·Coord Diff	-693.2190	0.0026	10.2170
2001	2002	3-D z-coord Diff	·891.5890	0.0025	·2.9070
2001	2002	3-D x-coord Diff	-286.6790	0.0026	·1.8260
2001	2002	3·D Y·Coord Diff	·693.2230	0.0030	10.2210
2001	2002	3-D z-coord Diff	·891.5780	0.0026	-2.9180
2014	2002	3-D X-Coord Diff	3799.0050	0.0129	3.0292
2014	2002	3·D Y·Coord Diff	2554.0180	0.0101	19.6183
2014	2002	3·D Z·Coord Diff	5296.7980	0.0113	-12.0600
2013	2001	3-D X-Coord Diff	718.2440	0.0059	4.8628
2013	2001	3-D Y-Coord Diff	-4643.7750	0.0083	9.3965
2013	2001	3·D z-coord Diff	·4222.2870	0.0059	-9.1487

FORHEQ successfully conpleted.

Geolab- V1.82S, (C) 1985/86/87 Bitl.lise Ideas Inc. [103207696] Page 4

Figure D-12. (Sheet 2 of 7)

U.S. ARMY ENGINEER TOPOGRAPHIC LABORATORIES
COYOTE DAM ADJUSTMENT NAD-83

A= 6378137.000 8= 6356752,314 XO: 0.000 YO" 0.000 ZO= 0.000

SOLVE: Solution (Iteration COU"It "' 1):

CODE	!DENT.	TYPE	INITIAL	0X	UPDATED
24	2001	LATITUDE	39 12 14.43422	0.01413	39 ⅋ 14.44836
24	2001	LONGITUDE	-123 11 6.45941	0.04476	-123 11 6.41465
24	2001	HEIGHT	Z43.86sn	13.93968	257.80545
24	2002	LATITUDE	39 11 37.00656	-0.06729	39 11 36.93927
24	2002	LONGITOOE	-123 11 0.94286	0.34171	-·123 11 0.60115
24	2002	HEIGHT	243.88154	21.63406	265.51561
94	\JGSXX	300SCAL	0.00000	·0.00161	·0.00161
94	\.IGSXX	3DD ROTX	0.00000	0.03270	0.03270
94	WGSXX	3DD ROIY	0.00000	·0.06406	-0.06406
94	WGSXX	300 ROTZ	0.00000	·0.04338	·0.04338

SOLVE successfully carpleted.

Geolab - V1.82S, {C) 1985/86/87 BitWise Ideas Inc, [103207696] Page 5

FORMEQ FOIIMEQ successfutty conpleted.

GeoLab - V1.82S, (C) 1985/86/87 BitWise Ideas Inc. [1032D7696J Page 6

SOIVI: Adjusted Values (Iteration Comt = 2):

COOE	!DENT-	TYPE	INITIAL	0X	ADJUSTEI
14	20D6	LATITOOE	39 11 34.37462	FIXED	
14	2006	LONGITUDE	·123 10 10.28988	FIXED	
14	2006	HEIGHT	336.08500	FIXED	
14	2013	LATITUDE	39 15 12.11624	FIXED	
14	2013	LONGITUDE	-123 13 17.48887	FIXED	
14	2013	HEIGHT	222.8350D	FIXED	
14	2D14	LATITUOE	39 7 57.41258	FIXED	
14	2014	LONGITUDE	·123 12 14.77684	FIXED	
14	2014	HEIGHT	190,17000	FIXED	
24	2001	LATITUDE	39 12 14.44836	0.0D000	39 12 14.44836
24	2001	LONGITUDE	-123 11 6.41465	0.00000	·123 11 6.41465
24	2001	HEIGHT	257.80545	-0.00000	257.80545
24	2002	LATITOOE	39 11 36.93927	0.00000	39 11 36.93927
24	2002	LONGITOOE	-123 11 0.60115	-0.00000	·123 11 0.60115
24	2002	HEIGHT	265.51561	0.00000	265.51561
94	\IGSXX	3DD SCAL	·0.00161	0.00000	-0.00161
94	WGSXX	3DD ROTX	D.D3270	·O.OOODD	O.D3270
94	WGSXX	30D ROTY	·O.D6406	O.OODDD	-0.06406
94	WGSXX	300 ROTZ	-D.D4338	0.00000	-0.04338

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Figure D-12. (Sheet 3 of 7)

U.S. ARMY ENGINEER TOPOGRAPHIC LABORATORIES
COYOTE DAM ADJUSTMENT NAD·83

A= 6378137.000 8= 6356752.314 XO= 0.000 YO= 0.000 ZO= 0.000

Adjusted car-tesiiWI Coordinates:

CODE	!DENT.	X·DOOROINATE	Y·COORDINATE	Z·COORDINATE
24	2001	·2708947.0978	·4142053.2284	4010056.1788
24	2002	-2709233.7715	·4142746.4512	4009164.5972

SOLVE successfuLLy conpleted.

Geolab- V1.82S, (C) 1985/86/87 Bft\lse Ideas Inc. [103207696] Page 8

INVERT: INVERT successfully completed

Geolab- V1.82S, (C) 1985/86/87 Bit\lise Ideas Inc. [103207696] Page 9

RESID:

STATION	3·0 COORD DIFFS	STO.OEV.	RESIDUAL	STO.OEV.	STAN.RES.
2001	-2708942.2350				
	-4142043.8310				
	4010047.0300				
2006	-2708275.6180	0.0050	0.0020	0.0041	0.4865
	·4143485.3790	0.0060	0.0043	0.0045	0.9530
	4009138.7500	0.0040	·0.0055	0.0026	-2.1060
========== End of Observation Set ==========					
2002	-2709230.7400				
	-4142726.8330				
	4009152.5340				
2006	-2:708277.4450	0.0030	-0.002:4	0.0016	-1.5309
	-4143475.1510	0.0050	·0.0031	0.0032:	·0.9650
	4009135.8240	0.0040	0.0063	0.002:6	2.3907
========== S======== End of Observation Set ==========					
2001	·2708941 .0950				
	·4142050.632:0				
	4010040.8370				
2002	·2709227.7640	0.0030	-0.0046	0.0020	-2.2625
	-4142743.8510	0.0040	-0.0036	0.0031	·1.1706
	4009149.2:480	0.0040	0.00n	0.0032	2.2786
========== End of Observation Set ==========					
2001	-2708946.1080				
	-4142048.2180				
	4010039-9500				
2002	·2709232:.7870	0.0040	0.0054	0.0033	1.6090
	-4142741.4410	0.0040	0.0004	0.0031	0.1285
	4009148.372:0	0.0040	·0.0038	0,0032	-1.1993
========== End of Observation Set ==========					
2014	-2713050.5170				
	-4145286.8310				
	4003867.5850				
2002	·2709251.5120	0.0180	-0.0035	0.0149	-0.2328
	-4142:732.8130	0.0160	-0.0015	0.0090	·0.1659
	4009164.3830	0.02:00	0.0047	0.0141	0.3373
==========S========== End of Observation Set					
2013	-2709663·6000				
	·4137421.4500				
	40142:63.6620				
2014	-2:713031.0290	0.0150	·0.0018	0.0105	-0.1739
	·4145312.4700	0.0460	0.0055	0.0419	0.1303
	4003852:.9890	0.0330	0.0010	0.02:93	0.0344

Geolab • V1.82S, (C) 1985/86/87 BitWise Ideas Inc. [103207696] Page 10

Figure D-12. (Sheet 4 of 7)

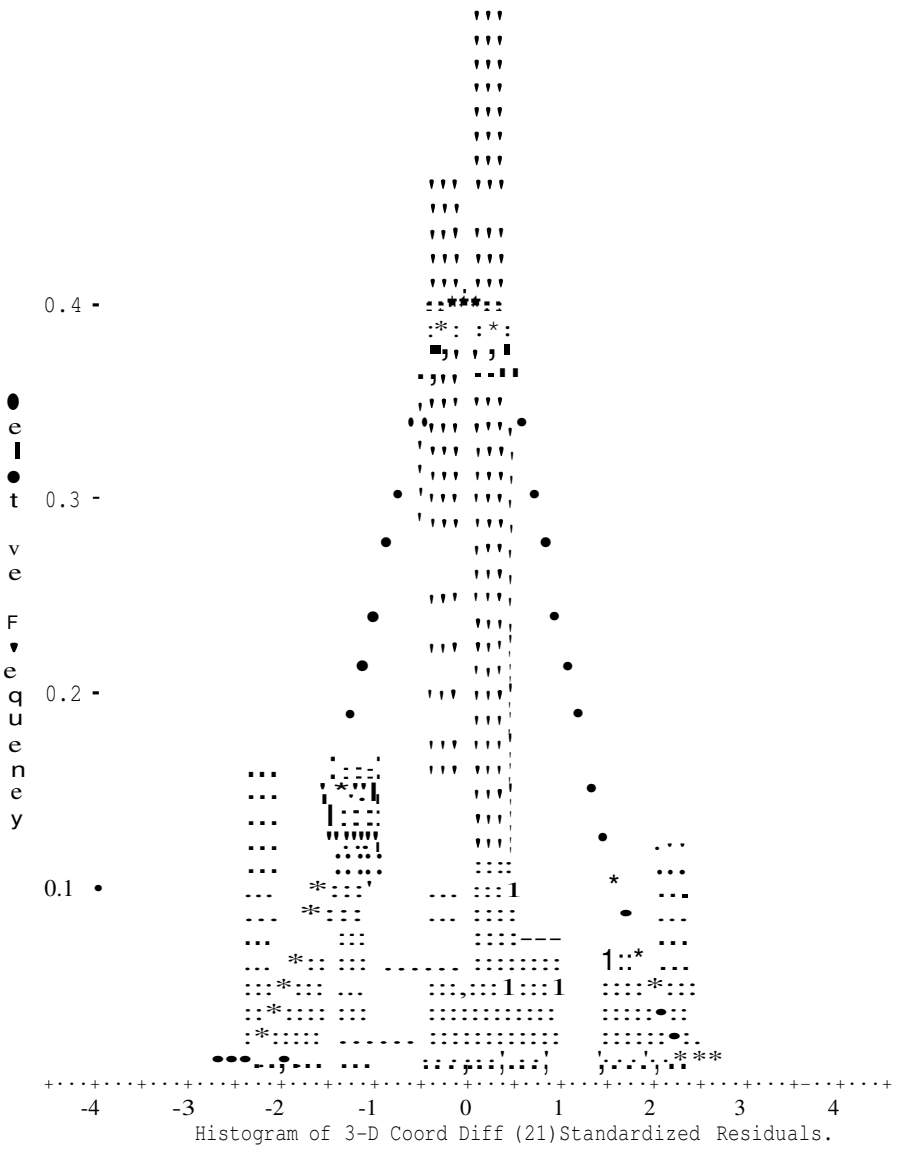
U.S. ARMY ENGINEER TOPOGRAPHIC LABORATORIES
COYOTE DAM ADJUSTMENT NAD-83

A= 6378137.000 B= 6356752.314 XO= 0.000 YO= 0.000 ZO= 0.000

STATION	3·0 COORD DIFFS	STD.OEV.	RESIDUAL	STD.DEV.	STAH.RES•
========== End of Observation Set ==========					
2013	•2709663.6000				
	·4137421.4500				
	4014263.6620				
2001	•2708945.3560	0.0070	0.0003	0.0026	0.1237
	·4142065.2250	0.0200	-0.0004	0.0137	-0.0312
	4010041.3750	0.0150	-0.0005	0.0083	·0.0555
========== End of Observation Set ==========					

Geolab • V1.82S, CC) 1985/86/87 BitWise Ideas Inc. [103207696] Page

RESID:



Histogram of 3-D Coord Diff (21)Standardized Residuals.

Geolab V1.82S, (C) 1985/86/87 BitWise Ideas Inc. t103207696J Page

Figure D-12. (Sheet 5 of 7)

U.S. ARMY ENGINEER TOPOGRAPHIC LABORATORIES
COYOTE DAM ADJUSTMENT NAD·83

A: 6378137.000 Bz 6356752.314 XO• 0.000 YO: 0.000 ZOE 0.000

RESID:

STATISTICS S U M M A R Y

Residual Critical Value Type	
Residual Critical Value	
Convergence Criterion	0.001000
Final Iterat[on counter Value	2
Confidence level Used	95.0000
Number of Flagged Residuals	0
Estimated Variance Factor	1.0944
NU!ber of Degrees of Freedc:tn	1\

Chi-Square Test on the Variance factor:

5.4919e·001 < 1.0000 < 3.1549e+000 1

THE TEST PASSES.

RESID successfully completed.

Geolab • V1.82S, (C)1985/86/87 BitWise Ideas Inc. [103207696) Page 13

ELLIPSE:

NOTE: All confidence regions were computed using the following factors:

Variance factor used •	1.09438
Estimated variance factor	,.09438
1-D expansion factor	,.960
2-D expansion factor •	2.448
3-D expansion factor	2.795

Note that.for relative confidence regions, prec1s1ons are computed from the ratio of the major semi-axis and the spatial distance between the two stations.

Error ellipses for which all covariance matrix elements were not computed by INVERT, are marked with an asterisk(*).

Geolab- V1.82S, (C) 1985/86/87 Bit'olise Ideas Inc. C103207696l Page 14

Figure D-12. (Sheet 6 of 7)

U.S. ARMY ENGINEER TOPOGRAPHIC LABORATORIES
COYOTE DAM ADJUSTMENT NAD·83

A: 6378137.000 B= 6356752.314 XO= 0.000 YO: 0.000 ZO= 0.000

ELLIPSE: AUXILIARY PARMETER COIIFIDENCE INTERVALS (95.000 %):

IDENT.	TYPE	CLASS	ADJ VALUE	1.9 6 SIGMA
WGSXX	3DD	SeAL	-0.0016	1.1261
		ROTX	0 0 0.03	0 0 0.82
		ROTY	0 0 -0.06	0 0 1.27
		ROTZ	0 0 ·0.04	0 0 1.37

Geolab • V1.62S, (C) 1985/86/87 BitWise Ideas Inc. [103207696] Page

ELLIPSE: 2·0 AJII 1·0 STATIOII COIIFIDEXCE REGIC»>S (95.000 %):

!DENT.	MAJOR SEH!·AXIS	MINOR SEMI-AXIS	AZ(MAJ)	VERTICAL
2001	0.0066	0.0048	107.22	0.0133
2002	0.0062	0.0044	125.62	0.0127

Geolab • V1.82S, (C) 1985/86/87 BitWise ideas Inc. [103207696] Page 16

ELLIPSE: 2·0 AND 1-D RELATIVE STATICll aJNFIDEIICE REGIOIS (95.000 1):

FROM	TO	MAJ.SEMI	HIN.SEMI	AZ(MA.J)	VERTICAL	SPATIAL OIST.	PRECISION
2001	2002	0.0045	0.0036	108.07	0.0082	1165.1856	3.846 PPM

GeoLab • V1.82S, (C) 1985/86/87 BitWise Ideas Inc. (103207696] Page 17

ELLIPSE: 3-D STATION CONFIDENCE REGIONS (95.000 1):

IOENT.	MAJOR SEMI-AXIS	MEDIUM SEMI-AXIS	MINOR SEMI-AXIS
2001	0.0191	0.0070	0.0056
	A=106.6 V:81.9	A=270.0 V= 7,8	A= 0.3 V= 2.3
2002	0.0182	0.0070	0.0051
	A= 90.0 V= 87.6	A=306.2 V: 1.9	A=216.2 V= 1.4

GeoLab - V1.82S, (C) 1985/86/87 BitWise Ideas Inc. (1032076961 Page 18

ELLIPSE: 3-0 REL.AHVE STATION eotFIDENCE RfGIONS (95.000 t.):

FROM	TO	MAJOR-SEMI	MEO.-SEMI	MINOR-SEMI	SPATIAL DIST.	PRECISION
2001	2002	0.0117	0.0050	0.0042	1165.1856	10.027 PPM
		A= OV=90A.,90V=OA=		OV=O		

ELLIPSE successful ty cOO"ple.ted.

GeoLab- V1.82S, (C) 1985/86/87 BitWise Ideas Inc. (103207696] Page 19

Figure D-12. (Sheet 7 of 7)

(1:10,000). The relative line accuracy between 2001 and 2002 on the constrained adjustment was 3.846 ppm, or 1:260,000. This indicates excellent connections with existing control.

d. The variance factor shown on page 14 of each adjustment is within acceptable limits (0.5 to 1.5). As such, it could be used to determine outlier limits for rejection of data, as explained in Chapter 11.

e. The residual corrections to each baseline component are shown on page 10 of each adjustment. Special review is made of the standardized residuals, which one will find is approximately comparable to normalized residuals in GEOLAB software. None of the residuals were flagged (based on Tau Max testing) for exceeding tolerance.

f. The 3D positional and relative confidence regions (ellipsoid) and 3D line accuracy precessions are shown at the end of each adjustment. These statistics are not applicable for most USACE work.

g. Of all the output statistics, only the residuals, standardized residuals, relative 2D/1D line precessions, and variance factor have useful application for USACE work. The histograms, Chi-square tests, 3D ellipsoid, etc. are useful only if one understands their derivation and application.

h. The results of the free and constrained adjustments in this example were not significantly different. This is usually not the case -- typically, station/line accuracies degrade on the constrained adjustment.

Section II
Survey No. 2: Precise Control Survey
(Dworshak Dam, Idaho)

D-7. General

A high precision GPS control survey may be performed at sites for structural deformation monitoring. Accurate control in the vicinity of the structure is critical. Absolute NGRS coordinate on monitoring points is of lesser importance. NGRS control may be brought into one of the reference points with GPS. Only the NGRS coordinates of this fixed point are held fixed for all subsequent adjustments in the vicinity of the structure.

D-8. Project Description

Survey example No. 2 was conducted in the vicinity of Dworshak Dam, Idaho. A diagram of the project is shown in Figure D-13. Baseline data from the NGRS control to one point (Fish Hatchery - 4001) at the project site were collected and other baseline data for baselines between 4001, Big Eddy (4002), and four points on the Dworshak Dam and Reservoir (4003, 4004, 4005, and 4006) as shown in Figure D-14. Loop closure checks were done for the complete network by using the loop closure routine shown in Figure D-15. The resultant precision for the loop is 0.43 ppm (1:2,300,000).

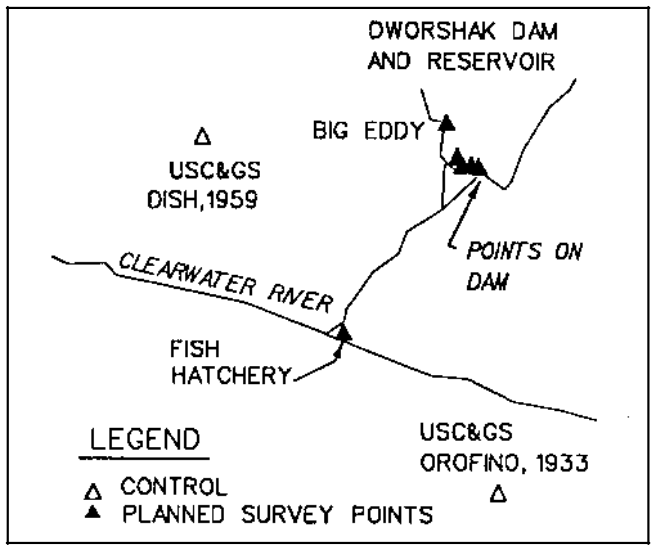


Figure D-13. Dworshak Dam and Project area

D-9. Adjustment

a. An IOB file for the adjustment based on the formulated baselines was set up. Station USC&GS Dish, 1959, and USC&GS Orofino, 1933, were held fixed to establish NGRS control on Corps of Engineers Station 4001 at the project site. Then, for the next adjustment, 4001 was held fixed to adjust station 4002, 4003, 4004, 4005, and 4006. This free adjustment is shown in Figure D-16. Analysis of the adjustment was done as in Survey No. 1 and detailed in Chapter 11.

b. The resultant adjustment statistics are shown on page 14 of Figure D-16. The 2D station confidence is on the order of 0.04 m (2DRMS) and $\pm$0.06 m in the vertical. The largest line accuracy is 36.322 ppm (1:27,000)

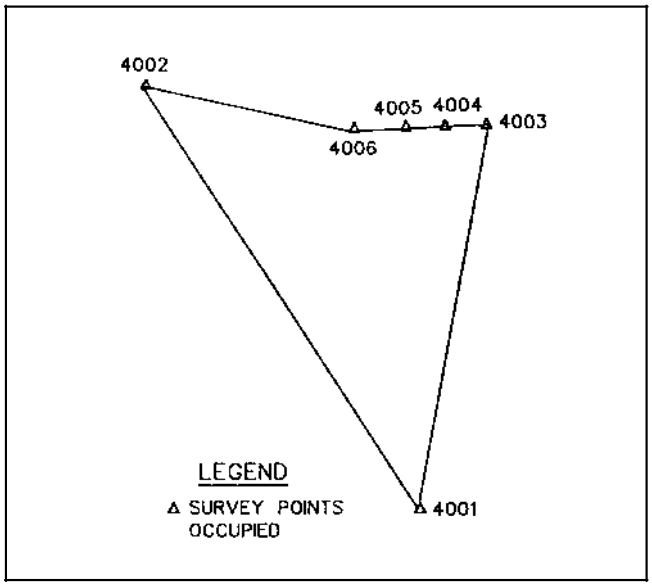


Figure D-14. GPS project diagram (Dworshak)

over a short (62 m) baseline. This would be acceptable even though a 1:100,00 relative accuracy is required. Due to fixed centering errors, maintaining 1:100,000 relative accuracies over lines less than 200 to 500 m is unrealistic.

Section III
Survey No. 3: Upper Saginaw River Control Project. (Saginaw, Michigan).

D-10. Planning Phase

a. The GPS survey was planned for 24-25 March 1993, Julian day 083 and 084 in the vicinity of Saginaw, Michigan.

b. This project was to establish Second-Order control, using GPS, at the Upper Saginaw River. The project area covered from Green Point down to the railroad bridge of the upper end of the condition survey project area, see Figure D-17. These control stations were to

```
Trimble Loop Closure Utility

Start Traverse at Station:  4006
Starting Coords :  46x30'56.88832"ØN   116x17'48.33684"ØW          489.943

Baseline 1
File Name: 06053001.FIX
From Station:  4006                    To Station:  4005
Distance Travelled (m):          82.829
Current Coords  :  46x30'55.20552"ØN   116x17'46.75486"ØW          500.412

Baseline 2
File Name: 05042993.FIX
From Station:  4005                    To Station:  4004
Distance Travelled (m):         124.262
Current Coords  :  46x30'54.30015"ØN   116x17'44.23756"ØW          489.809

Baseline 3
File Name: 04032991.FIX
From Station:  4004                    To Station:  4003
Distance Travelled (m):         214.384
Current Coords  :  46x30'51.68841"ØN   116x17'42.38493"ØW          497.376

Baseline 4
File Name: 01032992.FIX
From Station:  4003                    To Station:  4001
Distance Travelled (m):        2872.755
Current Coords  :  46x30'05.98881"ØN   116x18'27.67811"ØW          308.887

Baseline 5
File Name: 01023012.FIX
From Station:  4001                    To Station:  4002
Distance Travelled (m):        6122.940
Current Coords  :  46x31'41.46032"ØN   116x18'24.06337"ØW          490.036

Baseline 6
File Name: 02063001.FIX
From Station:  4002                    To Station:  4006
Distance Travelled (m):        7695.981
Current Coords  :  46x30'56.88826"ØN   116x17'48.33690"ØW          489.941

End Traverse at Station:  4006
Distance Travelled (m):        7695.981    Precision (ppm):        0.43
dx:     -0.001     dy:     0.001     dz:     -0.003     dh:     -0.002
Ending Coords   :  46x30'56.88826"ØN   116x17'48.33690"ØW          489.941
Reference Coords:  46x30'56.88832"ØN   116x17'48.33684"ØW          489.943
```

Figure D-15. Loop closure (Dworshak)

```
U.S. ARMY ENGINEER TOPOGRAPHIC LABORATORIES
DWORSHAK DAM
A=  6378137.000 B=  6356752.314  XO=  0.000  YO=  0.000  ZO=  0.000

PREPARE:

ASCII input file: <wal_l.iob>.

PREPARE successfully completed.

GeoLab-V1.82S,(C)l9B5/86/87BitWise Ideas Inc.[103207687]  Page  0
```

```
U.S. ARMY ENGINEER TOPOGRAPHIC LABORATORIES
DWORSHAK DAM
A   637B137.ooo B   6356752.314 xo   o.ooo Yo   o.ooo zo   o.ooo

GETUP:
```

PARAMETERS		OBSERVATIONS	
Description	Number	Description	Number
All Stations	6	Directions	0
Fixed Stations	1	Distances	0
Free 3-D Stations	5	Azimuths	0
Free 2-D Stations	0	Vertical Angles	0
Free 1-D Stations	0	Zenithal Angles	0
Coord. Parameters	**15**	**Angles**	**Q.**
Astra. Latitudes	0	He1ghts	0
Ast o. Longitudes	0	Height DifferenceJ	0
Geo1d Records	0	Aux1llary Params.	0
All Aux. Pars.	0	2-0 Cooras.	o
Direction Pars.	0	2-D Coord. Diffs.	0
scale Parameters	0	3-D Coords.	0
const nt Pars.	0	3-D Coord. Diffs.	60
Rotat1on Pars.	0		
Translation Pars.	----		
Total Parameters	15	Total Observations	60

Degrees of Freedom = 45

```
GeoLab-V1.82S,(C)19B5/B6/87BitWise Ideas Inc.[1032076B7] Page  1
```

Figure 0·16. GEOLAB adjustment output (Sheet 1 of 8)

U.S. ARMY ENGINEER TOPOGRAPHIC LABORATORIES
DWORSHAK DAM

A= 6378137.000 B= 6356752.314 XO= 0.000 YO= 0.000 ZO= 0.000

GETUP

SUMMARY OF SELECTED OPTIONS

OPTION	SELECTION
Computation Mode	Adjustment
Linear Unit	Metre
Maximum Iterations	2
Confidence Reg ons elected	All
Confldence Reqlon Dlmenslons	1-D and 2-D only
Print Input seation Data	Off
Variance Factor Knowledge	Known
Confidence Level for Statistics	95.000
Dual-Height Mode	Off
Print Solut.:j.on Mode	Only Adjusted Values
Printed Ellipsoidal Coordinates	5 Decimal Places
Pr.:i-nt AQ.justed X, Y, Z	On
Prlnt Hlstograms	On
Pr:j.nt Misclosures	On
Prlnt Residuals	On All Iterations
Variance Faytor Usaqe	Scale Confidence Regions
Residual Rejection Criterion	Tau Max
Angular Misclosure Limit Factor	10
Linear Misclosure Llmlt Factor	10
Convergence Criterion	0.001000

SETUP successfully completed.

GeoLab-V1.82S,(C)1985/86/87BitWise Ideas Inc.[103207687] Page 2

Figure 0·16. (Sheet 2 of 8)

U.S. ARMY ENGINEER TOPOGRAPHIC LABORATORIES
DWORSHAK DAM

A 6378137.000 S 6356752.314 xo 0.000 yo 0.000 zo 0.000

FORMEQ:

NOTE 6: Reordering was done.

AT	TO	OBS TYPE	OBSERVATION	APPROX.SIG.	MISCLOSURE
4001	4003	3-D x-coord Diff	2408.6880	0.0029	22.8708
4001	4003	3-D Y-Coord Diff	-193.5840	0.0016	25.8258
4001	4003	3-D Z-Coord Diff	1108.0180	0.0021	-26.6407
4004	4003	3-D X-Coord DDfffff	7.1790	0.0007	22.7040
4004	4003	3-D Y-Coord ...	-74.6270	0.0003	21.7690
4004	4003	3-D z-coord DDtffff	-50.0120	0.0006	-25.7900
4001	4004	3-D x-coord	2401.5070	0.0055	.1688
4001	4004	3-D y-Coord DDtffff	-118.9530	0.0065	4.0528
4001	4004	3-D Z-Coord ...	1158.0230	0.0062	-0.8437
4001	4002	3-D x-coord DDfffff	2108.6340	0.0061	-1.6862
4001	4002	3-D Y-Coord	1204.4260	0.0079	36.7548
4001	4002	3-D z-coord oDttfff	2160.2690	0.0067	-27.6797
4001	4003	3-D X-Coord	2408.6870	0.0055	22.8718
4001	4003	3-D Y-Coord Diff	-193.5780	0.0072	25.8198
4001	4003	3-D z-coord Diff	1108-0110	0.0062	-26.6337
4001	4005	3-D x-coord DDtffff	2359.1380	0.0047	-0.9472
4001	4005	3-D Y-Coord	-83.5390	0.0122•	5.9208
4001	4005	3-D z-coord Diff	1184.9630	0.0073	-7.2267
4005	4004	3-D x-coord Diff	42.3580	0.0008	1.1270
4005	4004	3-D Y-Coord Diff	-35.4190	0.0015	-1.8630
4005	4004	3-D z-coord Diff	-26.9330	0.0006	6.3760
4001	4002	3-D X-Coord Diff	2108.6240	0.0045	-1.6762
4001	4002	3-D Y-Coord Diff	1204.4190	0.0104	36.7618
4001	4002	3-D Z-Coord DDfffff	2160.2710	0.0063	-27.6817
4001	4006	3-D x-coord	2348.8140	0.0033	32.4128
4001	4006	3-D Y-Coord Diff	-28.3330	0.0019	24.3928
4001	4006	3-D Z-Coord Diff	1213.1260	0-0021	-23.8437
4006	4005	3-D X-Coord DDfffff	10.3400	0.0008	-33.3760
4006	4005	3-D Y-Coord ...	-55.2020	0.0004	-18.4760
4006	4005	3-D z-coord Diff	-28.1650	0.0007	16.6190
4002	4006	3-D X-Coord Diff	240.1770	0.0031	34.1020
4002	4006	3-D Y-Coord Diff	-1232.7570	0.0020	-12.3640
4002	4006	3-D z-coord Diff	-947.1440	0.0019	3.8370
4002	4005	3-D X-Coord Diff	250.5120	0.0027	0.7310
4002	4005	3-D Y-Coord Diff	-1287.9560	0.0040	-30.8430
4002	4005	3-D z-coord Diff	-975.3050	0.0031	20.4520
4001	4005	3-D X-Coord Diff	2359.1440	0.0055	-0.9532
4001	4005	3-D Y-Coord Diff	-83.5400	0.0067	5.9218
4001	4005	3-D Z-Coord Diff	1184.9690	0.0063	-7.2327
4001	4006	3-D X-Coord Diff	2348.8070	0.0054	32.4198
4001	400·6	3-D Y-Coord Diff	-28.3370	0.0066	24.3968
4001	4006	3-D z-coord Diff	1213.1310	0.0062	-23.8487
4002	4003	3-D X-Coord Diff	300.0520	0.0022	24.5590
4002	4003	3 D Y Coord Diff	1398.0030	0.0043	0.9360

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Figure D-16. (Sheet 3 of 8)

U.S. ARMY ENGINEER TOPOGRAPHIC LABORATORIES
DWORSHAK DAM

A= 6378137.000 B= 6356752.314 XO= 0.000 YO= 0.000 ZO= 0.000

FORMEQ:

AT	TO	OBS·TYPE	OBSERVATION	APPROX.SIG.	MISCLOSURE
4002	4003	3-D x-coord Diff	-1052.2550	0.0024	1.0430
4006	4003	3-D x-coord Diff	59.8780	0.0007	-9.5460
4006	4003	3-D Y-Coord Diff	-165.2500	0.0015	1.4320
4006	4003	3-D z-coord D"ff	-165.2500	0.0006	-2.7900
4001	4002	3-D X-Coord Diff	2108.6250	0.0045	-1.6772
4001	4002	3-D Y-Coord Diff	1204.4170	0.0104	36.7638
4001	4002	3-D z-coord Diff	2160.2740	0.0063	-27.6847
4001	4002	3-D X-Coord Diff	2108.6270	0.0043	-1.6792
4001	4002	3-D Y-Coord Diff	1204.4160	0.0028	36.7648
4001	4002	3-D z-coord Diff	2160.2680	0.0029	-27.6787
4001	4002	3-D X-Coord Diff	2108.6320	0.0063	-1.6842
4001	4002	3-D Y-Coord Diff	1204.4280	0.0078	36.7528
4001	4002	3-D z-coord Diff	2160.2620	0.0062	**-27.6727**
4001	4002	3-D X-Coord D"ff	2108.6250	0.0045	-1.6772
4001	4002	3-D Y-Coord Diff	1204.4170	0.0101	36.7638
4001	4002	3-D z-coord Diff	2160.2780	0.0061	**-26.6887**

FORMEQ **successfully completed.**

GeoLab-Vl.82S,(C)1985/86/87BitWise Ideas Inc.[103207687] **Page** 4

U.S. ARMY ENGINEER TOPOGRAPHIC LABORATORIES
DWORSHAK DAM

A 6378137.000 B 6356752.314 xo o.ooo Yo o.ooo zo o.ooo

SOLVE:

SOLVE successfully completed.

GeoLab-Vl.82S,(C)1985/86/87BitWise Ideas Inc.[103207687) Page 5

U.S. ARMY ENGINEER TOPOGRAPHIC LABORATORIES
DWORSHAK DAM

A= 6378137.000 B= 6356752.314 XO= 0.000 YO= 0.000 ZO= 0.000

FORMEQ:

FORMEQ successfully completed.

GeoLab-V1.82S,(C)1985/86/87BitWise Ideas Inc.[103207687] Page 6

Figure 0·16. (Sheet 4 of 8)

U-S. ARMY ENGINEER TOPOGRAPHIC LABORATORIES
DWORSHAK DAM

A 6378137 00 B 6356752.314 xo 0.000 YO 0.000 zo 0.00(

SOLVE:

Adjusted Values (Iteration Count = 2):

CODE	IDENT.	TYPE	INITIAL	DX	ADJUSTED
14	4001	LATITUDE	46 30 5.78733	FIXED	
14	2006	LONGITUDE	-116 19 17.36405	FIXED	
14	2006	HEIGHT	312.18200	FIXED	
24	4003	LATITUDE	46 30 51-48677	0.00000	46 30 **51.48677**
24	4003	LONGITUDE	-116 17 42.07099	0.00000	-116 17 42.07099
24	4003	HEIGHT	500.68216	0.00001	500.68217
24	4004	LATITUDE	46 30 54.09853	0.00000	46 30 54.09853
24	4004	LONGITUDE	-116 17 43.92366	-0.00000	-116 17 43.92366
24	4004	HEIGHT	493.11850	0.00000	493.11851
24	4002	LATITUDE	46 30 41-25876	0.00000	46 31 41-25876
24	4002	LONGITUDE	-116 18 23.74916	-0.00001	-116 18 23.74917
24	4002	HEIGHT	493.34210	0.00003	493-34213
24	4005	LATITUDE	46 30 55.00394	-0.00000	46 30 36.93927
24	4005	LONGITUDE	-116 17 46.44097	-0.00000	-116 17 46.44097
24	4005	HEIGHT	503-72111	0.00000	503.72111
24	4006	LATITUDE	46 30 56.68676	0.00000	46 30 **56.68676**
24	4006	LONGITUDE	-116 17 48.02294	0.00001	-116 17 48.02294
24	4006	HEIGHT	493.25364	0.00003	493.25367

GeoLab-V1.82S,(C)1985/86/87BitWise Ideas Inc.(103207687) Page 7

U.S. ARMY ENGINEER TOPOGRAPHIC LABORATORIES
DWORSHAK DAM

A 6378137.ooo B 6356752.314 xo o.ooo Yo o.ooo zo o.ooo

Adjusted Cartesian Coordinates:

CODE	IDENT.	X OORDINATE	Y OORDINATE	**Z-COORDINATE**
24	**4003**	**-1948002.5548**	**-3942346.3361**	4605137.8787
24	4004	**-1948009.7358**	-3942271-7102	4605187.8935
24	4002	-1948302.6080	-3940948.3316	4606190.1331
24	4005	-1948052.0934	-3942236.2903	**4605213.8271**
24	4006	-1948062.4335	-3942181-0887	4605242.9935

SOLVE successfully completed.

GeoLab-V1.82S,(C)1985/86/87Bitwise Ideas Inc.[103207687] Page 8

U.S. ARMY ENGINEER TOPOGRAPHIC LABORATORIES
DWORSHAK DAM

A= 63781374000 B= 6356752.314 XO= 0.000 YO= 0.000 ZO= 0.000

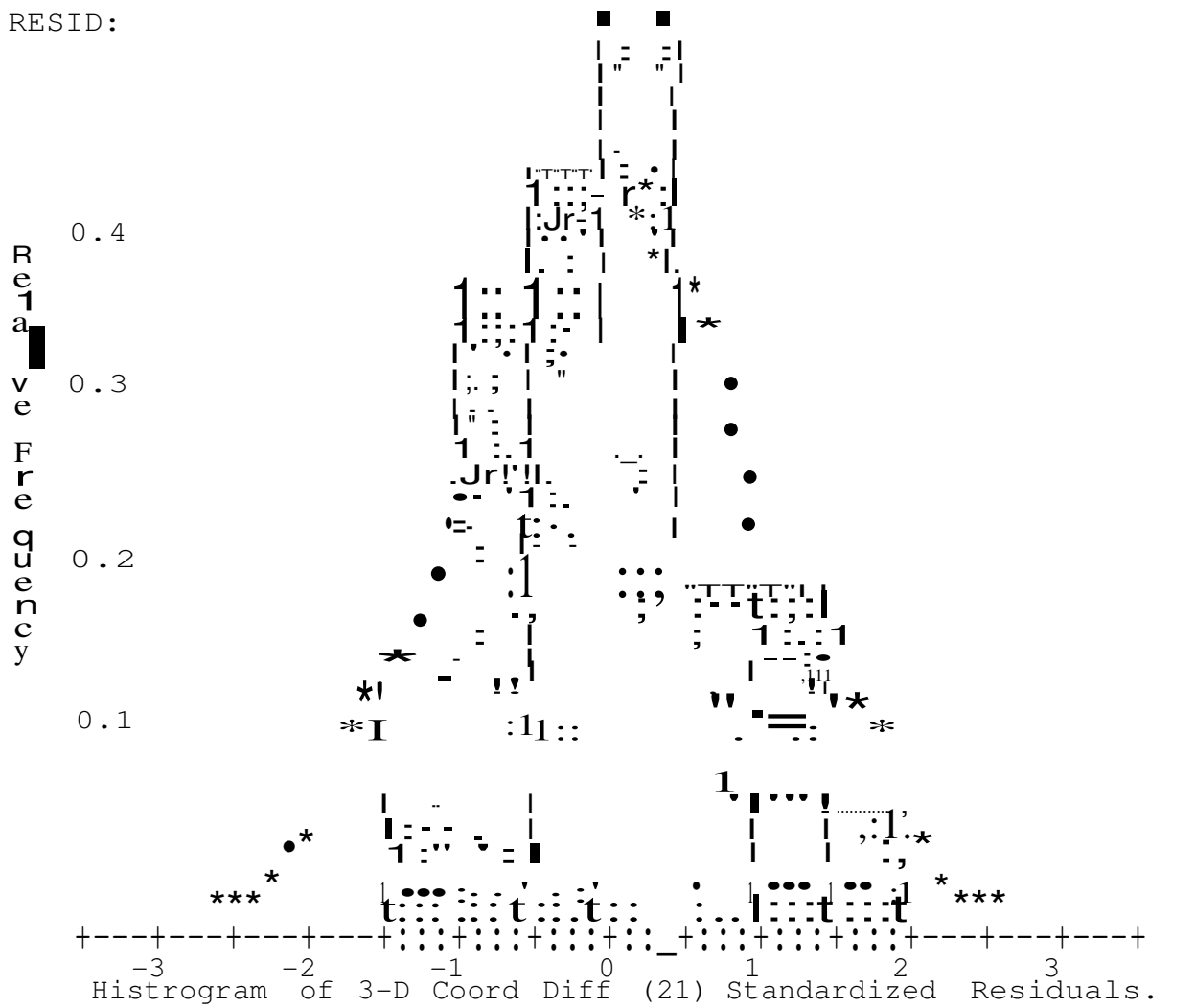
INVERT:

INVERT successfully completed.

GeoLab-V1.82S, (C)1985/86/87BitWise Ideas Inc.r1032076871 Page 9

Figure D-16. (Sheet 5 of 8)

U.S. ARMY ENGINEER TOPOGRAPHIC LABORATORIES
DWORSHAK DAM
A= 6378137.000 B= 6356752.314 XO= 0.000 YO= 0.000 ZO= 0.0C



GeoLab-V1.82S,(C)1985/86/87BitWise Ideas Inc.[103207687] Page 10

Figure D-16. (Sheet 6 of 8)

```
            U.S. ARMY ENGINEER TOPOGRAPHIC LABORATORIES
                          DWORSHAK DAM
A   6378137.000 B   6356752.314 xo   0.000 Yo   0.000 zo   0.000

RESID:

                 S T A T I S T I C S   S U M M A R Y

 ---------------------------------------------------------------
   Res dual Cr ttcal Value Type                  Tau Max
   Res dual Cr t cal Value                        3.3469
   COnvergence 9riterion                         0.001000
   F1nal 1terat1on Counter Value                        2
   Confidence Level Used                         95.0000
   Number of Flagged Residuals                         0
   Estimated Var1ance Factor                      0.8676
   Number of Degrees of Freedom                       45
 ---------------------------------------------------------------
            Chi-square Test on the Variance Factor:

            5.9685e-001  <  1-0000  <  1-3763e+000  ?

                      THE TEST PASSES.

RESID successfully completed.
---------------------------------------------------------------
GeoLab-V1.82S,(C)1985/86/87BitWise Ideas Inc.[103207687]  Page 11

            U.S. ARMY ENGINEER TOPOGRAPHIC LABORATORIES
                          DWORSHAK DAM
A   6378137.000 S   6356752.314 xo   0.000 Yo   0.000 zo   0.000

ELLIPSE:

   NOTE:  All confidence reqionwere
                  computed us1ng the following factors:

        Variance  factor used        =    0.86755

        Estimated variance factor   =    0.86755

        1-D expansion factor        =      1-960

        2-D expansion factor        =      2.448

        3-D expansion factor        =      2.795

    Note that, for relative confidence regions, p ecisions
    are compu ed from the ration of the major seml-axis
    and the spatial distance between the two stat1ons.

    Error ellipses for which all covariance matrix elements
    were not computed by INVERT, are marked with an asterick(*)

------ ---------------------------------------------------
GeoLab-V1.82S,(C)1985/86/87BitWise Ideas Inc.r1032076871 Page 12
```

Figure D-16. (Sheet 7 of 8)

U.S. ARMY ENGINEER TOPOGRAPHIC LABORATORIES
DWORSHAK DAM

A 6378137.000 B 6356752.314 xo 0.000 YO 0.000 zo 0.000

ELLIPSE:

2 D AND 1 D STATION CONFIDENCE REGIONS (95.000 %):

IDENT.	MAJOR SEMI-AXIS	MINOR SEMI-AXIS	AZ(MAJ)	**VERTICAL**
4003	0.0034	0.0022	76.62	0-0056
4004	0.0036	0.0023	82.71	0.0057
4002	0.0035	0.0026	89.02	0.0061
4005	0.0035	0.0023	82.89	**0.0057**
4006	0.0035	0.0022	79.03	**0.0056**

GeoLab-V1.82S,(C)1985/86/87BitWise Ideas Inc.[103207687] Page 13

U.S. ARMY ENGINEER TOPOGRAPHIC LABORATORIES
DWORSHAK DAM

A 6378137.000 B 6356752.314 xo 0.000 Yo 0.000 zo 0.000

ELLIPSE:

2 D and 1 D RELATIVE STATION CONFIDENCE REGIONS (**95.00** %):

FROM	TO	MAJ.SEMI	MIN.SEMI	AZ(MAJ)	VERT.	SPAT.DIST.	**PREC.**
4003	4004	0.0023	0.0008	89.79	0.0033	90.1225	25.220PPM
4003	4002	0.0033	0.0026	96.46	0.0057	1775.2993	1.847PPM
4003	4005	0.0025	0.0016	104.89	0.0038	143.1265	17.408PPM
4003	4006	0.0018	0.0014	130.30	0.0027	204.7957	8.998PPM
4004	**4002**	0.0035	**0.0027**	97.42	**0.0059**	**1685.7014**	**2.064PPM**
4004	4005	**0.0019**	**0.0014**	**128.56**	0.0027	**61.4342**	30.745PPM
4004	**4006**	0.0026	0.0016	102.27	**0.0039**	**118.4286**	**21.633PPM**
4002	4005	**0.0033**	**0.0025**	92.33	0.0056	1634.8752	2.019PPM
4002	4006	**0.0033**	0.0024	85.85	0.0056	**1573.0376**	**2.098PPM**
4005	4006	0.0023	0.0009	88.94	0.0033	62.8290	36.322PPM

ELLIPSE **successfully completed.**

GeoLab-Vl.82S,(C)l985/86/87BitWise Ideas Inc.[103207687) Page 14

Figure D-16. (Sheet 8 of 8)

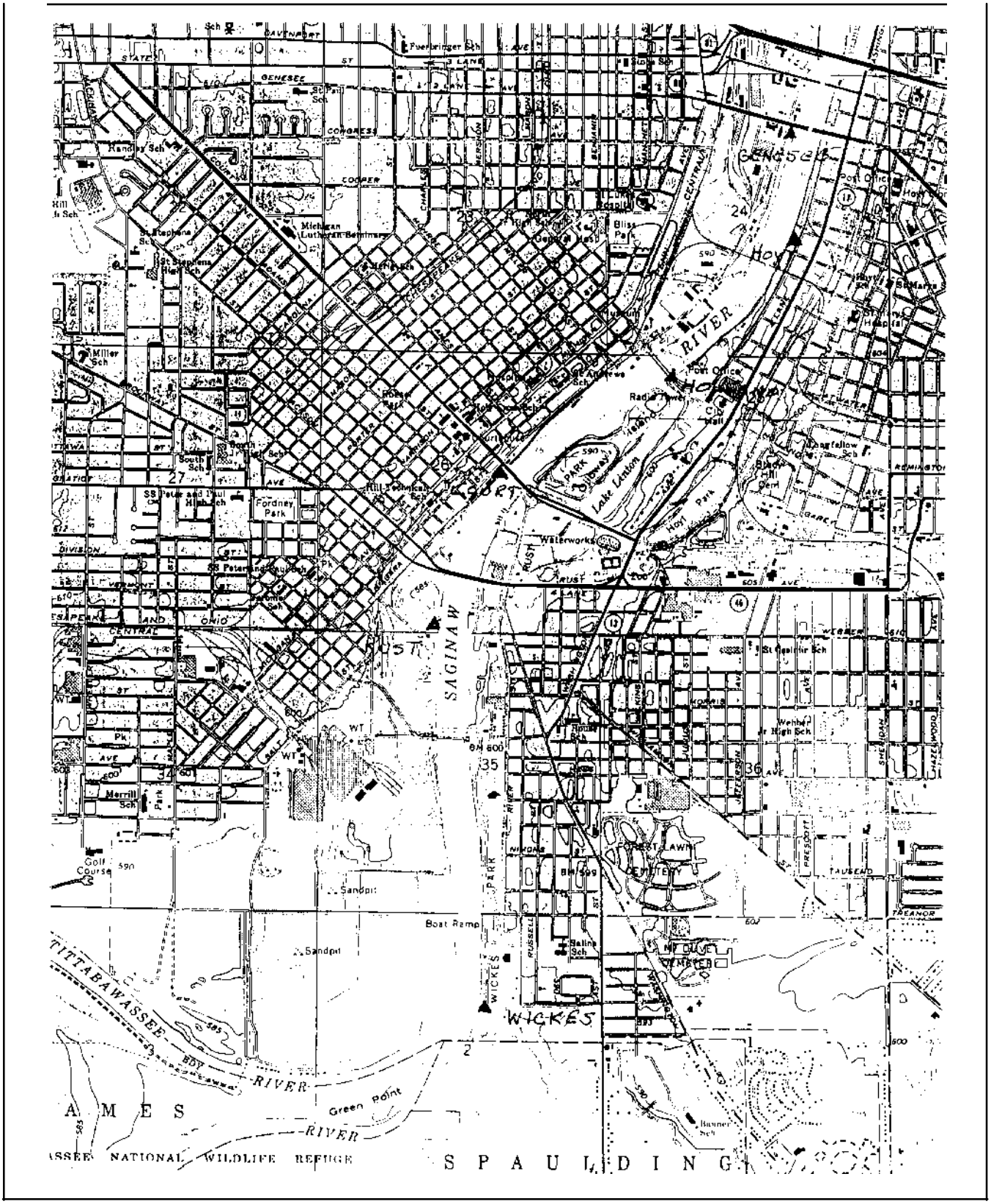


Figure D-17. Project area and control points, Upper Saginaw River project (Continued)

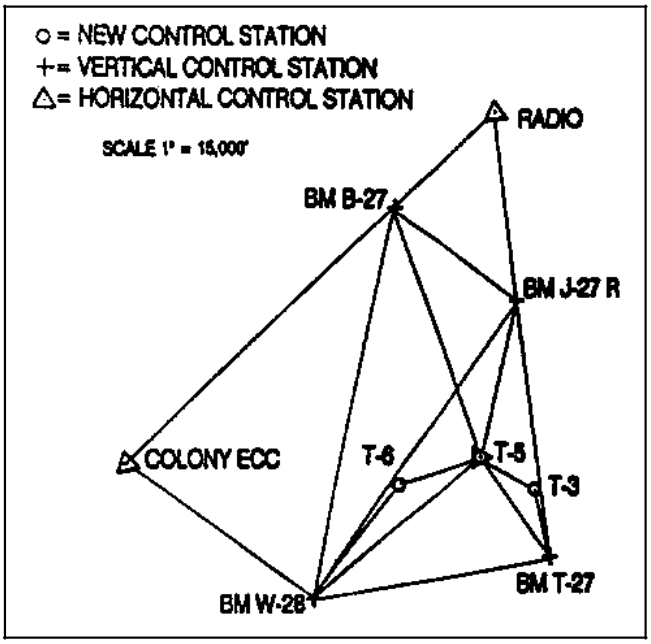


Figure D-17. (Concluded)

support digital mapping of the Upper Saginaw River. Saginaw's function was to provide horizontal control in this area for mapping purposes. Six points (3 pairs) were established, see Figure D-17. Control was brought in from two First-Order NGS horizontal control stations, stations Jonas and Parrish.

c. Four Ashtech Dual Frequency (L1/L2) GPS receivers and antennas with ground planes were used for this project.

d. Prior to any data collection, a preplanning survey was conducted to determine any obstructions (see Figure D-18) and examine existing control. Control station Jonas and Parrish had some sinking problems due to thawing ground. Station Jonas was readjusted during the survey but station Parrish was not.

e. A satellite visibility chart was run to determine occupation times for each session on both day 083 and day 084. The chart included the number of satellites and PDOP for the project area. The charts were run with an elevation mask of 20 deg (see Figure D-19) and 25 deg (see Figure D-20).

f. There were three survey sessions held on day 083 and one on day 084. Table D-5 lists sessions, occupation times, and stations occupied for day 083 and Table D-6 lists day 084 occupation times and stations.

D-11. Actual Survey

The survey was performed as planned, with three sessions on day 083 and one session on day 084. An observation log (see Figure D-21) for each station was recorded by the observer. This information was used during post-processing.

D-12. Data Processing and Adjustment

a. The GPS baselines were processed using Ashtech baseline reduction software (GPPS). All four sessions were processed. An output file from this program is shown in Figure D-22. From these results, session 083 A and B and 084 seemed to be satisfactory. Session 083 C tagged all the float solutions except for the vector between 4008 and 4009. The plots for these vectors, between 4008 and 4009, appeared to have been affected by the ionosphere.

b. After baseline processing was completed, a loop closure was performed to show closures with known control (see Figure D-23) and one was performed to show closures with the unknown control stations.

c. Once the closures were completed, a free adjustment and a constrained adjustment were performed on all processed baselines for Julian days 083 and 084. Figure D-24 was the input file used for the free adjustment. The constrained adjustment held fixed station PARRISH's X,Y,Z and station JONAS' X,Y. The results of the constrained adjustment are listed in Figure D-25.

d. After the final adjustment of the data, CORPSCON was used to convert the station latitude and longitude to state plane coordinates. This file is listed in Figure D-26.

D-13. Station Descriptions

Station descriptions with adjusted coordinates for each control station set were formulated. These are listed in Figure D-27.

" O.I'".S. f'REPLAI'INIi G SUIWEY "

PROJECT' . . f..i.f'PI;O._g _$__d_<ii_LHLI.W . . .-------

GTfITIOI-I lo'\ME= ...f:/_a,y_L_____ RIGHT OF ENTRY__y.J!f,;s_ DAIE;---___----

IiOI:O:lZDI,ITAL COI-ITRCIL: KNOWN_____ UI-IKNOWN___ (IF U II<NOWI'I GIVE APPROX. LAT/LOI'iG)

IF I<NOItJI'I IHVE VALUESI DAIUM_____ ---· PROJECfiOI'I_ ---------- __ ZONE__ ---· __

I.(IIITUDE_ .. __ • _ _----- --------- __ ---------- t-IoRnc_____------ ____ .

LOI'IG TUDE_·--·----·---·.--·---·-·---------- EAST

VERTICAI_ COI-ITROL I<I-I0WN....•----·--·-- UI-IKI-IOWI-1, (IF UI"I<NOWN GIVE APPROX. EI.EV.)

J.F I<NOWH GIVE VALU ES: DATUI'I_____ E L EV. F T . - - _ - - - I'IETERS-· - - - ·····

OBSt::VATION SITEc COI'IPLETE OI:.lSTRUCTIOI-1 POLAR I'IAP (SEE BELOW)/

ACCIiSSASt L1TV; CAR/TRUCK____. - - - HI(E_____....._ BOAT _____,..

J)lSTrlNCE VEHJ.CLE CAN DE PARKED TI1 STATIDI'h

PRIVATE PROPEI;.:TY_.....·-··----- PUBLIC PI;.:QPERTY -- Z·-:- - GATE ·I:;:EQUIRED_____

HOTIFJ.CA"fHJI--1 OF prmF'ERTV OWNER RELIUIRED PRIOR TO ACCESS ___,Na_ __

NAME: SAG. RIVER WALK IF YES PI-IO! E "-----··•.. --- _ ..-----..--..--

ODSTI'i:\JCT:l:DN PDLAI;.: 1'1AP:

J.fU)lCATE CHJSIT UCTIOI-IS;
EX. ·n;.:a::s. DUILDH•IGS•••
(SG: EXANI"LE ON BACIO

REMARKS:

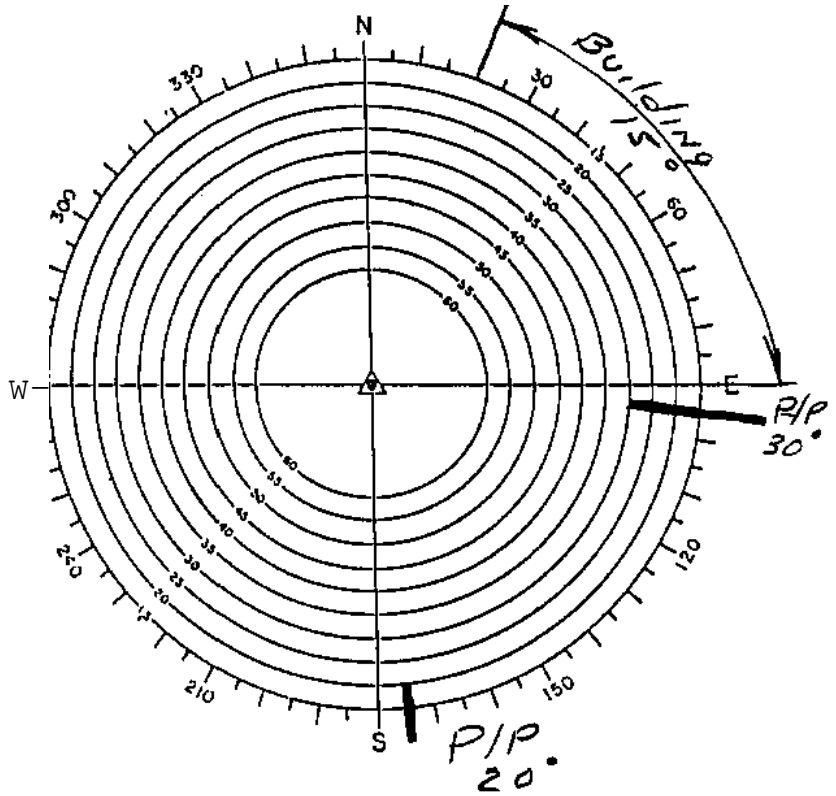


Figure 0-18. Preplanning survey, Upper Saginaw River project

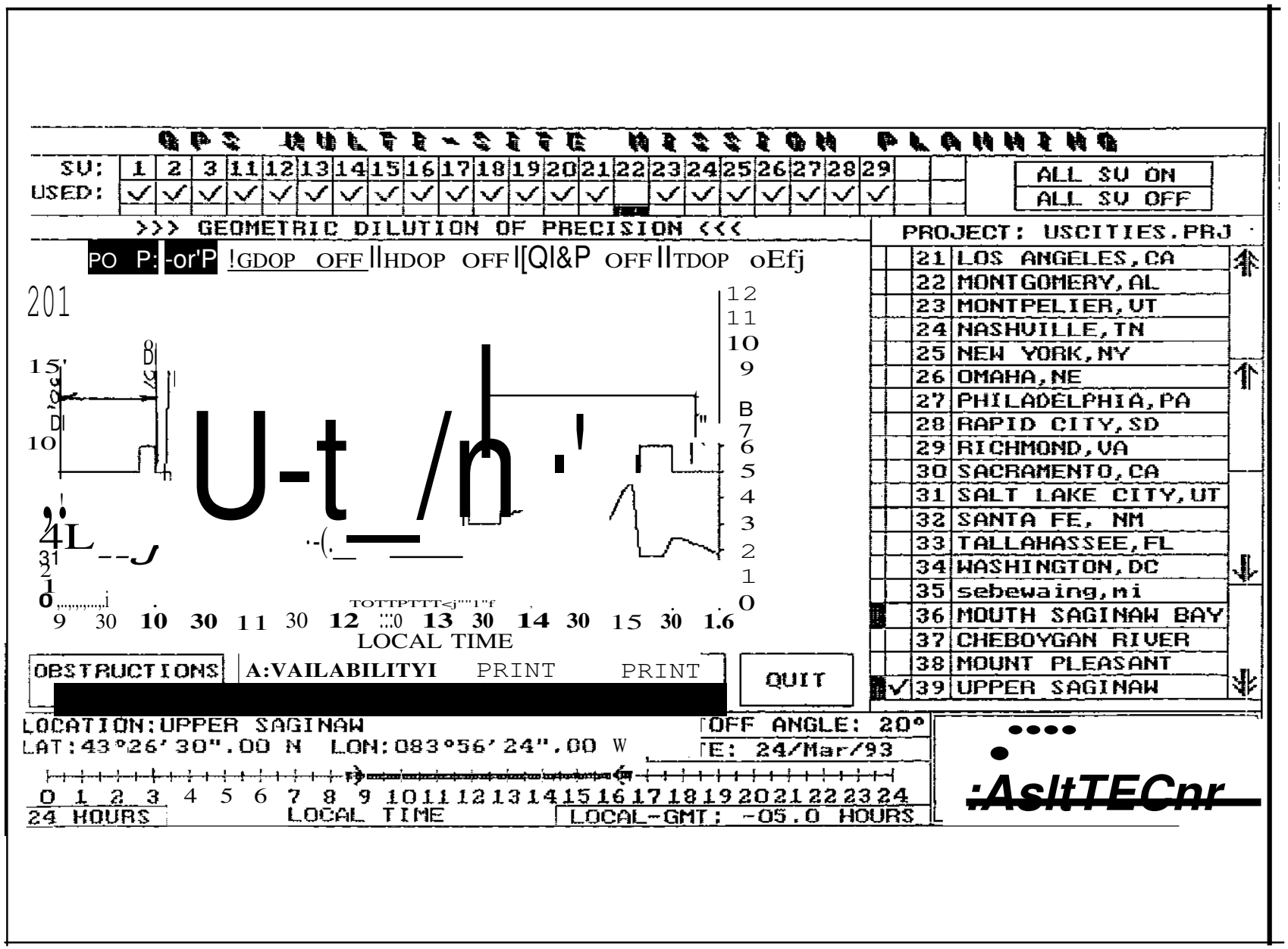


Figure D-19. Satellite visibility chart, elevation mask 20 deg

SV, r 1 a~ 3 11.t2.t3'.t4l.tsit6 n11aB'2o1212223 24 2s26 27128129~

USED; [v ·./ V v V -./l-./ V vlv V V V V V V V vlv!v

ALL SV oN

ALL SV OFF

GEOMETRIC DILUTION OF PRECISION <<<

PROJECT: u ciTIES.PRJ

hHH!:M•:MiGDOP OFFI\HDOP OFFI!QQQP OFFI!TDOP OFFI

21 LOS ANGELES.. CA

22 MONTGOMERY, R1

23 MONTPELIER.. \JT

24 NASHUJLLE.r TN

2:5 HEW YORK.. NY

26 OMAHA, NE

27 PHILADELPHIA,PA

28 RAPID CITY, SO

29 RICHMOND, VA

30 SACRAMENT O" CA

31 SALT LAKE CITY, UT

32 SAtHA FE.., NM

ing_,.Mi

33 TALLAHASSEE., FL

3_4 WASHINGTON, DC

LOCAL TIME

oBSTRUCTIONS IAVAILABILITYI r-=P=-R=.'"r-:-N=T" PRINT II QI'IT

OFF . OH . GRAPH . TABLE .

IOUNT

INAW

LAT:43°26'" 30". 00 N LOti:083°56" 24".00 H

IOH:UPPER SAGINAW

P)9 161:H:2131.4151t171.81.92021222324

24 HOURS LOCAL TIME LOCAL GMT: -05.O HOURS

∴Asnrecn

Figure D-20. Satellite visibility chart, elevation mask 25 dag

Table D-5
Day 083

Session A 0900-1000	Session B 1030-1130	Session C 1340-1540
HOYT	WICKES	WICKES
GENESSEE	RUST	RUST
HOLLAND	HOLLAND	JONAS
EWALD	EWALD	PARRISH

Table D-6
Day 084

Session A 1335-1535
HOYT
GENESEE
JONAS
PARRISH

CORPS OF ENGINEERS " GPS OBSEHVA'I.'ION LOG " SAG!t-.'\W AllliA Ob"b'ICE

PROJECT .Sec... t?.ucR_ --------..---___ ; '_____

OBSERVER NAME 6-JfEC.- DATE 3- Zt./- q 3 JULIAN DATE 083

****

SE:SSION "A"

STATION NAME'--'/:z'-/,.<;Q'-.)ffc..L_____ STATION a .1'-(00 9"

SKED.START o9oo ACTUAL START 085--> SK.ED.STOP /QOO ACTUAL STOP_____

ANTENNA H.E:IGHT: INCHES: B&FORE 59J.r{ AFI'ER ;5'/:u:.o-"<t<-"-- MEAN 59 .Yif

METERS: BEFORE /.50 51"\ AFTER /. 5'05 MEAN /. 505 Z

****

SESSION "B"

STATION NAME:_---IJIAI!.ll!.t;t:.lKS..C€ 5:> _____ STATION #___,qz.ec>'.<OLJ:8L----

5KED.START/Q3o ACTUAL START/030 SKED.STOPI/:3o ACTUAL STOP /['&0

ANTENNA HEIGHT: INCHES: BEFORE (n2.-?k Ali"£ERc_ 1."-'?'-"""" " ·-MEAN C, 2 '7(a

Mln'ERS: BEFORE /. 57'7 AFTER /,$I 9 MEAN /, $ '] i 1/

****

SESSION "C"

STATION NAME: .\I.J.!J.liJ:C..Lts=ts=lf00:':0! STATION *"---""/"""0"0"'-'8"------

SKED.STAR'r !34q ACTUAL START 1'3"05 SKKD.STOP J5'/ o ACTUAL STOP t5'-/ D

ANTENNA HEIGHT: INCHES: BEFOREL.J"'O!t"›-:"'-"- •=ER (:'/I\ MEAN &.'/ h

METERS: BEFORE /. (,. 31.... AFI'ER 1.636 MEAN 1.636

****

SESSION "D"

STATION NAME:_____ STATION _____

SKED.START_____ ACTUAL STAR'!'_____ SKED.S'I'OP•_____ ACTUAL STOP'----

ANTENNA HEIGHT: INCHES: BEFORH:_____ AF£ER_____ MEAN_____

METERS: BEio'QRE AFU MEANI_____

****

RECEIVER INFORMATION

6/N 50 I ANTENNA # OO I ANT. CABLE LBNGTH-'=:'-'''--- POWER SUPPLY 2'{V

GROUND PLANES USED L1 L2

****

COMMENTS:(WEATHER, PROBLEMS, OCCURENCES, ?)

Se!>S/ON nA" Re.c-. 11) ¢.S O/ !2.·15<!.O zt-23·25 (..o r..te:!. O'l!O 11- o0,15
6rw" , '(- o<J?o)

SESSION "B" " „ d. oJ- 1'-1- tS-2-o-c.r;-21 ('-"1 ll 1-:;. 1045
H <eo- (/2,C)

SESSION "C" " ·! Jf:' o -Jt./-t8·t9-zs-ze-z9 (1 'r "*J'i- sa OVER

Figure D-21. Observation log, Upper Saginaw River project

```
Ashtech, Inc. GPPS-L          Program: LINECOMP          Version: 4.5.00
                            Fri Mar 26 10:34:33 1993
Project information
GPS survey                  \25-character project name   [ The | is in column 26
- 1
0843A                       IS-character session name
Project information

Known-station parameters
00                          |Receiver identifier used in "LOGTIMES" file
000000                      |Project station number
1001                        |4-character short name
FIXED STATION               |25-character long name
503 003 005 — — — — — —     |25-character comment field
0                           |Position extraction (O=below,l=U-file,2=proj. file
)
N  43 33 32.67131           |Latitude deg-min-sec  (g=good;b=bad)
E 276 11 32.13854           |E-Longitude deg-min-sec (g=good;b-bad)
W  83 48 27.86146           |W-Longitude deg-min-sec (g=good;b=bad)
   150.7356                 |Ellipsoidal height  {m) (g=good;b=bad)
     0.0000                 |North antenna offset(m)
     0.0000                 |East antenna offset  (m)
  1.6990   0.1150   0.0000  |Vert antenna offset  (m): slantjradiusfadded_offset
    20.0                    |Temperature (degrees C)
    50.0                    |Humidity {percent)
  1010.0                    |Pressure {millibars)
U1001A93.084                |Measurement filename  (restricted to 24 characters)
Known-station parameters

Unknown-station parameters
00                          |Receiver identifier used in "LOGTIMES'i file
000000                      |Project station number
4005                        |4-character short name
UNKNOWN STATION             |25-character long name
504 004 007 — — — — — —     |25-character comment field
0                           |Position extraction (O=below,1=U-file,2=proj. file
)
N  43 26  1.65174           |Latitude deg-min-sec  (g=good;b=bad)
E 276  3 25.93899           |E-Longitude deg-min-sec (g=good;b=bad)
W  83 56 34.06101           |W-Longitude deg-min-sec (g=good;b=bad)
   149.5289                 |Ellipsoidal height  (m) (g=good;b=bad)
     0.0000                 |North antenna offset(m)
     0.0000                 |East antenna offset  (m)
  1.6350  0.1150  0.0000    |Vert antenna offset  (m): slantfradiusjadded_offset
    20.0                    |Temperature (degrees C)
    50.0                    |Humidity (percent)
  1010.0                    |Pressure (millibars)
U4005A93.084                |Measurement filename  (restricted to 24 characters)
Unknown-station parameters
```

Figure D-22. Output file, Upper Saginaw River project (Ashtech) (Sheet 1 of 5)

```
Run-time parameters
    ■                          | First epoch to process
   -1                          | Final epoch to process (-1 = last available)
20.0                           | Elevation cutoff angle (degrees)
 ■                             | Data to process (O=Wdln;l=L1;2=L2;3=Llc;6=RpdSt)
0.010000                       | Convergence criterion (meters)
00 00 00 00 00 00 00           | Omit these satellites (up to 7)
lO                             | Maximum iterations for tlsq and dlsq
00 00 00 00 00 00 00           | Forbidden reference SVs (up to 7)
yes                            | Apply trope delay correction
Run-time parameters

LINECOMP  4.5.00  12/11/92

FIXED U-File from Ll only receiver.
UNKWN U-File from Ll only receiver.

FIXED U-File used BROADCAST orbits.
UNKWN U-File used BROADCAST orbits.

common start of two UFILES: 1993/03/25 18:35:60.00
Common end   of two UFILES: 1993/03/25 20:32:60.00
    Selected first epoch:  1
    Selected last  epoch:  352
For SV 11 there are   221 triple-difference measurements.
For sv 18 there are   351 triple-difference measurements.
For SV 19 there are   351 triple-difference measurements.
For SV 27 there are    73 triple-difference meas rements.
For SV 28 there are   348 triple-difference measurements.
For SV 29 there are   338 triple-difference measurements.
Epoch interval (seconds): 20.000000


THE TRIPLE DIFFERENCE SOLUTION (L1)
Measure of geometry: 0.640415
num meas =  1329        num used =  1323         rms resid = o,002595(m)
Post-Fit Chisq    3459.383          NDF      ""    12.250


  Sigmax  (m):     0.870234
  sigmay  (m):     0.572256
  Sigmaz  (m):     0.270963
  x     y     z
x 1.00
y 0.71y 1.00
z-Oo40z-0.59z loOO

del station: 0.005074 Oo001394 -0.000650
   -Station!: FIXED STATION             Station2: UNKNOWN STATION

                (00000)     (1001)                    (00000)     (4005)
```

Figure D-22. (Sheet 2 of 5)

```
Latitude:  43.55907536  43 33 32.67131          43.43379221  43 26  1.65195

E-Long    276.19226071 276 11 32.13854        276.05720501 276  3 25.93803

W-Long     83.80773929  83 48 27.86146          83.94279499  83 56 34.06197

E-Height: 150.7356                              149.5416

Baseline vector:     -9839.2603     -10690.9170    -10098.3296

Mark! xyz        499359.2995  -4602470.6194   4372824.2683
Azl Ell Dl          218.17046       -0.0834     17694.1519
El Nl Ul         -10912.4583    -13919.7439       -1.1940
Mark2 xyz        489520.0392  -4613161.5364   4362725.9387
AZ2 EI2 O2           38.07750       -0.0757     17694.1519
E2 N2 U2          10935.0401     13919.4351        1.1940

Double-Difference Epochs:
  Prn:  11  start epoch:  132  End epoch:  352
  Prn:  18  Start epoch:    2  End epoch:  352
  Prn:  19  Start epoch:    2  End epoch:  352
  Prn:  27  Start epoch:  280  End epoch:  352
  Prn:  28  start epoch:    5  End epoch:  352
  Prn:  29  start epoch:    2  End epoch:  339


THE FLOAT DOUBLE DIFFERENCE SOLUTION (L1)
Measure of geometry: 0.103203     Wavelength = 0.190294  (mjcycle)
num meas =  1332        num used=   1317         rms_resid = 0.004061(m)
Post-Fit Chisq =    42.171           NDF      =    12.194

Reference  SV: 18
  sv       Ambiguity       FIT          Meas      SV     Ambiguity       FIT     Meas
  11        22406589.878£  a.024         211      19      21161231.999£  0.018   350
  27        10785453.076£  0.024          72      28      28836460.832£  0.022   348
  29         5129536.945£  0.021         336

  Sigmax (m):                0.015558
  Sigmay (m):                0.010159
  Sigmaz (m):                0.004803
  SigmaN (cy):               0.075992
  SigmaN (cy):               0.018403
  SigmaN (cy):               0.034642
  SigmaN (cy):               0.089934
  SigmaN (cy):               0.033807
  x     y     z               N     N      N      N     N
x 1.00
y 0.72y  1.00
z-0.5Dz-0.65z  1.00
N 0.97N  0.72N-0.59N  1.00
N-0.10N  0.42N-0.05N-0.05N 1.00
```

Figure D-22. (Sheet 3 of 5)

```
N-0.31N  Q,26N-0,05N-0.26N 0.67N  1.00
N 0.99N  0.76N-0.52N  0.9BN-O.OON-0.24N  1.00
N 0.89N  0.57N-0.60N  Q.93N-0.11N-0,32N  0.90N  1.00

del station: 0.000000 0.000000 0.000000
     Station!: FIXED STATION              Station2: UNKNOWN  STATION

                 (00000)     (1001)                    (00000)     (4005)
 Latitude:  43.55907536  43 33 32.67131          43.43379217  43 26  1.65179

 E-Long   : 276.19226071 276  11 32.13854        276.05720515  276   3 25.93854

 W-Long     83.80773929   83 48 27.86146          83.94279485   83 56 34.06146

 E-Height:  150.7356                               149.5272

 Baseline vector:     -9839.2497    -10690.9086    -10098.3429

 Mark1_xyz       499359.2995  -4602470.6194   4372824.2683
 Az1 Ell O1         218.17042       -0.0834     17694.1485
 El Nl Ul        -10912.4468    -13919.7486        -1.2084
 Mark2_xyz   !   489520.0498  -4613161.5280   4362725.9254
 Az2 El2 02          38.07746       -0.0756     17694.1485
 E2 N2 U2    !    10935.0287     13919.4398          1.2084


AMBIGUITY  RESOLUTION
                          1          2          3          4
Abs contrast          0.008      0.000      0.000      0.000
contrast                       100.000    100.000    100.000
Change  Chi2         38.426   4588.301   4624.842   5296.077
Bias  518:11       22406590   22406591   22406589   22406590
Bias  518:19       21161232   21161232   21161232   21161232
Bias  518:27       10785453   10785453   10785453   10785454
Bias  518:28       28836461   28836462   28836460   28836461
Bias  518:29        5129537    5129537    5129537    5129537
NDF=136.7000  Chi2=42.1709


THE FIXED  DOUBLE  DIFFERENCE  SOLUTION  (L1)
Measure  of  geometry:  0.030142     Wavelength = 0.190294  (m/cycle)
num meas  =  1332         num used =  1315         rms resid  = 0.005514(m)
Post-Fit  Chisq  =    77.434           NDF           12.176

Reference SV: 18                   Integer search Ratio =  100.000
  sv     Ambiguity        FIT    Meas      sv     Ambiguity        FIT    Meas
  11      22406590.000X  0.031   213       19      21161232.000X  0.029   350
  27      10785453.000X  0.053    65       28      28836461.OOOX  0.025   349
  29       5129537.000X  0.024   338

  sigmax  (m):      0.002257
```

Figure 0·22. (Sheet 4 of 5)

```
  Sigmay (m) :        0.005658
  Sigmaz (m) :        0.004546
  X      Y      Z
X 1.00
y 0.19y 1.00
z 0.12z-0.72z  1.00

del station:  o.oooo16  0.000949  -0.000715
   — Station!: FIXED STATION              Station2: UNKNOWN STATION

                (00000)     (1001)                    (00000)     (4005)
 Latitude:   43.55907536  43 33 32.67131          43.43379220  43 26  1.65191

 E-Long    276.19226071 276 11 32.13854         276.05720552 276  3 25.93986

 W-Long   :  83.80773929  83 48 27.86146          83.94279448  83 56 34.06014

 E-Height:  150.7356                              149.5220

 Baseline vector:     -9839.2208     -10690.8991     -10098.34·38

 Markl xyz       499359.2995  -4602470.6194   4372824.2683
 Azl Ell Dl         218.17035       -0.0835     17694.1272
 El Nl Ul        -10912.4172    -13919.7449       -1.2136
 Mark2 xyz       489520.0787  -4613161.5185   4362725.9246
 AZ2 EI2 02          38.07739       -0.0756     17694.1272
 E2 N2 U2    :    10934.9990     13919.4360        1.2136
Fri Mar 26 10:39:26  1993
```

Figure D-22. (Sheet 5 of 5)

```
 PROGRAM SHOOTER
Input: FILLNET.IN                          output: OSJOS4aa.lop


STARTING STATION NAME: 1001
 LINE FROM          TO                    OX          OY          OZ         LENGTH
   1  1001          4008     OBJJC  -11172.423 -14312.145 -13760.192  22781.646
  17  4008          4009     0833B    -412.530   1492.440   1614.982   2237.348
  14  4007          4009     0833B    -313.662   -602.201   -613.237    914.926
  11  4006          4007     OB33A    -864.616   -467.386   -388.225   1056.754
   9  4006          4004     0833A     628.445    613.864    569.761   1047.091
  24  4005          4004     0843A      60.920   -445.464   -475.513    654.417
  20  1001          4005     0843A   -9839.221 -10690.899 -10098.344  17694.127

      STATION            LATITUDE          LONGITUDE        ELEV.        GH
      1001               43 33 32.67152    83 48 27.85821   150.615     0.000
      4008               43 23 18.39708    83 57 49.93702   146.842     0.000
      4009               43 24 30.42613    83 58  1.19491   146.545     0.000
      4007               43 24 57.46166    83 57 44.51670   156.913     0.000
      4006               43 25 14.92267    83 57  4.10971   152.264     0.000
      4004               43 25 40.45135    83 56 33.44979   148.694     0.000
      4005               43 26  1.65131    83 56 34.05326   149.238     0.000
      1001               43 33 32.67072    83 48 27.85454   150.452     0,000

 TRAVERSE  LENGTH=  46.386 kilometers
 MISCLOSURES  (LAT., LON., ELEV., meters):   -0.025  -0.082  -0.163
                                                LOOP MISCLOSURE  =   4.0 ppm
    Since geoid heights are not given, the
    computed elevations may be seriously in error.


STARTING STATION NAME: 1002
 LINE FROM          TO                    OX          OY          OZ         LENGTH
  23  1002          4005     0843A    7853.486 -20463.167 -22275.296  31250.716
  10  4006          4005     0833A     567.529   1059.329   1045.274   1592.754
  12  4006          4007     0833B    -864.618   -467.386   -388.229   1056.757
  16  4008          4007     0833B     -98.867   2094.641   2228.220   3059.781
  18  4009          4008     0833C     412.552  -1492.436  -1614.997   2237.360
  13  4006          4009     0833B   -1178.280  -1069,587  -1001.466   1880.238
   9  4006          4004     0833A     628.445    613.864    569.761   1047.091
  24  4005          4004     0843A      60.920   -445.464   -475.513    654.417
   B  4005          4007     0833A   -1432.144  -1526.716  -1433.499   2537.088
  14  4007          4009     0833B    -313.662   -602.201   -613.237    914.926
   5  1002          4009     0833C    6107.640 -22591.898 -24322.208  33753.""028

      STATION            LATITUDE.         LONGITUDE        ELEV.        GH
      1002               43 42 37.45123    84 00 46.44187   162.300     0.000
      4005               43 26  1.65174    83 56 34.06100   149.529     0,000
      4006               43 25 14.92309    83 57  4.11762   152.555     0.000
      4007               43 24 57.46199    83 57 44.52470   157.201     0.000
      4008               43 23 18.39740    83 57 49.94506   147.130     0.000
```

Figure 0·23. Loop closure, Upper Saginaw River project (Continued)

4009	43 24 30.42676	83 58 1.20394	146.844	0.000
4006	43 25 14.92339	83 57 4.11865	152.566	0.000
4004	43 25 40.45206	83 56 33.45874	148.995	0.000
4005	43 26 1.65202	83 56 34.06221	149.540	0.000
4007	43 24 57.46234	83 57 44.52579	157.216	0.000
4009	43 24 30.42681	83 58 1.20400	146.848	0.000
1002	43 42 37.45140	84 00 46.44218	162.570	0.000

TRAVERSE LENGTH = 79.984 kilometers
MISCLOSURES (LAT., LON., ELEV., meters): 0.005 0.007 0.270
LOOP MISCLOSURE = 3.4 ppm

Since geoid heights are not given, the computed elevations may be seriously in error.

Figure D-23. (Concluded)

```
                                        FILLNET.IN
6378137.0    298.2572221  W    Y A 50 y N N N N
Fillnet Input File  083084 FREE ADJ      43.5  83.9
      1001           43 33 32.67152  083 48 27.85821   150.615
    1    0
      4008           43 23 18.39709  083 57 49.93704   146.842
    2    0
      4009           43 24 30.42636  083 58  1.19634   146.561
    3    0
FFF   1002           43 42 37.45123  084  0 46.44187   162.300
    4    0
      4004           43 25 40.44276  083 56 33.45850   148.717
    5    0
      4005           43 26  1.64290  083 56 34.06171   149.245
    6    0
      4007           43 24 57.45316  083 57 44.52581   156.933
    7    0
      4006           43 25 14.91409  083 57  4.11839   152.287
    8    0
*
  24  3 510  510 0.00 0.00 0.00  0.00 0.00 0.00 0.00 0.00
    4 1001           4006     0833C  -11172.423 -14312.145 -13760.192  610201020
    1    2
    4 1001           4009     0833C  -11584.984 -12819.715 -12145.194  610201020
    1    3
    4 1002           1001     0833C   17692.643  -9772.176 -12177.017  610201020
    4    1
    4 1002           4008     0833C    6520.196 -24084.335 -25937.204  610201020
    4    2
    4 1002           4009     0833C    6107.640 -22591.898 -24322.208  610201020
    4    3
    4 4004           4005     0833A     -60.916    445.465    475.513
    5    6
    4 4004           4007     0833A   -1493.060  -1081.250   -957.986
    5    7
    4 4005           4007     0833A   -1432.144  -1526.716  -1433.499
    6    7
    4 4006           4004     0833A     628.445    613.864    569.761
    8    5
    4 4006           4005     0833A     567.529   1059.329   1045.274
    8    6
    4 4006           4007     0833A    -864.616   -467.386   -388.225
    8    7
    4 4006           4007     08338    -864.618   -467.386   -388.229
    8    7
    4 4006           4009     08338   -1178.280  -1069.587  -1001.466
    8    3
    4 4007           4009     08338    -313.662   -602.201   -613.237
    7    3
    4 4008           4006     08338     765.751   2562.026   2616.450
    2    8
    4 4008           4007     08338     -98.867   2094.641   2228.220
    2    7
    4 4008           4009     08338    -412.530   1492.440   1614.982
    2    3
    4 4009           4008     0833C     412.552  -1492.436  -1614.997
    3    2
    4 1001           4004     0843A   -9778.301 -11136.364 -10573.856
```

Figure D-24. Input file for free adjustment, Upper Saginaw River project (Continued)

FILLNET.IN

```
1    5
4 1001          4005     0843A   -9839.221 -10690.899 -10098.3-44
1    6
4 1002          1001     0843A   17692.725  -9772.257 -12176.953
4    1
4 1002          4004     0843A    7914.403 -20908.632 -22750.807
4    5
4 1002          4005     0843A    7853.486 -20463.167 -22275.296
4    6
4 4005          4004     0843A      60.920   -445.464   -475.513
6    5
```

Figure D-24. (Concluded)

```
PROGRAM FILLNET, Version J.o.oo
LICENSED TO: ASHTECH INC-

Fillnet Input File  083084 CONSTRAINED      43.5    83.9

a    6378137.000   1/f =  298.2572221   W     Longitude positive WE
ST

PRELIMINARY COORDINATES:
                          LAT.            LON.        ELEV.    G.H.  CON
STR.

  1  FF    1001 43 33 32.66675   83 48 27..86095   150.615   0.000
  2        4008 43 23 18.39709   83 57 49.93704   146.842   0.000
  3        4009 43 24 30.42636   83 58  1.19634   146.561   0.000
  4  FFF   1002 43 42 37.45123   84  O 46.44187   162.300   0.000
  5        4004 43 25 40.44276   83 56 33.45850   148.717   0.000
  6        4005 43 26  1.64290   83 56 34.06171   149.245   0.000
  7        4007 43 24 57.45316   83 57 44.52581   156.933   0.000
  8        4006 43 25 14.91409   83 57  4.11839   152.287   0.000

GROUP 1, NO. OF VECTORS AND BIAS CONSTRAINTS:

 24      0.000   0.001    0.000  0.001    0.000   0.000    0.000   0.000

VECTORS:
                      OX          DY          DZ       LENGTH   ERROR  CODES

 1001    4008  -11172.423  -14312.145  -13760..192  22781.646  6102.0  102.
O  4
 1001    4009  -11584.984  -12819.715  -12145.194  21120.196  6102.0  102.
O  4
 1002    1001   17692.643   -9772.176  -12177.017  23596.711  6102.0  102.
0  4
 1002    4008    6520.196  -24084.335  -25937.204  35990.370  6102.0  102.
O  4
 1002    4009    6107.640  -22591.898  -24322.208  33753.028  6102.0  102.
O  4
 4004    4005     -60.916     445.465     475.513    654.418  3  51.0   51.
O  4
 4004    4007   -1493.060   -1081.250    -957.986   2077.515  3  51.0   51.
O  4
 4005    4007   -1432.144   -1526.716   -1433.499   2537.088  3  51.0   51.
O  4
 4006    4004     628.445     613.864     569.761   1047.091  3  51.0   51.
O  4
 4006    4005     567.529    1059.329    1045.274   1592.754  3  51.0   51-
O  4
 4006    4007    -864.616    -467.386    -388.225   1056.754  3  51.0   51-
O  4
```

Figure 0-25. Results of constrained adjustment, Upper Saginaw River project (Sheet 1 of 6)

4006	**4007**	-864.618	-467.386	-388.229	1056.757	3	**51.0**	51.0 4
4006	4009	**-1178.280**	**-1069.587**	-1001.466	**1880.238**	3	**51.0**	51.0 4
4007	**4009**	**-313.662**	**-602.201**	**-613.237**	**914.926**	3	**51.0**	51.0 4
4008	**4006**	765.751	2562.026	**2616.450**	3741.145	3	51.0	51.0 4
4008	4007	-98.867	2094.641	2228.220	3059.781	3	51.0	51.0 4
4008	4009	-412.530	1492.440	1614.982	2237.348	3	51.0	51.0 4
4009	4008	412.552	-1492.436	-1614.997	2237.360	3	51.0	51.0 4
1001	4004	-9778.301	-11136-364	-10573.856	18205.499	3	51.0	51.0 4
1001	**4005**	**-9839.221**	**-10690.899**	-10098.344	**17694.127**	3	51.0	51.0 4
1002	**1001**	17692-725	**-9772.257**	-12176.953	**23596.773**	3	51.0	51.0 4
1002	4004	**7914.403**	-20908.632	**-22750.807**	31896.832	3	**51.0**	51.0 4
1002	**4005**	7853.486	**-20463.167**	-22275.296	**31250.716**	3	51.0	51.0 4
4005	4004	**60.920**	-445.464	**-475.513**	654.417	3	51.0	51.0 4

SHIFTS:

1	**0.000**	0.000	**0.102**
2	**-0.190**	**-0.260**	**0.238**
3	**-0.181**	**-0.230**	0.226
4	**0.000**	**0.000**	**0.000**
5	**0.097**	-0.045	**0.222**
6	**0.095**	-0.047	**0.238**
7	**0.091**	-0.049	**0.223**
8	**0.095**	**-0.051**	0.222

ADJUSTED VECTORS, GROUP 1:

			DX,DY,DZ	V	DN,DE,DU	v	v'
1001	4008	0833C	**-11172.608**	-0-063	**-18960.149**	**0.017**	0.3
			-14312.293	**-0.093**	**-12630.231**	**-0.073**	**-1.1**
			-13760.130	0.105	**-10.059**	**0.135**	2-0
1001	**4009**	**0833C**	**-11585.141**	**-0.039**	**-16736.980**	0.014	0.2
			-1 819.845	**-0.085**	**-12881.834**	-0.048	**-0.S**
			-12145.133	0.095	-6.620	**0.124**	2.0
1002	1001	0833C	**17692.745**	0.058	**-16815.857**	**-0.014**	**-0.2**
			-9772.339	-0.070	**16554.120**	**0.051**	0.7
			-12177.068	**0.052**	**30.106**	**0.090**	1.3

Figure D-25. (Sheet 2 of 6)

1002	**4008**	0833C	6520.137	0.019	**-35776.006**	**0.007**	0.1
			-24084.632	-0-149	**3923.889**	**0.003**	0.0
			-25937.198	0.152	**20.048**	**0.214**	2.1
1002	4009	0833C	6107.605	**0.038**	**-33552.837**	**0.000**	0.0
			-22592.184	-0.148	3672-286	**0.022**	0.2
			-24322.201	0.144	**23.486**	0.208	2.2
4004	4005	0833A	-60.916	-0.001	654.286	-0.000	-0.0
			445.467	-0.000	-13.234	-0.001	-0.2
			475.516	0.000	1.327	0.000	0.0
4004	4007	0833A	-1493.074	-0.001	**-1325.757**	-0.001	-0.2
			-1081.252	0.001	-1599.518	-0.001	-0.2
			-957.990	-0.002	5.347	-0.002	-0.3
4005	4007	0833A	-1432.158	0.000	-1980.043	-0.000	-0.0
			-1526.719	0.002	-1586.285	0.000	0.0
			-1433.505	-0.002	**4.020**	**-0·.003**	**-0.4**
4006	4004	0833A	628.451	**-0.000**	**787.486**	-0.000	**-0.1**
			613.865	-0.001	**690.124**	-0.000	**-0.1**
			569.763	0.000	-2.121	**0.001**	0.1
4006	4005	0833A	**567.535**	**-0.002**	**1441.772**	-0.000	**-0.1**
			1059.333	-0.001	676.890	-0.002	-0.3
			1045.278	0.000	-0.794	**0.001**	0.1
4006	4007	0833A	-864.623	-0.001	-538.271	-0.001	-0.3
			-467.387	0.000	-909.394	**-0.001**	-0.1
			-388.227	**-0.002**	**3.227**	**-0.002**	**-0.2**
4006	**4007**	**08338**	-864.623	**0.001**	**-538.271**	**0.001**	0.3
			-467.387	**0.000**	**-909.394**	0.001	0.2
			-388.227	0.002	3.227	0.001	0.2
4006	**4009**	**08338**	**-1178.293**	**-0.003**	**-1372.338**	**0.002**	0.3
			-1069.590	0.001	**-1285.281**	-0.002	**-0.3**
			-1001.467	0.001	-8.729	**0.000**	0.0
4007	4009	**08338**	**-313.670**	-0.004	**-834.066**	**0.000**	0.1
			-602.203	0.001	**-375.887**	**-0.004**	-0.5
			-613.240	**-0.000**	**-11.955**	**-0.001**	**-0.1**
4008	4006	**08338**	**765.761**	-0.006	**3595.507**	**0.001**	0.2
			2562.037	**-0.001**	**1033.678**	-0.006	**-0.7**
			2616.464	0.002	12.167	0.002	0.2
4008	4007	**08338**	-98.862	-0.004	**3057.236**	**0.003**	0.4
			2094.651	**-0.002**	**124.284**	**-0.005**	**-0.6**

Figure 0·25. (Sheet 3 of 6)

			2228.237	0.005	15.393	0.005	0.6
4008	4009	0833B	-412.532	-0.007	2223.169	0.004	0.7
			1492.448	-0.002	-251.603	-0.007	-1.0
			1614-997	0.006	3.438	0.004	0.6
4009	4008	0833C	412.532	-0.015	-2223.169	0.006	1.2
			-1492.448	-0.002	251.603	-0.015	-1.9
			-1614.997	0.009	-3.438	0.007	0.9
1001	4004	0843A	-9778.397	0.005	-14577.156	-0.004	-0.1
			-11136.390	0.014	-10906.429	0.006	0.2
			-10573.904	-0.017	-0.012	-0.022	-0.8
1001	4005	0843A	-9839.312	0.007	-13922.870	-0.003	-0.1
			-10690.923	0.013	-10919.663	0.009	0.3
			-10098.389	-0.016	1.314	-0.020	-0.8
1002	1001	0843A	17692.745	-0.024	-16815.857	0.001	0.0
			-9772.339	0.011	16554.120	-0.022	-0.7
			-12177.068	-0.012	30.106	-0.019	-0.5
1002	4004	0843A	7914.349	0.002	-31393.013	0.001	0.0
			-20908.729	0.036	5647.691	0.006	0.1
			-22750.972	-0.032	30.094	-0.048	-1.0
1002	4005	0843A	7853.433	0.002	-30738.727	0.003	0.1
			-20463.262	0.036	5634.457	0.005	0.1
			-22275.456	-0.030	31.421	-0,046	-1.0
4005	4004	0843A	60.916	-0.003	-654.286	-0.000	-0.1
			-445.467	-0.001	13.234	-0.003	-0.4
			-475.516	-0.000	-1.327	0.000	0.0

S.E. OF UNIT WEIGHT 0.843

NUMBER OF –

OBS. EQUATIONS	74
UNKNOWNS	23
DEGREES OF FREEDOM	51
ITERATIONS	0

GROUP 1 ROT. ANGLES (sec.) AND SCALE DIFF. (ppm) :

HOR. SYSTEM	0.000	0.000	0.657	5.277
STD. ERRORS	0.001	0.001	0.166	0.804
XYZ SYSTEM	0.051	-0.473	0.452	

ADJUSTED POSITIONS:

Figure D-25. (Sheet 4 of 6)

		LAT.	LON.	ELEV.	STD. ERRORS (m)		
1	1001	43 33 32.66675	83 48 27.86095	1.50.717	0.000	0.000	0.019
2	4008	43 23 18.39093	83 57 49.94860	147.080	0.024	0.024	0.019
3	4009	43 24 30.42050	83 58 1-20657	146.787	0.022	0.023	0.019
4	1002	43 42 37.45123	84 0 46.44187	162.300	0.000	0.000	0.000
5	4004	43 25 40.44591	83 56 33.46051	148.939	0.020	0.020	0.019
6	4005	43 26 1-64599	83 56 34-06378	149.483	0.020	0.020	0-019
7	4007	43 24 57.45612	83 57 44.52799	157.156	0.022	0.022	0.019
8	4006	43 25 14.91718	83 57 4.12068	152.509	0.021	0.021	0.019

ACCURACIES (m) :

		D. LAT.	D. LON.	VERT.
1001	4008	0.024	0.024	0.014
1001	4009	0.022	0.023	0.014
1002	1001	0.000	0.000	0.019
1002	4008	0.024	0.024	0.019
1002	4009	0.022	0.023	0.019
4004	4005	0.002	0.004	0.004
4004	4007	0.003	0.004	0.004
4005	4007	0.003	0.004	0.004
4006	4004	0.003	0.004	0.004
4006	4005	0.003	0.004	0.004
4006	4007	0.002	0.003	0.003
4006	4007	0.002	0.003	0.003
4006	4009	0.003	0.004	0.004
4007	4009	0.003	0.004	0.004
4008	4006	0.004	0.005	0.004
4008	4007	0.004	0.005	0.004
4008	4009	0.003	0.004	0.004
4009	4008	0.003	0.004	0.004
1001	4004	0.020	0.020	0.014
1001	4005	0.020	0.020	0.014
1002	1001	0.000	0.000	0.019
1002	4004	0.020	0.020	0.019
1002	4005	0.020	0.020	0.019
4005	4004	0.002	0.004	0.004

****
**** ****

Figure D-25. (Sheet 5 of 6)

```
****                    ESTIMATES OF PRECISION                    ****
****                                                              ****
****         Based on the VECTOR ACCURACIES produced by           ****
****                          FILLNET                             ****
****                                                              ****
****      This is a reasonable estimate of the accuracies         ****
****        of the vectors in the network at 1 SIGMA.             ****
****                                                              ****
*****************************************************************
```

VECTOR		LENGTH	PPM(h)	RATIO(h)	PPM(v)	RATIO(V)
1001	4008	22781-793	1-5	1: 671215	0.6	1: 1627271
1001	4009	21120.326	1-5	1: 663584	0.7	1: 1508595
1002	1001	23596.882	0.0	1: 0	o.8	1: 1241941
1002	4008	35990.553	0.9	1: 1060382	0.5	1: 1894240
1002	4009	33753.209	0.9	1: 1060499	0.6	1: 1776485
4004	4005	654.421	6.8	1: 146333	6.1	1: 163605
4004	4007	2077.527	2.4	1: 415504	1-9	1: 519382
4005	4007	2537.102	2.0	1: 507420	1-6	1:. 634275
4006	4004	1047.096	4.8	1: 209419	3.8	1: 261774
4006	4005	1592.761	3.1	1: 318552	2.5	1: 398190
4006	4007	1056.761	3.4	1: 293091	2.8	1: 352254
4006	4007	1056.761	3.4	1: 293091	2.8	1: 352254
4006	4009	1880.249	2.7	1: 376046	2.1	1: 470062
4007	4009	914.932	5.5	1: 182971	4.4	1: 228733
4008	4006	3741.164	1-7	1: 584269	1-1	1: 935291
4008	4007	3059.800	2.1	1: 477854	1-3	1: 764950
4008	4009	2237.364	2.2	1: 447472	1-8	1: 559341
4009	4008	2237.364	2.2	1: 447472	1-8	1: 559341
1001	4004	18205.594	1-6	1: 643665	0.8	1: 1300400
1001	4005	17694.218	1-6	1: 625585	o.8	1: 126'3873
1002	1001	23596.882	0.0	1: 0	0.8	1: 1241941
1002	4004	31897.000	0.9	1: 1127729	0.6	1: 1678789
1002	4005	31250.879	0.9	1: 1104885	0.6	1: 1644783
4005	4004	654.421	6.8	1: 146333	6.1	1: 163605

Figure D-25. (Sheet 6 of 6)

```
                                        083084C.SPC
;Software: CORPSCON vJ.Ol, Agency: CORPS OF ENGINEERS SAGINAW
;Project: UPPER SAGINAW MAPPING,
;original Coordinates on NAD 83 Geographic Coordinates
;Translated Coordinates on NAO 83 State Plane Zone 2113,U.S. FOOT

1001. JONAS          ,13271491..47735,  750899.10875
4008 WICKS           ,13230401.67183.   688469-29439
4009 RUST            ,13229535.79827,   695757.90291
1002 PARRISH         ,13216876.80162,   805765.50958
4004 HOYT            ,13235976.88650,   702879.28348
4005 GENESSEE        ,13235921.56530,   705025.46304
4007 EWALD           ,13230753.74995,   698500.99009
4006 HOLLAND         ,13233727.24329,   700283.34945
|||!
```

Figure D-26. CORPSCON file, Upper Saginaw River project

U.S. ARMY ENGINEER DISTRICT – DETROIT

GENERAL INFORMATION

designation: HOYT
reference no. SAG-0613

project: SAGINAW RIVER
channel/reach: UPPER
sheet no.
USGS Quad: SAGINAW
NOAA' chart: 14867

community: SAGINAW
county: SAGINAW
state: MICHIGAN
Township/Range T.12N R.04E
section: 24

BORI20NTAL

datun: NAD83
lat: 4JG 25'40.44591 N
len: 83° 56'33,46051R W

y, 0.00 m (N)
X. 0.00 m (E)

y, 702,879.28 ft '(US) N
X. 13,235,976.89 ft (US) E

state: MICHIGAN
projection: LAMBERT
zone: 5
code: 2113

HORIZONTAL ORIGIN

agency: OSACE
order:
date: 03/23/93
method: GPS
set by: '. HENRY

Point Soul;"ce:

JONAS 1932
PARRISH

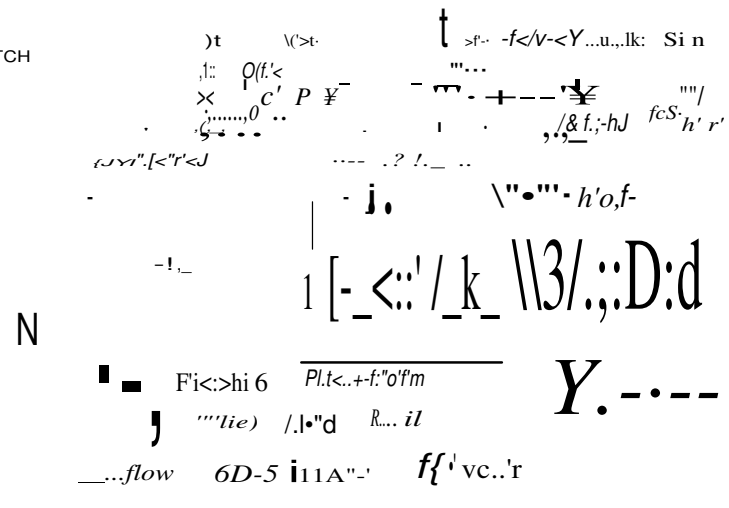
MOST RECENT RECOVERY
03/23/93 NEW

VERTICAL	feet	meters
!GLD 1955:	0.000	0.000
!GLD 1985:	0.000	0.000
NAVD 1988:	0.000	0.000
NGVD 1929:	0.000	0.000
pt. source:		
geoid. hgt:	0.000	0.000

PROPERXY OWNER
firr.J:
P.O.C. RIVER i'i'ALK
telephone:
access: car, boat

DESCRIPTION
STATION HOYT IS A BRASS DISK SET IN A SIX-INCH-OIA. CONCRETE MONUMENT FLUSH WITH THE GROUND. STATION IS 14.55 FT. SOOTH-WEST OF POST AT THE SOUTHWEST CORNER OF THE PARKING LOT. STATION IS ON THE EAST SIDE OF THE SAGINAW RIVER BETWEEN THOMPSON ST, AND HOYT ST. ANO ON THE WEST SIDE OF SOUTH WATER ST. TO REACH STATION FROM I-675, TAKE WASHINGTON ST. SOUTH TO HOYT ST., TURN RIGHT ON HOYT AND GO TO SOUTH WATER ST.• TURN RIGHT ON SOUTH WATER ST. AND PARKING LOT FOR RIVER WALK IS ON YOUR LEFT SIDE.

SKETCH



"'SAG-0613 SURVEY CONTROL DATA Desig: HOYT

Office of Record: Saginaw Area Office Printed on 11/04/93

Figure D-27. Descriptions of Stations Hoyt, Wickes, Eward, Rust, Holland, and Genesee {Sheet 1 of 6)

U.S. ARMY ENGINEER DISTRICT- OETROI'r

GENERAL INFORMATION

designation: WICKES
referenel!! no. SAG-0610

project: SAGINAW RIVER
ehannelJreach: UPPER
sheet no.
USGS Quad: SAGINAW
NOAA chart: 14867

community: SAGINAW
county: SAGINAW
state: MICHIGAN
Township/Range T.12N R.04E
section: 25

HORIZONTAL

datum: NAD83
lat: 43° 23'18.39093• N
len: 83° 57'49.94860• W

y, 0.00 m (N)
" 0.00 m (E)

y, 688,469.29 ft (OS) N
X, 13, 30,401.67 ft (US) E

state: MICHIGAN
projection: LAMBERT
zone: s
code: 113

HORIZONTAL ORIGIN

agency: UsACE
order:
date: 03/23/93
method: G?S
set by: D. HENRY

Point Source:

JONAS 1932
PARRISH

MOS'r RECEN'r RECOVERY
03/23/93 NEW

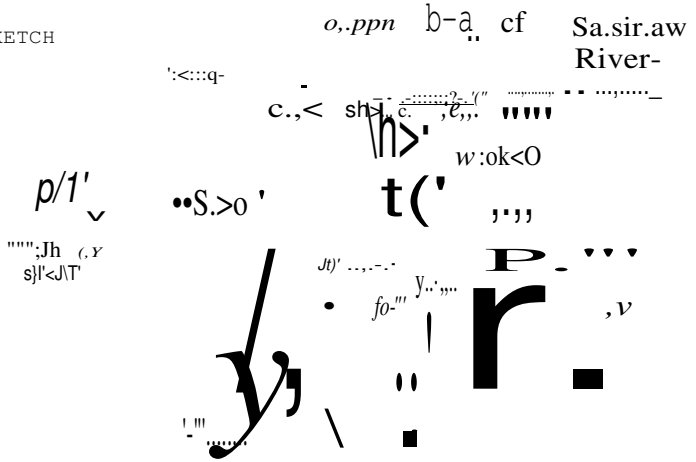
VERTICAL	feet	meters
IGLD 1955:	0.000	0.000
IGLO 1985:	0.000	0.000
NAVD 1988:	0.000	0.000
NGVD 1929:	0.000	0.000
pt. source:		
geoid. hgt:	0.000	0.000

PROPER'rY OWNER
firm:
P.o.c. WICKS PARK
telephone:
access: car, boat

DESCRIPTION

STATION WICKES IS AN ALUM. DISK IN A SIX-INCH-DIA. CONCRETE MONUMENT FLUSH WITH THE GROUND SURFACE. STATION IS AT THE VERY UPPER END OF THE SAGINAW RIVER ON THE EAST SIDE IN WICKS PARK. TO REACH STATION FROM THE INTERSECTION OF M-13 (WASHINGTON) AND I-675, GO SOUTH ON M-13 UNTIL YOU REACH WICKS PARK DRIVE, TURN RIGHT AND GO TO THE RIVER. STATION IS AT THE PARKING AREA WHERE WICKS PARX DRIVE TURNS TO THE NORTH.

SKETCH



Rof #. SAG-0610

SURVEY CONTROL DATA

Desir;: WICKES

Office of Record• Saginaw rea Office

Printed on 11f04j93

Figura D-27. (Sheet 2 of 6)

U.S, ARMY ENGINEER DISTRit:r – DE'J:ROIT

GENERAL INFORMATION	HORIZONTAL	BORIZON:L'AL ORIGIN	VERTICAL	feet	meters
designation: EWALD	datum: NAD83	agency: USAcE	IGLD 1955:	0.000	0.000
reference no. SAG-0611	lato 43G 24'57.4S612R N	order:	IGLn 1985:	0.000	0.000
	lon: SJG 57'44.52799R W	data: 03/23/93	NAVD 1988:	0.000	0.000
project: SAGINAW RIVER		method: GPS	NGVD 1929:	0.000	0.000
sheet no.	X. 0.00 m				
USGS Quad: SAGINAW		Point Sources			
channel/reach: UPPER	y, 0.00 m (N)	set by: D. HENRY	pt. source:		
NOAA chart: 14867	y, 698,500.99 ft (US) N		geoid. hgt:	0.000	0.000
	X. 13,230,753.75 ft (US) E	JONAS 1932			
community: SAGINAW		PARRISH	PROPERn ONNER		
county: SAGINAW	state: MICHIGAN		fir1ol.;		
state: MICHIGAN	projection: LAMBERT		P.O.C. ON BRIDGE		
Township/Range T.12N R.04E	zone: s	MOST R£CEin' RECOVERY	telephone;		
section: 26	code: 2113	03/23/93 NEW	access: , hike		

DESCRIPTION
STATION EWALD IS A BRASS DISK SET INTO A CONCRETE SIOEW X ON THE UPSTREAM SIDE OF THE COURT STREET BRIDGE OVER THE SAGINAW RIVER IN THE CITY OF SAGINAW. STATION IS 475 FT. (+-) WEST TO SOUTH HAMILTON STREET FROM STATION. STATION IS AT THE FIRST OBSERVATION PLATFORM FROM THE WEST SIDE OF THE BRIDGE. TO REACH COURT STREET BRIDGE FROM I-675, TAkE M-13 (WASHINGTON) SOUTH TO RUST DRIVE, TORN RIGHT AND IT TAKES YOU ACROSS THE COURT STREET BRIDGE AND STREET TURNS INTO·COURT STREET.

SI<ETCJI

e...j. £3t..nd ft,_.t;:.q,·.::. •• C.•«r"" +re:.:-

(.AJqlk o n· Srid-Jt: G.f,r.5'M E'"ALO

'No Ho,. •••·' - _ (-:)

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SAG-0611 SURVEY CONTROL DATA

Desig:

EW
AL
D

Office of Record: Saginaw rea Office

Printed on 11/04/93

Figure D-27. (Sheet 3 of 6)

U.S. ARMY ENGINEER DISTRICT - DETROIT

GENERAL INFORMATION

designation: RUST
reference no. SAG-0612

project: SAGINAW RIVER
channel/reach: UPPER
sheet no.
USGS Quad: SAGINAW
NOAA chart: 14867

community: SAGINAW
county: SAGINAW
state: MICHIGAN
Township/Range T.12N R.04E
section: 26

HORIZONTAL

datum: NAD83
lat: 43° 24'30.42050ft N
lon: 83• 58' 1.20657 W

y, 0.00 m (N)
Xo 0.00 m (E)

y, 6 5,757.90 ft (US) N
Xo 13,229,535.80 ft {US) E

state: MICHIGAN
projection: LAMBERT
zone: S
code: 2113

HORIZONTAL ORIGIN

agency: USACE
order:
date: 03/23/93
method: GPS
set by: D. HENRY

Point Sources

JONAS 1932
PARRISH

MOST RECENT RECOVERY
03/23/93 NEW

lll!liXICAL

	feet	meters
IGLD 1955:	0.000	0.000
lGLD 1985:	0.000	0.000
NAVD 1988:	0.000	0.000
NGVD 1929:	0.000	0.000

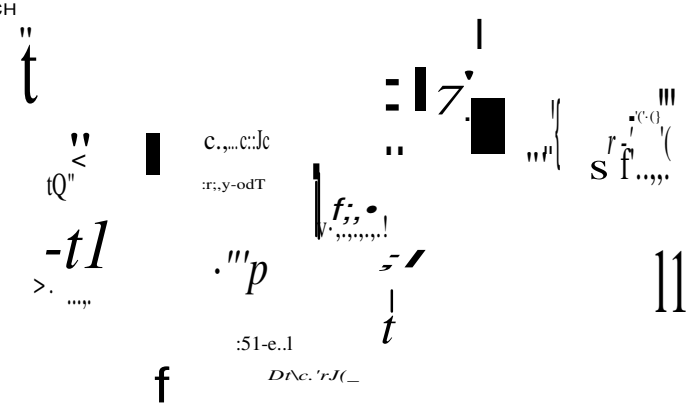
pt. source:

geoid. hgt: 0.000 0.000

PROP&Rn OWNER
firt:P.: SAGINAW
P.o.c. BOAT LAUNCH
telephone:
access: car, boat

DESCJUP'I'ION
STATION IS A BRASS DISK SET IN CONCRETE ON THE NORTH SIDE OF A BOAT LAUNCH RAMP (RUST AVE. BOAT LAUNCH) OWNED BY THE CITY OF SAGINAW. TO REACH STATION FROM THE RUST STREET BRIDGE (M-46) OVER THE SAGINAW RIVER, TAKE SOUTH HAMILTON SOUTH TO LEE STREET, GO EAST TO RIVER AND RUST AVE. BOAT LAUNCH IS AT THE END OF THE STREET, NOTE: THERE ARE TWO SIGNS DIRECTING YOU TO THE BOAT LAUNCH, LEE ST. & SOUTH HAMILTON, AND ONE NEAR THE BRIDGE ON THE WEST SIDE OF THE RIVER.

SKETCH



Ref / SAG-0612 SURVEY CONTROL DATA Desig: RUST

Office of Record: Saginaw rea Office Printed on 11/04/93

Figure D-27. (ShHt 4 of 6}

U.S. ARMY ENGINEER DISXRICT- DE'XROIT

GENERAL INFORMATION

designation: HOLLAND
reference no. SAG-0608

project: SAGINAW RIVER
channel/reach: UPPER
sheet no.
USGS Quad: SAGINAW
NOAA chart: 14867

community: SAGINAW
county: SAGINAW
state: MICHIGAN
Township/Range T.12N R.04E
section: 25

HORIZONTAL

datum: NAD83
lat: 43° 25'14.91718 N
lon: 83° 57' 4.12068" W

Y: 0.00 m (N)
X: 0.00 m (E)

Y: 700,283.35 ft (US) N
X: 13,233,727.24 ft (US) E

state: MICHIGAN
projection: LAMBERT
zone: S
code: 2113

HORIZONTAL ORIGIN

agency: tl'SACE
order:
date: 03/23/93
method.: GPS
set by: O.HENRY

Point Souree:

JONAS 1932
PARRISH

MOST RECENT RECOVERY
03/23/93 NEW

	feet	meters
IGLO 1955:	0.000	0.000
IGLD 1985:	0.000	0.000
NAVD 1988:	0.000	0.000
NGVD 1929:	0.000	0.000

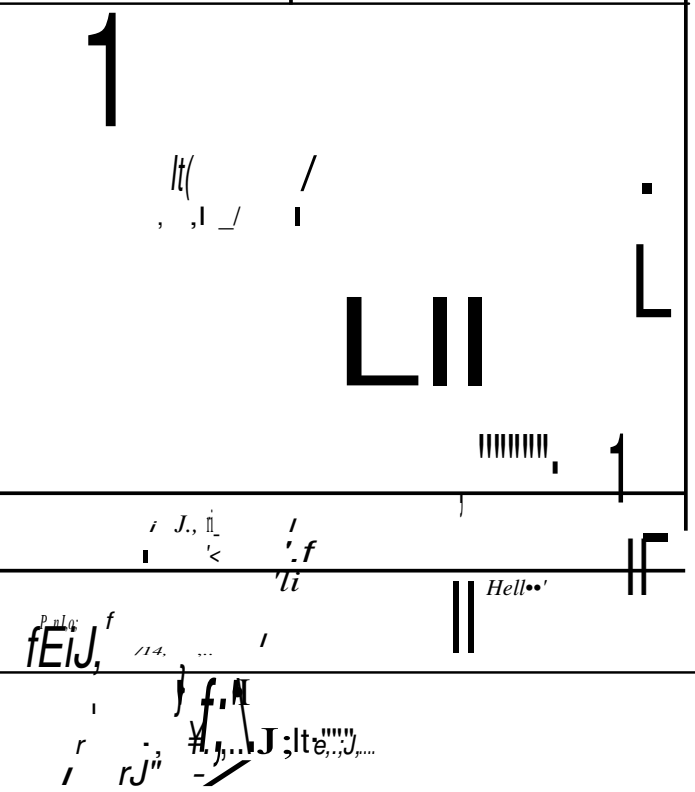
pt. source:

geoid.. hgt: 0.000 0.000

PROPERTY OWNER
firm:
P.o.c.
telephone:
access: , hike

DESCRIPTION
STATION HOLLAND IS A STANDARD BRASS DISK SET INTO A CONCRETE WALK ON THE UPSTREAM SIDE OF THE HOLLAND AVE. BRIDGE OVER THE SAGINAW RIVER. STATION IS ON THE EAST-BOUND SIDE OF SAID FOUR-LANE BRIDGE. REMINGTON ST. GOES TO THE WEST ACROSS THE BRIDGE AND HOLLAND ST. GOES TO THE EAST ACROSS THE BRIDGE.

SKETCH



Ref # SAG-0608 SURVEY CONTROL DATA Desig: HOLLAND

Office of Record:

Figure D-27. (Sheet 5 of 6)

tJ,S, ARMY ENGINEER DISTRICT- DETROI'r

GENERAL INFORMA'XIOH

designation: GENESEE
reference no. SAG-0609

project: SAGINAW RIVER
channel/reach: UPPER
sheet no.
USGS Quad: SAGINAW
NOAA chart: 14867

community: SAGINAW
county: SAGINAW
state: MICHIGAN
Township/Range T.llN R.04E
section: 2

BORIZON'XAL

datum: NAOS3
lat: 43° 26. 1.64599" N
lon: 93• 56'34.06378 W

y, 0.00 m (N)
X< 0.00 m (E)

y, 705,025.46 ft (US) N
X< 13,235,921.57 ft (US) E

state: MICHIGAN
projection: LAMBERT
zone: S
code: 2113

BORIZOORIGIN

agency: USACE
order:
date: 03/23/93
method: GPS
set by: D. HENRY

Point Source:

.JONAS 1932
PARRISH

MOS'r RECENT RECOVERY
03/23/93 NEW

""""ICAI.	feet	meters
!GLD 1955:	0.000	0.000
IGLD 1985:	0.000	0.000
NAVD 1988:	0.00a	0.000
NGVD 1929:	0.000	0.000
pt. source:		
geoid. hgt:	0.000	0.0a0

PROPERXY OWNER
fire :
P.O.C.
telephone:
access: car, boat

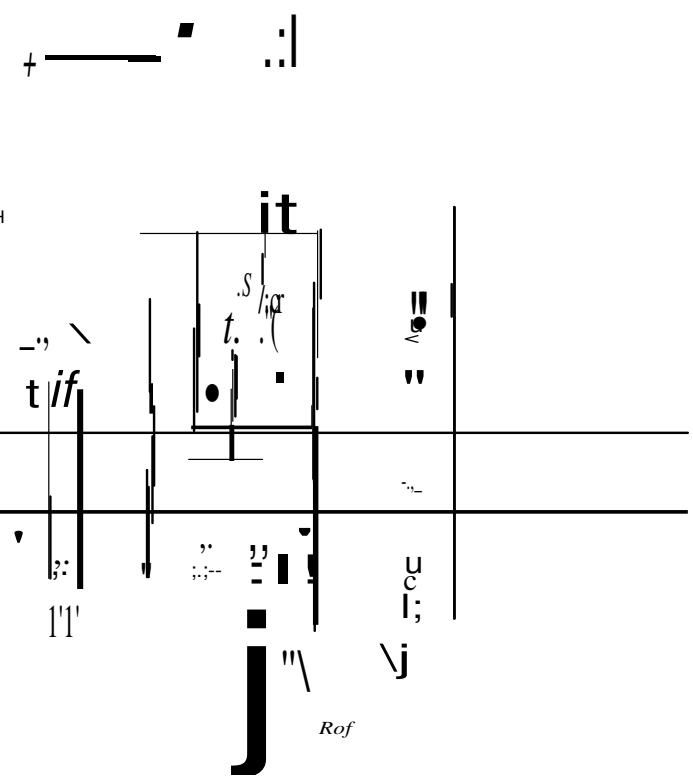
NORT

H NIAGARA. STATION IS 100 FT. WEST OF THE GENESEE STREET

DESCRIPTION
STATION GENESEE IS A STANDARD BRASS DISK SET IN CONCRETE AT THE SOUTHEAST CORNER OF THE INTERSECTION OF WEST GENESEE & NIAGARA. STATION IS ON CONCRETE THAT IS 2 FT. ABOVE THE SIDEWALK. STATION IS 2.1 FT. NORTH OF CONCRETE EDGE, 2.09 FT. WEST OF CONCRETE EDGE, 2.2 8 FT. SOUTH OF HANDRAIL, AND 37.41 FT. EAST-SOUTHEAST OF LIGHTPOST AT STREET CORNER.

TO REACH STATION FROM THE INTERSECTION OF M-13 (WASHINGTON) AND I-675, GO SOUTH ON M-13 TO GENESEE AND TURN RIGHT, GO ACROSS THE RIVER TIL tOU COME TO NIAGARA ST•• STATION IS AT TH S INTERSECTION.

SKETCH



1 SAG-0609 • <

Desig:

SURVEY CONTROL DATA

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Figure D-27. (Sheet 6 of 6)

Appendix E
Horn Lake, Mississippi, Stop-and-Go GPS Survey

E-1. General

In geographical areas with minimal obstruction of the sky, such as farming areas, along levees and open roads, stop-and-go GPS surveying can be a very effective and efficient method of establishing 2D and/or 3D project control. Stop-and-go surveying can be used to establish horizontal control for topographic and hydrographic surveys as well as 3D ground control for photogrammetric surveys.

E-2. Project Description

This example survey was conducted by the Memphis District in the vicinity of Horn Lake, Mississippi, approximately 15 miles south of downtown Memphis, Tennessee. A diagram of the project area is shown in Figure E-1. The project consisted of establishing 3D positions on a total of 23 photo control points.

E-3. Planning Phase

An initial search was performed to locate existing NGRS and USACE horizontal and vertical control within a 10-km radius of the center of the project area. It is important to note that the marks chosen to be occupied by

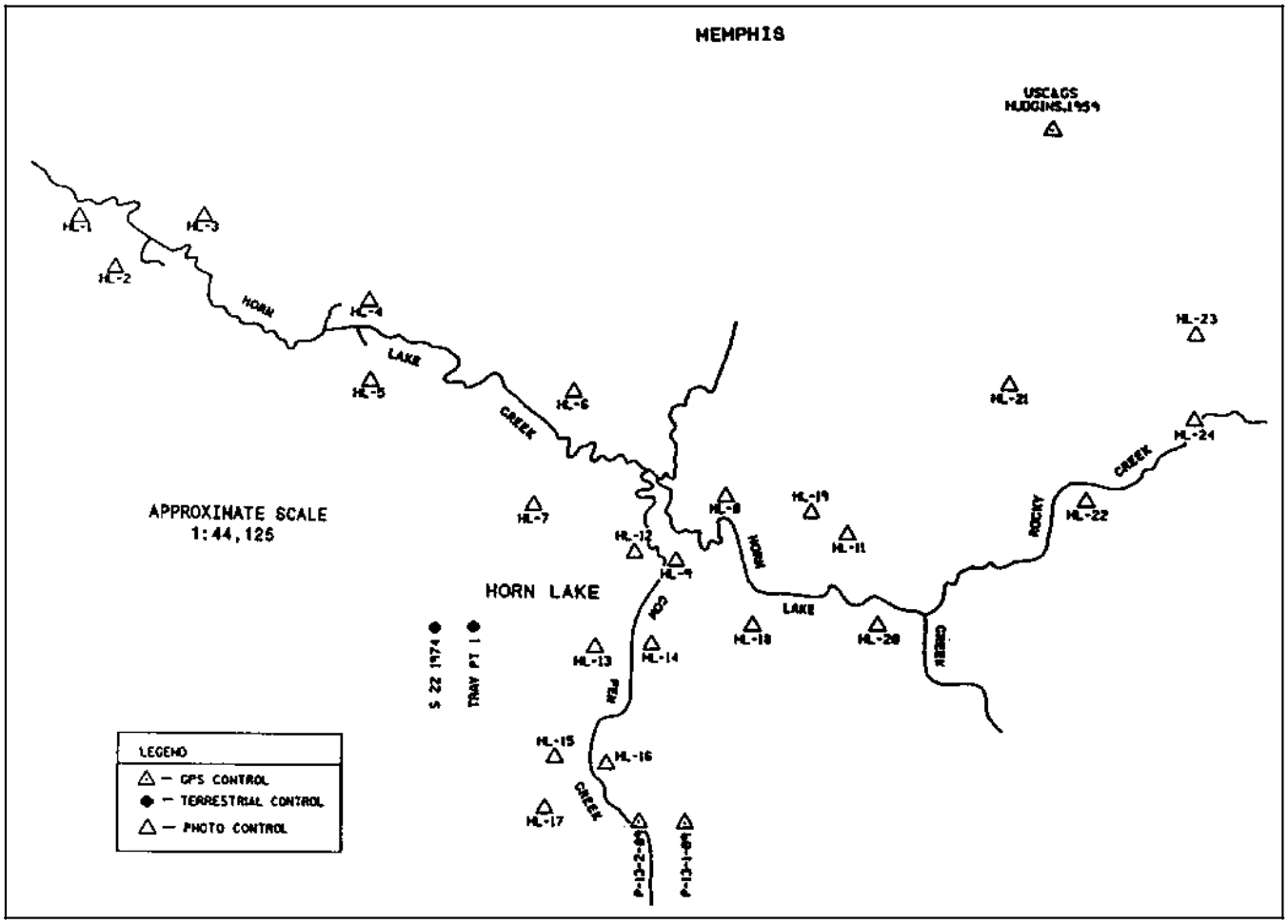

Figure E-1. Horn Lake Project diagram

the reference receiver(s) should be totally unobstructed. A momentary loss of lock (cycle slip) on one or more satellites by the reference receiver(s) could make it impossible to process some or all of the data obtained by the roving receiver(s).

a. Three NGRS horizontal and/or 3D control marks were recovered near the project area; however, due to obstructions at two of the sites, only the 3D mark USC&GS HUDGINS 1959 was suitable as a reference station. Preplanning analysis indicated a minimum of two reference stations were needed to economically obtain the required number of independent baseline measurements to each photo control point. Therefore, to meet this requirement, a pair of intervisible Type A monuments, as defined in EM 1110-1-1002, were installed near the southern limit of the project area with one of the sites (P-13-2-89) being totally free of obstructions greater than 15 degrees above the horizon. Initially, a static GPS survey was performed to establish horizontal positions on the two Type A monuments. A diagram of the initial horizontal control survey is shown in Figure E-2. Refer to the example surveys in Appendix D for details on performing a static horizontal control survey. Figure E-3 shows a partial output of the GEOLAB minimally constrained adjustment of the static baselines observed. A review of the GEOLAB adjustment output reveals the following:

(1) As shown the 2D and 1D station major semi-axis and minor semi-axis are at or less than the few-centimeter level.

(2) The 2D and 1D relative error ellipses between survey points are at or less than the few-centimeter level.

(3) The estimated variance factor in the statistics summary is low (close to a value of 1). Further analysis of the GEOLAB output in Figure E-3 indicates that the adjustment is very acceptable and that the adjusted positions of the two Type A monuments will be more than adequate for use as horizonal control for the stop-and-go survey. Reference stations USC&GS HUDGINS 1959 and P-13-2-89 were chosen because of their unobstructed view of the sky and also their location relative to the project area.

b. One NGRS vertical control mark and three USACE temporary benchmarks (TBM's) were recovered within the project area. The NGRS vertical control mark was 100 percent obstruction free and was thus included within the stop-and-go survey. However, due to obstructions at all three of the TBM's, it was decided not to include these marks within the GPS survey. Instead, differential levels were run from the TBM's to the nearest

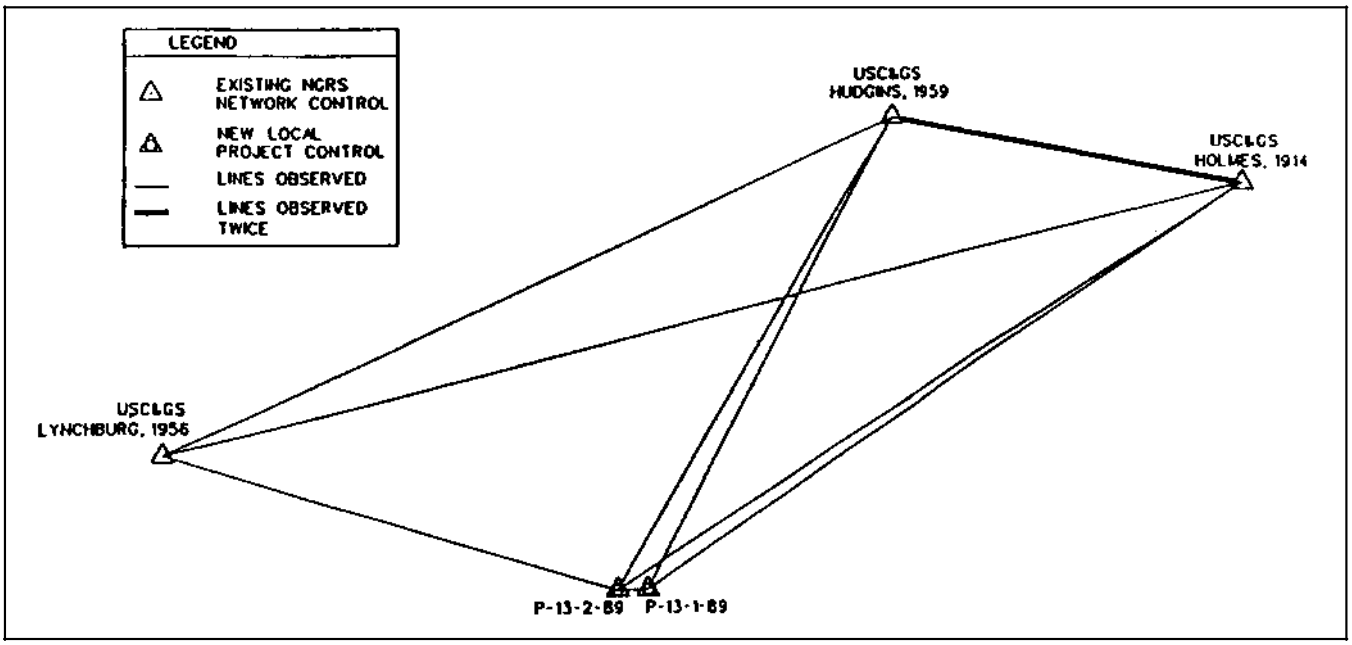

Figure E-2. Initial horizontal control survey

U.S. ARMY CORPS OF ENGIN.EERS - MEMPHIS DISTRICT
GPS #7 - HORN LAKE CREEK AERIAL PHOTO CONTROL

A= 6378137.000 8: 6356752.314 XO= 0.000 YO: 0.000 ZO= 0.000

ELLIPSE:

2-D AND 1-D STATION CONFIDENCE REGIONS (95.000 %):

IDENT.	MAJOR SEMI-AXIS	MINOR SEMI-AXIS	AZ(MAJ)	VERTICCIL
4098	0.0170	0.0116	119.60	0.0231
3095	0.0154	0.0092	118.54	o.ora9
1096	0.0338	0.0136	116.46	0.0333
4097	0.0174	0.0123	118.20	0.0247

GeoLab - V1.91S, (C) 1985/86/87/88/89 BitWise Ideas Inc. (103208976] Page 14

U.S. ARMY CORPS OF ENGINEERS - MEMPHIS DISTRICT
GPS U7 - HORN LAKE CREEK AERIAL PHOTO CONTROL

A= 6378137.000 B= 6356752.314 XO= 0.000 YO= 0.000 ZO= 0.000

ELLIPSE:

2-D AND 1-D RELATIVE STATION CONFIDENCE REGIONS (95.000 'o):

FRO	T	MAJ.SEMI	MIN.SEMI	AZ(MAJ}	VERTICAL	SPATIAL DIST.	PRECISION
3094	1096	0.0338	0.0136	116.46	0.0333	13216.8982	2.559 PPM
3094	4097	0.0174	0.0123	118.20	0.0247	8561.2490	2.029 PPM
3094	4098	0.0170	0.0116	119.60	0.0231	8872.2474	1.912 PPM
3094	3095	0.0154	0.0092.	118.54	0.0189	4254.4135	3.612 PPM
4098	1096	0.0309	0.0101	116.01	0.0274	5576.4108	5.539 PPM
4098	4097	0.0055	0.0045	84.37	0.0104	366.6958	14.958 PPM
4098	3095	0.0100	0.0085	135.51	0.0171	6444.1941	1.545 PPM
3095	1096	0.0316	0.0117	116.41	0.0300	9503.6545	3.321 PPM
3095	4097	0.0107	0.0095	125.96	0.0194	6257.967G	1.717 PPM

ElliPSE successfully completed.
12:20:35 - Monday, July lO, 1989

GooLab- V1.91S, (C)-1985/86/87/BB/89 BitWise Ideas Inc. [103208976) Page 15

Figure E-3. **GEOLAB** adjustment output (Continued)

```
                U.S. ARMY CORPS OF ENGINEERS - MEMPHIS DISTRICT
                 GPS ft7 - HORN LAKE CREEK AERIAL PHOTO CONTROL
A:  6378137.000 B=  6356752.314 XO:       0.000 YO:       0.000 ZO=       0.000

RESID:


 ---------------------------------------------------------------------------

                  S T A T I S T I C S    S U M M A R Y

 :-------------------------------------------------------------------------:

      Residual Critical Value Type                      Tau  Max
      Residual Cri'tical  Value                          3.1459
      Convergence Criterion                            0.001000
      Final Iteration Counter Value                           2
      Confidence  Level  Us d                           95.0000
      Number of Flagged Residuals                             0
      Estimated Variance Factor                          1.3100
      Number of Degrees of Freedom                           27
 ---------------------------------------------------------------------------:

                  Chi-Square  Test on the Variance Factor:

                  8.1BB7e-001   <  1.0000  <  2.427le+OOO   ?

                             THE TEST PASSES.

 ---------------------------------------------------------------------------

RESID successfully  completed.

 ---------------------------------------------------------------------------
Geolab- V1.91S, (C) 1985/86/87/88/89 BitWise Ideas Inc. C10 208976]  Page   12
```

Figure E-3. (Concluded)

photo control point. The four points circled in Figure E-4 had an established orthometric height. These heights were used to control the vertical adjustment of the GPS observations. This will be discussed further under the section on adjustments.

c. The aerial photography was completed and photo control points were subsequently selected from observable physical features. The GPS survey party had to locate the points from the photos and monument each on the ground. Obstruction limits at each point were noted during monumentation. After all 23 points were established, further analysis indicated that three of the points, HL-2, HL-5, and HL-7 could not be occupied because of extensive obstructions or no vehicular access. Terrestrial traversing was performed to HL-2 and HL-5 using HL-1 and HL-3 as control and to HL-7 using S 22 1974 and Trav Pt 1 as control. The traverse computations were performed subsequent to the final constrained least squares adjustment of the baselines observed during the stop-and-go survey.

E-4. GPS Field Observations

Four SPS (or C/A) code GPS receivers, tracking the carrier phase, were used for the survey. When performing a stop-and-go survey, it is required to maintain lock on at least four satellites. It is recommended that observation-times be scheduled when at least five satellites are visible, so that if lock is lost on one satellite, the survey can continue. All GPS field observations, both static and stop-and-go, were recorded on 28 and 29 June 1989 (days 179 and 180). The reference receiver at HUDGINS was set up to continually record data each day and left unmanned due to its secure location. The reference receiver at P-13-2-89 had one operator monitoring it and there were two personnel per roving receiver: one to drive the vehicle and operate the receiver and the other to position the antenna over the mark. Communication between operators was by two-way radio.

a. The antennas at the reference stations were mounted on a tripod using an optical plummet tribrach with an 8-minute bulls-eye level. The antenna for each roving receiver was mounted on a fixed-height range pole with a 10-minute bulls-eye level supported by a bipod. The antenna, range pole, and bipod were secured to the vehicle by a removable mobile rack shown in Figure E-5. Figure E-6 shows the setup of the antenna, range pole and bipod.

b. A satellite visibility chart was plotted for day 179 and is shown in Figure E-7. Static measurements were recorded for the first two sessions and the data used to establish horizontal positions on the two Type A monuments. Refer to Figure E-2 for a graphical representation of the baselines observed during sessions 1 and 2. The remainder of the five-satellite window for day 179 was used to record stop-and-go data. The observation schedule developed for day 179 is shown in Figure E-8. The upper portion of the schedule includes the ID number, the name and the position (exact if known, scaled if not) for each station included within the survey. Note that the photo control points were assigned a 5000 series ID. Chapter 8 of this manual discusses recommended conventions for assigning station ID numbers. It recommends a 9000 series number for temporary 3D control. The bottom portion of the schedule includes the date and day of the year in which observations are to be recorded, where each receiver will be for each session, when to start and stop each session (local time), and which satellites to observe.

c. Stop-and-go observations were recorded during the third session on day 179 and during the entire five-satellite window on day 180. During the third session of day 179, both roving receivers were initialized to both of the reference receivers by recording static data for approximately one hour. This method is also referred to as occupying a known baseline, since after post-processing the static data and the data are accepted according to the criteria in this manual, the baseline becomes known. It is important to note that this method requires a sufficient amount of data be collected to ensure that the integer cycle ambiguities are resolved in the baseline solution. Once the integer cycle ambiguity is resolved for a satellite, it remains constant as long as lock is maintained. At the moment lock is lost on a satellite, its integer cycle ambiguity becomes an unknown value and thus again requires resolution. Initially resolving the ambiguities and maintaining lock on at least four satellites is the key to stop-and-go surveying. If lock is not maintained on at least four satellites during a survey, the ambiguities for at least four satellites will need to be resolved again. This can be done during a survey by returning to the last occupied point, which becomes a known baseline after postprocessing. If this method is not practical or desirable, the survey should be stopped at the point of losing lock on at least four satellites and a new survey started. The new survey may be initialized either by recording approximately an hour of static data at a point which has not already been occupied, or by recording a few minutes of data at a point which has been previously occupied. When using the second method, the integer cycle ambiguities for the baselines from both reference receivers to the

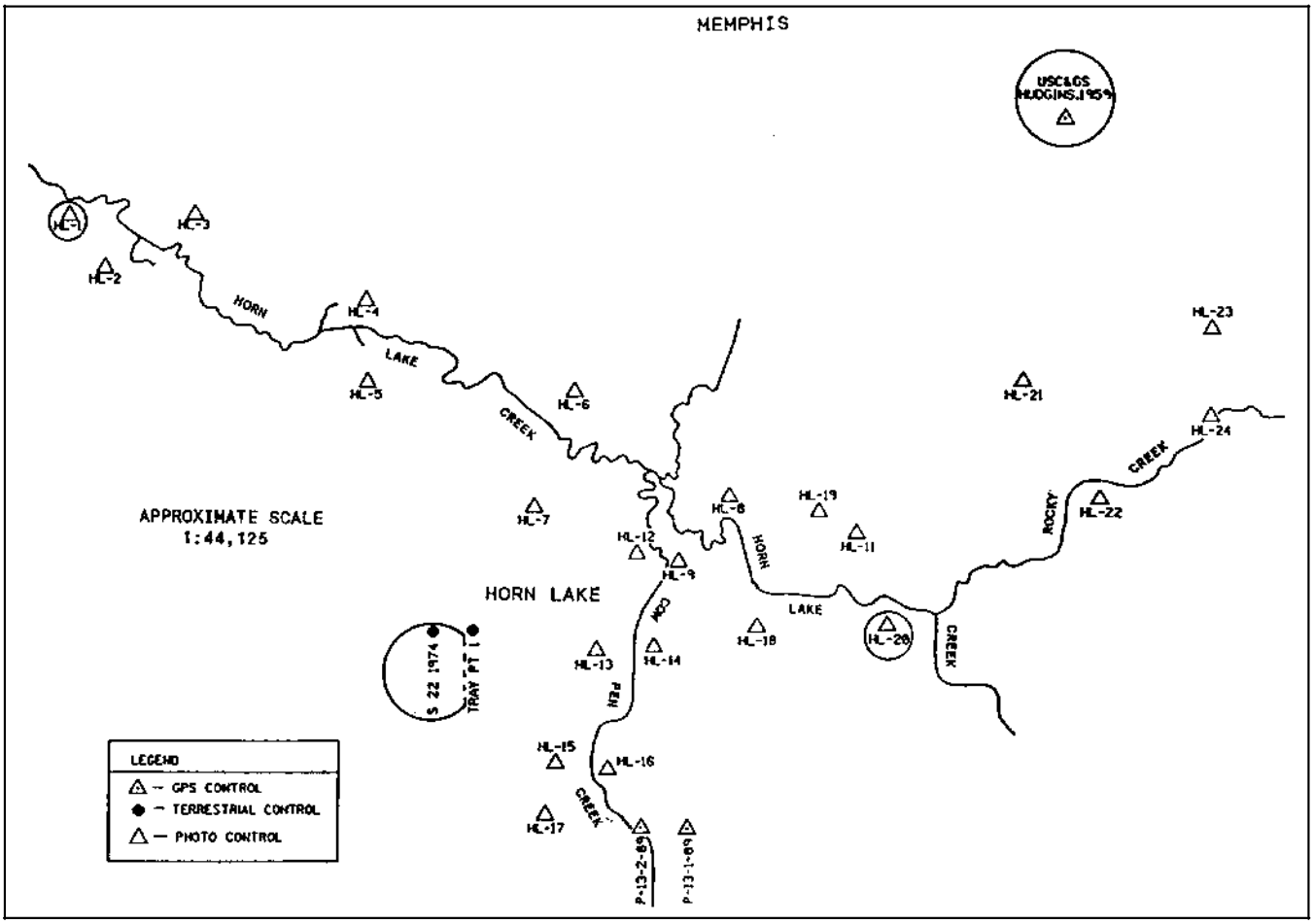

Figure E-4. Vertical project control

Figure E-5. Removable vehicle rack

Figure E-6. Antenna-range pole-bipod setup

point must have been resolved. Figures E-9 and E-10 show the baselines for which the integer cycle ambiguities were resolved by collecting static data for approximately one hour by roving receivers 1 and 2, respectively.

d. After initializing the stop-and-go survey, the rovers began to travel from point to point, collecting approximately 1.25 minutes of data at each point. This manual recommends data collection of at least 1.5 min at each point. Experience has shown this value should be used as a minimum and, depending on the length of the baselines observed and the accuracy required for the survey, observation times of up to 10 min may be necessary to ensure the desired results are obtained. A data logging sheet such as that shown in Chapter 8 was completed for each reference receiver. For each roving receiver, a stop-and-go field form as shown in Figure E-11 was completed. Figure E-12 shows a field form completed for roving receiver 1 on day 179. The paths taken by each of the rovers on days 179 and 180 can be graphically seen in Figures E-9 and/or E-10. The data collected for the initialization of the survey as well as the data collected at each subsequent point by rover 1 were recorded in one data file. It is recommended that static observations be recorded in a separate file from the stop-and-go data to conform to batch processing methods used in some manufacturer's software. This will be discussed further under the section on post-processing. Referring to Figure E-12, the following is a recommended scheme for recording the data such that a batch processing mode may be utilized.

(1) Start static survey at 22:04 occupying station 4097. Stop static survey at 23:00.

(2) After resetting the antenna over station 4097, start a stop-and-go survey and collect data at 4097 for approximately ten minutes.

(3) Travel to each subsequent point and collect data for at least 1.5 minutes.

(4) Upon losing lock travelling to station 5208, stop the stop-and-go survey.

(5) Continue to 5208, position antenna over mark and start a static survey at approximately 00:42.

(6) Stop the static survey at 01:45, which was very near the end of the four satellite window for day 179.

If additional time had been available in which five satellites were above 15 degrees, another stop-and-go survey could have been started and continued from 5208 to additional points subsequent to the static data collection.

E-5. Post-processing Stop-and-Go Data

At the end of each day's observations, all data were downloaded from the receivers to a portable 386 computer. All processing times quoted in this example are using a 386 computer with a math coprocessor with a 20-MHz clock processing speed. Using a computer with slower clock speeds will significantly increase processing time of all types of GPS data, not only stop-and-go. A review of all field data logging sheets for completeness and correctness was performed after downloading the data. Trimble's Trimvec-Plus survey software was used for all post-processing in this case.

a. First, all data collected in the static survey mode were post-processed and the quality of the solutions reviewed. Processed baselines from sessions 1 and 2 of day 179 were used to create a network in GEOLAB and adjusted separately from the photo control. The results of this adjustment have been discussed in paragraph E-3. Since the stop-and-go survey was initialized with known baselines, the dX, dY, and dZ values for the known baselines were required prior to processing the stop-and-go data. These values were obtained from the solution output of the static observations. Figures E-13 and E-14 show the solution summaries for the baselines from each of the reference receivers to roving receiver 1. Notice that the integers were found for each baseline and that the

Table of Azimuth, [illegible]
Date : 28 Jun 1989
Time : 15:00 -> 21:00
Cut-off Elevation : 12°

Time	Satellite 3		Satellite [illegible]		Satellite [illegible]		Satellite [illegible]		[illegible]		[illegible]		[illegible]		[illegible]		[illegible]		[illegible]		Satellite [illegible]	
	AZ	EL	AZ	EL	AZ	EL	AZ	EL													AZ	
15:00	--	--	331°	43°	[illegible]	67°	--	--	221°	27°	--	--	--	--								
15:10	--	--	331°	48°	[illegible]	71°	--	--	225°	31°	--	--	--	--								
15:20	--	--	331°	53°	259°	74°	--	--	229°	35°	--	--	--	--								
15:30	--	--	331°	58°	278°	76°	--	--	233°	39°	--	--	--	--							START	
15:40	--	--	329°	63°	302°	76°	327°	14°	239°	42°	--	--	--	--								
15:50	--	--	325°	68°	322°	74°	327°	19°	244°	46°	--	--	--	--								
16:00	--	--	317°	73°	337°	71°	327°	23°	251°	49°	--	--	--	--								
16:10	--	--	303°	77°	348°	67°	327°	28°	258°	52°	--	--	--	--								
16:20	--	--	277°	79°	357°	64°	326°	32°	265°	54°	--	--	--	--								
16:30	--	--	246°	79°	4°	60°	324°	37°	274°	56°	--	--	243°	13°							START	
16:40	--	--	224°	75°	10°	56°	321°	41°	283°	58°	--	--	247°	16°								
16:50	--	--	212°	71°	15°	52°	318°	45°	293°	59°	--	--	251°	19°								
17:00	--	--	205°	66°	20°	49°	313°	49°	303°	59°	--	--	256°	22°								
17:10	--	--	201°	60°	25°	45°	306°	53°	313°	59°	330°	13°	260°	24°								
17:20	--	--	199°	55°	29°	42°	299°	56°	322°	59°	328°	17°	265°	27°	--							
17:30	--	--	197°	49°	33°	38°	289°	57°	332°	59°	326°	21°	270°	29°	143°							
17:40	--	--	195°	44°	37°	35°	279°	58°	341°	58°	324°	25°	275°	32°	140°							
17:50	--	--	194°	38°	42°	32°	269°	58°	350°	56°	320°	28°	281°	34°	137°							
18:00	--	--	193°	33°	46°	29°	259°	56°	358°	55°	317°	31°	286°	36°	134°							
18:10	--	--	192°	28°	50°	26°	251°	54°	6°	53°	312°	34°	292°	38°	130°							
18:20	--	--	192°	23°	54°	23°	243°	50°	13°	52°	307°	36°	298°	40°	127°							
18:30	--	--	191°	18°	58°	21°	237°	47°	20°	50°	302°	38°	304°	42°	122°							
18:40	--	--	190°	14°	62°	18°	232°	42°	27°	48°	296°	39°	310°	44°	118°							
18:50	--	--	--	--	66°	16°	228°	38°	33°	46°	289°	39°	317°	46°	113°							
19:00	284°	14°	--	--	70°	13°	225°	34°	39°	44°	283°	39°	323°	47°	107°							
19:10	288°	16°	--	--	--	--	221°	29°	46°	42°	277°	38°	330°	49°	101°							
19:20	293°	18°	--	--	--	--	219°	25°	51°	40°	271°	36°	337°	50°	94°							
19:30	297°	21°	--	--	--	--	216°	21°	57°	38°	265°	34°	345°	52°	87°							
19:40	301°	23°	--	--	--	--	214°	16°	63°	36°	260°	31°	353°	53°	80°							
19:50	305°	26°	--	--	--	--	212°	12°	68°	34°	255°	28°	1°	54°	74°							
20:00	310°	28°	--	--	--	--	--	--	74°	32°	251°	25°	9°	55°	67°							
20:10	314°	31°	--	--	--	--	--	--	79°	29°	247°	22°	18°	56°	62°							
20:20	319°	34°	--	--	--	--	--	--	84°	27°	243°	18°	27°	56°	57°							
20:30	323°	37°	--	--	--	--	--	--	89°	24°	239°	15°	36°	57°	53°							
20:40	328°	40°	--	--	--	--	--	--	94°	22°	--	--	45°	56°	49°							
20:50	332°	43°	--	--	--	--	--	--	98°	19°	--	--	54°	56°	47°							
21:00	337°	47°	--	--	--	--	--	--	103°	16°	--	--	63°	55°	44°							

[illegible] Latitude :
Longitude :
Zone :

Figure E-7. Satellite visibility chart

GPS PROJECT No. 7-K
HORN LAKE CREEK PHOTO CONTROL Stop and Go SURVEY
HORN LAKE, MISSISSIPPI

STATION NUMBER	STATION NAME	LATITUDE	LONGITUDE	HEIGHT
3094	HOLMES 1914	34-59-27.00296	89-57-22-44228	123.897
3095	HUDGINS 1959	34-59-52.56136	90-00-07-30092	106.019
1096	LYNCHBERG 1956	34-57-45.46270	90-05-48.68871	94.000
4097	P-13-1-89	34-56-54-00000	90-02-03.00000	91.000
4098	P-13-2-89	34-56-54.00000	90-02-18.00000	84.000
2099	S 22 1974	34-57-45.00000	90-03-18.00000	80.902
5201	HL-1	34-59-30	90-05-05	74.000
5202	HL-2	34-59-18	90-05-00	75.000
5203	HL-3	34-59-30	90-04-30	72.000
5204	HL-4	34-59-13	90-03-38	75.000
5205	HL-5	34-58-40	90-03-38	75.000
5206	HL-6	34-58-45	90-02-35	79.000
5207	HL-7	34-58-15	90-02-45	79.000
5208	HL-8	34-58-20	90-01-47	80.000
5209	HL-9	34-58-02	90-02-02	78,000
5211	HL-11	34-58-10	90-01-08	81.000
5212	HL-12	34-58-05	90-02-17	80.000
5213	HL-13	34-57-40	90-02-28	80.000
5214	HL-14	34-57-38	90-02-20	80.000
5215	HL-15	34-57-12	90-02-40	84.000
5216	HL-16	34-57-10	90-02-22	83.000
5217	HL-17	34-56-58	90-02-43	84.000
5218	HL-18	34-57-45	90-01-40	80.000
5219	HL-19	34-58-15	90-01-20	85.000
5220	HL-20	34-57-45	90-01-00	82.000
5221	HL-21	34-58-47	90-00-19	96.000
5222	HL-22	34-58-20	89-59-55	91.000
5223	HL-23	34-59-02	89-59-13	100.000
5224	HL-24	34-58-39	89-59-13	90.000

WEDNESDAY JUNE 28, 1989 (179)

SESSION 1	SESSION 2	SESSION 3
HUDGINS (3095)	HUDGINS (3095)	HUDGINS (3095)
P-13-2-89(4098)	P-13-2-89(4098)	P-13-2-89(4098)
HOLMES (3094)	HOLMES (3094)	ROVER 2 BEGIN
LYNCHBURG(1096)	P-13-1-89(4097)	ROVER 1 BEGIN
START: 15:40	START: 17:05	START: 18:05
STOP: 16:50	STOP: 18:00	STOP: 20:45
sv•s:03,0G,os,o9, 11,12,13,14	SV's:03,06,08,09 11,12,13,14	SV's:OJ,06,0B,09, 11,12,13,14

Figure E-8. Observation schedule

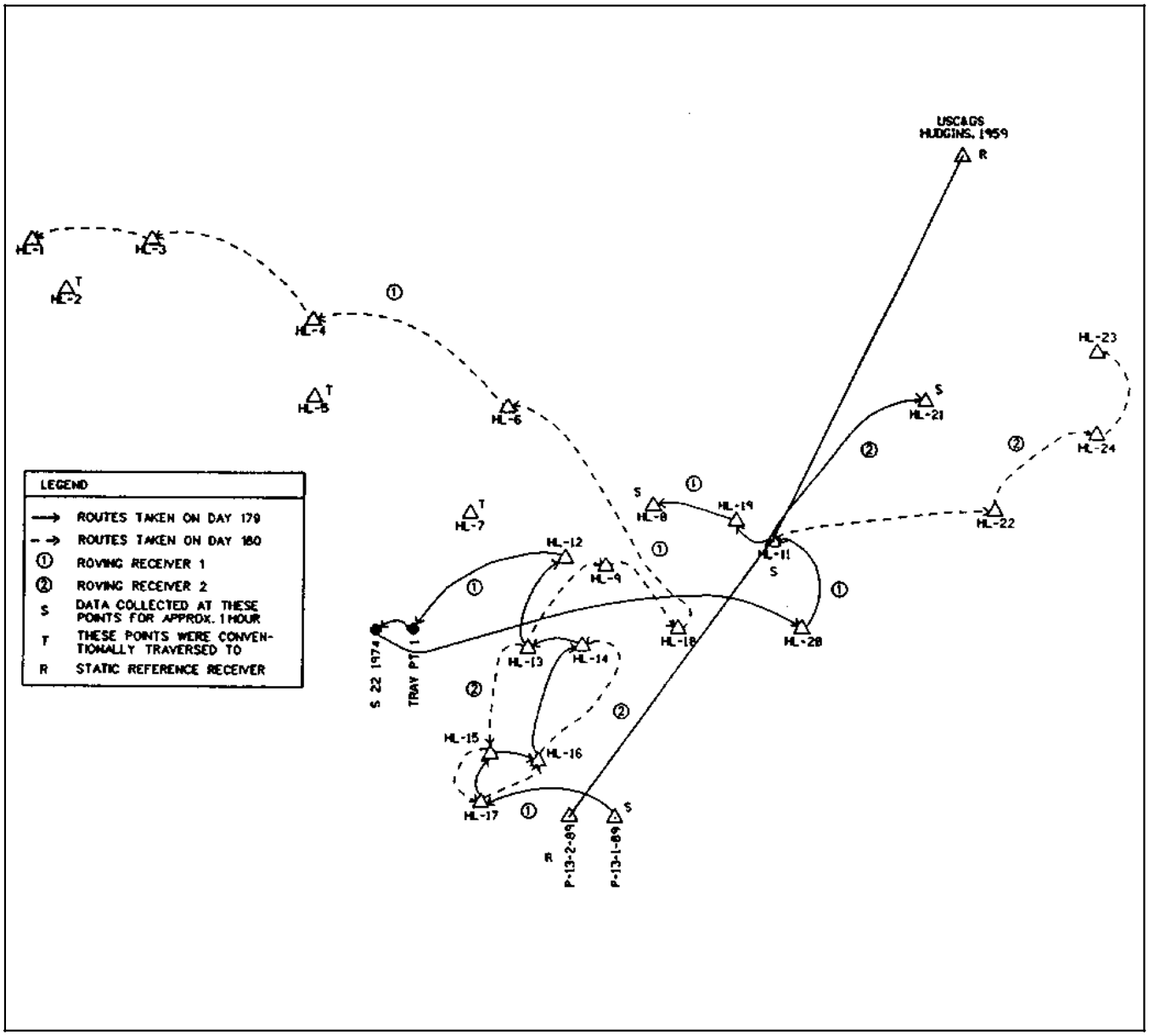

Figure E-9. Observation routes and initialization of rover 1

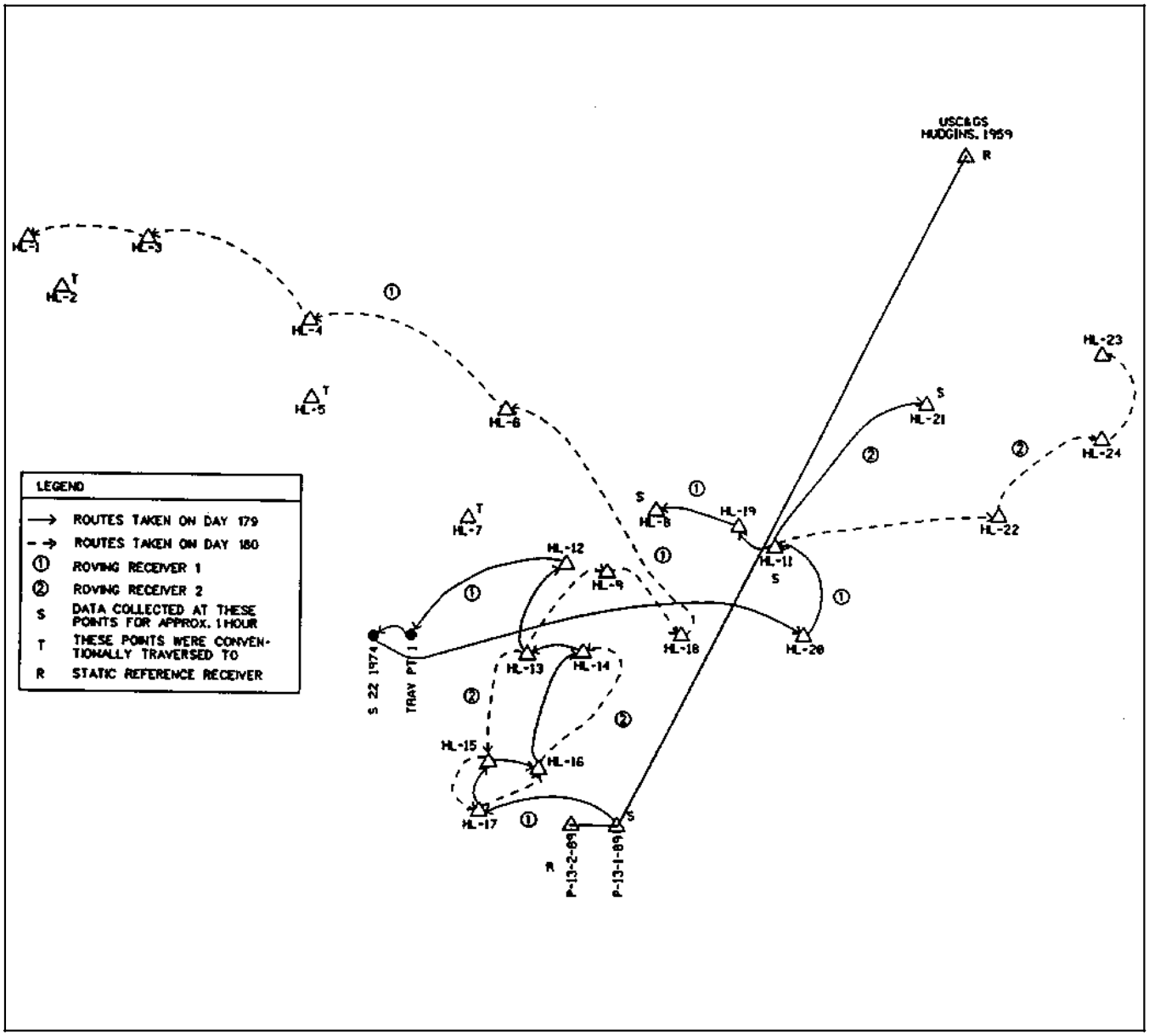

Figure E-10. Observation routes and initialization of rover 2

U.S. ARMY CORPS OF ENGINEERS
STOP & GO KINEMATIC GPS FIELD FORM

****

PROJECT NAME LOCALITY
OBSERVER AGENCY/FIRM
RECEIVER S/N
ANTENNA S/N
DATA RECORDING UNIT S/N
ANTENNA MOUNTING DEVICE
DATE (MM DO YY) DAY OF YEAR: LAST CALIBRATED:

****

STATIC REFERENCE RECEIVERS

	RECEIVER		RECEIVER 2		RECEIVER 3	
STATION NAME						
STATION NUMBER						
UTC TIME OF OBSERVATION	START	STOP	START	STOP	START	STOP

****

STOP & GO ROVING RECEIVER

STATION NUMBER	STATION NAME	ANTENNA HEIGHT	DATA SET #	COMMENTS

PAGE 1 SHEET ____ OF

Figure E-11. Stop-and-go kinematic field form (Continued)

U.S. ARMY CORPS OF ENGINEERS STOP
& GO KINEMATIC GPS FIELD FORM

****

STOP & GO ROVING RECEIVER CON'T

STATION NUMBER	STATION NAME	ANTENNA HEIGHT	DATA SET It	COMMENTS

****

ADDITIONAL COMMENTS

PAGE 2

Figure E-11. (Concluded)

U.S. ARMY CORPS OF ENGINEERS
STOP & GO KINEMATIC GPS FIELD FORM

PROJECT NAME	2N LAKE	GPS-7K	LOCALITY HORN LAKE, MS
OBSERVER	-E Y C.[	LS	AGENCY/FIRM CoE, MEMPHIS D
RECEIVER			S/N 2820A00242
ANTENNA			S/N 2923A00242
DATA			S/N 2820A00242
ANTENNA MOUNTING			LAST CALIBRATED: 06
DATE (MM 00 YY)			OF YEAR 179

STATIC REFERENCE RECEIVERS

	RECEIVER		RECEIVER 2		RECEIVER 3	
STATION NAME	HuD&.tN:5		P-13-Z-89			
STATION NUMBER	30'75		-</098			
UTC TIME OF OBSERVATION	START	STOP	START	STOP	START	STOP
	Z0.'3	o/:.(..j5	zz:o.:J	o1:6{r;.		

STOP & GO ROVING RECEIVER

STATION NUMBER	STATION NAME	ANTENNA HEIGHT	DATA SET #	COMMENTS
'10"17	P-13-I·S	1.93		L(>sr ?AiAV£1 io IlEA" Fr.
'-lo97	P-1'3-1·8,	"	Z	R r'''R ll T. /?t! INJ-ru"r1..1"ilo.lf
5"1..11	1-\L-17	"	3	ANT..... "Dv -ru'R.e.&p
5'"11	J4\..-"	"	'-j	R L£oc.c:_....H1 G:. o.
5-7 IS	H L-15	"	5	
7Z //	RIS.-rvn..... Pr A	"	C.	''' IVAI'- A,. {' - /'IJ-/ £NO O /"f AEua.J o.ou. Rc. BA•'l>c. 0Y!;li! t:oFk...J .la6£.<•
5"2/(,	H L- fi,	"	7	
5ZJ'{	f/L-t'-1	"	8	
5Z/3	1/L-IJ	"	'|	
5212.	HL-IZ.	"	/O	
7Z£2.	!-rruv f'r /	"	| |	P< /VA•t. Ar .N/£1>4 c$ ..oo..... Rl> a...;s,.., £ oP /-J t:>ltAl 1AM. ;e .
Zo"/9	S 2'2 /'171./:	"	/2.	S .,vcrl HAtt.K •• C,_.,,; IC"r /fi£A-"OWIH.l.-
5zzo	i-/L -Z.O	"	/3	

PAGE SHEET 1 OF 1

Figure E-12. Example stop-and-go kinematic field fonn (Continued)

U.S. ARMY CORPS OF ENGINEERS STOP
& GO KINEMATIC GPS FIELD FORM

****
STOP & GO ROVING RECEIVER CON'!

STATION NUMBER	STATION NAME	ANTENNA HEIGHT	DATA SET #	COMMENTS
5Z. II	lll.-1/	;.tn3	11	
5Zf'f	f/L-1'1	"	/5	
5Z08	111--$	"	/{,	I•:sr c.'< ""T.C.c «G.,,....<0 7'i·II:J PM.J't' O,.... .., ••|:| :5-r,.rH....H-d r-'&.. co.'4./Z

TO 01:45 UTC

****
ADDITIONAL COMMENTS

~~7212 TRAV Pc 1 AND 2099-522 1974 WILL BE USED~~

AS BEGINNING AND ENDING HORIZONTAL CONTROL FOR TRAVERSE -r. ,IIL--7. 522 1974 WILL BE USED AS VERTICAL CONTROL FOR DIFFERENTIAL LEVELS TO -7_

Figure E-12. (Concluded)

```
 TRIMVEC GPS RELATIVE POSITIONING SOLUTION SUMMARY:  VERSION 89.062

 SOLUTION OUTPUT FILE: D:\179\OUT\95971792.fix

 STATION 1:   Station ID: 3095  Session #: 179-1     Jun 28, 1989 19:22
Data-logging start time = 20:39     Data-logging stop  time = 01:45

 STATION 2:   Station ID: 4097  Session #: 179-2     Jun 28, 1989 22:04
Data-logging start time = 22:04     Data-logging stop  time = 23:00

 STATION COORDINATES:

Sta        Ant (m)      Latitude              Longitude            Hgt (m)
 1           1.409   34:59'52.56136" N    90:00'07.30092" W      106.019
 2 [TRP]     1.963   34:56'53.54740" N    90:02'03.76506" W       91.051
 2 [FLT]     1.963   34:56'53.54594" N    90:02'03.76283" W       91.073
 2 [FIX]     1.963   34:56'53.54605" N    90:02'03.76258" W       91.089

Origin of station 1 coordinates : User input

 SOLUTION SUMMARY:

Solution        dx (m)         dy (m)         dz (m)       dh (m)      RDOP
TRIPLE        -2955.290      -3148.922      -4529.085     -14.969     4.329
FLOAT         -2955.234      -3148.966      -4529.109     -14.946     0.354
*FIXED        -2955.228      -3148.977      -4529.097     -14.930     0.048
FLT-FIX          -0.006          0.011          -0.012      -0.015

Solution  Slope (m)     sig   Epochs/Rejected  Epoch interval  Epoch increment
TRIPLE    6257.9599  [0.064]     102/  6            150 (secs)       5 (epochs)
FLOAT     6257.9727  [0.032]     546/ 27             30 (secs)       1 (epochs)
FIXED     6257.9668  [0.014]     545/ 28             30 (secs)       1 (epochs)

Fixed solution quality factor:   10.1
Fixed solution rms:             0.039 (cycles)
Maximum float - fixed delta:      1.2 (cm)

Integers found, RMS is OK, FIXED solution recommended.
```

Figure E-13. Static solution summary 3095 -> 4097

```
 TRIMVEC GPS RELATIVE POSITIONING SOLUTION SUMMARY:  VERSION 89.062

 SOLUTION OUTPUT FILE: D:\179\OUT\98971792.fix

 STATION 1:   Station ID: 4098  Session #: 179-1     Jun 28, 1989 20:38
Data-logging start time = 20:42     Data-logging stop  time = 01:45

 STATION 2:   Station ID: 4097  Session #: 179-2     Jun 28, 1989 22:04
Data-logging start time = 22:04     Data-logging stop  time = 23:00

 STATION COORDINATES:

Sta        Ant (m)      Latitude              Longitude             Hgt (m)
 1           1.590   34:56'53.35126" N    90:02'18.20974" W        83.300
 2 [TRP]     1.963   34:56'53.54487" N    90:02'03.76471" W        91.136
 2 [FLT]     1.963   34:56'53.54503" N    90:02'03.76453" W        91.114
 2 [FIX]     1.963   34:56'53.54458" N    90:02'03.76338" W        91.120

Origin of station 1 coordinates : User input

 SOLUTION SUMMARY:

Solution        dx (m)          dy (m)          dz (m)       dh (m)       RDOP
TRIPLE          366.528          -3.238           9.379        7.836      4.303
FLOAT           366.533          -3.217           9.371        7.814      0.354
*FIXED          366.562          -3.230           9.363        7.820      0.047
FLT-FIX          -0.029           0.013           0.008       -0.006

Solution  Slope (m)     sig   Epochs/Rejected  Epoch interval  Epoch increment
TRIPLE     366.6626  [0.106]     107/  1            150 (secs)        5 (epochs)
FLOAT      366.6667  [0.006]     570/  3             30 (secs)        1 (epochs)
FIXED      366.6960  [0.002]     569/  4             30 (secs)        1 (epochs)

Fixed solution quality factor:   29.7
Fixed solution rms:             0.024 (cycles)
Maximum float - fixed delta:      2.9 (cm)

Integers found, RMS is large. (see Trimvec Manual).
```

Figure E-14. Static solution summary 4098 -> 4097

quality factors were fairly high, meaning that the integer-cycle ambiguities were resolved in both solutions with a high degree of reliability. Even though the RMS was slightly large in comparison to the length of the baseline from 4098 to 4097, the fixed solution quality factor was high and thus the results of the fixed solution are recommended. Had sufficient data not been collected to resolve the integer cycle ambiguities, additional static data collection would be required. An attempt to process stop-and-go data using values from static solutions in which the integers were not found may give erroneous results for the baselines processed. The dX, dY, and dZ values listed for the fixed solution in Figures E-13 and E-14 were used to post-process the stop-and-go data.

b. After all static data were processed, summaries of the stop-and-go sessions were printed. These summaries document the events of the session and the time of their occurrence in GPS seconds of the week. Figure E-15 shows the summary of events that took place during the stop-and-go session on day 179 between the reference receiver at station 3095 and roving receiver initializing on station 4097. The stop-and-go session summary conveys the following details of the survey.

(1) The data file names for the reference and remote (roving) receivers.

(2) The kinematic (stop-and-go) data set number. This number was automatically incremented by one each time a point was occupied.

(3) The station ID of the point being occupied.

(4) The time in seconds that the data set began.

(5) The height of the roving receiver's antenna above the point being occupied.

(6) The time in seconds that the data set ended.

(7) The amount of time in minutes and seconds that data were recorded at the point being occupied.

(8) The last epoch of data recorded before missing satellite PRN 14. The satellite was missing because a cycle slip occurred or a loss of data occurred during download from the receiver to the computer.

(9) The last epoch of data recorded before a cycle slip occurred on satellite PRN 6.

(10) The number of satellites the receiver was locked onto after missing PRN 14 and a cycle slip on PRN 6.

(11) At this point, lock was not maintained on at least four satellites. The survey was reinitialized by returning to the last point occupied; also a new route was chosen to the next point.

(12) The travel time in minutes and seconds that it took to move to the next point, or in this case, to go back to the last occupied point.

(13) The typical observation time at each stop-and-go point.

(14) At this point, lock could not be maintained on at least four satellites. The low elevation of the remaining visible satellites indicated that reinitialization would have been futile.

(15) Since there was slightly over an hour of the four-satellite window remaining on day 179, the survey continued to station 5208 where static observations were recorded for 63 minutes.

(16) Stations within a linked data set were stations consecutively occupied while lock was maintained on at least four satellites. At the point when lock was no longer maintained on at least four satellites, a new linked data set was started.

(17) The station occupation data indicate how many times each point was occupied and to which data set each occupation corresponds.

Figure E-16 shows the summary of events that took place during the stop-and-go session on day 179 between the reference receiver at station 4098 and roving receiver initializing on station 4097. Figures E-15 and E-16 are similar, but they are not exactly the same. A comparison of the two summaries reveals that other than the reference receivers being at different locations, the only other difference is in some of the times when cycle slips or missing satellite data occurred. Since the data from the roving receiver were common to both summaries, the differences in times of missing satellite data were due to obstructions at the reference receiver's location. The roving receiver operator can observe only cycle slips occurring at his receiver. Each receiver in the stop-and-go mode is able to warn the operator with a series of beeps when it no

```
Trimble Automated Kinematic Processor,  Version 83.120
Kinematic summary of Session: 179

Reference Receiver Data File: 30951791@
Remote Receiver Data File:    40971792
Reference PRN ;t:             11 @                                    @

KINEMATIC DATA SET:  1   ID: 4097   Time:   338835@ Ant height: 2.0000
    New Scenario Add  SV            PAN:   339210
     12                   Time: SV Count:   339210
                    6   Time: Last Before   339360
    Missing             PAN: 12   Time:    339360
    SV Count:           5         Time:    339405   *STATIC INITIALIZATION
          Recovered SV   PAN: 12   Time:   339405    (OR KNOWN BASELINE
    SV Count:           6         Time:    340260    AFTER PROCESSING)
   New Scenario Add  SV   PAN: 14   Time:  340260
    SV Count:           7         Time:    341985® Ant height: 2.0000
END OF KINEMATIC DATA   ID: 4097   Time:
OBSERVATION TIME: 55:15 ®

    Last Before Missing   PRN: 14   Time:   342225 (6)'''
       Last Before Slip   N:  s     Time:   342225
    SV Count:           5           Time:   342225
       Last Before Slip  'i¥N:  8   Time:   342240
       last Before Slip   PRN:  9   Time:   342240
       Last Before Slip   PRN: 11   Time:   342240
       Last Before Slip   PRN: 12   Time:   342240
       Last Before Slip   PRN: 13   Time:   342240
    SV Count:           0           Time:   342240
       After cycle Slip   PRN:  6   Time:   342270   *LOST LOCK ON SATELLITES
       After Cycle Slip   PRN:  8   Time:   342270    WHILE MOVING, RETURNED
       After Cycle Slip   PRN:  9   Time:   342270    TO LAST OCCUPIED POINT.
       After Cycle Slip   PRN: 11   Time:   342270    (SEE DATA SET 2 BELOW)
       After Cycle Slip   PRN: 12   Time:   342270
           Recovered SV   PRN: 14   Time:   342270
    SV Count:           6           Time:   342270
       After Cycle Slip   PRN: 13   Time:   342315
    SV Count:           7           Time:   342315
       Last Before Slip   PRN:  6   Time:   342330
       Last Before Slip   PRN: 14   Time:   342330
    SV Count:           5           Time:   342330
       After Cycle Slip   PRN: 14   Time:   342375
    SV count:           6           Time:   342375
       After Cycle Slip   PRN:  6   Time:   342420
    Last Before Missing   PRN:  8   Time:   342420
    Last Before Missing   PRN: 14   Time:   342420
    SV Count:           5           Time:   342420
           Recovered SV   PRN:  8   Time:   342465
    SV Count:           6           Time:   342465
           Recovered SV   PRN: 14   Time:   342480
    SV Count:           7           Time:   342480
MOVE TIME:  9:44 CD

KINEMATIC DATA SET:  2   ID: 4097   Time:   342585    Ant height: 2.0000
END OF KINEMATIC DATA    ID: 4097   Time:   342645    Ant height: 2.0000
OBSERVATION TIME:  1:15  *RETURNED TO REINITIALIZE WITH KNOWN BASELINE
                 ®>
```

Figure E-15. Kinematic session summary 3095 -> 4097 (Sheet 1 of 6)

```
      Last Before Slip   PRN:  6   Time:   342810
   SV Count:          6            Time:   342810
      After Cycle Slip   PRN:  6   Time:   342840
   SV Count:          7            Time:   342840
MOVE TIME:  6:59

KINEMATIC DATA SET:  3   .ID: 5217   Time:   343080    Ant height: 2.0000
END OF KINEMATIC DATA    10: 5217   Time:   343260    Ant height: 2.0000
OBSERVATION TIME:  3:15  *SETUP WAS DISTURBED DURING OCCUPATION,
                          SEE DATA SET 4 FOR REOCCUPATION

MOVE TIME:   0:59

KINEMATIC DATA SET:  4   ID: 5217   Time:   343335    Ant height: 2.0000
END OF KINEMATIC DATA    10: 5217   Time:   343395    Ant height: 2.0000
OBSERVATION TIME:  1:15

   last Before Missing   PRN:  8   Time:   343545
   SV count:          6            Time:   343545
MOVE TIME:  4' 0

KINEMATIC DATA SET:  5   ID: 5215   Time:   343650    Ant height: 2.0000
KINEMATIC DATA SET:  5   10: 5215   Time:   343680    Ant height: 2.0000
          Recovered SV   PRN:  8   Time:   343710
   SV Count:          7            Time:   343710
END OF KINEMATIC DATA    ID: 5215   Time:   343710    Ant height: 2.0000
OBSERVATION TIME:  1:15

   Last Before Missing   PRN:  8   Time:   343845
   SV count:          6            Time:   343845
          Recovered SV   PRN:  8   Time:   343935
   Last Before Missing   PRN:  6   Time:   343935
          Recovered SV   PRN:  6   Time:   343965
   SV Count:          7            Time:   343965
   Last Before Missing   PRN:  8   T.ime:  343980
   SV count:          6            Time:   343980
   Last Before Missing   PRN:  6   Time:   344010
   SV Count:          5            Time:   344010
          Recovered SV   PRN:  6   Time:   344130
   SV Count:          6            Time:   344130
MOVE TIME:  7:14

KINEMATIC DATA SET:  6   ID: 7211   Time:   344160    Ant height: 2.0000
KINEMATIC DATA SET:  6   ID: 7211   Time:   344220    Ant height: 2.0000
END OF KINEMATIC DATA    ID: 7211   Time:   344220    Ant height: 2.0000
OBSERVATION TIME:  1:15  *THIS POINT WAS ESTABLISHED TO RETURN TO IN CASE
                          LOCK WAS LOST ON THE WAY TO POINT 5216

   Last Before Missing   PRN:  6   Time:   344250
   SV Count:          5            Time:   344250
   New Scenario Lost SV   PRN:  6   Time:   344415
MOVE TIME:  4:14

KINEMATIC DATA SET:  7   ID: 5216   Time:   344490    Ant height: 2.0000
END OF KINEMATIC DATA    ID: 5216   Time:   344550    Ant height: 2.0000
OBSERVATION TIME:  1:-15
```

Figure E-15. (Sheet 2 of 6)

```
      Last Before S1;p     PRN: 12    Time:    344700
   SV Count:            4             Time:    344700
         Recovered SV    PAN:  8     Time:    344730
   SV count:            5             Time:    344730
      After Cycle Slip    PRN: 12    Time:    344745
   SV Count:            6             Time:    344745
   Last Before Missing    PRN:  8    T1me:    344760
   SV Count:            5             Time:    344760
MOVE TIME:   6:29

KINEMATIC DATA SET:  8    ID: 5214   Time:    344955    Ant height: 2.0000
END OF KINEMATIC DATA    10: 5214    Time:    345015    Ant height: 2.0000
OBSERVATION TIME:  1:15

          Recovered  SV    PAN:  8   Time:    345165
      Last Before S1 ip    PAN:  8   Time:    345165
      After Cycle S1;p     PAN:  8   Time:    345210
   SV Count:            6             Time:    345210
      Last Before S1 ip    PAN:  8   Time:    345270
   SV Count:            5             Time:    345270
  New Scenario  Lost SV    PAN:  8   Time:    345330
MOVE TIME:   5:30

KINEMATIC DATA SET:  9    ID: 5213   Time:    345360    Ant height: 2.0000
END OF KINEMATIC DATA     ID: 5213   Time:    345420    Ant height: 2.0000
OBSERVATION TIME:  1:14

MOVE TIME:  6' 0

KINEMATIC DATA SET: 10    ID: 5212   Time:    345795    Ant height: 2.0000
END OF KINEMATIC DATA     ID: 5212   Time:    345855    Ant height: 2.0000
OBSERVATION TIME:  1:15

  New Scenario Add  SV    PRN:  3    Time:    345900
   SV Count:            6             Time:    345900
   Last Before Missing    PRN:  3    T-1me:   345960
   SV Count:            5             Time:    345960

   SV Count:            6             Time:    346050
MOVE TIME:   6:44

KINEMATIC DATA SET: 11    ID: 721 2  Time:    345275    Ant height: 2.0000
END OF KINEMATIC DATA     ID: 7212   Time:    345335    Ant height: 2.0000
OBSERVATION TIME:  1:15

      Last Before s1ip    PRN:  3    T1me:    345485
   SV Count:            5             Time:    345485
      After Cycle S1 ip    PRN:  3   Time:    346515
   SV count:            6             Time:    346515
MOVE TIME:   3:14

KINEMATIC DATA SET: 12    IO: 2099   Time:    346545    Ant height: 2.0000
END OF KINEMATIC DATA     ID: 2099   Time:    346520    Ant height: 2.0000
OBSERVATION TIME:  1:30
```

Figure E-15. (Sheet 3 of 6)

```
        Last Before Slip   PRN:  9   Time:   346815
    SV Count:           5            Time:   346815
        After Cycle Slip   PRN:  9   Time:   346845
    SV Count:           6            Time:   346845
    Last Before Missing    PRN:  9   Time:   346890
    SV Count:           5            Time:   346890
            Recovered SV   PRN:  9   Time:   346935
        Last Before Slip   PRN:  9   Time:   346935
        After Cycle Slip   PRN:  9   Time:   347010
    SV Count:           6            Time:   347010
MOVE TIME:  8:15

KINEMATIC DATA SET: 13   ID: 5220   Time:   347130    Ant height: 2.0000
END OF KINEMATIC DATA    ID: 5220   Time:   347190    Ant height: 2.0000
OBSERVATION TIME:  1:15

MOVE TIME:  4:29

KINEMATIC DATA SET: 14   ID: 5211   Time:   347475    Ant height: 2.0000
END OF KINEMATIC DATA    ID: 5211   Time:   347535    Ant height: 2.0000
OBSERVATION TIME:  1:15

        Last Before Slip   PRN:  9   Time:   347730
    SV Count:           5            Time:   347730
        After Cycle Slip   PRN:  9   Time:   347760
    SV Count:           6            Time:   347760
MOVE TIME:  3:45

KINEMATIC DATA SET: 15   ID: 5219   Time:   347775    Ant height: 2.0000
END OF KINEMATIC DATA    ID: 5219   Time:   347835    Ant height: 2.0000
OBSERVATION TIME:  1:15

    Last Before Missing    PRN:  9   Time:   347895
        Last Before Slip   PRN:  3   Time:   347895
    SV Count:           4            Time:   347895
        After Cycle Slip   PRN:  3   Time:   347940
        Last Before Slip   PRN:  3   Time:   347940
        Last Before Slip   PRN: 11   Time:   347940
    SV Count:           3            Time:   347940 η *AT THIS POINT LOCK WAS
        After Cycle Slip   PRN: 11   Time:   347970   NOT MAINTAINED ON AT
    SV Count:           4            Time:   347970   LEAST 4 SATELLIES
        Last Before Slip   PRN: 13   Time:   347986
    SV Count:           3            Time:   347986
    Last Before Missing    PRN: 12   Time:   348000
    SV Count:           2            Time:   348000
        After Cycle Slip   PRN:  3   Time:   348015
        After Cycle Slip   PRN: 13   Time:   348015
        Last Before Slip   PRN:  3   Time:   348015
        Last Before Slip   PRN: 11   Time:   348015
        Last Before Slip   PRN: 13   Time:   348015
        Last Before Slip   PRN: 14   Time:   348015
    SV Count:           0            Time:   348015
```

Figure E-15. (Sheet 4 of 6)

```
        After Cycle Slip   PRN: 11   Time:   348045
            Recovered SV   PRN: 12   Time:   348045
        After Cycle Slip   PRN: 14   Time:   348045
        Last Before Slip   PRN: 12   Time:   348045
    SV Count:           2            Time:   348045
        After Cycle Slip   PRN:  3   Time:   348075
        After Cycle Slip   PRN: 12   Time:   348075
        After Cycle Slip   PRN: 13   Time:   348075
    SV Count:           5            Time:   348075
            Recovered SV   PRN:  9   Time:   348090
    SV Count:           6            Time:   348090
MOVE TIME:  5: 0

KINEMATIC DATA SET: 16   ID: 5208 (o) Time:   348150    Ant height: 2.0000
KINEMATIC DATA SET: 16   ID: 5208   Time:   348195    Ant height: 2.0000
    Last Before Missing   PRN:  9   Time:   348420
    SV Count:           5            Time:   348420   *DUE TO THE ABOVE LOSS OF
   New Scenario Lost SV   PRN:  9   Time:   348435    LOCK, THIS POINT WAS
    Last Before Missing   PRN: 12   Time:   351180    OCCUPIED FOR 63 MINUTES
    SV Count:           4            Time:   351180    AND THE DATA PROCESSED
   New Scenario Lost SV   PRN: 12   Time:   351195    AS A STATIC BASELINE.
END OF KINEMATIC DATA    ID: 5208   TIME:   351930
OBSERVATION TIME: 63:00

Linked Data Set # 1:   - 4097
(p) Linked Data Set # 2:   - 4097 - 5217 - 5217 - 5215 - 7211 - 5216 - 5214
                           - 5213 - 5212 - 7212 - 2099 - 5220 - 5211 - 5219
Linked Data Set # 3:   - 5208
```

Figure E-15. (Sheet 5 of 6)

STATION OCCUPATION INFORMATION (4)

```
MARK ID: 4097   Occupations:   2
Data Set ID:    1
Data Set ID:    2

MARK ID: 5217   Occupations:   2
Data Set ID:    3
Data Set ID:    4

MARK ID: 5219   Occupations:   1
Data Set ID:   15

MARK ID: 5215   Occupations:   1
Data Set ID:    5

MARK ID: 5216   Occupations:   1
Data Set ID:    7

MARK ID: 7211   Occupations:   1
Data Set ID:    6

MARK ID: 5214   Occupations:   1
Data Set ID:    8

MARK ID: 5213   Occupations:   1
Data Set ID:    9

MARK ID: 5212   Occupations:   1
Data Set ID:   10

MARK ID: 7212   Occupations:   1
Data Set ID:   11

MARK ID: 2099   Occupations:   1
Data Set ID:   12

MARK ID: 5220   Occupations:   1
Data Set ID:   13

MARK ID: 5211   Occupations:   1
Data Set ID:   14

MARK ID: 5208   Occupations:   1
Data Set ID:   16
```

Figure E-15. (Sheet 6 of 6)

```
Trimble Automated Kinematic Processor, Version 89.120
Kinematic Summary of Session: 179

Reference Receiver Data File: 40981791
Remote Receiver Data File:    40971792
Reference PRN =               11

KINEMATIC DATA SET:       ID: 4097   Time:   338835    Ant height: 2.0000
   New Scenario Add  SV   PRN: 12   Time:   339210
    SV Count:           6            Time:   339210

    SV count:           5            Time:   339360    *STATIC INITIALIZATION
           Recovered SV   PRN: 12   Time:   339405     (OR KNOWN BASELINE
    SV Count:           6            Time:   339405      AFTER PROCESSING)
   New scenario Add  sv   PRN: 14   Time:   340320

           Recovered SV   PRN: 14   Time:   340425
    sv count:           7            Time:   340425
END OF KINEMATIC DATA     ID: 4097   Time:   341985    Ant height: 2.0000
OBSERVATION TIME: 55:15

    Last Before Missing   PRN: 14   Time:   342225
       Last Before Slip   PRN:  6   Time:   342225
    SV Count:           5            Time:   342225
       Last Before Slip   PRN:  8   Time:   342240
       Last Before Slip   PRN:  9   Time:   342240
       Last Before Slip   PRN: 11   Time:   342240
       Last Before Slip   PRN: 12   Time:   342240
       Last Before Slip   PRN: 13   Time:   342240
    sv Count:           0            Time:   342240    *LOST LOCK ON SATELLITES
       After Cycle Slip   PRN:  6   Time:   342270     WHILE MOVING, RETURNED
       After Cycle Slip   PRN:  8   Time:   342270     TO LAST OCCUPIED POINT.
       After Cycle Slip   PRN:  9   Time:   342270     (SEE DATA SET 2 BELOW)
       After Cycle Slip   PRN: 11   Time:   342270
       After Cycle Slip   PRN: 12   Time:   342270
           Recovered SV   PRN: 14   Time:   342270
    SV Count:           6            Time:   342270
       After Cycle Slip   PRN: 13   Time:   342315
    sv count:           7            Time:   342315
       Last Before Slip   PRN:  6   Time:   342330
       Last Before Slip   PRN: 14   Time:   342330
    SV Count:           5            Time:   342330
       After Cycle Slip   PRN: 14   Time:   342375
    SV Count:           6            Time:   342375
       After Cycle Slip   PRN:  6   Time:   342420
    Last Before Missing   PRN:  8   Time:   342420
    Last Before Missing   PRN: 14   Time:   342420
    SV Count:           5            Time:   342420
           Recovered SV   PRN:  8   Time:   342465
    SV count:           6            Time:   342465
           Recovered SV   PRN: 14   Time:   342480
    SV Count:           7            Time:   342480
MOVE TIME:   9:44
```

Figure E-16. Kinematic session summary 4098 -> 4097 (Sheet 1 of 6)

```
KINEMATIC DATA SET:  2    10: 4097    Time:    342585    Ant height:  2.0000
END OF KINEMATIC DATA     IO: 4097    Time:    342645    Ant height:  2.0000
OBSERVATION TIME:  1:15   *RETURNED TO REINITIALIZE WITH KOWN BASELINE

       Last Before Slip   PRN:  6   Time:    342810
    SV Count:          6            Time:    342810
       After cycle S1;p   PRN:  6   Time:    342840
    SV Count:          7            Time:    342840
MOVE TIME:  6:59

KINEMATIC DATA SET:  3    ID: 5217    Time:    343080    Ant height: 2.0000
END OF KINEMATIC DATA     ID: 5217    Time:    343260    Ant height: 2.0000
OBSERVATION TIME:  3:15   *SETUP DISTURBED DURING OCCUPATION,
                           SEE DATA SET 4 FOR REOCCUPATION.
MOVE TIME:  0:59

KINEMATIC DATA SET:  4    10: 5217    Time:    343335    Ant height: 2.0000
END OF KINEMATIC DATA     10: 5217    Time:    343395    Ant height: 2.0000
OBSERVATION TIME:  1:15

MOVE TIME:  4: O

KINEMATIC DATA SET:  5    ID: 5215    Time:    343650    Ant height: 2.0000
KINEMATIC DATA SET:  5    ID: 5215    Time:    343680    Ant height: 2.0000
END OF KINEMATIC DATA     ID: 5215    Time:    343710    Ant height: 2.0000
OBSERVATION TIME:  1:15

    Last Before Missing   PRN:  8   Time:    343845
    SV Count:          6            Time:    343845
           Recovered SV   PRN:  8   Time:    343935
    Last Before Missing   PRN:  6   Time:    343935
           Recovered SV   PRN:  6   Time:    343965
    SV Count:          7            Time:    343965
    Last Before Missing   PRN:  6   Time:    344010
    SV Count:          6            Time:    344010
    Last Before Missing   PRN:  8   Time:    344055
    SV Count:          5            Time:    344055
           Recovered SV   PRN:  6   Time:    344130
    Last Before Missing   PRN:  6   Time:    344130
   New Scenario Lost SV   PRN:  6   Time:    344145
           Recovered SV   PRN:  8   Time:    344145
    SV Count:          6            Time:    344145
MOVE TIME:  7:14

KINEMATIC DATA SET:  6    ID: 7211    Time:    344160    Ant height: 2.0000
KINEMATIC DATA SET:  6    ID: 7211    Time:    344220    Ant height: 2.0000
END OF KINEMATIC DATA     ID: 7211    Time:    344220    Ant height: 2.0000
OBSERVATION TIME:  1:15   *THIS POINT WAS ESTABLISHED TO RETURN TO IN CASE
                           LOCK WAS LOST ON THE WAY TO POINT 5216.
       Last Before Slip   PRN:  8   Time:    344295
    SV Count:          5            Time:    344295
       After Cycle Slip   PRN:  8   Time:    344340
    SV Count:          6            Time:    344340
    Last Before Missing   PRN:  8   Time:    344370
    SV count:          5            Time:    344370
           Recovered SV   PRN:  8   Time:    344430
    SV Count:          6            Time:    344430
MOVE TIME:  4:14
```

Figure E-16. (Sheet 2 of 6)

```
KINEMATIC DATA SET:  7    ID: 5216   Time:   344490    Ant height: 2.0000
END OF KINEMATIC DATA     ID: 5216   Time:   344550    Ant height: 2.0000
OBSERVATION TIME:   1:15

    Last Before Missing   PRN:  8   Tlme:   344655
    SV count:          5            Time:   344655
       Last Before Slip   PRN: 12   Time:   344700
    SV Count:          4            Time:   344700
          Recovered SV   PRN:  8   Time:   344730
    SV Count:          5            Time:   344730
       After cycle Slip   PRN: 12   Time:   344745
    SV Count:          6            Time:   344745
    Last Before Missing   PRN:  8   Time:   344775
    SV Count:          5            Time:   344775
          Recovered SV   PRN:  8   Time:   344865
    SV count:          6            Time:   34486 5
MOVE TIME:   6:29

KINEMATIC DATA SET:  8    ID: 5214   Time:   344955    Ant height: 2.0000
END OF KINEMATIC DATA     ID: 5214   Time:   345015    Ant height: 2.0000
OBSERVATION TIME:   1:15

    Last Before Missing   PRN:  8   Time:   345090
    SV count:          5            Time:   345090
          Recovered SV   PRN:  8   Time:   345165
       Last Before sl;p   PRN:  8   Time:   345165
       After Cycle slip   PRN:  8   Time:   345210
    SV count:          6            Time:   345210
       Last Before slip   PRN:  8   Time:   345270
    SV Count:          5            Time:   345270
       After Cycle slip   PRN:  8   Time:   345345
    SV count:          6            Time:   345345
MOVE TIME:  5:30

KINEMATIC DATA SET:  9    ID: 5213   Time:   345360    Ant height: 2.0000
END OF KINEMATIC DATA     ID: 5213   Time:   345420    Ant height: 2.0000
OBSERVATION TIME:  1:14

    Last Before Missing   PRN:  8   Time:   345480
    SV Count:          5            Time:   345480
   New Scenario Lost SV   PRN:  8   Time:   345495
MOVE TIME:  6' 0

KINEMATIC DATA SET: 10    ID: 5212   Time:   345795    Ant height: 2.0000
END OF KINEMATIC DATA     ID: 5212   Time:   345855    Ant height: 2.0000
OBSERVATION TIME:  1:15

   New Scenario Add  SV   PRN:  3   Time:   345900
    SV Count:          6            Time:   345900
MOVE TIME:  6:44

KINEMATIC DATA SET: 11    D: 7212    Time:   346275    Ant height: 2.0000
END OF KINEMATIC DATA     D: 7212    Time:   345335    Ant height: 2.0000
OBSERVATION TIME:  1:15

       Last Before slip   PRN:  3   Time:   346485
    SV Count:          5            Time:   346485
       After Cycle Slip   PRN:  3   Time:   346515
    SV Count:          6            Time:   346515
MOVE TIME:  3:14
```

Figure E-16. (Sheet 3 of 6)

```
KINEMATIC DATA SET: 12    ID: 2099    Time:   346545    Ant height: 2.0000
END OF KINEMATIC DATA     ID: 2099    Time:   346620    Ant height: 2.0000
OBSERVATION TIME:  1:30

      Last Before S1;p    PAN:  9    Time:   346815
   SV Count:            5            Time:   346815
      After cycle Slip    PRN:  9    Time:   346845
   SV Count:            6            Time:   346845
   Last Before Missing    PAN:  9   Time:   346890
   SV Count:            5            Time:   346890
          Recovered SV    PAN:  9    Time:   346935
      Last Before S1ip    PAN:  9    Time:   346935
      After Cycle Slip    PAN:  9    Time:   347010
   SV Count:            6            Time:   347010
MOVE TIME:  8:15

KINEMATIC DATA SET: 13    ID: 5220    Time:   347130    Ant height: 2.0000
END OF KINEMATIC DATA     10: 5220    Time:   347190    Ant height: 2.0000
OBSERVATION TIME:  1:15

MOVE TIME: 4:29

KINEMATIC DATA SET: 14    ID: 5211    Time:   347475    Ant height:  2.0000
END OF KINEMATIC DATA     ID: 5211    Time:   347535    Ant height: 2.0000
OBSERVATION TIME:  1:15

      Last Before s1;p    PRN:  9    Time:   347730
   SV count:            5            Time:   347730
      After cycle s1ip    PRN:  9    Time:   347760
   SV Count:            6            Time:   347760


KINEMATIC DATA SET: 15    IO: 5219    Time:   347775    Ant height: 2.0000
END OF KINEMATIC DATA     ID: 5219    Time:   347835    Ant height: 2.0000
OBSERVATION TIME:  1:15

   Last Before Missing    PRN:  9    Time:   347895
      Last Before Slip    PRN:  3    Time:   347895
   SV Count:            4            Time:   347895
      After Cycle s1ip    PRN:  3    Time:   347940
      Last Before s1ip    PRN:  3    Time:   347940
      Last Before s1ip    PRN: 11    Time:   347940
   SV count:            3            Time:   347940
      After Cycle Slip    PRN: 11    Time:   347970
   SV Count:            4            Time:   347970
      Last Before s1;p    PRN: 13    Time:   347986
   SV Count:            3            Time:   347986    *AT THIS POINT LOCK WAS
   Last Before Missing    PRN: 12   Time:   348000     NOT MAINTAINED ON AT
   sv Count:            2            Time:   348000     LEAST 4 SATELLITES.
      After Cycle Slip    PRN:  3    Time:   348015
      After Cycle s1ip    PRN: 13    Time:   348015
      Last Before s1ip    PRN:  3    Time:   348015
      Last Before Slip    PRN: 11    Time:   348015
      Last Before Slip    PRN: 13    Time:   34801 5
      Last Before s1ip    PRN: 14    Time:   34801 5
   SV Count:            0            Time:   348015
      After Cycle s1;p    PRN: 11    Time:   348045
          Recovered SV    PRN: 12    Time:   348045
      After Cycle s1ip    PRN: 14    Time:   348045
      Last Before Slip    PRN: 12    Time:   348045
```

Figure E-16. (Sheet 4 of 6)

```
        After Cycle Slip   PRN: 11   Time:   348045
            Recovered SV   PRN: 12   Time:   348045
        After Cycle Slip   PRN: 14   Time:   348045
        Last Before Slip   PRN: 12   Time:   348045
    SV Count:           2            Time:   348045
        After Cycle Slip   PRN:  3   Time:   348075
        After Cycle Slip   PRN: 12   Time:   348075
        After Cycle Slip   PRN: 13   Time:   348075
    SV Count:           5            Time:   348075
            Recovered SV   PRN:  9   Time:   348090
    SV Count:           6            Time:   348090
MOVE TIME:  5: 0

KINEMATIC DATA SET: 16   ID: 5208 (O) Time:   348150    Ant height: 2.0000
KINEMATIC DATA SET: 16   ID: 5208   Time:   348195    Ant height: 2.0000
    Last Before Missing   PRN:  9   Time:   348420
    SV Count:           5            Time:   348420   *DUE TO THE ABOVE LOSS OF
   New Scenario Lost SV   PRN:  9   Time:   348435    LOCK, THIS POINT WAS
    Last Before Missing   PRN: 12   Time:   351180    OCCUPIED FOR 63 MINUTES
    SV Count:           4            Time:   351180    AND THE DATA PROCESSED
   New Scenario Lost SV   PRN: 12   Time:   351195    AS A STATIC BASELINE.
END OF KINEMATIC DATA    ID: 5208   TIME:   351930
OBSERVATION TIME: 63:00

Linked Data Set # 1:   - 4097
(P) Linked Data Set # 2:   - 4097 - 5217 - 5217 - 5215 - 7211 - 5216 - 5214
                           - 5213 - 5212 - 7212 - 2099 - 5220 - 5211 - 5219
Linked Data Set # 3:   - 5208
```

Figure E-16. (Sheet 5 of 6)

```
                    STATION OCCUPATION INFORMATION
                    ------------------------------

MARK ID: 4097   Occupations:   2
Data Set ID:    1
Data Set ID:    2

MARK ID: 5217   Occupations:   2
Data Set ID:    3
Data Set ID:    4

MARK ID: 5219   Occupations:   1
Data Set ID:   15

MARK ID: 5215   Occupations:   1
Data Set ID:    5

MARK ID: 5216   Occupations:   1
Data Set ID:    7

MARK ID: 7211   Occupations:   1
Data Set ID:    6

MARK ID: 5214   Occupations:   1
Data Set ID:    8

MARK ID: 5213   Occupations:   1
Data Set ID:    9

MARK ID: 5212   Occupations:   1
Data Set ID:   10

MARK ID: 7212   Occupations:   1
Data Set ID:   11

MARK ID: 2099   Occupations:   1
Data Set ID:   12

MARK ID: 5220   Occupations:   1
Data Set ID:   13

MARK ID: 5211   Occupations:   1
Data Set ID:   14

MARK ID: 5208   Occupations:   1
Data Set ID:   16
```

Figure E-16. (Sheet 6 of 6)

longer has lock on at least four satellites. The receiver CANNOT warn the roving receiver operator to reinitialize when a combination of the data from the rover and the data from the reference receiver no longer has lock on at least the same four satellites. If the survey is not reinitialized, the data collected subsequent to the loss of lock cannot be processed. Therefore, to ensure that all data collected can be processed, it is very important to chose a location for the reference receiver that has very little or no obstructions of the sky greater than 15 deg above the horizon.

c. If the stop-and-go data have to be manually post-processed, the rule of thumb is it takes twice as long to process the data as it does to collect it. In other words, if stop-and-go data were collected for 2 hr (including move time), it will take approximately 4 hr to post-process the data. If two reference receivers were utilized, it will take approximately 8 hr because twice as many baselines will have to be processed. Manual processing is very labor intensive because each cycle slip must be fixed before processing can continue. As stated previously, when a cycle slip occurs on a satellite, the integer cycle ambiguity for that satellite becomes unknown. When lock is recovered on the satellite, its integer cycle ambiguity must be once again resolved. The ambiguity is resolved by fixing the cycle slip. Missing satellite data are treated as a cycle slip and also require fixing during post-processing. Processing time varies with the number of cycle slips that occurred during the session; the fewer the cycle slips, the quicker the processing will proceed. The actual stepwise procedures of manual processing are beyond the scope of this manual and may vary depending on the software being used. The receiver manufacturer should be consulted for available post-processing training.

d. Some software has a batch mode for post-processing stop-and-go data. To save hours in post-processing time, this option should always be used when possible. Before stop-and-go data are collected, a thorough understanding of the batch processing requirements is strongly recommended. The field procedures used may be modified to meet the batch processing requirements.

e. All stop-and-go baselines observed on days 179 and 180 were manually post-processed. Figure E-17 shows a solution file for the baseline from the reference receiver at 3095 to the roving receiver at 4097. The file naming convention is different from that used for static solution files. Using the file name shown in Figure E-17 as an example, the convention for an eight-digit file name with a three-character extension is as follows.

40971795.k01

where

4097 = the ID of the station being occupied by the roving receiver

179 = the day of the year observations were recorded

5 = the last digit of the ID of the station being occupied by the reference receiver

k = part of extension denoting the file as kinematic

01 = part of extension that is incremented by one each time a station is reoccupied by the same rover on the same day

The solution output for stop-and-go baselines is very similar to the double-difference fixed solution for static baselines. Refer to the survey examples in Appendix D for an annotated output of a double-difference fixed solution.

f. Figure E-9 indicates stations HL-11, HL-13, HL-14, HL-15, HL-16, and HL-17 were occupied at different times by both rovers. Station HL-11 was occupied statically by rover 2 and kinematically by rover 1. The other five stations were occupied kinematically by both rovers. Table E-1 shows the repeatability of the values within baseline solutions comparing a static fixed solution to a stop-and-go kinematic solution and also two kinematic solutions processed from data obtained on different days. The comparisons are shown for baselines processed from both reference receivers. Analysis indicates the repeatability between the static and kinematic solutions was generally less than 20 ppm and that between the two kinematic solutions was about the same. The repeatability in the Y component was consistently the worst of the three components. The expected setup error of the range pole and bipod is greater than an optical plummet tribrach and tripod. This will affect the repeatability of two kinematic baselines, especially if the baselines are processed from data collected by different rovers. Relatively speaking, these results exceed in all cases Second-Order Class II precision requirements and in all cases but two, Second-Order Class I requirements.

```
                                                  07/10/89     13:45:42.30

                    TRIMBLE NAVIGATION, LTD
                      585 NORTH MARY AVENUE
                  SUNNYVALE, CALIFORNIA   94086
                            U.S.A.

                         PROGRAM TRIMVEC
               GPS RELATIVE POSITIONING SOLUTION
                         VERSION 89.062MB

 File name: 40971795.k01
Coordinate system- WGS-84

Type solution:  Double difference
Value of L12: 1
  l1 solution

Start date/time: 1989/ 6/28     20:39:60.     day of year 179   tow    333600.
Stop  date/time: 1989/ 6/29      1:45: 0.     day of year 180   tow    351900.


Data available:

station:
sat:11  :..,.-..-.--.--.-.-.,,.--..--.--.-.---.---.-----.---.-.--.-.-.---.-.-.--:
sat: 8  :.....................................,........
sat: 6  :.........................................
sat: 9  ;.......................................................
sat:13                                                          ............'
sat:12
sat:14                          ..............................................'
sat: 3                                                  ......................'


station:   2
sat:11                      ....................................................'
sat:  8
sat:  6
sat:  9
sat:13                      ....................................................'
sat:12
sat:14                          ..............................................'
sat:  3                                                 ......................'

 Broadcast  ephemeris  file  used:  D:\179\30951791.eph

SATELLITE          IOOE     HEALTH    WEEK NO.       TOW( sec)       URA(m)
    11             184          0        494      349200.00          2.8
     8              52         60        494      342000.00         32.0
     6              27          0        494      342030.00          4.0
     9              11          0        494      345600.00          2.8
    13              69          0        494      349200.00          2.8
    12             194          0        494      349200.00          4.0
    14               7          0        494      349200.00          5.7
     3             245          0        494      349230.00          2.0
```

Figure E-17. Kinematic solution output 3095 ·> 4097 (Sheet 1 of 4)

```
Broadcast satellite clock correction values
   prn          af0                af1                af2              toe
    11  -.30360044910-03  -.50022208600-11   .00000000000+00   .35640+06
     8  -.60757389290-03  -.59230842450-10  -.27755575620-16   .34920+06
     6  -.28733536600-03  -.17962520360-10   .00000000000+00   .34920+06
     9  -.35859551280-03  -.16939338820-10  -.27755575620-16   .35280+06
    13   .41933218020-03   .21600499170-11   .00000000000+00   .35640+06
    12   .83323987200-03   .37516656450-11   .00000000000+00   .35640+06
    14   .56467484680-04   .59117155620-11   .00000000000+00   .35640+06
     3   ,15179580080-03  -.14665602070-10  -.27755575620-16   .35640+06


No message file for station

Origin of station   coordinates   User input

  STATION (mark)    3095

input data file      D:\179\30951791.dat

 antenna height(m)      1.409

met values used:  pressure(mb)          1013.0
                  temperature(deg C)      20.0
                  relative humidity(%)    50.0

  x (m)         -185.143      lat  (dms)  N   34    59  52.56136
  Y (m)      -5230645.165     elon (dms)  E  269    59  52.69908
  z (m}       3537739.935     wlon (dms)  W   90     0   7.30092
                              ht (m)          106.0190

No message file for station  2

  STATION (mark)  2 4097

input data file      0:\179\40971792.dat

 antenna height(m)      1.963

met values used:  pressure(mb)          1013.0
                  temperature(deg C)      20.0
                  relative humidity(%)    50.0

  x (m)         -3140.364     lat  (dms)  N   34    56  53.54605
  Y (m)      -5233794.156     elon (dms)  E  269    57  56.23770
  z (m)       3633210.847     wlon (dms)  W   90     2   3.76230
                              ht (m)          91.1048


Vector  1 originates at station   ends at station  2

 Vector Standard Deviations  (m)
                     dx              dy              dz

 Vector         .27401510-02   .64182400-02   .49066200-02

 Vector correlation matrix
                dx(Ol)      dy(Ol)      dz(01)

     dx(0t )  1.0000000
     dy(Ot)   -.7430828   ,.0000000
     dz(Ot)    .6281730  -.8394194  1.0000000
```

Figure E-17. (Sheet 2 of 4)

```
STATION 1 TO  STATION  2

slope distance (m)        6257.9635     sigma (m)      .0022

normal section azimuth (dms)  208 10 42.06
vertical angle (dms)            0 -9 53.01

 east(m)   north(m)   up(m)       -2955.109      -5516.259        -17.992

Delta lat(dms)     0   -2   59.01531
Delta. lon(dms)    0   -1   56.46138
Delta ht(m)   -14.9142

 correlations for baseline 1:

                  d>         dy         dZ       trap     bias 1     bias 2
              bias 3     bias 4     bias 5     bias 6     bias 7
       d>  1.0000000
       dy  -.7430828  1.0000000
       dz   .6281730  -.8394194  1.0000000
     trap   .0000000   .0000000   .0000000  1.0000000
   bias 1   .0000000   .0000000   .0000000   .0000000  1.0000000
   bias 2   .0000000   .0000000   .0000000   .0000000   .0000000  1.0000000
   bias 3   .0000000   ,0000000   .0000000   .0000000   .0000000   .0000000
          1,0000000
   bias 4   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000
            .0000000  1•0000000
   bias 5   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000
            .0000000   .0000000  1.0000000
   bias 6   .0000000   .0000000   .0000000   .0000000   .0000000   ,0000000
            .0000000   .0000000   .0000000  1•0000000
   bias 7   .0000000   .0000000   .0000000   .0000000   .0000000   .0000000
            .0000000   .0000000   .0000000   .0000000  1•0000000

                              solution      Sigma
    dx {m)                   -2955.22Q       .003
    dy (m)                   -sua.99t        .006
    dz {m)                   -4529.088       .005
  trap (%)                        .000       .000
 bias 1  (cycle)            9588533.000      .000
 bias 2  {cycle)            7281643.000      .000
 bias 3  (cycle)           -1603291.000      .000
 bias 4  (cycle)            4361315.000      .000
 bias 5  (cycle)            7690266.000      .000
 bias 6  {cycle)            9590043,000      .000
 bias 7  (cycle)                   .coo      .000
 Rdop{norm to 60 sec) is        .295 (m/cycle)

 All Baseline Vectors:
                    dx(m)        dy(m)        dz(m)      dist(m)      dh(m)

From  1 To  2    -2955.220    -3148.991    -4529.088     6257.964    -14.914

  Interval between epochs (sec)  15.0
  Epoch increment     1
  Number of measurements used in solution    30
  Number of measurements rejected             0
  RMS (cycles)        .039       ·
```

Figure E-17. (Sheet 3 of 4)

```
 Elevation mask (deg)      15.0
 Edit multiplier    3.5
 Modified Hopfield troposphere model used

Best tracking C/A code positions
Station  1
Pdop        2.4
  x (m)          -186.448      lat  (dms)  N    34    59  52.57129
  y (m)      -5230628.653      elon (dms)  E   269    59  52.64760
  z (m)       3637728.748      wlon (dms)  W    90     0   7.35241
                               ht (m)            86.0759
clock offset(s)           .50214212D-03
freq  offset(s/s)         .70699674D-09

 Code calibration(m)     Carrier calibration(m)
0 -  1          .1860                      .0003
0 -  2         -.0625                     -.0004
0 -  3         -.3057                     -.0005
0 -  4         -.2056                     -.0004
0 -  5        -2.9268                      .0000
0 -  6        -3.0786                     -.0001
0 -  7        -3.0503                     -.0005
0 -  8        -3.0967                     -.0006
0 -  9        -3.0073                     -.0005
Station  2
Pdop        2.5
  x (m)        -3142.263      lat  (dms)  N    34    56  53.56441
  y (m)      -5233776.319      elon (dms)  E   269    57  56.16241
  z (m)       3633199.073      wlon (dms)  W    90     2   3.83759
                               ht (m)            69.7407
clock offset(s)           .54571078D-03
freq  offset(s/s)        -.13415415D-09

 Code calibration(m)     Carrier calibration(m)
0 -  1          .0161                     -.0000
0 -  2         -.0752                     -.0004
0 -  3         -.0518                     -.0002
0 -  4         -.0840                     -.0005
0 -  5         -.1821                     -.0001
0 -  6         -.0806                      .0002
0 -  7         -.0786                     -.0003
0 -  8         -.0518                     -.0009
0 -  9         -.1606                     -.0009
```

Figure E-17. (Sheet 4 of 4)

Table E-1
Repeat Baseline Comparison

File Name	dX	dY	dZ
95111791.FIX	-1564.664	-1813.619	-2636.200
52111795.k01	-1564.666	-1813.590	-2636.214
Diff in meters	0.002	0.029	0.014
Diff in ppm	1.3	16.0	5.3
98111791.FIX	1757.126	1332.128	1902.257
52111798.k01	1757.113	1332.164	1902.226
Diff in meters	0.013	0.036	0.031
Diff in ppm	7.4	27.0	16.3
52131795.k01	-3572.835	-2316.710	-3359.378
52131805.k01	-3572.853	-2316.729	-3359.378
Diff in meters	0.018	0.050	0.029
Diff in ppm	5.0	21.6	8.6
52131795.k01	-251.058	829.025	1179.100
52131808.k01	-251.061	829.020	1179.111
Diff in meters	0.003	0.005	0.011
Diff in ppm	11.9	6.0	9.3

E-6. Adjustments

GEOLAB adjustment software was used to adjust this example survey. An IOB file was created by adding processed static and kinematic baselines from data obtained on days 179 and 180. Three separate network adjustments were performed using this file.

a. The first adjustment was run holding only USC&GS HUDGINS fixed in three dimensions. This adjustment provided a check of the internal precision of the GPS observations. A partial listing of the output for adjustment one is shown in Figure E-18. The data indicated the following:

(1) As shown on page 1 of the GEOLAB adjustment, the number of redundant measurements, or degrees of freedom, within the adjustment was high (87).

(2) As shown on page 31, the 2D and 1D station major semi-axis and minor semi-axis were at or less than the few-centimeter level.

(3) As shown on pages 32 and 33, the 2D and 1D relative error ellipses between survey points were at or less than the few-centimeter level. The precision of all baselines within the adjustment exceeded 30 ppm and 87 percent exceeded 10 ppm.

(4) As shown on page 28, the histogram indicates some of the residuals were higher than anticipated. These higher residuals fell outside of the bell-shaped curve.

(5) As shown on page 29, the estimated variance factor in the statistics summary is somewhat high. Higher residuals and variance factors than seen with static data can be expected when adjusting stop-and-go baselines. Although some high residual values exist in the adjustment, the precision of all baselines relative to their length are within Second-Order Class II requirements and 87 percent are within First-Order requirements. Longer occupation times may help to improve some of the statistical values and baseline precisions if higher orders of accuracy are desired.

b. The second adjustment was run holding USC&GS HUDGINS fixed in three dimensions and P-13-2-89 fixed in two dimensions. This adjustment was performed to obtain the final adjusted horizontal positions of all of the photo control points occupied using GPS. After obtaining the adjusted positions from GEOLAB, terrestrial traverse computations were performed to obtain positions on the remaining photo control points. A partial listing of the output for adjustment two is shown in Figure E-19. Here, the statistical values and relative errors increased only slightly compared to adjustment one after holding a second point fixed. The relative precision of all baselines in the adjustment still exceed Second Order Class II requirements.

c. The third and final adjustment was ran holding USC&GS HUDGINS fixed in three dimensions and S 22 1974, HL-1 and HL-20 fixed in one dimension. All heights fixed in the adjustment were orthometric or relative to the geoid. If elevations relative to the geoid are desired, a separate vertical adjustment is required holding only one point fixed horizontally. Horizontal and vertical adjustments should not be combined because precisions in the horizontal plane will affect precisions in the vertical plane and vice versa. A partial listing of the output for adjustment three is shown in Figure E-20. Page 33 of the output indicates that the 1D confidence region for each station in the adjustment is less than 0.1 m.

E-7. Project Summary

Positions in 3D were developed for 23 photo control points as well as 2D positions for two new Type A monuments.

a. The field work for the survey was completed in approximately 35 hr with a task breakdown as follows.

(1) 8 hr for presurvey reconnaissance, 2-man crew.

```
------- --------- ----------------- ------------------------------ -
                U.S. ARMY CORPS OF ENGINEERS - MEMPHIS DISTRICT
        HORN LAKE CREEK PHOTO CONTROL - GPS STOP & GO KINEMATIC SURVEY
A=  6378137.000  B:  6356752.314  XO=       0.000  YO:       0.000  ZO=       0.000

PREPARE:

09:34:43 - Tuesday, October 09, 1990

Input from:    <GPS7K_l.iob>
Output to:     <GPS7K_l.LST>

PREPARE successfully completed.

--------------------------------------------------------------------------------
GeoLab - Vl.91S, (C)1985/86/87/BB/89 BitWise Ideas Inc. (103208976)  Page    O




--------------------------------------------------------------------------------
                U.S. ARMY CORPS OF ENGINEERS - MEMPHIS DISTRICT
        HORN LAKE CREEK PHOTO CONTROL -·GPS STOP & GO KINEMATIC SURVEY
A:  6378137.000 a:  6356752.314 XO:       0.000  YO:       0.000  ZO:       0.000
--------------------------------------------------------------------------------
GETUP:


 ---------------------------------------------------------------------------
:            PARAMETERS                              OBSERVATIONS            !
:-------------------------------------------------------------------------:
:  Description    :     Number       :  Description           Number      :
:-------------------------------------------------------------------------:
  All Stations                24        Directions                  0
  Fixed Stations   :           1        Distances                   0
  Free 3-D Stations           23        Azimuths                    0
  Free 2-D Stations            0        Vertical Angles             0
  Free 1-D Stations            0        Zenithal Angles             0
  Coord. Parameters           69        Angles                      0
  Astra. Latitudes             0        Heights                     0
  Astra. Longitudes            0        Height Differences          0
  Geoid Records                0        Auxiliary Params.           0
  All Aux. Pars.               0        2-D Coords.                 0
  Direction Pars.              0        2-D Coord. Diffs.           0
  Scale Parameters             0        3-D coords.                 0
  Constant Pars.               0        3-D Coord. Diffs.         156
  Rotation Pars.   :           0
  Translation Pars.:           0
                  '
                  '
  Total Parameters :          69        Total Observations        156
 ---------------------------------------------------------------------------
                      Degrees of Freedom :       87
 ---------------------------------------------------------------------------


 ---------------------------------------------------------------------------
 GeoLab - V1.91S, (C)1985/86/87/88/89 BitWise Ideas Inc. (103208976)  Page    1
```

Figure E-18. IVInimally constrained horizontal adjustment (Sheet 1 of 6)

```
                U.S. ARMY CORPS OF ENGINEERS  - MEMPHIS DISTRICT
        HORN LAKE CREEK PHOTO CONTROL - GPS STOP & GO KINEMATIC SURVEY
    6378137.000  6=  6356752.314  XO=       0.000  YO=       0.000  ZO:       0.000

RESID:

   0.4 -
R
e
l
a
t
i
v
e
   0.3 -
F
e
q
u
e
n
c
y
   O.Z -
   O.1
   +---+---+---+---+---+---+---+---+---+---+---+---+ --+---+---+---+---+---+---+
      -4      -3      -2      -1       0       1       2       3       4
                Histogram  of 3-D Coord  Diff  (156)  Standardized  Residuals

 ------- ----------------------------------------------------------------------
 Geolab-  V1.91S, (C) 1985/86/87/88/89 BitWise Ideas Inc.  [103208976)  Page  ZB
```

Figure E-18. (Sheet 2 of 6)

```
--------------------------------------------------------------------------------
                U.S. ARMY CORPS OF ENGINEERS - MEMPHIS DISTRICT
        HORN LAKE CREEK PHOTO CONTROL - GPS STOP & GO KINEMATIC SURVEY
A=  6378137.000  B=  6356752.314  XO=       0.000 YO=       0.000 ZO=       0.000
--------------------------------------------------------------------------------
RESID:



 ------------------------------------------------------------------------------

                   S T A T I S T I C S    S U M M A R Y

'-----------------------------------------------------------------------------

      Residual  Critical  Value  Type                      Tau Max
      Residual  Critical  Value                             3.6542
      Convergence Criterion                               0.001000
      Final Iteration counter Value                              2
      Confidence  Level Used                              95.0000
      Number of Flagged Residuals                              29
       stimated Variance Factor                            9.2151
      Number of Degrees of Freedom                             87

 ---------------------------------------- ----------------------------------:
                                                                            ¦
                   Chi-Square Test on the Variance Factor:

                   6.9901e+OOO  <  1.0000  <  1.2708e+001  ?

     !!!!¦!!!!!!!!!!!!!!!!!!!   THE TEST FAILS   !!!!!!!!!!!!!!!!!!!!!!!!!

 ------------------------------------------------------------------------------

RESID successfully  completed.


--------------------------------------------------------------------------------
GeoLab - V1.91S, (C) 1985/86/87/88/89 BitWise Ideas Inc. [103208976]  Page   29
```

Figure E-18. (Sheet 3 of 6)

U.S. ARMY CORPS OF ENGINEERS - MEMPHIS DISTRICT
HORN LAKE CREEK PHOTO CONTROL - GPS STOP & GO KINEMATIC SURVEY
A= 6378137.000 B= 6356752.314 XO= 0.000 YO= 0.000 ZO= 0.000

ELLIPSE:

2-D AND 1-D STATION CONFIDENCE REGIONS (95.000 %):

IDENT.	MAJOR SEMI-AXIS	MINOR SEMI-AXIS	AZ(MAJ)	VERTICAL
4098	0.0037	0.0030	145.07	0.0084
4097	0.0111	0.0098	104.55	0.0231
5211	0.0086	0.0079	76.51	0.0167
5221	0.0229	0.0137	4.04	0.0536
5208	0.0353	0.0135	1.88	0.0593
5213	0.0079	0.0059	114.15	0.0117
2099	0.0190	0.0128	23.44	0.0402
5212	0.0227	0.0085	9.19	0.0985
5214	0.0139	0.0078	153.79	0.0406
5215	0.0076	0.0055	160.93	0.0217
5216	0.0056	0.0035	157.21	0.0196
5217	0.0152	0.0107	143.90	0.0344
5219	0.0167	0.0103	11.22	0.0322
5220	0.0143	0.0096	17.16	0.0295
7212	0.0102	0.0073	24.15	0.0219
5222	0.0069	0.0057	87.95	0.0139
5224	0.0150	0.0122	94.27	0.0321
5223	0.0078	0.0063	101.33	0.0176
5209	0.0074	0.0060	66.59	0.0113
5218	0.0123	0.0097	128.12	0.0201
5206	0.0116	0.0086	142.23	0.0263
5201	0.0125	0.0082	28.16	0.0260
5203	0.0115	0.0044	8.95	0.0540

Geolab - V1.91S, (C) 1985/86/87/88/89 BitWise Ideas Inc. [103208976) Page 31

Figure E-18. (Sheet 4 of 6)

U.S. ARMY CORPS OF ENGINEERS - MEMPHIS DISTRICT
HORN LAKE CREEK PHOTO CONTROL - GPS STOP & GO KINEMATIC SURVEY

A= 6378137.000 B= 6356752.314 XO= 0.000 YO= 0.000 ZO= 0.000

ELLIPSE:

2-D AND 1-0 RELATIVE STATION CONFIDENCE REGIONS (95.000 %):

FROM	TO	MAJ.SEMI	MIN.SEMI	AZ(MAJ)	VERTICAL	SPATIA DIST.	PRECISION	
4098	4097	0.0110	0.0097	99.22	0.0227	366.6975	29.965	PPM
4098	5211	0.0082	0.0071	72.51	0.0145	2912.1464	2.824	PPM
4098	5221	0.0231	0.0140	3.76	0.0541	4613.1049	5.003	PPM
4098	5208	0.0353	0.0132	1.93	0.0591	2733.5199	12.901	PPM
4098	2099	0.0188	0.0124	23.86	0.0395	2209.5900	8.528	PPM
4098	5212	0.0226	0.0081	9.40	0.0983	2184.0854	10.334	PPM
4098	5214	0.0140	0.0078	153.61	0.0398	1476.6279	9.461	PPM
4098	5215	0.0079	0.0057	158.56	0.0214	801.5978	9.828	PPM
4098	5216	0.0060	0.0039	154.86	0.0183	542.8320	10.996	PPM
4098	5217	0.0151	0.0106	143.88	0.0340	661.3902	22.792	PPM
4098	5219	0.0168	0.0104	11.02	0.0324	2891.5861	5.799	PPM
4098	5220	0.0139	0.0091	18.11	0.0286	2566.7333	5.434	PPM
4098	7212	0.0097	0.0064	26.24	0.0204	2016.1771	4.824	PPM
4098	5222	0.0070	0.0059	89.23	0.0142	4430.4221	1.574	PPM
4098	5224	0.0150	0.0122	94.28	0.0321	5477.8680	2.742	PPM
4098	5213	0.0076	0.0056	114.08	0.0113	1463.0776	5.162	PPM
4098	5223	0.0080	0.0065	102.72	0.0180	5905.2055	1.354	PPM
4098	5209	0.0078	0.0067	68.72	0.0132	2151.8382	3.631	PPM
4098	5218	0.0119	0.0094	127.14	0.0189	1886.0709	6.326	PPM
4098	5206	0.0118	0.0088	142.32	0.0268	3467.4965	3.412	PPM
4098	5203	0.0114	0.0041	9.23	0.0538	5895.6948	1.932	PPM
4098	5201	0.0127	0.0084	27.81	0.0264	6501.9484	1.947	PPM
4098	3095	0.0037	0.0030	145.07	0.0084	6444.1890	0.580	PPM
4097	3095	0.0111	0.0098	104.55	0.0231	6257.9628	1.776	PPM
3095	5211	0.0086	0.0079	76.51	0.0167	3561.8762	2.428	PPM
3095	5208	0.0353	0.0135	1.88	0.0593	3860.2180	9.155	PPM
3095	5221	0.0229	0.0137	4.04	0.0536	2049.7519	11.170	PPM
3095	5213	0.0079	0.0059	114.15	0.0117	5423.8080	1.456	PPM
3095	2099	0.0190	0.0128	23.44	0.0402	6228.3592	3.056	PPM
3095	5212	0.0227	0.0085	9.19	0.0985	4670.3247	4.871	PPM
3095	5214	0.0139	0.0078	153.79	0.0406	5123.7279	2.718	PPM
3095	5215	0.0076	0.0055	160.93	0.0217	6286.9779	1.201	PPM
3095	5216	0.0056	0.0035	157.21	0.0196	6093.8864	0.915	PPM
3095	5217	0.0152	0,0107	143.90	0.0344	6657.5099	2.288	PPM
3095	5219	0.0167	0.0103	11.22	0.0322	3553.0160	4.696	PPM
3095	5220	0.0143	0.0096	17.16	0.0295	4130.2034	3.452	PPM
3095	7212	0.0102	0.0073	24.15	0.0219	5986.6100	1.705	PPM
3095	5222	0.0069	0.0057	87.95	0.0139	2948.5824	2.328	PPM
3095	5224	0.0150	0.0122	94.27	0.0321	2553.4890	5.881	PPM
3095	5223	0.0078	0.0063	101.33	0.0176	1964.3998	3.985	PPM
3095	5209	0.0074	0.0060	66.59	0.0113	4497.4302	1.649	PPM
3095	5218	0.0123	0.0097	128.12	0.0201	4558.2365	2.702	PPM
3095	5206	0.0116	0.0086	142.23	0.0263	4289.4530	2.703	PPM
3095	5201	0.0125	0.0082	28.16	0.0260	7706.4120	1,628	PPM

Geo ab - V1.91S, (C) 1965/86/87/88/89 BitWise Ideas Inc. [103208976] Page 32

Figure E-18. (Sheet 5 of 6)

U.S. ARMY CORPS OF ENGINEERS - MEMPHIS DISTRICT
HORN LAKE CREEK PHOTO CONTROL - GPS STOP & GO KINEMATIC SURVEY

A:: 6378137.000 8::: 6356752.314 XO::: 0.000 YO:: 0.000 ZO::: 0.000

ELLIPSE:

2-D AND 1-D RELATIVE STATION CONFIDENCE REGIONS (95.000 %):

FROM	TO	MAJ.SEMI	MIN.SEMI	AZ(MAJ)	VERTICAL	SPATIAL DIST.	PRECISION
3095	5203	0.0115	0.0044	8.95	0.0540	6734.0519	1.709 **PPM**

ELLIPSE successfully completed.
09:40:34 - Tuesday, October 09, 1990

Geolab- V1.91S, (C) 1985/86/87/88/89 BitWise Ideas Inc. (103208976) Page 33

Figure E-18. (Sheet 6 of 6)

```
                U.S. ARMY CORPS OF ENGINEERS - MEMPHIS DISTRICT
        HORN LAKE CREEK PHOTO CONTROL - GPS STOP & GO KINEMATIC SURVEY
A::  6378137.000 B=  6356752.314 XO:      0.000 YO=       0.000 ZO:::      0.000

PREPARE:

10:00:35 - Tuesday, October 09, 1990

Input from:    <GPS7K_2.iob>
Output to:     <GPS7K_2.LST>

PREPARE successfully completed.


--------------------------------------------------------------------------------
GeoLab - VL91S, (C) 1985/86/87/88/89 BitWise Ideas Inc. (103208976) Page    0



                U.S. ARMY CORPS OF ENGINEERS - MEMPHIS DISTRICT
        HORN LAKE CREEK PHOTO CONTROL - GPS STOP & GO KINEMATIC SURVEY
A:::  6378137.000 B=  6356752.314 XO::      0.000 YO=       0.000 ZO=      0.000
--------------------------------------------------------------------------------
GETUP:


 ---------------------------------------------------------------------------

 :-------------------------------------------------------------------------:
 :   Description              Number        :  Description      \      Number      :
 :-------------------------------------- -------------------------------------:
   All Stations                24            Directions                  0
   Fixed Stations    :          1            Distances                   0
   Free 3-D Stations:          23            Azimuths                    0
   Free 2-D Stations            0            Vertical Angles             0
   Free 1-D Stations            0            Zenithal Angles             0
   Coord. Parameter$           69            Angles                      0
   Astro. latitudes             0            Heights                     0
   Astro. longitudes            0            Height Differences          0
   Geoid Records All            0            Auxiliary Params.           0
   Aux. Pars.                   0            2-D Coords.
   Direction Pars.              0            2-D Coord. Diffs.           0
   Scale Parameters :           0            3-D Coords.                 0
   Constant Pars.   ¦           0            3-D Coord. Diffs.         156
   Rotation Pars.   :           0
   Translation Pars.:           0

 , Total Parameters :          69          , Total Observations:       158
 :-------------------------------------------------------------------------
 :                      Degrees of Freedom :::        89
 ---------------------------------------------------------------------------


--------------------------------------------------------------------------------
Geolab- Vl.91S, (C) 1985/86/87/88/89 BitWise Ideas Inc. [103208976) Page    1
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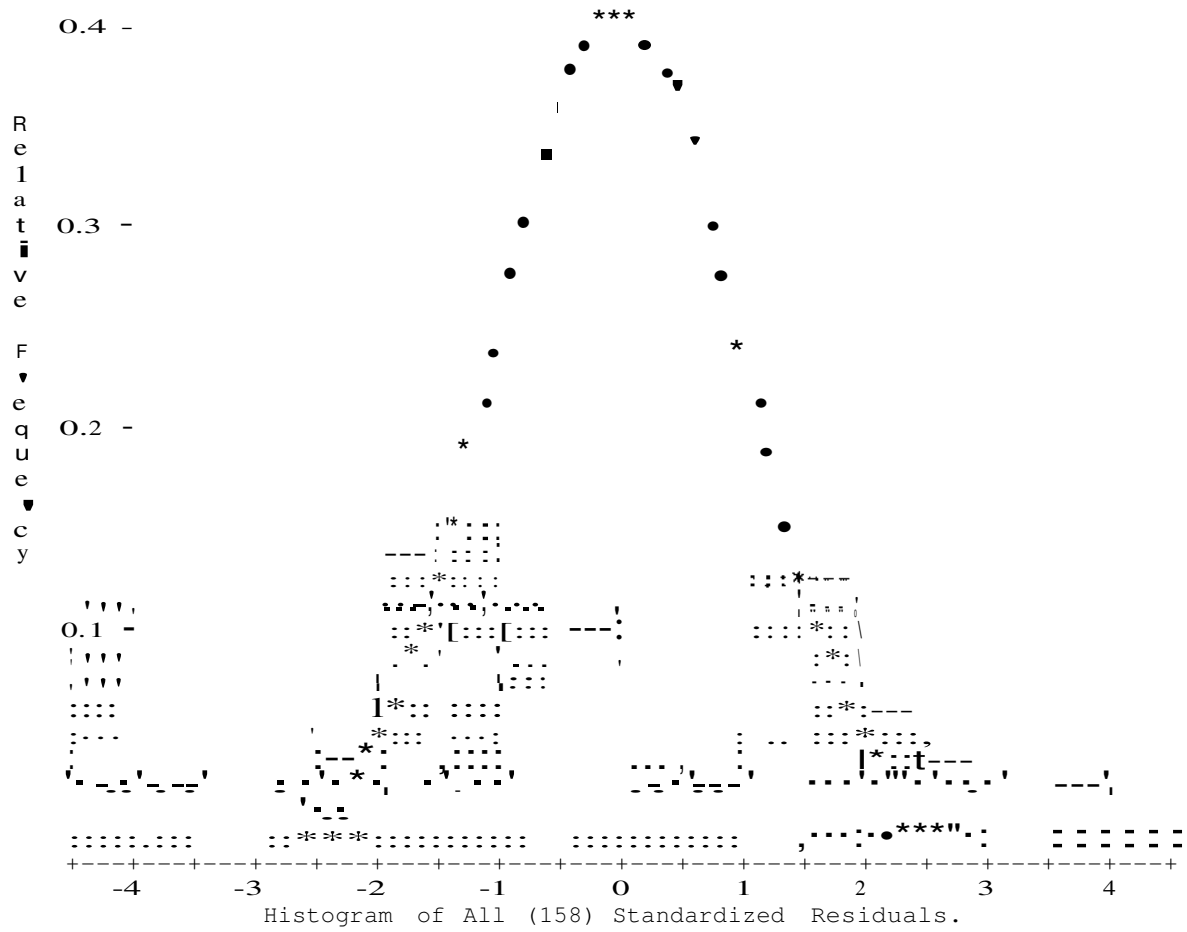
Figure E-19. Fully constrained horizontal adjustment (Sheet 1 of 6)

U.S. ARMY CORPS OF ENGINEERS - MEMPHIS DISTRICT
HORN LAKE CREEK PHOTO CONTROL - GPS STOP & GO KINEMATIC SURVEY

A 6378137.000 B= 6356752.314 XO= 0.000 YO= 0.000 ZO= 0.000

RESID:



GeoLab- V1.91S, (C) 1985/86/87/BB/89 BitWise Ideas Inc. (103208976] Page 30

Figure E-19. (Sheet 2 of 6)

```
                U.S. ARMY CORPS OF ENGINEERS - MEMPHIS DISTRICT
          HORN LAKE CREEK PHOTO CONTROL - GPS STOP & GO KINEMATIC SURVEY
A:  6378137.000 B=  6356752.314 XO=       0.000 YO=       0.000 ZO:       0.000
-------------------------------------------------------------------------------
RESID:


 ------------------------------------------------------------------------------

                    STATISTICS     S U M M A R Y

 ------------------------------------------------------------------------------

     Residual Critical Value Type                    Tau Max
     Residual Critical Value                          3.6597
     Convergence  Criterion                         0.001000
     Final Iteration Counter Value                         2
     Confidence Level Used                           95.0000
     Number of Flagged Residuals                          35
     Estimated Variance Factor                       13.2102
     Number of Degrees of Freedom                         89

 ------------------------------------------------------------------------------

                  Chi-SQuare  Test on the Variance  Factor:

                  1.0050e+OOl  <  1.0000  <  1.8146e+OOl  ?

     !!!!!!!!!!!!!!!!!!!!!!!!!!  THE TEST FAILS   !!!!!!!!!!!!!!!!!!!!!!!!!

 ------------------------------------------------------------------------------

RESID successfully  completed.


 GeoLab - Vl.91S,  (C) 1985/86/87/88/89 BitWise  Ideas  Inc.  (103208976)  Page   31
```

Figure E-19. (Sheet 3 of 6)

U.S. ARMY CORPS Of ENGINEERS - MEMPHIS DISTRICT
HORN LAKE CREEK PHOTO CONTROL - GPS STOP & GO KINEMATIC SURVEY

A:: 6378137.000 B= 6356752.314 XO= 0.000 YO= 0.000 ZO= 0.000

ELLIPSE:

2-0 AND 1-D STATION CONFIDENCE REGIONS (95.000 %);

!DENT.	MAJOR SEMI-AXIS	MINOR SEMI-AXIS	AZ(MAJ)	VERTICAL
4098	0.0040	0.0034	145.07	0.0099
4097	0.0133	0.0117	103.56	0.0276
5211	0.0103	0.0093	74.85	0.0199
5221	0.0274	0.0165	4.04	0.0642
5208	0.0423	0.0161	1.90	0.0710
5213	0.0094	0.0070	113.66	0.0140
2099	0.0228	0.0152	23.58	0.0481
5212	0.0272	0.0101	9.26	0.1179
5214	0.0167	0.0093	153.80	0.0486
5215	0.0090	0.0065	160.93	0.0259
5216	0.0066	0.0042	157.23	0.0235
5217	0.0182	0.0128	143.89	0.0411
5219	0.0200	0.0123	11.25	0.0385
220	0.0170	0.0114	17.47	0.03:;3
7212	0.0121	0.0085	24.83	0.0262
5222	0.0082	0.0068	87.45	0.0166
5224	0.0180	0.0146	94.13	0.0385
5223	0.0093	0.0075	101.03	0.0210
5209	0.0089	0.0072	66.56	0.0136
5218	0.0147	0.0116	127.81	0.0241
5206	0.0139	0.0103	142.23	0.0315
5201	0.0150	0.0098	28.21	0.0311
5203	0.0137	0.0052	9.10	0.0646

Geolab - Vl.91S, (C) 1985/86/87/88/89 BitWise Ideas Inc. (103208976] Page 33

Figure E-19. (Sheet 4 of 6)

U.S. ARMY CORPS OF ENGINEERS - MEMPHIS DISTRICT
HORN LAKE CREEK PHOTO CONTROL - GPS STOP & GO KINEMATIC SURVEY

A= 6378137.000 B= 6356752.314 XC= 0.000 YO= 0.000 ZO= 0.000

ELLIPSE:

2-0 AND 1-0 RELATIVE STATION CONFIDENCE REGIONS (95.000 %):

FROM	TO	MAJ.SEMI	MIN.SEMI	AZ(MAJ)	VERTICAL	SPATIAL DIST.	PRECISION
4098	4097	0.0131	0.0116	99.26	0.0271	366.6987	35.831 PPM
4098	5211	0.0098	0.0085	72.49	0.0174	2912.1468	3.381 PPM
4098	5221	0.0276	0.0167	3.85	0.0647	4613.1075	5.981 PPM
4098	5208	0.0422	0.0159	1.94	0.0707	2733.5206	15.445 PPM
4098	2099	0.0226	0.0149	23.87	0.0473	2209.5901	10.210 PPM
4098	5212	0.0270	0.0096	9.41	0.1176	2184.0857	12.372 PPM
4098	5214	0.0167	0.0093	153.65	0.0477	1476.6292	11.304 PPM
4098	5215	0.0093	0.0068	159.03	0.0256	801.5979	11.644 PPM
4098	5216	0.0070	0.0045	155.32	0.0219	542.8330	12.936 PPM
4098	5217	0.0180	0.0127	143.88	0.0407	661.3897	27.271 PPM
4098	5219	0.0200	0.0124	11.12	0.0388	2891.5879	6.933 PPM
4098	5220	0.0167	0.0109	18.11	0.0342	2566.7336	6.506 PPM
4098	7212	0.0116	0.0077	26.24	0.0244	2016.1771	5.776 PPM
4098	5222	0.0083	0.0070	88.31	0.0170	4430.4238	1.873 PPM
4098	5224	0.0180	0.0146	94.14	0.0385	5477.8695	3.280 PPM
4098	5213	0.0090	0.0067	113.86	0.0135	1463.0782	6.169 PPM
4098	5223	0.0095	0.0077	101.99	0.0215	5905.2073	1.611 PPM
4098	5209	0.0093	0.0078	67.94	0.0157	2151.8403	4.314 PPM
4098	5218	0.0143	0.0112	127.13	0.0226	1886.0714	7.572 PPM
4098	5206	0.0141	0.0105	142.28	0.0321	3467.4980	4.065 PPM
4098	5203	0.0136	0.0049	9.29	0.0644	5895.6951	2.311 PPM
4098	5201	0.0151	0.0100	27.97	0.0315	6501.9487	2.326 PPM
4098	3095	0.0040	0.0034	145.07	0.0099	6444.1920	0.620 PPM
4097	3095	0.0133	0.0117	103.56	0.0276	6257.9643	2.119 PPM
3095	5211	0.0103	0.0093	74.85	0.0199	3561.8789	2.885 PPM
3095	5208	0.0423	0.0161	1.90	0.0710	3860.2203	10.956 PPM
3095	5221	0.0274	0.0165	4.04	0.0642	2049.7523	13.373 PPM
3095	5213	0.0094	0.0070	113.66	0.0140	5423.8102	f.726 PPM
3095	2099	0.0228	0.0152	23.58	0.0481	6228.3617	3.653 PPM
3095	5212	0.0272	0.0101	9.26	0.1179	4670.3272	5.823 PPM
3095	5214	0.0167	0.0093	153.80	0.0486	5123.7294	3.250 PPM
3095	5215	0.0090	0.0065	160.93	0.0259	6286.9790	1.435 PPM
3095	5216	0.0066	0.0042	157.23	0.0235	6093.8876	1.090 PPM
3095	5217	0.0182	0.0128	143.89	0.0411	6657.5119	2.732 PPM
3095	5219	0.0200	0.0123	11.25	0.0385	3553.0171	5.620 PPM
3095	5220	0.0170	0.0114	17.47	0.0353	4130.2059	4.118 PPM
3095	7212	0.0121	0.0085	24.83	0.0262	5986.6129	2.026 PPM
3095	5222	0.0082	0.0068	87.45	0.0166	2948.5833	2.778 PPM
3095	5224	0.0180	0.0146	94.13	0.0385	2553.4896	7.035 PPM
3095	5223	0.0093	0.0075	101.03	0.0210	1964.4001	4.759 PPM
3095	5209	0.0089	0.0072	66.56	0.0136	4497.4308	1.974 PPM
3095	5218	0.0147	0.0116	127.81	0.0241	4558.2390	3.215 PPM
3095	5206	0.0139	0.0103	142.23	0.0315	4269.4539	3.234 PPM
3095	5201	0.0150	0.0098	28.21	0.0311	7706.4128	1.948 PPM

GeoLab - V1.91S, (c) 1985/86/87/86/89 8itWise Ideas Inc. (103208976) Page 34

Figure E-19. (Sheet 5 of 6)

U.S. ARMY CORPS OF ENGINEERS - MEMPHIS DISTRICT
HORN LAKE CREEK PHOTO CONTROL - GPS STOP & GO KINEMATIC SURVEY

A 6378137.000 B:: 6356752.314 XO::: 0.000 YO= 0.000 ZO= 0.000

ELLIPSE:

2-D AND 1-D RELATIVE STATION CONFIDENCE REGIONS (95.000 %):

FROM	TO	MAJ.SEMI	MIN.SEMI	AZ(MAJ)	VERTICAL	SPATIAL DIST.	PRECISION
3095	5203	0.0137	0.0052	9.10	0.0646	6734.0532	2.040 PPM

ELLIPSE successfully completed.
10:06:34 - Tuesday, October 09, 1990

GeoLab- V1.91S, (C) 1985/86/97/89/89 BitWise Ideas Inc. (103209976) Page 35

Figure E-19. (Sheet 6 of 6)

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                U.S. ARMY CORPS OF ENGINEERS - MEMPHIS DISTRICT
        HORN LAKE CREEK PHOTO CONTROL - GPS STOP & GO KINEMATIC SURVEY
A:::  6378137.000 8:   6356752.314 XO=       0.000> YO:       0.000  ZO:::       0.000

PREPARE:

10:29:30 - Tuesday, October 09, 1990

Input from:    <GPS7K_3.iob>
Output to:     <GPS7K_3.LST>

PREPARE successfully completed.

Geolab - V1.91S, (C) 1985/86/87/88/89 BitWise Ideas Inc.  Page 0


                U.S. ARMY CORPS OF ENGINEERS - MEMPHIS DISTRICT
        HORN LAKE CREEK PHOTO CONTROL - GPS STOP GO KINEMATIC SURVEY
A=  6378137.000  8::  6356752.314  XO=       0.000  YO=       0.000  ZO=       0.000

GETUP:


 PARAMETERS                                  OBSERVATIONS
 Description        Number          Description        Number
 All Stations          24           Directiens            0
 Fixed Stations    :    1           Distances             0
 Free 3-D Stations:    23           Azimuths              0
 Free 2-D Stations:    0            Vertical Angles       0
 Free 1-D Stations:    0            Zenithal Angles       0
 Coord. Parameters:    69           Angles                0
 Astra. L.atitudes  :  0            Heights
 Astra. Longitudes:    0            Height Differences    0
 Geoid Records         0            Auxiliary Params.     0
 All Aux. Pars.        0            2-D Coords.           0
 Direction Pars.       0            2-D Coord. D1ffs.     0
 Scale Parameters      0                Coards.           0
 Constant Pars.        0                Coord. Diffs.     156
 Rotation Pars.        0
 Translation Pars.     0

 Total Parameters      69           Total Observations    159

                    Degrees of Freedom =        90


GeoLab- V1.91S, (C) 1985/86/87/88/89 BitWise Ideas Inc. [103208976]  Page    1
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Figure E-20. Fully constrained vertical adjustment (Sheet 1 of 6)

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U.S. ARMY CORPS OF ENGINEERS - MEMPHIS DISTRICT
HORN LAKE CREEK PHOTO CONTROL - GPS STOP & GO KINEMATIC SURVEY
A   6378137.000 8=   6356752.314 XO:::       0.000 YO=       0.000 ZO=       0.000
RESID:

0.4 -
0.3 -
0.2 -
0.1 -
-4   -3   -2   -1   0   1   2   3   4
Histogram of All (159) Standardized Residuals.
GeoLab - V1.91S, (C) 1985/86/87/BB/89 BitWise Ideas Inc. (103-208976) Page 30
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Figure E-20. (Sheet 2 of 6)

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--------------------------------------------------------------------------------
                U.S. ARMY CORPS Of ENGINEERS - MEMPHIS DISTRICT
        HORN LAKE CREEK PHOTO CONTROL - GPS STOP & GO KINEMATIC SURVEY
A=  6378137.000 B=  6356752.314 XO=       0,000 YO=       0.000 ZO=       0.000

RESID:


                    STATISTICS    SUMMARY


      Residual Critical Value Type                    Tau  Max
      Residual Critical Value                          3.6624
      Convergence  Criterion                          0.001000
      Final  Iteration  Counter  Value                     2
      confidence  Level  Used                         95.0000
      Number  of  Flagged  Residuals                      30
      Estimated  Variance  Factor                      9.3212
      Number of Degrees of Freedom                        90
 ----------------------------------------------------------------------------:

                  Chi-Square  Test  on  te Variance  Factor:

                  7.1012e+000  <  1.0000  <  1.2779e+001  ?

     !!!!/!!!!!!!!!!!!!!!!!!!!   THE  TEST  FAILS   !!!!!!!!!!!!!!!!!!!!!!!!

RESID successfully  completed.


GeoLab - VL91S, (C) 1985/86/87/88/89 BitWise Ideas Inc. [103208976] Page  >1
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Figure E-20. (Sheet 3 of 6)

U.S. ARMY CORPS OF ENGINEERS - MEMPHIS DISTRICT
HORN LAKE CREEK PHOTO CONTROL - GPS STOP & GO KINEMATIC SURVEY

A= 6376137.000 B= 6356752.314 XO:: 0.000 YO= 0.000 ZO= 0.000

ELLIPSE:

2-D AND 1-0 STATION CONFIDENCE REGIONS (95.000 %):

IDENT.	MAJOR SEMI-AXIS	MINOR SEMI-AXIS	AZ(MAJ)	VERTICAL
4096	0.0037	0.0030	144.69	0.0080
4097	0.0112	0.0099	104.44	0.0232
5211	0.0087	0.0079	76.37	0.0166
5221	0.0230	0.0136	4.04	0.0539
5208	0.0355	0.0136	1.89	0.0596
5213	0.0079	0.0060	114.13	0.0117
2099	0.0129	0.0125	134.78	0.0006
5212	0.0229	0.0086	9.20	0.0990
5214	0.0140	0.0076	153.78	0.0407
5215	0.0076	0.0055	160.67	0.0217
5216	0.0056	0.0035	157.13	0.0196
5217	0.0153	0.0108	143.89	0.0345
5219	0.0166	0,0103	11.22	0.0323
5220	0.0098	0.0087	129.60	0.0006
7212	0.0103	0.0073	24.26	0.0219
5222	0.0069	0.0058	67.89	0.0139
5224	0.0151	0.0123	94.25	0.0323
5223	0.0079	0.0063	101.29	0.0176
5209	0.0075	0.0060	66.59	0.0114
5218	0.0124	0,0098	128.06	0.0201
5206	0.0117	0.0066	142.23	0.0264
5201	0.0090	0.0082	31.01	0.0006
5203	0.0116	0.0044	8.97	0.0542

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Figure E-20. (Sheet 4 of 6)

U.S. ARMY CORPS OF ENGINEERS - MEMPHIS DISTRICT
HORN LAKE CREEK PHOTO CONTROL - GPS STOP & GO KINEMATIC SURVEY

A= 6378137.000 B= 6356752.314 XO: 0.000 YO= 0.000 ZO: 0.000

ELLIPSE:

2-0 AND 1-D RELATIVE STATION CONFIDENCE REGIONS (95.000 %):

FROM	TO	HAJ.SEMI	MIN.SEHI	Al(HAJ)	VERTICAL	SPATIAL OIST.	PRECISION
4098	4097	0.0110	0.0098	99.29	0.0228	366.6974	30.134 PPM
4098	5211	0.0083	0.0072	72.51	0.0146	2912.1465	2.841 PPM
4098	5221	0.0232	0.0141	3.77	0.0543	4613.1048	5.031 PPM
4098	5208	0.0355	0.0133	1.94	0.0594	2733.5198	12.975 PPM
4098	2099	0.0127	0.0123	153.61	0.0080	2209.5932	5.731 PPM
4098	5212	0.0227	0.0081	9.40	0.0988	2184.0853	10.393 PPM
4098	5214	0.0141	0.0078	153.61	0.0401	1476.6279	9.515 PPM
4098	5215	0.0079	0.0058	158.62	0.0215	801.5977	9.882 PPM
4098	5216	0.0060	0,0039	154.93	0.0184	542.8319	11.054 PPM
4098	5217	0.0152	0.0106	143.88	0.0342	661.3901	22.922 PPM
4098	5219	0.0169	0.0105	11.04	0.0326	2891.5859	5.832 PPM
4098	5220	0.0093	0.0084	140.18	0.0080	2566.7382	3.642 PPM
4098	7212	0.0098	0.0064	26.24	0.0205	2016.1771	4.852 PPM
4098	5222	0.0070	0.0059	89,11	0.0142	4430.4221	1.583 PPM
4098	5224	0.0151	0.0123	94.26	0.03'23	5477.8680	2.758 PPM
4098	5213	0,0076	0.0056	113.97	0.0113	1463.07?4	5.189 PPM
4098	5223	0.0080	0.0065	102.62	0.0180	5905.2054	1.361 PPM
4098	5209	0.0079	0.0067	66.68	0.0131	2151.8379	3.652 PPM
4098	5218	0.0120	0.0094	127.14	0.0190	1886.0709	6.362 PPM
4098	5206	0.0119	0.0088	142.30	0.0269	3467.4963	3.430 PPM
4098	5203	0.0115	0.0041	9.24	0.0541	5895.6947	1.943 PPM
4098	5201	0.0092	0,0085	23.95	0.0080	6501.9478	1.419 PPM
4098	3095	0.0037	0.0030	144.69	0.0080	6444.1888	0.579 PPM
4097	3095	0.0112	0.0099	104.44	0.0232	6257.9628	1.785 PPM
3095	5211	0.0087	0.0079	76.37	0.0166	3561.8760	2.441 PPM
3095	5208	0.0355	0.0136	1.89	0.0596	3860.2179	9.207 PPM
3095	5221	0.0230	0.0138	4.04	0.0539	2049.7519	11.234 PPM
3095	5213	0.0079	0.0060	114.13	0.0117	5423.8080	1.464 PPM
3095	2099	0.0129	0.0125	134.78	0.0006	6228.3515	2.073 PPM
3095	5212	0.0229	0.0086	9.20	0.0990	4670.3246	.4.898 PPM
3095	5214	0.0140	0.0078	153.78	0.0407	5123.7278	2.733 PPM
3095	5215	0.0076	0.0055	160,87	0.0217	6286.9777	1.207 PPM
3095	5216	0.0056	0.0035	157.13	0.0196	6093.8863	0.919 PPM
3095	5217	0.0153	0.0108	143.89	0.0345	6657.5098	2.301 PPM
3095	5219	0.0168	0.0103	11.22	0.0323	3553.0159	4.723 PPM
3095	5220	0.0098	0.0087	129.60	0.0006	4130.1976	2.364 PPM
3095	7212	0.0103	0.0073	24.26	0.0219	5986.6100	1.714 PPM
3095	5222	0.0069	0.0058	87.89	0.0139	2948.5823	2.341 PPM
3095	5224	0.0151	0.0123	94.25	0.0323	2553.4888	5.915 PPM
3095	5223	0.0079	0.0063	101.29	0.0176	1964.3997	4.007 PPM
3095	5209	0.0075	0.0060	66.59	0.0114	4497.4302	1.659 PPM
3095	5218	0.0124	0.0098	128.06	0.0201	4558.2364	2.717 PPM
3095	5206	0.0117	0.0086	142.23	0.0264	4289.4530	2.719 PPM
3095	5201	0.0090	0.0082	31.01	0.0006	7706.4127	1.165 PPM

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Figure E-20. (Sheet 5 of 6)

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                U.S. ARMY CORPS OF ENGINEERS - MEMPHIS DISTRICT
        HORN LAKE CREEK PHOTO CONTROL - GPS STOP & GO KINEMATIC SURVEY
A=  6378137.000  8::  6356752.314  XO=       0.000  YO=       0.000  ZO=       0.000
--------------------------------------------------------------------------------
ELLIPSE:

2-D AND 1-0 RELATIVE STATION CONFIDENCE REGIONS  ( 95.000 %):

FROM     TO       MAJ.SEMI  MIN.SEMI  AZ(MAJ)  VERTICAL  SPATIAL DIST.    PRECISION

3095     5203       0.0116    0.0044    8.97   0:0542     6734.0520    1.718 PPM

ELLIPSE succes fully completed.
10:36:17 - Tuesday, October 09, 1990

GeoLab- V1.91S, (C) 1985/86/87/88/89 BitWise Ideas Inc. [103208976] Page 35
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Figure E-20. (Sheet 6 of 6)

(2) 5 hr to set temporary photo control points and obtain visibility information at each site, 2-man crew.

(3) 2 hr to install two Type A monuments, 3-man crew.

(4) 5 hr to perform necessary Third-Order traverse and leveling, 4-man crew.

(5) 15 hr to collect static and stop-and-go GPS data, 5-man crew.

b. A conservative estimate of the field operations required by a 4-man party to 3D-position the 23 photo control points using conventional terrestrial methods was approximately 70 hr. The accuracies obtained from the final horizontal adjustment of the GPS data exceeded the requirements of the project. The accuracies obtained from the final vertical adjustment of the GPS data met the requirements.

Appendix F
Field Reduction and Adjustment of GPS Surveys

F-1. General

This appendix contains sample data reduction, adjustment, and analysis of GPS surveys. It is intended for guidance to field personnel performing field-to-finish survey work with the GPS. GPS survey data can (and should) be evaluated as soon as possible after observations are completed, preferably within 1 or 2 days. This appendix covers evaluation of internal closures, external closures, adjustment techniques, and evaluation of the adequacy of these results. A PC-based least squares adjustment package is not necessary to perform acceptable final field adjustments. Most USACE GPS work, other than baseline reductions, can be analyzed and adequately adjusted using simple hand-held calculators, as shown herein.

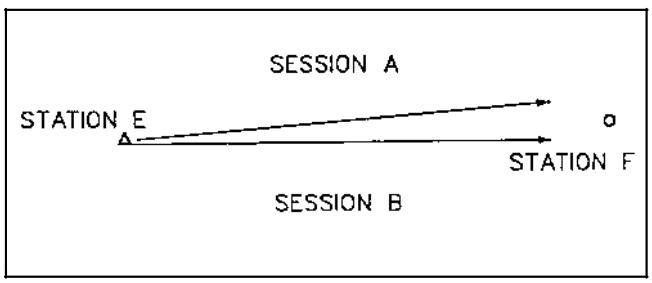

Figure F-1. Spur line adjustment

F-2. Mean Coordinate Adjustment of Spur Lines

If spur lines are observed twice between points E and F, as shown in Figure F-1, a simple mean adjustment computation is recommended. This method is applicable not only to carrier phase measurements but also code phase positioning techniques. It is important that the user determine the acceptable closure limits. This evaluation simply involves comparing the differences between multiple sessions taken over the same baseline. Alternately, a double spur line can be considered as a loop, from which the internal loop closure can be computed. Two independent baseline sessions were observed between points E and F, as shown in Table F-1.

The known geocentric coordinates of point E are:

X = 1108302.838
Y = -4856338.733
Z = 3970134.434

Computing the 3D misclosure between the vectors:

$$(0.002^2 + (-)0.002^2 + 0.001^2)^{1/2} = 0.003 \text{ m}$$

$$\text{3D vector distance} = (113.841^2 + 44.284^2 + 18.800^2)^{1/2} = 123.589 \text{ m}$$

The relative accuracy estimate between the two vectors is then:

0.003/123.589 or 1:41,200 (acceptable)

Given the acceptable check between the two observations, the vectors for the two sessions can be simply averaged. Since E is the known station, the mean vector components shown in Table F-1 can be applied to the geocentric coordinates of E to position station F.

Point E adjusted geocentric coordinates:

X = 1108302.838 + (-)113.841 = 1108188.997
Y = -4856338.733 + 44.284 = -4856294.449
Z = 3970134.434 + 18.800 = 3970153.234

Final geographic coordinates and/or SPCS coordinates of point F can then be transformed using the techniques

Table F-1
Baseline Sessions

Vector	Julian Day	Baseline Session	DX m	DY m	DZ m
E-F	135	A	-113.842	44.283	18.800
E-F	135	B	-113.840	44.285	18.799
Vector Differences			0.002	-0.002	0.001
Mean Vector Component			-113.841	44.284	18.800

given in Chapter 11. The position should be identified as a "no check" point as would be done in conventional survey practice.

F-3. Field Adjustment of GPS Triangle

This example illustrates the various methods which may be used to evaluate the internal and external accuracies of a GPS survey in the field. In addition, both an approximate and rigorous least squares adjustment are performed on the same GPS data to illustrate the small differences in results.

Multiple GPS baseline sessions are observed on the triangle ETLE-HEC2-ETLN, as shown in Figure F-2. Station ETLN is the unknown point for which coordinates are desired to an accuracy of 1 part in 10,000 (Third-Order, Class I). Stations ETLE and HEC2 are fixed, with the following geocentric (WGS 84) metric coordinates:

	X	Y	Z
HEC2	1108302.838	-4856338.733	3970134.434
ETLE	1108314.518	-4856507.916	3969923.835
Diff:	-11.680	169.183	210.599

(The above geocentric coordinates may have been computed in the field using the algorithms given in Chapter 11 on either NAD 83 or NAD 27 datums)

Observed and mean vectors from the baseline reductions are shown in Tables F-2 and F-3.

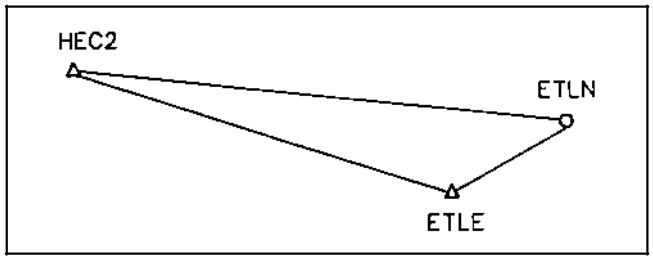

Figure F-2. GPS triangle vector adjustment

F-4. Internal GPS Loop Closure Check

A loop closure check is performed by arbitrarily letting one set of coordinates equal to zero, then algebraically adding vector components around the loop back to the initial point. Care must be taken in applying the correct vector signs based on the observed vector direction.

Letting station ETLE be fixed (X = Y = Z = 0), and using Session A for line ETLE-HEC2 and ETLE-ETLN and Session B for line ETLN-HEC2, and proceeding counterclockwise around the loop:

$$x = 98.418 + (-110.083) + (-)(-11.676) = +0.011 \text{ m}$$

$$y = 9.929 + (-)(-159.250) + (-)169.179 = 0.000 \text{ m}$$

Table F-2
Observed Vectors from Sessions A and B

Vector	Session	dx	dy	dz
ETLE-ETLN	A	98.418	9.929	-30.837
ETLE-HEC2	A	-11.676	169.179	210.612
ETLN-HEC2	A	-110.094	159.251	241.448
ETLE-ETLN	B	98.405	9.932	-30.834
ETLE-HEC2	B	-11.676	169.184	210.602
ETLN-HEC2	B	-110.083	159.250	241.444

Table F-3
Mean Vector Components for Sessions A and B

Mean Vector	dx	dy	dz	Distance
ETLE-ETLN	98.412	9.930	-30.836	103.607
ETLE-HEC2	-11.676	169.182	210.607	270.396
ETLN-HEC2	-110.089	159.251	241.446	309.478

z = -30.837 +(-)(-241.444) + (-)210.612 = (-)0.005 m

(Note that any sequence of session vectors could have been used to perform this check)

Linear 3D closure = $(0.011^2 + 0.000^2 + -0.005^2)^{1/2}$
= 0.012 m

3D vector distance = (103.607 + 270.396 + 309.478)
= 683.5 m

Where the individual vector distances were computed by taking the square of the sum of the squares of the component vectors.

The relative accuracy estimate of the loop closure is then:

0.012/683.5 or 1:57,000 (acceptable)

This relative accuracy estimate (1 part in 57,000) is based on the internal loop closure results, and indicates that the basic GPS observations are acceptable for subsequent constrained adjustment of station ETLN in the fixed network of HEC2 and ETLE.

F-5. Verification of GPS Distances Over Fixed Baselines

The following computation checks the adequacy of the GPS observations over the existing fixed network, i.e., between HEC2 and ETLE. Computing the difference between the mean session vector (from Table F-3) and true vector components over the fixed baseline between ETLE and HEC2:

Delta X = -11.676 - -11.680 = 0.004
Delta Y = 169.182 - 169.183 = -0.001
Delta Z = 210.607 - 210.599 = 0.008

The linear misclosure over the baseline is then checked relative to the length of the line:

Linear 3D closure = $(0.004^2 + 0.001^2 + 0.008^2)^{1/2}$
= 0.009 m

The relative accuracy estimate of the baseline closure is then:

0.009/270.4 or 1:30,000 (OK)

This indicates that the observed baseline vector agrees with the fixed control scheme on the order of 1 part in 30,000. Had this check been poor--say only 1 part in 2,500--this would more than likely indicate a problem with the fixed control network, given the excellent internal loop closures obtained. In such instances, additional fixed control points would have to be connected.

F-6. External Closure Verification (GPS Traverse)

This computation illustrates the process for checking the external closure on a GPS traverse run from ETLE to ETLN, and closing on HEC2 (i.e., vector ETLE-ETLN (Session A) and vector ETLN-HEC2 (Session B)). The GPS traverse vectors (Figure F-3) are summed forward as described previously.

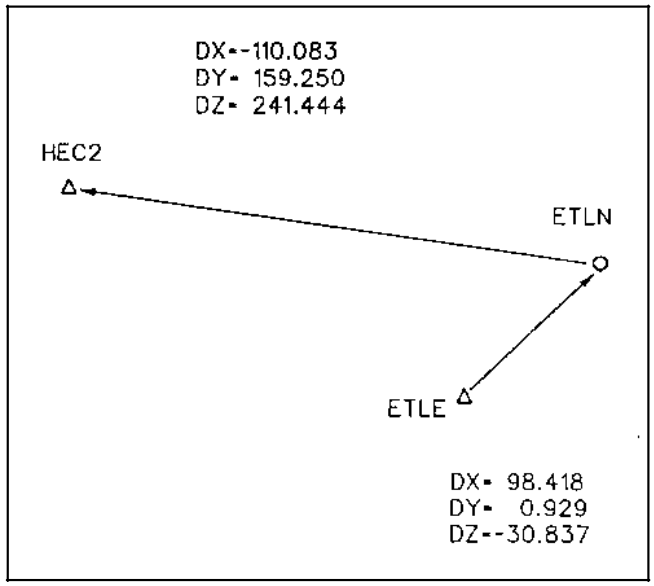

Figure F-3. External traverse closure checks

X_{HEC2} = 1108314.518 + 98.418 +(-110.083)
= 1108302.853

Y_{HEC2} = -4856507.916 + 9.929 + 159.250
= -4856338.737

Z_{HEC2} = 3969923.835 +(-30.837) + 241.444
= 3970134.442

Comparing the difference between these computed points and the fixed (i.e., published) points for HEC2:

X = measured/computed coordinate - true coordinate

= 1108302.853 - 1108302.838 = 0.015 m

Y = -4856338.737 - (-4856338.733) = (-) 0.004 m

Z = 3970134.442 - 3970134.434 = 0.008 m

The linear misclosure at the traverse closing point (HEC2) then checked relative to the total length of the traverse. This is performed similarly to conventional traverses except that three dimensions and no azimuth misclosures are involved:

$$\text{Linear 3D closure} = (0.015^2 + 0.004^2 + 0.008^2)^{1/2} = 0.017 \text{ m}$$

3D traverse length = 103.6 + 309.5 = 413.1 m

The relative accuracy estimate of the absolute (external) traverse closure is then:

0.017/413.1 or 1:24,000 (OK)

This result is consistent with the previous check over the fixed baseline ETLE-HEC2 and the internal loop closure results. (In practice, GPS traverses will have more legs than this example, and a GPS observation may not have been made between fixed network points.)

The misclosures at HEC2 could be balanced over the two traverse legs using one of the traverse balancing methods given in Chapter 11. From this, the adjusted coordinates of ETLN could be obtained. Since this involves more computation, the simple mean adjustment method in paragraph F-7 is more practical.

F-7. Approximate Adjustment of ETLN Using Mean Coordinate Values

The coordinates of station ETLN are then computed by finding the mean of the coordinates as computed forward from each fixed station, using the mean vectors in Table F-3:

$$X_{ETLN}(1) = X_{ETLE} + dx_{ETLE\text{-}ETLN} = 1108314.518 + 98.412 = 1108412.930$$

$$X_{ETLN}(2) = X_{HEC2} + dx_{HEC2\text{-}ETLN} = 1108302.838 + 110.089 = 1108412.927$$

(Note the sign of the vector HEC2-ETLN is reversed from that observed -- ETLN-HEC2)

Given the small X-coordinate difference (3 mm), a simple mean adjustment is justified, as opposed to a more rigorous and time-consuming least squares adjustment.

$$\text{Mean } X_{ETLN} = [\, X_{ETLE}(1) + X_{ETLE}(2) \,] / 2 = [\, 1108412.930 + 1108412.927 \,] /2 = 1108412.928$$

The averaged Y and Z coordinates of ETLN are also computed in a manner similar to that for the X:

$$\text{Mean } Y_{ETLN} = -4856497.985$$

$$\text{Mean } Z_{ETLN} = 3969892.994$$

F-8. Least Squares Adjustment Using FILLNET

To compare the results of this approximate mean adjustment with a least squares solution, all baseline observations from Sessions A and B were input into FILLNET.

Each GPS baseline was given equal relative weighting, as shown. The output from the FILLNET adjustment is shown in Figure F-4 and includes annotations denoting significant statistics resulting from the adjustment. The resultant standard error of unit weight and normalized residuals are significantly below the nominal value of "1.0" indicating that the initial (i.e., a priori) baseline relative weighting ($\pm$5H/10V mm + 2 ppm) was somewhat high. None of the normalized residuals exceeded three times the standard error of unit weight ($\pm$1.95); thus, no observations would be rejected.

The relative line accuracy estimates all exceed 1:10,000; thus the constrained survey meets intended accuracy criteria. Since the FILLNET relative precision estimates are given at the 1-sigma level, they must be divided by 2 to relate to FGCC standards at the 2-sigma (95 percent confidence) level. Thus, the smallest ratio from ETLE to ETLN (1:24,313) is evaluated as 1:12,156 in order to assess compliance with FGCC Third-Order (I) criteria.

The resultant adjusted position of ETLN (in NAD 83 geographical coordinates) from this FILLNET run was:

Latitude: 38° 44' 26.43969"

Longitude: 77° 08' 36.34637"

These coordinates may then be transformed to X-Y-Z geocentric coordinates using the HP calculator algorithms given in Chapter 11 and then compared with the meaned values from the preceding approximate adjustment:

$$\text{L/S } X_{ETLN} = 1108412.928$$

$$\text{L/S } Y_{ETLN} = -4856497.986$$

$$\text{L/S } Z_{ETLN} = 3969893.000$$

```
PROGRAM FILLNET, Version 3.0.00
LICENSED TO: ASHTECH INC.


Fillnet Input File  jim                     38.7    77.1

a =  6378137.000    1/f =  298.2572235   W      Longitude positive WEST

PRELIMINARY COORDINATES:
                       LAT.             LON.        ELEV.    G.H.  CONSTR.

   1  FFF   ETLE 38 44 27.46754   77  8 40.41060    -7.020   0.000
   2        ETLN 38 44 26.61017   77  8 36.40653     8.066   0.000
   3  FFF   HEC2 38 44 36.19465   77  8 39.32344    -5.900   0.000

GROUP 1, NO. OF VECTORS AND BIAS CONSTRAINTS:

   6      0.000  0.001    0.000  0.000    0.000  0.000    0.000  0.000

VECTORS:
                    DX         DY         DZ      LENGTH   ERROR CODES

ETLE   ETLN      98.418      9.929    -30.837    103.613  5 52.0 102.0  3
ETLN   HEC2    -110.094    159.251    241.448    309.481  5 52.0 102.0  3
ETLE   HEC2     -11.676    169.184    210.602    270.394  5 52.0 102.0  4
ETLE   ETLN      98.405      9.932    -30.834    103.600  5 52.0 102.0  4
ETLE   HEC2     -11.676    169.184    210.602    270.394  5 52.0 102.0  4
ETLN   HEC2    -110.083    159.250    241.444    309.474  5 52.0 102.0  4

SHIFTS:
    1   0.000   0.000   0.000
    2  -5.258   1.454 -24.857
    3   0.000   0.000   0.000

ADJUSTED VECTORS, GROUP 1:
                           DX,DY,DZ   V       DN,DE,DU   v      v'

ETLE   ETLN     253 A        98.411 -0.005     -31.750  0.001   0.2
                              9.932  0.002      98.145 -0.005  -0.8
                            -30.837 -0.001      -9.689 -0.004  -0.3

ETLN   HEC2     253 A      -110.092  0.005     300.849 -0.004  -0.6
                            159.251  0.001     -71.760  0.005   0.8
                            241.436 -0.004      10.627 -0.002  -0.2

ETLE   HEC2     253 B       -11.680 -0.000     269.099  0.002   0.3
                            169.183 -0.001      26.385 -0.001  -0.1
                            210.600  0.003       0.938  0.003   0.2

ETLE   ETLN     253 B        98.411  0.008     -31.750 -0.005  -0.7
                              9.932 -0.001      98.145  0.007   1.0
                            -30.837 -0.004      -9.689 -0.001  -0.1

ETLE   HEC2     253 B       -11.680 -0.000     269.099  0.002   0.3
                            169.183 -0.001      26.385 -0.001  -0.1
                            210.600  0.003       0.938  0.003   0.2

ETLN   HEC2     253 B      -110.092 -0.006     300.849  0.001   0.2
                            159.251  0.002     -71.760 -0.006  -0.8
                            241.436 -0.000      10.627 -0.003  -0.2

S.E. OF UNIT WEIGHT =     0.593
```

Figure F-4. FILLNET least squares adjustment of ETLN (Continued)

```
NUMBER OF -
   OBS. EQUATIONS              19
   UNKNOWNS                     7
   DEGREES OF FREEDOM          12
   ITERATIONS                   0


GROUP  1 ROT. ANGLES (sec.) AND SCALE DIFF. (ppm):

HOR. SYSTEM          0.000   3.133  -2.570 -15.571
STD. ERRORS          0.001   3.618   1.807   8.762
XYZ SYSTEM           2.606   2.655  -1.607

ADJUSTED POSITIONS:

                   LAT.             LON.         ELEV.    STD. ERRORS (m)

   1  ETLE    38 44 27.46754   77  8 40.41060    -7.020 0.000 0.000 0.000
   2  ETLN    38 44 26.43966   77  8 36.34630   -16.791 0.003 0.003 0.005
   3  HEC2    38 44 36.19465   77  8 39.32344    -5.900 0.000 0.000 0.000

ACCURACIES (m):
                                 D. LAT.    D. LON.     VERT.

 ETLE           ETLN             0.003      0.003      0.005
 ETLN           HEC2             0.003      0.003      0.005
 ETLE           HEC2             0.000      0.000      0.000
 ETLE           ETLN             0.003      0.003      0.005
 ETLE           HEC2             0.000      0.000      0.000
 ETLN           HEC2             0.003      0.003      0.005


*****************************************************************
****                                                         ****
****                  ESTIMATES OF PRECISION                 ****
****                                                         ****
****        Based on the VECTOR ACCURACIES produced by       ****
****                          FILLNET                        ****
****                                                         ****
****      This is a reasonable estimate of the accuracies    ****
****        of the vectors in the network at 1 SIGMA.        ****
****                                                         ****
*****************************************************************

   VECTOR         LENGTH     PPM(h)  RATIO(h)    PPM(v)  RATIO(v)

ETLE   ETLN        103.607    41.1  1:   24313    48.3  1:   20721
ETLN   HEC2        309.471    13.7  1:   72900    16.2  1:   61894
ETLE   HEC2        270.391     0.0  1:       0     0.0  1:       0
ETLE   ETLN        103.607    41.1  1:   24313    48.3  1:   20721
ETLE   HEC2        270.391     0.0  1:       0     0.0  1:       0
ETLN   HEC2        309.471    13.7  1:   72900    16.2  1:   61894
```

Figure F-4. (Concluded)

Position differences (least squares - mean adjustments):

dX = 0.000 dY = 0.001 dZ = 0.006

Based on these results, the difference in results between a least squares and simple mean adjustment, for this case, is not significant.

If this were a survey obtained under contract, then a free adjustment would have been used to measure contract performance, not a constrained adjustment. The previous loop/line checks would have adequately served as a free adjustment in checking internal adequacy. Failure of a constrained survey adjustment to meet minimum relative accuracy standards (presuming the free adjustment did) indicates a problem with the existing network, or connections thereto.

The free adjustment of the same scheme shown in Figure F-5 illustrates the overall improvement in relative accuracy estimates over the constrained adjustments. Although the GPS vector standard errors were decreased from those used in the constrained adjustment, this will have no effect on the relative distance accuracy ratios in a free adjustment. As with the constrained adjustment, the precision ratios must be divided by 2.

```
PROGRAM FILLNET, Version 3.0.00
LICENSED TO: ASHTECH INC.


Fillnet Input File  jim                     38.7    77.1

a =  6378137.000    1/f =  298.2572235   W      Longitude positive WEST

PRELIMINARY COORDINATES:
                       LAT.             LON.        ELEV.    G.H.  CONSTR.

   1  FFF   ETLE 38 44 27.46754   77  8 40.41060    -7.020   0.000
   2        ETLN 38 44 26.61017   77  8 36.40653     8.066   0.000
   3        HEC2 38 44 36.19465   77  8 39.32344    -5.900   0.000

GROUP 1, NO. OF VECTORS AND BIAS CONSTRAINTS:

   6      0.000  0.001    0.000  0.001    0.000  0.001    0.000  0.001

VECTORS:
                    DX         DY         DZ      LENGTH   ERROR CODES

ETLE   ETLN      98.418      9.929    -30.837    103.613  5 52.0 102.0  3
ETLN   HEC2    -110.094    159.251    241.448    309.481  5 52.0 102.0  3
ETLE   HEC2     -11.676    169.184    210.602    270.394  5 52.0 102.0  4
ETLE   ETLN      98.405      9.932    -30.834    103.600  5 52.0 102.0  4
ETLE   HEC2     -11.676    169.184    210.602    270.394  5 52.0 102.0  4
ETLN   HEC2    -110.083    159.250    241.444    309.474  5 52.0 102.0  4

SHIFTS:
    1   0.000   0.000   0.000
    2  -5.259   1.456 -24.857
    3   0.004   0.004   0.004

ADJUSTED VECTORS, GROUP 1:
                           DX,DY,DZ   V       DN,DE,DU   v      v'

ETLE   ETLN     253 A        98.413 -0.005     -31.751  0.001   0.2
                              9.931  0.002      98.146 -0.005  -0.8
                            -30.838 -0.001      -9.690 -0.004  -0.3

ETLN   HEC2     253 A      -110.089  0.005     300.855 -0.004  -0.6
                            159.252  0.001     -71.758  0.005   0.8
                            241.444 -0.004      10.632 -0.002  -0.2

ETLE   HEC2     253 B       -11.676 -0.000     269.103  0.002   0.3
                            169.183 -0.001      26.388 -0.001  -0.1
                            210.605  0.003       0.942  0.003   0.2

ETLE   ETLN     253 B        98.413  0.008     -31.751 -0.005  -0.7
                              9.931 -0.001      98.146  0.007   1.0
                            -30.838 -0.004      -9.690 -0.001  -0.1

ETLE   HEC2     253 B       -11.676 -0.000     269.103  0.002   0.3
                            169.183 -0.001      26.388 -0.001  -0.1
                            210.605  0.003       0.942  0.003   0.2

ETLN   HEC2     253 B      -110.089 -0.006     300.855  0.001   0.2
                            159.252  0.002     -71.758 -0.006  -0.8
                            241.444 -0.000      10.632 -0.003  -0.2

S.E. OF UNIT WEIGHT =     0.593
```

Figure F-5. Free adjustment of network (Continued)

```
NUMBER OF -
   OBS. EQUATIONS              22
   UNKNOWNS                    10
   DEGREES OF FREEDOM          12
   ITERATIONS                   0


GROUP  1 ROT. ANGLES (sec.) AND SCALE DIFF. (ppm):

HOR. SYSTEM          0.000   0.000   0.000   0.000
STD. ERRORS          0.001   0.001   0.001   0.001
XYZ SYSTEM           0.000   0.000   0.000

ADJUSTED POSITIONS:

                   LAT.             LON.         ELEV.    STD. ERRORS (m)

   1  ETLE    38 44 27.46754   77  8 40.41060    -7.020 0.000 0.000 0.000
   2  ETLN    38 44 26.43961   77  8 36.34626   -16.791 0.002 0.002 0.005
   3  HEC2    38 44 36.19477   77  8 39.32328    -5.896 0.002 0.002 0.005

ACCURACIES (m):
                                 D. LAT.    D. LON.     VERT.

ETLE           ETLN             0.002      0.002      0.005
ETLN           HEC2             0.002      0.002      0.005
ETLE           HEC2             0.002      0.002      0.005
ETLE           ETLN             0.002      0.002      0.005
ETLE           HEC2             0.002      0.002      0.005
ETLN           HEC2             0.002      0.002      0.005


*****************************************************************
****                                                         ****
****                  ESTIMATES OF PRECISION                 ****
****                                                         ****
****        Based on the VECTOR ACCURACIES produced by       ****
****                          FILLNET                        ****
****                                                         ****
****      This is a reasonable estimate of the accuracies    ****
****        of the vectors in the network at 1 SIGMA.        ****
****                                                         ****
*****************************************************************

   VECTOR         LENGTH     PPM(h)  RATIO(h)    PPM(v)  RATIO(v)

ETLE   ETLN        103.608    27.4  1:   36470    48.3  1:   20722
ETLN   HEC2        309.477     9.1  1:  109352    16.2  1:   61895
ETLE   HEC2        270.395    10.5  1:   95599    18.5  1:   54079
ETLE   ETLN        103.608    27.4  1:   36470    48.3  1:   20722
ETLE   HEC2        270.395    10.5  1:   95599    18.5  1:   54079
ETLN   HEC2        309.477     9.1  1:  109352    16.2  1:   61895
```

Figure F-5. (Concluded)

Appendix G
Guide Specification for NAVSTAR Global Positioning System (GPS) Surveying Services

INSTRUCTIONS

G-1. General

This guide specification is intended for use in preparing Architect-Engineer (A-E) contracts for professional surveying and mapping services where use of GPS methods is an integral part of the effort. These specifications are applicable to all A-E contracts used to support U.S. Army Corps of Engineers (USACE) civil works and military construction design, construction, operations, maintenance, regulatory, and real estate activities. Since GPS is only a tool for supporting topographic, photogrammetric, or hydrographic surveys, an exclusive GPS survey contract would not normally be developed -- these specifications would be incorporated in a traditional site plan mapping, photogrammetric mapping, or hydrographic surveying contract. This guide specification is intended for contracts which are obtained using PL 92-582 (Brooks Act) qualification-based selection procedures.

G-2. Coverage

This guide specification contains the technical standards and/or references necessary to specify the more common static and kinematic differential (carrier phase tracking) GPS surveying methods which are currently (1994) in use. It is intended to support precise GPS control surveys performed for engineering and construction purposes. This guide supports the following types of differential GPS carrier phase surveying:

- Static Differential GPS Positioning.
- Rapid Static Differential GPS Positioning.
- Stop-and-Go Differential GPS Positioning.
- Kinematic GPS Differential Positioning.
- Pseudo-kinematic Differential GPS Positioning.
- Real-time On-the-Fly Differential GPS Positioning.

Continuing redevelopments of the above applications, along with the evolution of newer GPS survey techniques, mandate that these guide specifications be continuously evaluated by USACE Commands to insure they are technologically current.

G-3. Applicability

The following types of negotiated A-E contract actions are supported by these instructions:

a. Fixed-price surveying service contracts requiring GPS control.

b. Indefinite delivery type (IDT) surveying contracts.

c. A multi-discipline surveying and mapping IDT contract in which GPS surveying services is a line item supporting other surveying, mapping, hydrography, and/or photogrammetry services.

d. A work order or delivery order placed against an IDT contract.

e. Design and design-construct contracts which include incidental surveying and mapping services (including Title II services). Both fixed-price and IDT contracts are supported by these instructions.

G-4. Contract Format

The contract format outlined in this guide follows that prescribed in EFARS 15.406-1. This contract format is designed to support PL 92-582 (SF 252) qualification based A-E procurement actions.

G-5. General Guide Use

In adapting this guide specification to any project, specific requirements will be changed as necessary for the work contemplated. Changes will be made by deletions or insertions within this format. With appropriate adaptation, this guide form may be tailored for direct input in the Standard Army Automated Contracting System (SAACONS). Clauses and/or provisions shown in this guide will be renumbered during SAACONS input.

G-6. Insertion of Technical Specifications

This guide is intended to be used in coordination with Engineer Manual (EM) 1110-1-1003, NAVSTAR GPS Surveying.

a. This manual shall be attached to and made part of any service contract for GPS surveying. The manual contains complete specifications and quality control criteria for the total (field-to-finish) execution of a GPS control survey. References to this EM are made throughout this guide. These references will normally suffice for most USACE GPS survey specifications; however the guide also identifies areas where deviations from this manual must be considered.

b. Technical specifications for GPS surveying which are specific to the project (including items such as the scope of work, procedural requirements, and accuracy requirements) will be placed under Section C of the SF 252 (Block 10). The prescribed format for developing the technical specifications is contained in this guide specification. Project-specific technical specifications shall not contain contract administrative functions -- these should be placed in more appropriate sections of the contract, which are indicated in EFARS 15.406-1 or Part 14 of the Federal Acquisition Regulations (FAR).

c. Standards and other specifications referenced in this guide specification should be checked for obsolescence and for dates and applicability of amendments and revisions issued subsequent to the publication of this specification. Use Engineer Pamphlet (EP) 25-1-1, Index of USACE/OCE Publications. Maximum use should be made of existing EM's, Technical Manuals, and other recognized industry standards and specifications.

d. Throughout Section C of this guide, the specification writer must elect a contract performance method: (1) the government designs the GPS occupation/observing schedule, or (2) the contractor designs his performance method based on the criteria given in EM 1110-1-1003. Selection of the first method depends on the GPS survey expertise of the specification writer. This method also transfers much of the contract risk to the government. The second method is the preferred contract procedure.

G-7. Alternate Clauses/Provisions or Options

In order to distinguish between required clauses and optional clauses, required clauses are generally shown in capital letters. Optional or selective clauses, such as would be used in a work order, are generally in lower case. In other instances, alternate clauses/provisions may be indicated by brackets "[ ]" and/or clauses preceded by a single asterisk "*". A single asterisk signifies that a clause or provision which is inapplicable to the particular section may be omitted, or that a choice of clauses may be made depending upon the technical surveying and mapping requirement. Clauses requiring insertion of descriptive material or additional project-specific specifications are indicated by either ellipsis or underlining in brackets (e.g., "[...]" "[_____]"). In many instances, explanatory notes are included regarding the selection of alternate clauses or provisions.

G-8. Notes and Comments

General comments and instructions used in this guide are contained within asterisk blocks. These comments and instructions should be removed from the final contract.

G-9. Indefinite Delivery Type Contracts and Individual Work Order Assignments

Contract clauses which pertain to IDT contracts, or delivery orders thereto, are generally indicated by notes adjacent to the provision. These clauses should be deleted for fixed-price contracts. In general, sections dealing with IDT contracts are supplemented with appropriate comments pertaining to their use. Work orders against a basic IDT contract may be constructed using the format contained in Section C of this guide. This contract section is therefore applicable to any type of GPS service contracting action.

THE CONTRACT SCHEDULE

SECTION A

SOLICITATION/CONTRACT FORM

****

NOTE: Include here Standard Form 252.

****

SF 252 -- (Block 5): PROJECT TITLE AND LOCATION

****

NOTE: The following sample titles represent projects under which static or kinematic GPS surveys are expected to play a significant role in developing basic project control, photo control, or local site plan mapping control. GPS surveys are used to support subsequent photogrammetric, plane table/total station site plan mapping, and construction layout operations.

****

{Fixed-price contract -- sample title}:

PROJECT CONTROL AND PHOTOGRAMMETRIC MAPPING CONTROL SURVEYS USING KINEMATIC DIFFERENTIAL NAVSTAR GPS IN SUPPORT OF SITE PLAN MAPPING FOR PRELIMINARY CONCEPT DESIGN OF FAMILY HOUSING COMPLEX ALPHA, FORT _____, ALABAMA.

PROJECT CONTROL REFERENCE SURVEYS USING KINEMATIC DIFFERENTIAL NAVSTAR GPS POSITIONING FOR BOUNDARY DEMARCATION SURVEYS OF _____ [PROJECT], _____, CALIFORNIA.

{Indefinite Delivery Type contract -- sample title}:

INDEFINITE DELIVERY CONTRACT FOR GEODETIC CONTROL, TOPOGRAPHIC MAPPING, AND RELATED SURVEYING SERVICES IN SUPPORT OF VARIOUS *[CIVIL WORKS] [MILITARY CONSTRUCTION] PROJECTS *[IN] [ASSIGNED TO] THE _____ DISTRICT.

SECTION B

SERVICES AND PRICES/COSTS

****

NOTE: The fee schedule for photogrammetric mapping and related survey services should be developed in conjunction with the preparation of the independent government estimate (IGE) along with the technical specifications. The unit of measure (U/M) used in a fee schedule for GPS mapping services is generally established on a daily rate basis (i.e., crew-day). U/Ms based on "per occupied point" or "per baseline observation" are no longer recommended given the high variability in GPS equipment production.

The table below contains sample fee schedules which may be tailored for use on most GPS control surveying or mapping service contracts. The guide writer should select those line items applicable to the project, or for those projects envisioned over the course of an IDT contract. Other line items may be added which are unique to the project(s). If applicable, a separate fee schedule for

contract option periods should be developed and negotiated during contract negotiations and included with the contract during initial award. Unit prices shall include direct and indirect overheads. Profit is not included on IDT contract unit prices.

Procedures for estimating line item unit prices (U/P) are described in EM 1110-1-1000. Determination of these estimated unit prices should conform to the detailed analysis method, or "seven-item breakdown." The scope of each scheduled line item used in Section B must be thoroughly defined -- either with the line item in Section B or at its corresponding reference in Section C of the contract. Many of the line item units of measure are comprised of costs from a variety of sources. These sources are combined in the IGE to arrive at the scheduled rate. Survey crew day rates normally include labor, travel, transportation, expendable materials, and numerous other items which are developed as part of the IGE. However, large items, such as travel, may be separately scheduled.

On IDT contracts, the specification writer should strive to avoid scheduling items which have little probability of being required during the contract period. Since each line item must be separately estimated and negotiated, considerable government (and contractor) resources may be consumed in developing negotiated unit costs for unused items. Individual line items should not be included on an IDT contract unless there is a fair degree of assurance that these items will be required on a subsequent work order.

In addition, the specification writer should attempt to include only those line items that represent a major cost activity/phase in performing GPS surveying and mapping. Cost estimating emphasis and resources should be placed on major cost items, such as field crew labor. Avoid cluttering the schedule with small and relatively insignificant (to the overall project cost) supply and material items; again, minimizing the administrative costs of estimating and negotiating these items. These should be included as part of a major line item or be contained in the firm's overhead. Examples of normal supply items which the guide user should avoid scheduling are field survey books or bundles of 2" x 2" survey stakes. These items would, however, be compensated for in the IGE. Care must be taken (in developing these schedules with the IGE) to preclude against duplication of costs between line items or overheads. Specific personnel and equipment requirements should be identified and itemized in applicable contract sections. This is particularly important when breaking out GPS receiver costs. The guide user (and cost estimator) must have a good working knowledge of GPS field mapping and data reduction processes to properly allocate time and costs.

The following schedules may be tailored for either A-E fixed-price or A-E IDT contracts. For fixed-price contracts, the estimated quantities are available from the government estimate. For IDT contracts, a unit quantity for each line item would be negotiated and included in the basic contract. Daily units of measure (U/M) may be modified to hourly or other nominal units if needed. Lump sum or areal U/M (e.g., per baseline observation) may be developed for some of the services, although this is not recommended. The item numbers shown are for reference in this guide only -- they would be renumbered in the final contract.

****

ITEM	DESCRIPTION	QUAN	U/M	U/P	AMOUNT
0001	Registered/Licensed Land Surveyor-Office	[1]	Day		
0002	Registered/Licensed Land Surveyor-Field	[1]	Day		
0003	Civil Engineering Technician -- Field Party Supervisor (Multiple Crews)	[1]	Day		
0004	Engineering Technician (Draftsman)-Office	[1]	Day		
0005	Supervisory Survey Technician (Field)	[1]	Day		
0006	Surveying Technician -- GPS Instrumentman/Recorder	[1]	Day		
0007	Surveying Aid -- Rodman/Chainman {Conventional surveys}	[1]	Day		
0008	[Two][Three][Four][___]- Man [Static] [Kinematic] GPS Survey Party [___] GPS Receiver(s) [___] Vehicle(s) [___] Computer(s) {Detail specific personnel/equipment requirements in applicable contract sections - see PARC IL 92-4}	[1]	Crew Day		
0009	Additional GPS Receiver {Add Item 0006 observers as necessary}	[1]	Day		
0010	{Travel/Per Diem -- add line item if not included in above items}	[1]	Day		
0011	Survey Technical (Office Computer)	[1]	Day		
0012					
0013					

SECTION C

STATEMENT OF WORK

C.1 GENERAL. THE CONTRACTOR, OPERATING AS AN INDEPENDENT CONTRACTOR AND NOT AN AGENT OF THE GOVERNMENT, SHALL PROVIDE ALL LABOR, MATERIAL, AND EQUIPMENT NECESSARY TO PERFORM THE PROFESSIONAL SURVEYING *[AND MAPPING WORK] *[FROM TIME TO TIME] DURING THE PERIOD OF SERVICE AS STATED IN SECTION D, IN CONNECTION WITH PERFORMANCE OF *[_____] SURVEYS *[AND THE PREPARATION OF SUCH MAPS] AS MAY BE REQUIRED FOR *[ADVANCE PLANNING,] [DESIGN,] [AND CONSTRUCTION] [or other function] [ON VARIOUS PROJECTS] *[specify project(s)] . THE CONTRACTOR SHALL FURNISH THE REQUIRED PERSONNEL, EQUIPMENT, INSTRUMENTS, AND TRANSPORTATION, AS NECESSARY TO ACCOMPLISH THE REQUIRED SERVICES AND FURNISH TO THE GOVERNMENT REPORTS AND OTHER DATA TOGETHER WITH SUPPORTING MATERIAL DEVELOPED DURING THE FIELD DATA ACQUISITION PROCESS. DURING THE PROSECUTION OF THE WORK, THE CONTRACTOR SHALL PROVIDE ADEQUATE PROFESSIONAL SUPERVISION AND QUALITY CONTROL TO ASSURE THE ACCURACY, QUALITY, COMPLETENESS, AND PROGRESS OF THE WORK.

****

NOTE: The above clause is intended for use on an IDT contract for survey services. It is not exclusive to GPS-performed surveys. It may be used for Fixed-price service contract by deleting appropriate IDT language and adding the specific project survey required. This clause is not repeated on individual delivery orders.

****

C.2 LOCATION OF WORK.

****

NOTE: Use the following clause for a fixed-scope contract or individual work order.

****

C.2.1. *[STATIC] [KINEMATIC] SURVEYS USING NAVSTAR GPS EQUIPMENT SHALL BE PERFORMED AT [...] *[list project area or areas required]. *[A MAP DETAILING THE WORK SITE IS ATTACHED AT SECTION G OF THIS CONTRACT.]

****

NOTE: Use the following when specifying an indefinite delivery contract for surveying and mapping services.

****

C.2.2. SURVEYING SERVICES SHALL BE PERFORMED IN CONNECTION WITH PROJECTS *[LOCATED IN] [ASSIGNED TO] THE [_____] DISTRICT. *[THE _____ DISTRICT INCLUDES THE GEOGRAPHICAL REGIONS WITHIN *[AND COASTAL WATERS] [AND RIVER SYSTEMS] ADJACENT TO:]

* _____
{list states, regions, etc.}

****

NOTE: Note also any local points-of-contact, right-of-entry requirements, clearing restrictions, installation security requirements, etc.

****

C.3 TECHNICAL CRITERIA AND STANDARDS.

REFERENCE STANDARDS:

C.3.1. U.S. ARMY CORPS OF ENGINEERS EM 1110-1-1003, NAVSTAR GPS SURVEYING. THIS REFERENCE IS ATTACHED TO AND MADE PART OF THIS CONTRACT. (SEE CONTRACT SECTION G).

C.3.2. U.S. ARMY CORPS OF ENGINEERS EM 1110-1-1002, SURVEY MARKERS AND MONUMENTATION. *[THIS REFERENCE IS ATTACHED TO AND MADE PART OF THIS CONTRACT. (SEE CONTRACT SECTION G).]

C.3.3. *[List other applicable USACE reference manuals and standards].

****

NOTE: Reference may also be made to other applicable Engineer Manuals or standard criteria documents. Such documents need not be attached to the Contract; if attached, however, reference should be made to their placement in contract Section G.

****

C.4 WORK TO BE PERFORMED. PROFESSIONAL NAVSTAR GPS SURVEYING AND MAPPING SERVICES TO BE PERFORMED UNDER THIS CONTRACT ARE LISTED BELOW. UNLESS OTHERWISE INDICATED IN THIS CONTRACT *[OR IN DELIVERY ORDERS THERETO], EACH REQUIRED SERVICE SHALL INCLUDE FIELD-TO-FINISH EFFORT.

****

NOTE: The following clauses under this paragraph may be used for either Fixed-price service contracts, IDT work orders under an IDT contract, or IDT contracts where GPS control services are part of a schedule of various survey disciplines. Clearly identify the functional requirements of any GPS surveys, including recommended static or kinematic procedures.

Fixed-scope contracts: Detail specific GPS surveying and mapping technical work requirements and performance criteria which are necessary to accomplish the work.

IDT contracts and work orders: Since specific project scopes are indefinite at the time a basic contract is prepared, only general technical criteria and standards can be outlined. Project or site-specific criteria will be contained in each delivery order, along with any deviations from technical standards identified in the basic IDT contract. The clauses contained herein are used to develop the general requirements for a basic IDT contract. Subsequent delivery orders will reference these clauses; adding project-specific work requirements as required. Delivery order formats should follow the outline established for the basic IDT contract.

****

C.4.1. GENERAL REQUIREMENTS (GPS SURVEYS). BASIC PROJECT CONTROL SURVEYS SHALL BE PERFORMED USING PRECISE DIFFERENTIAL CARRIER-PHASE TRACKING NAVSTAR GPS MEASUREMENT PROCEDURES. DIFFERENTIAL GPS BASELINE VECTOR OBSERVATIONS SHALL BE MADE IN STRICT ACCORDANCE WITH THE CRITERIA CONTAINED IN EM 1110-1-1003, EXCEPT AS MODIFIED OR AMPLIFIED HEREIN. THE GPS MEASUREMENT TECHNIQUE TO BE EMPLOYED IN MEASURING RELATIVE BASELINE VECTORS FOR *[PROJECT CONTROL] [PHOTO CONTROL] [TOPOGRAPHIC SITE PLAN MAPPING] IS *[STATIC] [STOP-AND-GO] [RAPID STATIC] [KINEMATIC] [RTK] [OTF] [PSEUDO-KINEMATIC], *[OR COMBINATIONS THEREOF]. *[CONVENTIONAL SURVEY METHODS SHALL BE USED TO DENSIFY SUPPLEMENTAL POINTS RELATIVE TO ESTABLISHED GPS STATIONS.] *[SPECIFIC GPS BASELINES TO BE OCCUPIED AND OBSERVED IN THE DIFFERENTIAL MODE ARE INDICATED IN THESE SPECIFICATIONS.]

C.4.2. HORIZONTAL ACCURACY REQUIREMENTS. NEW *[PRIMARY] STATIONS SHALL BE ESTABLISHED TO A *[_____]-ORDER, *[CLASS *[___]] RELATIVE ACCURACY CLASSIFICATION, OR *[___ PART IN _____]. *[SUPPLEMENTAL TOPOGRAPHIC/PHOTOGRAMMETRIC MAPPING POINTS SHALL BE ESTABLISHED TO A *[_____]-ORDER, *[CLASS *[___]] RELATIVE ACCURACY CLASSIFICATION, OR *[___ PART IN _____].] *[GPS HORIZONTAL ACCURACY REQUIREMENTS SPECIFIED FOR NEWLY POSITIONED STATIONS SHALL BE BASED ON A FREE (UNCONSTRAINED) ADJUSTMENT OF OBSERVATIONS AND SHALL MEET THE RELATIVE ACCURACY AND/OR LOOP MISCLOSURE CRITERIA INDICATED IN EM 1110-1-1003.]

****

NOTE: Note that accuracy classifications, and related contract quality control and acceptance, are based on a free adjustment of the work -- not a constrained adjustment to fixed/existing control which often is of less accuracy than the new GPS work. Horizontal accuracy classifications exceeding Second-Order, Class I (i.e., 1:50,000) will not normally be specified for USACE control work. GPS derived topographic mapping control need only meet general positional mapping requirements based on the site plan scale -- refer to ASPRS horizontal and vertical accuracy standards.

****

C.4.3. * VERTICAL ACCURACY REQUIREMENTS. GPS-DERIVED ELEVATIONS SHALL HAVE STANDARD ERRORS NOT EXCEEDING *[____] OR SHALL BE COMMENSURATE WITH THE CONTOUR INTERVAL OF THE FINAL TOPOGRAPHIC MAP BEING PRODUCED.

****

NOTE: When GPS techniques are used to establish vertical elevations for photo or topo mapping projects, the required vertical accuracy must be specified. Extreme caution must be employed in specifying the use of GPS in densifying vertical control -- its application for engineering and construction work is limited.

****

C.4.4. PROCEDURAL OBSERVATION REQUIREMENTS. NETWORK DESIGN, STATION AND BASELINE OCCUPATION REQUIREMENTS FOR STATIC AND KINEMATIC SURVEYS, SATELLITE OBSERVING TIME PER BASELINE, BASELINE REDUNDANCIES, AND CONNECTION REQUIREMENTS TO EXISTING NETWORKS, SHALL FOLLOW THE CRITERIA GIVEN IN EM 1110-1-1003, EXCEPT AS MODIFIED IN THESE SPECIFICATIONS.

****

NOTE: At this point, indicate any exceptions, modifications, and/or deviations from EM 1110-1-1003. The specification writer may optionally elect to have the contractor design his observing procedures in accordance with general EM 1110-1-1003 criteria. Alternatively, specific baselines or stations requiring occupation may be specified. Use of either option depends on the GPS and geodetic survey experience/expertise of the specification writer. The preferred method is to allow the maximum flexibility be given to the contractor to determine the most optimum network design (interconnections, traverses, loops, spurs, etc.). In specifying baselines/points that have been monumented, contingencies should be allowed for resetting marks and/or eccentric observations due to obscured satellite visibility. Maximum use of more efficient kinematic control densification methods (as opposed to static methods) should be specified.

****

C.4.5. * SPECIFIC BASELINES TO BE MEASURED.

****

NOTE: Use the above clause only if the government specification writer is designing the network.

****

*(1) THE FOLLOWING BASELINES SHALL BE OBSERVED ON THIS PROJECT: [...] *[list specific station-station baselines and any requirements for redundant observations]

*(2) THESE BASELINES ARE INDICATED BY [...] *[specify line symbol] ON THE ATTACHED MAP IN SECTION G.

C.4.6. NEW STATIONS TO BE *[MONUMENTED AND] OCCUPIED.

(1) THE FOLLOWING *[...] *[indicate number of] STATIONS ARE TO BE OCCUPIED AND POSITIONED USING GPS SURVEY TECHNIQUES: *[list/tabulate new stations name and/or area designation, accuracy requirements (order/class), redundant occupations, etc.]

(2) THE NEW STATIONS *[GENERAL LOCATIONS] ARE INDICATED WITH A *[...] *[indicate map symbol used] ON THE ATTACHED MAP. *[ACTUAL STATION LOCATION WITHIN THE GENERALLY DEFINED AREA SHALL BE SELECTED BY THE CONTRACTOR AND SHALL BE LOCATED SUCH THAT ADEQUATE SATELLITE VISIBILITY IS AFFORDED.]

C.4.7. EXISTING NETWORK CONTROL STATIONS TO BE OCCUPIED AND CONNECTED.

(1) A TOTAL OF *[...] *[specify number of] EXISTING HORIZONTAL CONTROL STATIONS SHALL BE USED TO REFERENCE HORIZONTAL GPS OBSERVATIONS ON THIS SURVEY. A LISTING OF THESE FIXED POINTS *[IS SHOWN BELOW] [IS SHOWN IN ATTACHMENT G.*]. FIXED COORDINATES ARE *[NAD 27] [NAD 83] [WGS 84 GEOCENTRIC] [...].

****

NOTE: List each existing control station(s) or, alternately, refer to a map or tabulation attachment in contract Section G.

****

(2) A TOTAL OF *[...] [specify number] VERTICAL CONTROL STATIONS (BENCHMARKS) SHALL BE OCCUPIED AND USED TO CONTROL AND/OR PROVIDE VERTICAL ORIENTATION REFERENCE TO GPS VERTICAL COMPONENTS. A LISTING OF THESE FIXED BENCHMARKS *[IS SHOWN BELOW] [IS SHOWN IN ATTACHMENT G.*]. ELEVATIONS FOR ALL FIXED BENCHMARKS ARE BASED ON *[NGVD 29] [NAVD 88] [IGLD-55] [...] DATUM. GEOID SEPARATION IS *[...] [ASSUMED TO BE ZERO].

****

NOTE: List or reference attachment for existing benchmarks.

****

(3) REQUIRED GPS BASELINE CONNECTIONS TO EXISTING CONTROL IS SHOWN ON ATTACHMENT G.* IN SECTION G. THESE FIXED POINTS SHALL BE USED IN PERFORMING A FINAL CONSTRAINED ADJUSTMENT OF ALL NEW WORK. HORIZONTAL POINTS ARE INDICATED BY A [...], VERTICAL POINTS BY A [...], COMBINED POINTS BY A [...], AND GPS BASELINES BY A [...].

****

NOTE: Use the above clause when existing control points to be connected are specified in the contract.

****

(4) ALL HORIZONTAL AND VERTICAL MONUMENTS ARE KNOWN TO BE IN-PLACE AS OF *[date]. DESCRIPTIONS FOR EACH POINT *[WILL BE PROVIDED PRIOR TO CONTRACT AWARD] *[ARE ATTACHED AT CONTRACT SECTION G]. THE SOURCE AGENCY, AND ESTIMATED ACCURACY, OF EACH POINT IS INDICATED ON THE DESCRIPTION. *[A GPS OBSTRUCTION SKETCH IS SHOWN ON (HAS BEEN ADDED

TO) THE DESCRIPTIONS.] *[IF SATELLITE VISIBILITY IS OBSCURED AT AN EXISTING STATION, THEN A NEW MARK SHALL BE SET AT THE RATE FOR ITEM [____] IN SECTION B.] *[THE CONTRACTOR'S FIELD REPRESENTATIVE SHALL IMMEDIATELY NOTIFY THE GOVERNMENT'S CONTRACTING OFFICER REPRESENTATIVE IF EXISTING CONTROL POINTS HAVE BEEN DISTURBED AND/OR SATELLITE VISIBILITIES ARE NOT AS INDICATED IN THE FURNISHED DESCRIPTIONS.]

****

NOTE: Use the following clause(s) only when network design and observation schedule/sequence will be determined by the contractor.

****

(5) * UNLESS OTHERWISE SPECIFIED IN THESE INSTRUCTIONS, AT LEAST *[ONE] [TWO] [THREE] [____] EXISTING (PUBLISHED) CONTROL STATIONS MUST BE OCCUPIED IN THE NETWORK. CONNECTION METHODS AND REDUNDANCY ARE AT THE CONTRACTOR'S OPTION. PRIOR TO USING ANY CONTROL POINTS, THE MONUMENTS SHALL BE CHECKED TO ENSURE THAT THEY HAVE NOT BEEN MOVED OR DISTURBED.

C.4.8. NEW STATION MONUMENTATION, MARKING, AND OTHER CONTROL REQUIREMENTS.

(1) ALL STATIONS SHALL BE MONUMENTED IN ACCORDANCE WITH EM 1110-1-1002, SURVEY MARKERS AND MONUMENTATION. MONUMENTATION FOR THIS PROJECT SHALL BE TYPE *[...] FOR HORIZONTAL AND TYPE *[...] FOR VERTICAL; PER EM 1110-1-1002 CRITERIA. *[MONUMENTATION SHALL BE DEFINED TO INCLUDE THE REQUIRED REFERENCE MARKS AND AZIMUTH MARKS REQUIRED BY EM 1110-1-1002.]. *[ALL MONUMENTS FOR NEW STATIONS ARE CURRENTLY IN PLACE AND DESCRIPTIONS ARE ATTACHED AT SECTION G.] *[IF SATELLITE VISIBILITY SHOWN ON THE DESCRIPTIONS IS OBSCURED AT AN EXISTING STATION, THEN A NEW MARK SHALL BE SET AT THE RATE FOR ITEM *[____] IN SECTION B.]

****

NOTE: Deviations from EM 1110-1-1002 should be indicated as required. USACE project control rarely requires supplemental reference/azimuth marks -- the optional specification clauses below should be tailored accordingly.

****

*(2) At each station, angle and distance measurements shall be made between a network station and reference marks and azimuth marks set which were established in accordance with the requirements set forth in EM 1110-1-1002. All observations shall be recorded in a standard field book.

*(a) For reference marks, two (2) directional positions are required (reject limit ±10 " arc) and with steel taping performed to the nearest ±0.01 foot.

*(b) Four directional positions are required to azimuth marks. The reject limit for a one-second theodolite is ±5 seconds. Azimuth mark landmarks shall be easily defined/described natural features or structures which are of sufficient distance to maintain a *[± ___]-second angular accuracy. *[_____-order astronomic azimuths shall be observed to azimuth marks.]

*(c) A compass reading shall be taken at each station to reference monuments and azimuth marks.

C.4.9. STATION DESCRIPTION AND RECOVERY REQUIREMENTS.

(1) STATION DESCRIPTIONS AND/OR RECOVERY NOTES SHALL BE WRITTEN IN ACCORDANCE WITH THE INSTRUCTIONS CONTAINED IN EM 1110-1-1002. [FORM *[_____] SHALL BE USED FOR THESE DESCRIPTIONS.] DESCRIPTIONS SHALL BE *[WRITTEN] [TYPED].

(2) DESCRIPTIONS *[ARE] [ARE NOT] REQUIRED FOR *[EXISTING] [AND/OR NEWLY ESTABLISHED] STATIONS.

(3) RECOVERY NOTES *[ARE] [ARE NOT] REQUIRED FOR EXISTING STATIONS.

C.4.10. MINIMUM OCCUPATION TIMES FOR OCCUPIED BASELINES. BASELINES SHALL BE OCCUPIED FOR A PERIOD OF TIME WHICH IS CONSISTENT WITH THE SPECIFIED ACCURACY REQUIREMENT FOR THE PROJECT AND/OR PARTICULAR NEW STATION/LINE. RECOMMENDED MINIMUM OCCUPATION TIMES ARE CONTAINED IN EM 1110-1-1003. UNLESS OTHERWISE STATED IN THESE SPECIFICATIONS, THE CRITERIA SHOWN IN THIS MANUAL SHALL BE FOLLOWED FOR EACH PROJECT AND/OR OBSERVED BASELINE. MINIMUM OCCUPATION TIMES FOR KINEMATIC GPS SURVEY OBSERVATIONS SHALL BE CONSISTENT WITH MANUFACTURER RECOMMENDATIONS AND REQUIRED ACCURACIES OF TOPOGRAPHIC FEATURES.

C.4.11. TYPE AND NUMBER OF GPS RECEIVER UNITS TO BE DEPLOYED.

(1) THE CONTRACTING OFFICER RESERVES THE RIGHT TO REQUEST PUBLISHED DOCUMENTATION ON THE ACCURACY/QUALITY OF THE HARDWARE/SOFTWARE USED FOR THIS PROJECT. ALL GPS RECEIVERS AND POST-PROCESSING SOFTWARE USED UNDER THIS *[CONTRACT] [ASSIGNMENT] SHALL BE SUBJECT TO REVIEW BY THE CONTRACTING OFFICER. SYSTEM COMPONENTS SUBJECT TO REVIEW SHALL INCLUDE:

(A) RECEIVERS
(B) ANTENNAS
(C) POWER SOURCE
(D) DATA RECORDING UNITS AND STORAGE MEDIA
(E) REAL-TIME OR POST-PROCESSING HARDWARE AND SOFTWARE

(2) A MINIMUM OF [...] GPS FIELD RECEIVER UNITS SHALL BE CONTINUOUSLY AND SIMULTANEOUSLY DEPLOYED DURING THIS *[ASSIGNMENT] [PROJECT].

****

NOTE: Add any applicable variations due to project specific requirements.

****

C.4.12. FIELD GPS OBSERVATION RECORDING PROCEDURES.

(1) FIELD LOG *[SHEETS] [FORM] [NOTES] SHALL BE COMPLETED FOR EACH STATION OF EACH SESSION AND SUBMITTED TO THE GOVERNMENT. MINIMUM DATA FOR STATIC AND KINEMATIC OBSERVATIONS TO BE INCLUDED ON THESE FIELD LOG RECORDS ARE DESCRIBED IN EM 1110-1-1003.

(2) RAW SATELLITE TRACKING DATA, BASELINE REDUCTION DATA, AND ADJUSTMENT SOLUTIONS SHALL BE RECORDED AND SUBMITTED TO THE GOVERNMENT ON *[___-INCH FLOPPY DISKS] [A PRE-APPROVED MEDIUM].

(3) IT SHALL BE THE RESPONSIBILITY OF THE CONTRACTOR TO ASSURE THAT AMPLE OBSERVATIONS ARE CONDUCTED SO THAT ALL POINTS ARE INTERCONNECTED IN A COMPLETE INTERCONNECTING NETWORK OR GPS TRAVERSE SURVEY; AND/OR IN ACCORDANCE WITH THE REQUIRED BASELINE MEASUREMENTS SPECIFIED HEREIN. *[ADEQUATE FIELD COMPUTATIONAL CAPABILITY SHALL EXIST IN ORDER TO VERIFY MISCLOSURES PRIOR TO SITE DEPARTURE.]

C.4.13. BASELINE DATA REDUCTION REQUIREMENTS (CONTROL SURVEYS).

(1) SOFTWARE FOR POST-PROCESSING OF SATELLITE TRACKING DATA SHALL BE SUBJECT TO APPROVAL BY THE CONTRACTING OFFICER. ALL SOFTWARE MUST BE ABLE TO PRODUCE FROM THE RAW DATA RELATIVE POSITION COORDINATES *[AND CORRESPONDING VARIANCE-COVARIANCE STATISTICS WHICH IN TURN CAN BE USED AS INPUT TO THREE-DIMENSIONAL NETWORK ADJUSTMENT PROGRAMS.]

****

NOTE: Baseline output statistics are generally only specified when rigorous least-squares adjustments are required; and then only if the specified adjustment software utilizes such statistics. This is not applicable to topographic surveying uses of GPS.

****

(2) BASELINE PROCESSING SHALL BE COMPLETED FOR ALL BASELINES AND SELECTED FOR USE IN THE FINAL NETWORK ADJUSTMENT BASED ON AN ANALYSIS OF THE STATISTICAL DATA AND RELATIVE SPATIAL RELATIONSHIPS BETWEEN POINTS. TEST CONSTANTS GIVEN FOR A PARTICULAR SOFTWARE SYSTEM SHALL BE COMPARED TO THE PROCESSED RESULTS AND ANY SUSPECT BASELINE THAT DOES NOT MEET THE CRITERIA SHALL BE REOBSERVED OR NOT INCLUDED IN THE FINAL ADJUSTMENT. BASELINE ACCEPTANCE AND REJECTION CRITERIA ARE CONTAINED IN EM 1110-1-1003.

C.4.14. FINAL ADJUSTMENT REQUIREMENTS (CONTROL SURVEYS). GPS SURVEY TRAVERSE LOOPS AND NETWORKS SHALL BE ADJUSTED AND EVALUATED IN ACCORDANCE WITH THE PROCEDURES AND CRITERIA OUTLINED IN EM 1110-1-1003. FINAL VECTOR MISCLOSURES MAY BE PROPORTIONATELY DISTRIBUTED AMONG THE OBSERVED VECTORS USING EITHER APPROXIMATE OR LEAST-SQUARES ADJUSTMENT TECHNIQUES DESCRIBED IN EM 1110-1-1003.

(1) ADJUSTMENTS ARE NORMALLY PERFORMED USING X-Y-Z GEOCENTRIC COORDINATES RELATIVE TO THE WGS 84 SPHEROID. TRANSFORMED FINAL ADJUSTED HORIZONTAL DATA SHALL BE EXPRESSED IN *[SPCS] [UTM] [GEOGRAPHIC] [GEOCENTRIC] [OTHER] COORDINATES, AND SHALL BE REFERENCED TO *[NAD 27] [NAD 83] [PROJECT] DATUM. FINAL COORDINATES SHALL BE TABULATED IN *[METERS] [FEET] [other] TO ONLY *[___] DECIMAL POINTS OF PRECISION. *[FINAL ADJUSTED VERTICAL DATA FOR TOPOGRAPHIC MAPPING APPLICATIONS SHALL BE SHOWN AS ORTHOMETRIC HEIGHTS ON *[NGVD 29] [NAVD 88] [other] VERTICAL DATUM. GPS-DERIVED ELEVATIONS SHALL BE ROUNDED TO THE NEAREST *[METER] [FOOT].]

* (2) FOR PROJECT CONTROL SURVEYS AN ADJUSTMENT ANALYSIS SHALL INCLUDE THE FOLLOWING:

* (a) GPS TRAVERSE LOOPS SHALL BE ANALYZED RELATIVE TO THE INTERNAL CLOSURE CRITERIA GIVEN IN EM 1110-1-1003. INTERNAL ACCEPTABILITY OF THE WORK WILL BE BASED ON THE MAGNITUDE OF THE THREE-DIMENSIONAL VECTOR MISCLOSURES RELATIVE TO THE LOOP LENGTH. SUCH LOOP CLOSURE ANALYSIS WILL BE CONSIDERED THE INTERNAL, MINIMALLY CONSTRAINED, FREE ADJUSTMENT. LOOPS/LINES WITH INTERNAL MISCLOSURE RATIOS IN EXCESS OF THOSE SPECIFIED IN THIS CONTRACT SHALL BE REOBSERVED. MISCLOSURES BETWEEN EXTERNAL FIXED CONTROL MAY BE DISTRIBUTED USING THE APPROXIMATE DISTRIBUTION METHODS GIVEN IN EM 1110-1-1003. FINAL CONSTRAINED ACCURACY ESTIMATES WILL BE BASED ON RELATIVE MISCLOSURES AT FIXED POINTS.

****

NOTE: The following clauses apply only to rigorous least-squares adjustment techniques. Note that EM 1110-1-1003 does not require that a rigorous least-squares adjustment be performed for

USACE control work. The guide specifications writer must establish the technical requirement for such an adjustment method and modify the clauses in this section accordingly.
****

(b) * WHEN A FREE (OR MINIMALLY CONSTRAINED) LEAST-SQUARES ADJUSTMENT IS PERFORMED ON THE BASELINE VECTORS, A CLASSIFICATION BASED ON THIS INTERNAL ADJUSTMENT SHALL BE DERIVED AND EVALUATED AGAINST THE MINIMUM ALLOWABLE STANDARDS SHOWN IN EM 1110-1-1003 FOR THE GIVEN REQUIRED ACCURACY. THIS FREE ADJUSTMENT, ALONG WITH AN ANALYSIS OF THE BASELINE REDUCTION DATA, WILL BE USED IN EVALUATING THE CONTRACTUAL ACCEPTABILITY OF THE OBSERVED NETWORK. STATION *[_____] SHALL BE HELD FIXED FOR THIS UNCONSTRAINED ADJUSTMENT. THE NORMALIZED RESIDUALS SHALL BE COMPUTED AND ANALYZED RELATIVE TO THE CRITERIA CONTAINED IN EM 1110-1-1003. THE VARIANCE OF UNIT WEIGHT FOR THE MINIMALLY CONSTRAINED NETWORK ADJUSTMENT SHALL CONFORM TO THE CRITERIA GIVEN IN EM 1110-1-1003. RELATIVE LINE ACCURACIES SHALL BE COMPUTED FOR PAIR OF POINTS ON THE NETWORK USING STATISTICAL DATA CONTAINED IN THE FREE ADJUSTMENT. THESE RELATIVE LINE ACCURACIES SHALL NOT EXCEED THE REQUIRED ACCURACY CLASSIFICATIONS PRESCRIBED FOR THE WORK. STATIONS/BASELINES/NETWORK AREAS WITH FREE ADJUSTMENT RELATIVE ACCURACIES NOT MEETING THE REQUIRED CRITERIA MUST BE REOBSERVED; IT IS THEREFORE CONTINGENT ON THE CONTRACTOR TO ENSURE THAT MISCLOSURE TOLERANCES ARE CHECKED IN THE FIELD.

(c) * A CONSTRAINED LEAST-SQUARES ADJUSTMENT SHALL BE PERFORMED HOLDING *[FIXED] [PARTIALLY CONSTRAINED] THE COORDINATES OF THE STATIONS LISTED UNDER THE EXISTING CONTROL CLAUSE IN THIS CONTRACT SECTION. FOR THE PURPOSE OF THESE SPECIFICATIONS, BOTH FULLY CONSTRAINED AND PARTIALLY CONSTRAINED POINTS ARE REFERRED TO AS “FIXED” POINTS. THE CONSTRAINED LEAST SQUARES ADJUSTMENT SHALL USE MODELS WHICH ACCOUNT FOR: THE REFERENCE ELLIPSOID FOR THE REFERENCE CONTROL, THE ORIENTATION AND SCALE DIFFERENCES BETWEEN THE SATELLITE AND NETWORK CONTROL DATUMS, GEOID-ELLIPSOID RELATIONSHIPS, AND DISTORTIONS AND/OR RELIABILITY IN THE NETWORK CONTROL.

****
NOTE: Few USACE surveys for engineering and construction require rigorous geodetic adjustments; therefore, these clauses should be specified with caution. A variety of free and/or constrained adjustment combinations may be specified. Specific stations to be held fixed may have been indicated in a prior contract section or the contractor may be instructed to determine the optimum adjustment, including appropriate weighting for constrained points. When fixed stations are to be partially constrained, then appropriate statistical information must be provided -- either variance-covariance matrices or relative positional accuracy estimates which may be converted into approximate variance-covariance matrices in the constrained adjustment.
****

[1] *WHEN DIFFERENT COMBINATIONS OF CONSTRAINED ADJUSTMENTS ARE PERFORMED DUE TO INDICATIONS OF ONE OR MORE FIXED STATIONS CAUSING UNDUE BIASING OF THE DATA, AN ANALYSIS SHALL BE MADE AS TO A RECOMMENDED SOLUTION WHICH PROVIDES THE BEST FIT FOR THE NETWORK. ANY FIXED CONTROL POINTS WHICH SHOULD BE READJUSTED (TO ANOMALIES FROM THE ADJUSTMENT(S)) SHOULD BE CLEARLY INDICATED IN A FINAL ANALYSIS RECOMMENDATION.

[2] *THE FINAL ADJUSTED HORIZONTAL AND/OR VERTICAL COORDINATE VALUES SHALL BE ASSIGNED AN ACCURACY CLASSIFICATION BASED ON THE LEAST-SQUARES ADJUSTMENT STATISTICAL RESULTS AND IN ACCORDANCE WITH THE CRITERIA INDICATED IN EM 1110-1-1003. THIS CLASSIFICATION SHALL INCLUDE BOTH THE RESULTANT GEODETIC/CARTESIAN COORDINATES AND THE BASELINE DIFFERENTIAL RESULTS. THE FINAL ADJUSTED COORDINATES SHALL STATE THE 95%

CONFIDENCE REGION OF EACH POINT AND THE (TWO-SIGMA) RELATIVE LINE ACCURACY IN PARTS PER MILLION (PPM) BETWEEN ALL POINTS IN THE NETWORK.

(3) *FINAL ADJUSTED COORDINATE LISTINGS SHALL BE PROVIDED ON HARD COPY *[AND ON *[___] [specify] COMPUTER MEDIA].

(4) * A SCALED PLOT SHALL BE SUBMITTED WITH THE ADJUSTMENT REPORT SHOWING THE PROPER LOCATIONS AND DESIGNATIONS OF ALL STATIONS ESTABLISHED.

C.5 SUBMITTAL REQUIREMENTS:

C.5.1. SUBMITTAL SCHEDULE: THE COMPLETED SURVEY REPORT SHALL BE DELIVERED WITHIN *[___DAYS AFTER NOTICE TO PROCEED IS ISSUED] *[By calendar date]

****

NOTE: Include a more detailed submittal schedule breakdown if applicable to project.

****

C.5.2. SUBMITTED ITEMS: SUBMITTALS SHALL CONFORM TO THOSE SPECIFIED IN EM 1110-1-1003 *[EXCEPT AS MODIFIED HEREIN].

****

NOTE: Reference should be made to EM 1110-1-1003 for typical GPS survey submittal requirements. Modify and/or add items as required.

****

C.5.3. PACKAGING AND MARKING: PACKAGING OF COMPLETED WORK SHALL BE ACCOMPLISHED SUCH THAT THE MATERIALS WILL BE PROTECTED FROM HANDLING DAMAGE. EACH PACKAGE SHALL CONTAIN A TRANSMITTAL LETTER OR SHIPPING FORM, IN DUPLICATE, LISTING THE MATERIALS BEING TRANSMITTED, BEING PROPERLY NUMBERED, DATED AND SIGNED. SHIPPING LABELS SHALL BE MARKED AS FOLLOWS:

U.S. ARMY ENGINEER DISTRICT, _____
ATTN: _____
*[include office symbol and name]
CONTRACT NO. _____
*[DELIVERY ORDER NO. _____]
[STREET/PO BOX] _____
*[complete local mailing address]

*HAND-CARRIED SUBMISSIONS SHALL BE PACKAGED AND MARKED AS ABOVE, AND DELIVERED TO THE FOLLOWING OFFICE ADDRESS:

_____
*[insert office/room number as required]

****

NOTE: In this section, also reference any automated data submittal requirements for GPS observations, if applicable.

****

C.6 PROGRESS SCHEDULES AND WRITTEN REPORTS.

C.6.1. *PRE-WORK CONFERENCE:

****

NOTE: Detail any requirements for a pre-work conference after contract award, including requirements for preparing written reports for such conferences.

****

SECTION D

CONTRACT ADMINISTRATION DATA

SECTION E

SPECIAL CONTRACT REQUIREMENTS

SECTION F

CONTRACT CLAUSES

****

NOTE: Detailed breakouts of personnel and equipment requirements to be furnished by the contractor should be listed in these sections.

****

SECTION G

LIST OF ATTACHMENTS

G.1. U.S. ARMY CORPS OF ENGINEERS EM 1110-1-1003, NAVSTAR GPS SURVEYING. THIS REFERENCE IS ATTACHED TO AND MADE PART OF THIS CONTRACT.

****

NOTE: List any other attachments called for in contract section C or in other contract sections. This includes items such as:

- Marked-up project sketches/drawings.

- Station/monument descriptions or recovery notes.

- Lists of baseline connections to existing network.

- Lists of fixed (existing) stations to be connected with and adjusted to.

****

SECTION H

PRESENTATIONS, CERTIFICATIONS AND OTHER
STATEMENTS OF OFFERERS

SECTION I

INSTRUCTIONS, CONDITIONS, AND NOTICES TO OFFERERS

Appendix H
Guide Specification for "Geodetic Quality" NAVSTAR Global Positioning System (GPS) Survey Receivers and Related Equipment/ Instrumentation

INSTRUCTIONS

H-1. General

This guide specification supersedes the USACE guide CW-01334.2, 21 June 1991, "Procurement of NAVSTAR Global Positioning System (GPS) Survey Receivers and Related Instrumentation/Equipment." This guide specification is intended for use in preparation and review of specifications for geodetic quality GPS survey instrumentation, equipment, and software. The equipment may be used in static or kinematic applications where centimeter-level applications are required. The GPS data may be post-mission processed to generate positions, or the data may be computed in real time, if the appropriate software and data link are used. This guide includes the technical requirements needed to develop formally advertised specifications.

H-2. Applicability

This guide applies to differential GPS (DGPS) survey systems that provide a three-dimensional baseline between two antennas to an accuracy of about 1 cm or better. Applications include establishing and/or extending precise engineering and construction control, creating digital elevation models, camera station positioning for aerial photogrammetry, hydrographic survey vessel positioning, and tidal/water surface measuring for civil works and military construction projects. This guide supports precise differential static, kinematic, pseudo-kinematic, stop-and-go, and on-the-fly survey modes, in both post mission processing and real time applications. This guide is not intended to support real-time GPS code tracking systems that provide meter-level accuracies for general positioning or navigation applications. (Note that the equipment designed to meet the geodetic needs are generally capable of also meeting the less stringent differential code applications but at much greater cost.) Refer to Appendix I for differential code based equipment to support general meter-level positioning and navigation applications.

H-3. Coverage

This guide follows the Uniform Contract Format for supply solicitations, as outlined in Part 14.201 of the Federal Acquisition Regulations (FAR).

a. This guide may be used for either direct bid solicitations or proposal request solicitations, depending on the complexity of the required system. Evaluation factors (Part IV, Section M) are provided for contracts involving a technical review of proposals. The use of a technical review is optional.

b. A sample "Supplies of Services and Prices" schedule is included in this guide for insertion in Part I, Section B of the contract. Technical performance requirements for a DGPS survey system are in Part I, Section C (Description/ Specifications). Other contract sections that require clauses specific to DGPS equipment are noted. Nontechnical supply contract clauses/provisions, which are incorporated in Parts I, II, III, and IV of the procurement specifications, should be developed by each respective Field Operating Activity (FOA) using appropriate FAR and supplemental guidance.

c. Continuing developments in GPS survey instrumentation and techniques mandate that these guide specifications be continuously evaluated by USACE commands to ensure they are technologically current.

H-4. References

The specification writer must be thoroughly familiar with the basic GPS operating functions (e.g., determining the optimum number and technical characteristics of GPS receivers, auxiliary support equipment and instrumentation, baseline reduction software, and network adjustment criteria) to define the technical requirement options contained in this guide. Additional guidance is found in the HQUSACE POLICY MEMORANDUM, Subject: "Acquisition and Use of Differential Global Positioning System (DGPS) Equipment for USACE Activities," dated 27 January 1994. Other topical information on DGPS is contained in EM 1110-2-1003 "Hydrographic Surveying."

H-5. DGPS System Requirements

This guide may be used to procure a complete "field-to-finish" DGPS survey system. This includes the six scheduled items in Section B: (1) GPS receivers, (2) a microcomputer system, (3) GPS baseline reduction software, (4) network adjustment software, (5) a data link for real time applications, and (6) onsite training. If desired, the system may also be configured to operate with the "On-The-Fly" software developed by USACE under the Dredging Research Program. Some vendors may also supply software providing similar capability. If GPS receivers are being added to an existing system or suite of equipment, then only item (1) above would be required in the solicitation, with other items deleted as necessary. Also note that, in

general, mixing receivers from different manufacturers may not work with all techniques and software.

H-6. Alternate Clauses/Provisions or Options

Alternate clauses/provisions throughout this guide specification are indicated by a single asterisk. This asterisk signifies that provisions that are not applicable to the particular procurement should be deleted. Clauses requiring insertion of descriptive material are indicated by an asterisk and in brackets (e.g., *[ ]). When a choice of items exists, they are normally contained in successive brackets.

H-7. Notes and Comments

General comments and instructions used in this guide are contained within asterisk blocks and highlighted in bold type. These blocked comments and instructions should be removed from the final contract.

H-8. Submittal For Review and Approval

If specifications for NAVSTAR GPS survey systems are required to be submitted to higher authority for review and approval, they shall include printed copies of this guide specification, as revised for the particular procurement action. Guidance on review requirements for GPS systems is contained in the HQUSACE POLICY MEMORANDUM, Subject: "Acquisition and Use of Differential Global Positioning System (DGPS) Equipment for USACE Activities," dated 27 January 1994.

Part I - The Contract Schedule

Section A

Solicitation/Contract Form

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NOTE: Include here Standard Form 33 (Solicitation, Offer and Award) or Standard Form 26 (Award/Contract), as applicable.

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Section B

Supplies or Services and Prices/Costs

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NOTE: The sample below represents a typical schedule for procurement of GPS instrumentation and related equipment. This schedule must be tailored based on the specific technical requirements outlined in Section C of the contract.

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Supplies/Services and Prices

Item No.	Description	Quantity	U/M	U/P	Amt
0001	Precise GPS survey receiver system, related equipment, software, data link, and other components, in accordance with the technical specifications found in Section C.	*[___]	EA	___	___

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add for RFP evaluation or if necessary

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* [Evaluation will be made on the basis of the technical data under the guidelines found in Section M. Failure to show compliance with the specifications will require rejection of the bid.]

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NOTE: The following items are included if a full "field-to-finish" differential GPS survey system is required. Alternately, selected items may be used if the solicitation is to upgrade or add to existing GPS equipment.

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0002	*[Micro-computer system, as specified in Section C.]	___		___	___	___

Item No.	Description	Quantity	U/M	U/P	Amt
0003	* [GPS baseline reduction software, as specified in Section C.]	___	___	___	___
0004	* [Network adjustment software, as specified in Section C.]	___	___	___	___
0005	* [Data link for real-time applications, as specified in Section C.]	___	___	___	___
0006	* [GPS receiver system, data reduction, processing and adjustment software training.]	___	___	___	___

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NOTE: Add other items to the schedule as necessary. These may include tripods, tribrachs, spare batteries, data storage devices, communication/modem devices, software/hardware for navigation (e.g., survey vessel positioning and guidance control). Hardware/software interface requirements to existing survey systems (e.g., hydrographic systems) may also be separately scheduled.

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Section C Description /

Specifications

C.1. General DGPS Description. The DGPS to be procured under this solicitation is intended for use in *[static and/or kinematic] positioning applications using the GPS carrier phase as the principle observable. The system will yield 3-dimensional vectors between a reference and "rover" station to an accuracy of *[10 mm + 2 ppm or better on baselines of 1 to 50 km when operating in a static mode] [and] *[3 cm or better on baselines up to 25 km when operating in a kinematic mode]. *[The system is intended to operate in real time with the incorporation of a communications link, as specified further in Section C of this solicitation.] *[The system will have the capability to resolve the initial integer cycle ambiguity in a robust manner, automatically, while the rover is constantly in motion, known as on-the-fly (OTF), with no more than 60 sec of data, on baselines up to 25 km in length.] *[The OTF ambiguity resolution software will operate in *[real time] *[and/or] *[post processing] applications]. *[The system procured under this solicitation will interface to, and operate with, the USACE OTF software distributed by the U.S. Army Topographic Engineering Center, ATTN: CETEC-TD-GS (OTF software), 7701 Telegraph Rd, Alexandria, Virginia 22315-3864.]

C.2. Receiver Requirements. Unless otherwise specified, the performance requirements given below shall be met by the GPS receivers in conjunction with the antenna assembly and antenna cable.

C.2.1. GPS Signal Levels. GPS receivers delivered shall acquire and track GPS signals and otherwise perform as specified herein, when the signal levels from GPS satellites incident at the antenna are within the range of minimum to maximum levels specified in ICD-PGS-200B-PR.

C.2.2. Cryptographic Keys. *[Unless otherwise specified,] GPS receivers shall perform as specified herein without requiring cryptographic keys, whether or not GPS selective availability (SA) and/or anti-spoofing (AS) are activated.

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NOTE: Two versions of C.2.3. are given. L1 only receivers are adequate for static geodetic survey operations. Robust kinematic operations and OTF ambiguity resolution requires more capable hardware observing the full wavelength L1 and full wavelength L2 carrier phase. Choose one of the two given C.2.3 appropriately.

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*[C.2.3. GPS Observables. The GPS receivers delivered shall provide, at a minimum, the following time-tagged observables: full L1 C/A code, L1 P-code, continuous full wavelength L1 carrier phase, L2 P-code, and continuous full wavelength L2 carrier phase.]

*[C.2.3. GPS Observables. The GPS receivers delivered shall provide, at a minimum, the following time-tagged observables: full L1 C/A code and continuous full wavelength L1 carrier phase.]

(1) Measurement Time Tags. Signal measurements (observables) shall be time tagged with the time of receipt of the signal referenced to the receiver clock. Time tags shall have a resolution of 1 µsec or better. Time tags shall be within 1 msec with respect to GPS time.

(2) Carrier Phase Accuracy. The receiver shall have L1 {*the following is required for OTF operation*} *[and l2 full wavelength] carrier-phase measurement accuracies of 0.75 cm (RMS) or better, exclusive of the receiver clock offset.

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NOTE: The following C.2.3. (3) is for OTF operation only.

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*[(3) Code Accuracy. The receiver shall have an L1 C/A-code phase measurement accuracy of 30 cm (RMS) or better, exclusive of receiver clock time and frequency offsets.]

C.2.4. Receiver Output. The GPS receiver shall be able to output the GPS observables as described in C.2.3. with a latency of less than 1 sec *[and, simultaneously, a differential code position and the timing information stated in 2.6]. The GPS receivers shall be able to output the information from the full GPS navigation message, as specified in ICD-GPS-200 REVB-PR. This shall include ephemeris data, almanac data, ionospheric parameters, and coordinated universal time (UTC) parameters. The UTC and ephemeris data shall be available by request or if a change has occurred in those parameters.

C.2.5. Receiver Data Rate. The GPS observable data described above shall be available at a minimum of a 1 Hz rate.

C.2.6. 1 Pulse Per Second (PPS) Output. GPS receivers delivered shall have a 1 PPS time strobe and its associated time tag. The 1 PPS pulse and time tag shall be accessible through a port (or ports) on the GPS receiver so that external system components can be time synchronized to UTC time.

C.2.7. Internal Receiver Testing. The receiver shall perform a self test and checks to detect electronic malfunctions and/or faulty data collection, including cycle slips. The receiver shall provide immediate *[audio] *[visual] notification of failures. The receiver shall perform any needed calibrations automatically.

C.2.8. Reinitialization. The receiver shall be capable of reinitializing itself and resume normal operation after a power interruption without operator assistance. The data collected by the GPS receiver shall not be lost due to power interruption but stored in the receiver or other archiving media.

C.2.9. Multiple Satellite Tracking. The receiver must be capable of tracking and observing all signals previously stated on a minimum of eight satellites simultaneously, each on an independent channel.

C.2.10. Operating Conditions. The GPS receivers delivered shall meet the following criteria:

(1) Successfully acquire and track unobstructed GPS satellites, visible 5 deg and higher above the horizon, in all weather conditions.

(2) Operate at humidity ranges of 0 to 100 percent.

(3) Operate within the temperature range of -20 ºC to +50 ºC.

*[(4) Be waterproof and able to operate in an ocean environment aboard open survey launches.]

*[(5) Operate in heavy rain, 50.8 mm/day (2 in./day).]

*[(6) Operate in fog.]

*[(7) Operate in and resist corrosion in salty air conditions.]

C.2.11. Receiver Power Requirements. The GPS receivers delivered shall meet the following criteria:

(1) Be self protecting from power surges, spikes, and reverse polarity.

(2) Allow the operator to switch power sources (AC, DC, or battery) while maintaining receiver operation and without loss of stored data.

(3) Provide a *[visual] *[audible] warning for low power.

(4) Be capable of operating using *[a battery pack] *[and] *[or] *[AC power] *[and] *[or] *[12-v DC] *[24-v DC] *[external DC power].

*[(5) The battery pack shall meet the following criteria:]

*[(a) Contain rechargeable battery/batteries which can operate the receiver for at least 3.5 hr on a single (re)charge.]

*[(b) Be *[either] *[internal] *[or] *[external] to the receiver.]

*[(c) Include all cables, hardware, etc. necessary to connect/install the battery pack. The batteries shall be water and dust tight and be protected from damage and inadvertent shorting of the terminals.]

*[(6) For operation using *[AC] *[and] *[external DC] *[power.]

*[(a) When operating under *[AC] *[or] *[DC] power, the unit shall be capable of simultaneously charging the battery pack. The battery pack shall power the receiver if the normal power supply is interrupted.]

*[(b) The AC power supply *[shall be internal] *[may be internal or external] to the receiver.]

*[(c) The power supply/battery charger shall provide all voltages necessary to operate the receiver and (re)charge the battery pack.]

*[(d) The power supply/battery charger shall be designed to automatically protect the battery pack from overcharging.]

*[(e) All cables and connectors needed to connect the power supply/battery charger to the power line *[and receiver] shall be included.]

*[(f) The AC power supply/battery charger shall operate from *[115-v] *[and 230-v] ac (±10 percent) *[50/] 60 Hz, single phase power.]

*[(g) The unit shall operate from external *[12-v DC] *[24-v DC] *[9 to 32-v DC] power.]

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NOTE: Not all manufacturers provide a battery that is internal to the receiver. Moving the battery pack external to the receiver does not affect the functioning; it is a matter of design. For example, doing this could substantially decrease the size of the unit. Different manufacturers have different setups for the batteries. The District is encouraged to know what will work best for them based upon District requirements and determine the necessary battery life.

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C.2.12. Manuals. At least two sets of complete operation and maintenance manuals shall be included with each receiver and shall cover all auxiliary components furnished with each receiver. *[Updates shall be furnished as they become available.]

C.2.13. Field Planning. The receiver shall have internal software that, as a minimum, is capable of computing the availability and positions of satellites for any given time and the current position of the GPS receiver *[and terrestrial position] using data gathered by the GPS receiver.

*[C.2.14. Dimensions. The dimensions of the receiver shall not exceed *[___] length by *[___] width by *[___] height, all such that one person can easily transport the unit.]

*[C.2.15. Weight. The receiver shall be transportable by one person. [One complete field station consisting of receiver, battery pack, antenna, and antenna cable shall not exceed * [___] kg * (__) lbs.]

*[C.2.16. Data Logger. The receiver shall be capable of recording and controlling data on an *[internal]*[external] storage device. This device shall be capable of storing a minimum of *[4] *[6] *[8] *[___] megabytes (mb) of data.]

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NOTE: The DATA LOGGER (C.2.16.) option is required by those who wish to store data within the receiver for post mission processing. Without this capability, some external device, such as a computer and interfacing software, will be required to perform the data logging. Memory should be specified to cover the maximum expected recording durations and rates.

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*[C.2.17. Additional Options for Meter-level DGPS Operations.]

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NOTE: This entire section is optional. It is possible for "geodetic type" GPS receivers as described previously to perform differential code (meter-level) positioning using standard broadcast messages from systems such as the U.S. Coast Guard radio beacon network. If this type of positioning is required, then the following options should be included in the solicitation. Use of the USACE's OTF software does not depend on the following options.

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*[(1) Format. The reference station receiver shall output dgps correction data in the radio technical commission for maritime services special committee 104 (RTCM SC-104) format, version 2.1 and U.S. Coast Guard Broadcast Standard.]

*[(2) Format. The remote station receiver shall accept and apply correction data in RTCMM SC-104 format, version 2.1.]

*[(3) Accuracy. Real time positioning accuracy relative to the reference station shall be *[2] *[6] m *[2] DRMS within a range of at least 42 km (25 miles) from the reference station.]

*[(4) Waypoints. The receivers shall have the ability to accept up to *[___] waypoints which can be selected by the helmsman.]

*[(5) Position Rate. The receiver shall be capable of providing output position fixes at rates within the range of [__] Hz to [__] Hz.]

*[(6) Velocity. The receiver shall be capable of determining *[velocity and] position while moving at speeds of up to [5.14] * [___] meters per sec (*[10] *[___] knots).]

*[C.2.18. Additional Options for Geodetic Grade Static Survey Operations.]

*[(1) Accuracy Specification. The GPS reference receiver shall be capable, when used in conjunction with a remote GPS receiver, of 10 mm + 2 ppm accuracy or better on baselines of 1 to 50 km in length when used in the static differential mode. The receivers shall have an accuracy of 10 mm or better on baselines less than 1 km.]

*[(2) Data Collection. The receiver shall not require over 1 hr of continuous data collection with a minimum of four satellites in order to achieve the accuracy requirements stated in Paragraph C.2.18 (1).]

C.2.19. GPS Antenna Assembly.

(1) Antenna Mount. The GPS antenna shall be capable of being mounted on a standard surveyor's tripod with a 5/8-in. by 11-in. threaded stud *[or to a standard wild type tribrach].

(2) Antenna Phase Center. The center instability of the 3-dimensional phase center of the GPS antenna shall be no greater than 3 mm.

(3) Receiver/Antenna Separation. The system shall allow the antenna to be located at least *[30] *[___] m from the receiver so that it can be operated remotely from the receiver with no system degradation.

(4) Antenna Cables. *[One] *[___] antenna cable(s) shall be furnished with each receiver. *[[One] *[each] of these cables should be at least *[__] m,] * [and the other cable should be at least *[__] m.] All appropriate connectors should already be attached to the cable ends. *[These cables shall be capable of being cascaded for a total length of *[___] m of cable for setup flexibility.]

(5) GPS Survey Antenna. Survey antennas shall receive GPS signals at the l1 *[and l2] frequency *[frequencies] and provide these signals to the GPS receiver. The antenna shall have an omnidirectional horizontal pattern and shall incorporate features which minimize multipath error.

*[(6) Antenna Assembly. The antenna assembly shall include the following items:

*[(a) A method to minimize ice and snow buildup.]

*[(b) A method to reduce bird nesting capability.]

*[(c) The ability to withstand strong winds up to * [___] meters per sec (*[___] knots).]

*[(d) A method to orient (to north) after mounting.]

*[(e) A mechanical mark for height measurement with known offset from phase center.]

*[(f) Operation within the temperature range of -40 °C to +65 °C.]

*[(g) Dimensions. The dimensions of the antenna shall not exceed *[45 cm] in length by *[45 cm] in width by *[15 cm] in height, all so that one person can easily transport the unit.]

*[(h) A method to reduce the effects of multipath.]

*[(i) A method to amplify the signal for cable lengths in excess of 15 m.]

*[(7) Each antenna shall be 100 percent sealed/watertight. *[One] *[___] GPS antenna shall be provided with each GPS receiver unit.]

*[(8) Antenna Pole. An antenna pole shall be provided for use during survey operations. It shall be *[a fixed height pole of 2 m] *[extendable from a length of 1 m (±0.2 m) to 2 m (with a variance of ±0.5m)] and shall allow rapid attachment and detachment of the GPS survey antenna. The pole shall include a built-in leveling device and legs which are *[collapsible and attached] *[detachable].]

*[(9) Tribrach. A standard tribrach (with adapters) shall be provided with each antenna. The tribrach shall allow the antenna to be mounted atop the tripod. The tribrach shall be able to be mounted on top of a

standard surveyor's tripod with a 5/8-in. threaded stud and shall include adapters to allow mounting of standard target sets.]

*[(10) Vehicular Antenna Mount. A survey antenna mount shall be provided that can easily be attached or detached from the vehicle. This mount shall be designed so that it remains firmly in place at speeds of up to 88.5 kmph (55 mph) on a level roadway. The mount shall be designed so that its use does not require vehicle modification.]

C.2.20. Input and Output (I/O) Ports.

(1) Standards. All I/O ports will be compatible with the RS-232 standard.

(2) I/O Ports. *[I/O ports shall be compatible with any processor, data terminal, or storage devices used in the positioning system.] *[The vendor shall provide complete documentation of the I/O ports including connector, signal descriptors, connector pin outs, communications protocols, command and message descriptions, need to set up the receiver and extract and decode the observed data.]

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NOTE: The following options [C.2.20(3) and C.2.20(4)] are not required for the OTF system operation. They would be used for differential code position interface to marine systems such as electronic charts or hydrographic survey systems.

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*[(3) Real time positional data out of the remote receiver will adhere to the National Maritime Electronics Association (NMEA) 0183 data sentences format and will be output over an RS-232 compatible port.]

*[(4) The receiver shall have the capability to output the data, position fixes, and calibration data through a RS-232 compatible serial port.]

C.3. Microcomputer Systems. The microcomputer shall be a portable, *[notebook style,] IBM compatible, microcomputer that is fully compatible with all software and hardware supplied under this solicitation. In addition, the following minimum features shall be included:

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NOTE: For operation of the USACE OTF software, one microcomputer is required for each GPS receiver. A notebook style IS HIGHLY recommended.

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C.3.1. Operate with the microsoft disk operating system (MSDOS) version 5.0 or later.

C.3.2. Utilize a *[486] *[pentium] processor.

C.3.3. Have a clock speed of at least *[33] MHz.

C.3.4. Have a minimum of *[250] megabytes of storage capacity on an internal hard drive, with a 20 msec access speed.

C.3.5. Have a minimum *[16] megabyte of random access memory.

C.3.6. Have one 3.5-in. high density disk drive.

C.3.7. Have a VGA graphics adapter.

C.3.8. Be capable of operating from the same power source as the GPS receiver.

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NOTE: The following item, (C.3.9.), is required for the operation of the USACE OTF software and may not be required for any vendor supplied OTF or kinematic procedure.

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*[C.3.9. Have four serial ports that are available for external use after connecting any mouse trackball, or other device included by the computer manufacturer for operating that computer.

(1) The board for the additional serial ports shall have the host addresses starting at 300 hexadecimal and the interrupts slaved to IRQ5.]

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NOTE: Microcomputer and printer requirements must be tailored to existing USACE Command computer resources. Since this item will generally be based in the field, a dual capability may be required in the District office. Refer to EM 1110-1-1003 for additional details on GPS baseline computation and adjustment requirements.

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C.4. GPS Baseline Processing and Reduction Software.

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NOTE: The USACE OTF software may be used to compute 3-dimensional coordinate differences and positions of the "object" station. This software only uses the OTF ambiguity resolution technique, and is not suited for classic "static" GPS applications. This software is suited for kinematic application and will operate in real-time or post mission processing modes. A number of vendors have similar capability.

Based on FOA requirements, baseline processing software or adjustment software may not be a requirement of this solicitation.

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C.4.1. General. The GPS baseline processing software must be fully compatible with the receivers and microprocessors listed in Paragraphs C.2. and C.3.

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NOTE: If the microprocessor is NOT included as part of this solicitation, then the type of processor must be given to verify software compatibility.

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C.4.2. Data Computations. The baseline reduction software shall compute, at a minimum, *[the carrier-phase integer cycle ambiguity using static and kinematic techniques, including those commonly known as "known

baseline," "rapid static," "antenna swap," "stop-and-go," and "OTF"] *[and subsequently] the 3-dimensional differential baseline components between observation stations, within the accuracy specifications given in Paragraph C.1.

C.4.3. Ephemerides. The baselines computations must utilize both the broadcast and precise ephemerides.

C.4.4. Output Data. The results of the baseline processing shall be in any user-selected form, such as *[geocentric coordinates,] *[state plane coordinates based on the North American Datum of 1927,] *[state plane coordinates based on the North American Datum of 1983,] *[and] *[or] *[universal transform mercator projection coordinates].

C.4.5. Batch Processing. The software shall have the capability to post mission process data sets unattended in a batch mode.

C.4.6. Multiple Copies. The Government shall be allowed to operate the software simultaneously on *[_____] microcomputer systems.

C.4.7. Absolute Point Positioning. The software shall be capable of processing pseudo-range data to obtain single point positions of a single receiver.

*[C.4.8. Real-Time Capability. The software shall be capable of resolving carrier cycle integer ambiguities in real time when the observing stations are connected via a communications link *[as specified elsewhere in this solicitation] using the computational procedure given in Paragraph C.4.2., and subsequently compute 3-dimensional differential baseline components.]

*[C.4.9. Real-Time Output. The results of the real-time baseline processing shall be in any user-selected form, such as geocentric coordinates, state plane coordinates based on the North American Datum of 1927, or universal transform mercator projection coordinates. The results will be time tagged with an accuracy of 50 msec, at the time of signal reception at the antenna. The results will be written to a memory device *[both]*[internal and] external to the device performing the computations and shall be sent to an external computer system, at the selection of the user.]

C.4.10. Updates. All baseline processing software updates shall be provided for a period of *[4] years from the date of delivery.

C.5. Network Adjustment Software.

C.5.1. The network adjustment software shall allow for the direct input of data from the post mission processing software specified in Paragraph C.4. The adjustment software shall include routines to easily edit, correct, manipulate, and output results. The software shall have the capability of simultaneously adjusting a minimum of 100 stations. *[The software shall be fully compatible with the microprocessor listed in Paragraph C.3.]

C.5.2. The network adjustment software shall be based on the theory of least squares. It shall be capable of performing both minimally and fully constrained adjustments. Output statistics shall include relative line (distance) accuracies between all points in the network and point confidence limits for each point in the network. Normalized residuals shall be displayed for all input vectors.

C.5.3. The network adjustment software shall transform geocentric coordinates and geographic coordinates to any user defined projection, such as the North American Datum of 1927 state plane coordinate system.

C.5.4. Multiple Copies. The Government shall be allowed to operate the software simultaneously on *[_____] microcomputer systems.

C.5.5. Updates. All baseline processing software updates shall be provided for a period of *[4] years from the date of delivery.

C.5.6. Geoid Modelling. The software shall include the most recent geoid model available to the public from the national geodetic survey.

*[C.5.7. The network adjustment software shall accept and incorporate data from conventional survey methods such as angles, distance, and elevation differences.]

C.6. Data Link for Real-Time Applications.

C.6.1. The data link shall be completely functionally integrated with the receivers and processors procured under this solicitation. This includes the incorporation of modems for the complete interface of radio to processor/receiver.

C.6.2. The data link shall provide data from the reference station to the "roving" station to allow the system to compute positions of the roving station using a kinematic processing technique, as specified in Paragraph C.1. of this solicitation, at a rate of at least one position per second, with no more than one (1) percent loss of position data. The data link equipment shall be identical at both stations to allow transmission from the "roving" station to the reference station. The kinematic processing technique shall not be a function of the data link used. The data link shall transmit all receiver raw observables, as specified in Paragraph C.2. of this solicitation, to the other receiver used in the differential GPS system.

C.6.3. *[The data link system shall operate at the *[VHF frequency of _____]*[VHF frequencies of ___ ___ ___]]. *[The data link shall operate at a frequency that does not require lincensure for use.] *[The data link shall utilize a commercially available carrier phase broadcast that follows the criteria found elsewhere in Section C of this specification. The proposal will include a fee schedule for prescription and monthly service.]

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NOTE: The frequency used for a VHF broadcast must be coordinated with the FOA frequency manager. Modulation rates and/or channel bandwidth requirements also may have to be specified. The unlicensed frequency will also be low power, hence, very short range.

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*[C.6.4. The data link shall have an omnidirectional broadcast range of *[8]*[16]*[24]*[32]*[40] km (*[5]*[10]*[15]*[20]*[25] miles) and maintain the positioning capability stated in Paragraph C.6.2.]

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NOTE: Today, the maximum range of the OTF technology is about 26.6 km (25 miles). Additionally, the longer ranges require increased power, thus, more licensing restriction.

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*[C.6.5. A mounting kit shall be included to mount the data link antenna to a mast or range pole.]

*[C.6.6. The data link antenna shall be *[suitable for installation on small hydrographic survey launches (less

than 7 m)] *[and]*[have an antenna cable of at least *[____] m]].

*[C.6.7. Power Supply. The data link (including modem) shall operate on the same power source as the GPS receiver.]

C.7. Training.

C.7.1. Upon delivery, the vendor shall provide training of at least *[4] days at *[location] *[to *[4] persons] on the operation of all software and hardware delivered as part of this contract.

*[C.7.2. At a future date, determined by the contracting officer based on coordination with the vendor, and not exceeding 6 months after delivery, the vendor will give an additional *[2] days training at *[location].]

C.8. Miscellaneous Requirements.

C.8.1. All power cables, computer cables, and any other item not mentioned in these specifications needed to make this equipment fully operable shall be furnished as part of this contract.

*[C.8.2. Ruggedized shipping containers shall be furnished for all hardware delivered under this solicitation.]

*[C.8.3. Survey Planning. Survey planning software shall be provided that, as a minimum, includes the following items: tabular and graphic satellite rise/set times, elevations, and azimuths for user-specified geographic locations and times; sky plots of SV positions with provisions for plotting satellite obstructions on the screen; listing of DGOP, PDOP, HDOP, and VDOP; and the selection of specific SV constellations to support in-depth kinematic survey planning.

*[C.8.4. All *[hardware]*[and]*[software] updates will be provided to the Government for a period of * [___] years from the date of delivery, free of charge or delivery cost.]

*[C.8.5. The vendor shall provide repair and maintenance of all hardware delivered under this solicitation for a period of *[___(--)] years, free of charge.]

****

NOTE: At this point, other unique items may be added to the requirements if called for and/or requiring specification in Section B. Any specific vessel installation requirements for receivers, data links or antenna should be added. As-built vessel drawings or installation sketches should be attached to the contract at Part III, Section J. If DGPS is to be integrated with an existing navigation and/or survey system, manuals, drawings, etc. associated with that system should be referenced and attached at Section J. Both hardware and software connections and modifications to the existing system must be detailed if such effort is to be an item of work under this contract.

****

Section D Packaging and

Marking

D.1. Preparation for Delivery. The system shall be packaged for shipment in accordance with the supplier's

standard commercial practice.

D.2. Packaging and Marking. Packaging shall be accomplished so that the materials will be protected from handling damage. Each package shall contain a properly numbered, dated, and signed transmittal letter or shipping form, in duplicate, listing the materials being transmitted. Shipping labels shall be marked as follows:

U.S. Army Engineer District, _____
ATTN: {include office symbol and name}
Contract No. _____
[Street/PO Box] {complete local mailing address}

Section E Inspection and Acceptance

E.1. Acceptance Test. All equipment and related components obtained under these specifications shall be fully certified prior to contract award as meeting the performance and accuracy in Section C. *[Any test previously performed for the Federal Geodetic Control Subcommitee (FGCS) will be acceptable for such certification by the vendor; otherwise the vendor shall be required to demonstrate, at the vendor's expense, the acceptability of the system in the manner prescribed in Paragraph E.2. If the FGCS test is to be used in lieu of a demonstration acceptance test, all results from the FGCS test shall be supplied to the contracting officer for evaluation by technical personnel.]

E.2. Final Acceptance Test. At the option of the Government, a final acceptance test will be performed to demonstrate total system conformance with the technical specifications and requirements in Section C.

E.2.1. The acceptance test will be conducted with the system operating in the modes stated in Paragraph C.1. of this solicitation.

E.2.2. The DGPS positional accuracy will be tested against the accuracy and ranges specified in Paragraph C.1. of this solicitation. The resultant DGPS accuracy will be evaluated with the 1 DRMS error statistic. Inaccuracies in the comparitive testing network / system will be properly allowed for in assessing the test results.

E.2.3. Final acceptance testing will be performed at *[the point of delivery indicated in Section D] *[_____], and will be performed within *[____] days after delivery. The supplier will be notified of the results within *[____] days after delivery. If the equipment fails to meet the acceptance test(s), the supplier will be given *[____] days after notification thereof to make any modification(s) necessary to enable retesting. The supplier will be notified of the place, date, and time of testing and, at his option, may send a representative to attend such tests.

E.2.4. If after a second test, the system fails to perform in accordance with the technical specifications, the Government will *[_____].

****
NOTE: The applicable contract clause and provisions must be referenced here.
****

E.3. Warranty Provisions. For 1 year after delivery by the vendor, all equipment failures, other than those due to abuse, shall be corrected free of charge. Equipment shall be repaired within 5 working days of receipt at the repair facility, or loaner equipment will be provided at no expense to the Government until repairs are completed and the equipment has been returned to the district. The cost of shipping equipment to the vendor for repair shall be paid by the Government while the vendor will pay for returning the equipment to the District.

Section F Deliveries or

Performance

F.1. Delivery and final acceptance of all equipment shall be made within *[___] days after contract award. Delivery shall be made at the USACE facilities at the address identified in Paragraph D.2. of this solicitation. Final acceptance will depend upon all equipment meeting all requirements specified in this contract.

F.2. The contractor shall deliver all material and articles for shipment in a manner that will ensure arrival at the specified delivery point in satisfactory condition and that will be acceptable to carriers at the lowest rates. The contractor shall be responsible for any and all damage until the equipment is delivered to the Government.

Section G

Contract Administration Data

Section H

Special Contract Requirements

Part II - Contract Clauses

Section I - Contract Clauses

Part III - Contract Clauses

Section J - List of Documents, Exhibits, and Other Attachments

Part IV - Representations and Instructions

Section K - Representations, Certifications, and Other
Statements of Bidders

Section L - Instructions, Conditions, and Notices to Bidders

****

NOTE: Add applicable contract clauses and provisions to the above parts/sections as required by the FAR and other supplemental regulations.

****

Part IV - Representations and Instructions

Section M - Evaluation Factors for Award

****

NOTE: The following clauses would be used if the solicitation requires an evaluation of proposals for award. See the introduction to this guide for the necessity of a formal proposal evaluation.

****

M.1. Price Basis. Bidders are advised that all bids are solicited on a firm fixed-price basis, and bids submitted on any other than a fixed-price basis will be rejected. Bids submitted on a basis other than free on board (FOB) destination will be rejected.

M.2. Evaluation Criteria.

M.2.1. Technical Factors. The technical part of the proposal shall clearly and fully describe the system to be furnished. Descriptive literature, manuals, and/or reports supplied by the Offeror will be the basis of the evaluation. They should clearly address all items found in the specifications. It is imperative that the Offeror respond to all items in the specifications in like language so the evaluation will compare all products from a common standard. Simple statements such as "conform", which indicate understanding of the requirements, are not adequate. Similarly, phrases which imply or state that the product meets or exceeds the specifications without providing adequate data for the evaluators to make comparisons with those specifications are not adequate.

M.2.2. Pricing Factors. The Offeror shall submit a lump sum firm-fixed-price in accordance with Part I, The Schedule, Section B.

M.2.3. Preliminary Assessment Procedure. A preliminary assessment will be performed to determine if the Offeror's proposal is acceptable or can be made acceptable without major modification.

M.2.4. Evaluation Procedure. The evaluation will be based on the Offeror's compliance with a set of technical requirements consisting of the following items:

(1) System Operational Characteristics and Capacities. This includes, but is not limited to, accuracy, number of independent channels, kinematic capability, data link system performance, ease of operation, and versatility.

(2) System Physical Characteristics and Capacities. This includes, but is not limited to, weight, energy requirements, ease of use, and protection from the environment.

(3) *[Post processing software,] *[network adjustment software,]*[and] field planning software. This includes, but is not limited to, adequacy of software for the specified task, ease of use, documentation, versatility, graphics capabilities, and support.

(4) Warranty, support services, and miscellaneous items.

(5) Proposals will be evaluated on the factors listed above by having assigned values that contribute to a total score. Baseline values will be established by the criteria found in the specifications. Weighting of the scores is in descending order of the above factors, with the most important listed at the top and the least important listed last. A technical team will evaluate each technical proposal and assign a point score. For those proposals that do not meet a pre-established minimum score as submitted, but which the Government decides could be made acceptable by the submission of more information, technical discussions may be conducted to obtain clarification or enhancement of any such proposals. After these discussions, a final point score will be assigned to each proposal by the team.

M.2.5. Proposal Completeness. Failure to submit all required information will result in the proposal not being evaluated.

M.2.6. Number of Technical and Price Proposals. *[One] technical and *[one] cost proposal(s) shall be submitted by each Offeror.

M.2.7. Final Acceptance Test. The system (equipment and/or software) may be required to undergo a final field acceptance test as described in Section E of this contract. Final award shall be contingent on this acceptance test.

M.3. Award Procedures.

M.3.1. The Government will select for contract award the best overall proposal whose final offer is the most advantageous to the Government considering the price and the technical factors included in the solicitation.

M.3.2. The Government may award a contract on the basis of initial offers received, without discussions. Therefore, each initial offer should contain the Offeror's best terms from a cost or price and technical standpoint.

M.4. Suggested Proposal Submittal Requirements.

****

NOTE: The following is a list of hardware and software items/options that should be provided by bidders to determine their capability of providing an adequate DGPS-based positioning system. These items should be tailored to specific system requirements as developed in Section C of this solicitation, and would be used only when technical proposals are being evaluated.

****

M.4.1 GPS Receivers.

Signal levels .
Operation without cryptographic keys.
Observables.
- Measurement time tags.
- Carrier phase signals and accuracy.
- Code phase signals and accuracy.

Receiver output.
Receiver data rate.
PPS output.
Internal receiver testing.

Reinitialization.
Multiple satellite tracking.
Operating conditions.
- 5 deg SV acquisition.
- Humidity range.
- Temperature range.
- Waterproof.
- Corrosion resistance.

Power requirements.
- Surge protection.
- Power transfer from AC to DC and reverse.
- Low power warning.
- External power source.
- Battery pack.
- Charge/recharge capacity.
- Battery connections/cables.

Manuals.
Field planning software.
Dimensions.
Weight.
Data logging device.
RTCM output.
RTCM input.
Waypoints.
Position update rate.
Velocity output.
Antenna.
- 5/8-in. by 11-in. mounting.
- Phase center stability.
- Cable length and quantity.
- Frequency reception.
- Environmental considerations.
- Waterproof.
- Antenna pole.
- Tribrach.
- Vehicle mount.

Input/Output ports.
- RS-232 standard.
- Compatability with other components.
- NMEA position string.
- Serial port.

M.4.2. Microcomputer Systems.

Software/hardware compatibility.
DOS operating system.
Processor chip.
Clock speed.
Hard drive capacity and access speed.

Random access memory.
3.5-in. disk drive.
VGA graphics adapter.
Power source.
Four extra serial ports (in addition to a mouse port).

M.4.3. Baseline Processing Software.

Compatibility with receivers and microcomputers.
Data computations.
Ephemerides.
Output data.
Batch processing.
Multiple copies.
Absolute point positioning.
Real-time output.
Updates.

M.4.4. Network Adjustment Software.

Compatibility with other software supplied.
100 station minimum.
Theory of Least Squares.
Transformation capability.
Multiple copies.
Updates.
Conventional survey data input.

M.4.5. Data Link for Real-Time Application.

Compatibility with receivers and microcomputers.
1-sec update rate.
Transmission of raw observables.
Frequency.
Broadcast range.
Data loss (less than 1 percent).
Mounting kit.
Power supply.

M.4.6. Training.

At delivery.
At future date.

M.4.7. Miscellaneous Requirements.

Cables, etc.
Shipping containers.
Survey planning software.

Hardware and software updates.
Maintenance and repair.

Appendix I
Guide Specification for Code Phase Differential NAVSTAR Global Positioning System (GPS) Survey Receivers and Related Equipment/ Instrumentation

INSTRUCTIONS

I-1. General

This guide specification supersedes the USACE guide CW-01334.3, 21 June 1991, "Procurement of a Real-Time Differential Global Positioning System (DGPS)". This guide specification is intended for use in preparation and review of specifications for a real-time differential global positioning system (DGPS), generally for use on hydrographic survey vessels and dredges. However, the system may be used for many other applications. The DGPS positions may be computed in real time with the use of the proper data links or, if desired, it may be post-mission processed to generate positions. This guide includes the technical requirements needed to develop formally advertised specifications.

I-2. Applicability

This guide applies to DGPS survey systems providing an expected accuracy of 1 to 6 m (2drms). Typical applications encompass positioning hydrographic survey vessels and dredges in support of Civil Works river and harbor construction. Applications may include any number of activities requiring real-time positioning of moving platforms at the stated accuracy level. The DGPS system specified measures the broadcast code phase to develop pseudo range corrections at a shore-based reference station. (This may be a reference station installed by the USACE, the U.S. Coast Guard, or some other "differential data provider", if the appropriate standard message format is used.) The reference station corrections are subsequently transmitted to the mobile user via a communications link, where the mobile user computes a corrected position based on the mobile GPS data and the received pseudo range corrections. This guide is not intended to support GPS carrier-phase measuring systems that provide centimeter-level accuracies. Refer to Appendix H for differential carrier- based equipment to support higher accuracy applications.

I-3. Coverage

This guide follows the Uniform Contract Format for supply solicitations, as outlined in Part 14.201 of the Federal Acquisition Regulations (FAR).

a. This guide may be used for either direct bid solicitations or proposal request solicitations, depending on the complexity of the required system. Evaluation factors (Part IV, Section M) are provided for contracts involving a technical review of proposals. The use of a technical review is optional.

b. A sample "Supplies of Services and Prices" schedule is included in this guide for insertion in Part I, Section B of the contract. Technical performance requirements for a DGPS survey system are in Part I, Section C (Description/ Specifications). Other contract sections that require clauses specific to DGPS equipment are noted. Nontechnical supply contract clauses/provisions, which are incorporated in Parts I, II, III, and IV of the procurement specifications, should be developed by each respective Field Operating Activity (FOA) using appropriate FAR and supplemental guidance.

c. Continuing developments in DGPS survey instrumentation and techniques mandate that these guide specifications be continuously evaluated by USACE commands to ensure they are technologically current.

I-4. References

The specification author must be thoroughly familiar with the basic GPS functions (e.g., determining the optimum number and technical characteristics of GPS receivers, and auxiliary support equipment and instrumentation) to define the technical requirement options contained in this guide. Additional guidance is found in the HQUSACE POLICY MEMORANDUM, Subject: "Acquisition and Use of Differential Global Positioning System (DGPS) Equipment for USACE Activities," dated 27 January 1994, and topical information on DGPS is contained in EM 1110-2-1003 (Hydrographic Surveying).

I-5. DGPS System Requirements

This guide may be used to procure a complete DGPS real-time survey system. This includes reference station GPS receiver and processor unit, remote (vessel) station GPS receiver and processor unit, a communication link, and onsite training. If GPS receivers are being added to an existing system or suite of equipment, then only the first item would be required in the solicitation, with other items deleted as necessary. Also note that, in general, mixing receivers from different manufacturers may not work with all techniques and software.

I-6. Alternate Clauses/Provisions or Options

Alternate clauses/provisions throughout this guide specification are indicated by a single asterisk. This asterisk signifies that provisions that are not applicable to the particular procurement should be deleted. Clauses requiring the insertion of descriptive material are indicated by an asterisk and in brackets (e.g., *[ ]). When a choice of items exists, they are normally contained in successive brackets.

I-7. Notes and Comments

General comments and instructions used in this guide are contained within asterisk blocks and highlighted in bold type. These blocked comments and instructions should be removed from the final contract.

I-8. Submittal For Review and Approval

If specifications for NAVSTAR GPS survey systems are required to be submitted to higher authority for review and approval, they shall include printed copies of this guide specification, as revised for the particular procurement action. Guidance on review requirements for GPS systems is contained in the HQUSACE POLICY MEMORANDUM, Subject: "Acquisition and Use of Differential Global Positioning System (DGPS) Equipment for USACE Activities", dated 27 January 1994.

Part I - The Contract Schedule

Section A

Solicitation/Contract Form

****

NOTE: Include here Standard Form 33 (Solicitation, Offer and Award) or Standard Form 26 (Award/Contract), as applicable.

****

Section B

Supplies or Services and Prices/Costs

****

NOTE: The sample below represents a typical schedule for procurement of GPS instrumentation and related equipment. This schedule must be tailored based on the specific technical requirements outlined in Section C of the contract.

****

Supplies/Services and Prices

Item No.	Description	Quantity	U/M	U/P	Amt
0001	Real-time DGPS survey system, related equipment, software, data link, and other components, in accordance with the technical specifications found in Section C.	*[___]	EA	___	___

****

Add for RFP evaluation or if necessary

****

* [Evaluation will be made on the basis of the technical data under the guidelines found in Section M. Failure to show compliance with the specifications will require rejection of the bid.]

****

NOTE: The following items are included as separate components if the solicitation is to upgrade or add to existing GPS equipment.

****

0002	*[Micro-computer system, as specified in Section C.]	___	___	___	___

Item No.	Description	Quantity	U/M	U/P	Amt
0003	* [DGPS post processing and planning, software as specified in Section C.]	___	___	___	___
0004	* [Data link for real-time applications, as specified in Section C.]	___	___	___	___
0005	* [DGPS receiver system, data link, and software training.]	___	___	___	___

****

NOTE: Add other items to the schedule as necessary. These may include spare batteries, data storage devices, communication/modem devices, software/hardware for navigation (e.g., survey vessel positioning and guidance control). Hardware/software interface requirements to existing survey systems (e.g., hydrographic systems) may also be separately scheduled.

****

Section C

Description/Specifications

C.1. General DGPS System Description. The DGPS system to be procured under this solicitation is intended for use in real-time positioning applications using the GPS code phase as the principle observable. The system will yield positions of a "rover" station to an accuracy of *[6 m, 2 DRMS, or better on baselines up to 300 km with respect to a stationary reference station.] *[The system procured under this solicitation will interface to, and operate with, *[the hydrographic surveying package] *[_____]*[and]*[or]*[the electronic display and information system]*[_____].]

C.1.1. General DGPS System Components. Each real-time GPS-based positioning system shall possess at least the following major components:

(1) Integrated GPS receiver/data link receiver-transmitter (referred to as the “DGPS receiver”).
(2) Integrated GPS/data link antenna.
(3) Supporting software.
(4) DGPS receiver controller.

C.2. Receiver Requirements. Unless otherwise specified, the performance requirements given below, shall be met by the GPS receivers in conjunction with the antenna assembly and antenna cable.

C.2.1. GPS Signal Levels. GPS receivers delivered shall acquire and track GPS signals and otherwise perform as specified herein, when the signal levels from GPS satellites incident at the antenna are within the range of minimum to maximum levels specified in ICD-GPS-200 REV. B-PR.

C.2.2. Cryptographic Keys. GPS receivers shall perform as specified herein without requiring cryptographic keys, whether or not GPS selective availability (SA) and/or anti-spoofing (AS) are activated.

C.2.3. Code Accuracy. The receiver shall have an l1 C/A-code phase measurement accuracy of 30 cm (RMS) or better, exclusive of receiver clock time and frequency offsets. Signal measurements (observables) shall be time tagged with the time of receipt of the signal, referenced to the receiver clock. Time tags shall have a resolution of 1 µsec or better. Time tags shall be within 1 msec with respect to GPS time.

C.2.4. Receiver Output. The GPS receiver shall be able to output the GPS observables as described in C.2.3. with a latency of less than 1 sec. The GPS receivers shall be able to output the information from the full GPS navigation message, as specified in ICD-GPS-200 REV. B-PR. This shall include ephemeris data, almanac data, ionospheric parameters and coordinated universal time (UTC) parameters. The UTC and ephemeris data shall be available by request or if a change has occurred in those parameters.

C.2.5. Receiver Data Rate. The GPS observable data described above shall be available at a minimum of a 1 Hz rate.

C.2.6. 1 Pulse Per Second (PPS) output. GPS receivers delivered shall have a 1 PPS time strobe and its associated time tag. The 1 PPS pulse and time tag shall be accessible through a port (or ports) on the GPS receiver so that external system components can be time synchronized to UTC time.

C.2.7. Internal Receiver Testing. The receiver shall perform self tests and checks to detect electronic malfunctions and/or faulty data collection, including cycle slips. The receiver shall provide immediate *[audio] *[visual] notification of failures. The receiver shall perform any needed calibrations automatically.

C.2.8. Reinitialization. The receiver shall be capable of reinitializing itself and resume normal operation after a power interruption without operator assistance. The data collected by the GPS receiver shall not be lost due to power interruption but stored in the receiver or other archiving media.

C.2.9. Multiple Satellite Tracking. The DGPS receiver shall be capable of simultaneously and continuously tracking a minimum of six satellites and shall simultaneously and continuously receive and decode the GPS navigation message from each satellite.

C.2.10. Operating Conditions. The GPS receivers, *[including its antenna,] delivered shall meet the following criteria:

(1) Successfully acquire and track unobstructed GPS satellites, visible 5 deg and higher above the horizon, in all weather conditions.

(2) Operate at humidity ranges of 0 to 100 percent.

(3) Operate within the temperature range of -20 ºC to +50 ºC.

*[(4) Be waterproof and able to operate in an ocean environment aboard open survey launches.]

*[(5) Operate in heavy rain (2 in./day).]

*[(6) Operate in fog.]

*[(7) Operate in and resist corrosion in salty air conditions.]

*[(8) Operate in snow.]

C.2.11. Receiver Power Requirements. The GPS receivers delivered shall:

(1) Be self protecting from power surges, spikes, and reverse polarity.

(2) Allow the operator to switch power sources (AC, DC, or battery) while maintaining receiver operation and without loss of stored data.

(3) Provide a *[visual] *[audible] warning for low power.

(4) Be capable of operating using *[a battery pack] *[and] *[or] *[110-v AC power] *[and] *[or] *[12-v DC power] *[24-v DC power] *[external DC power].

*[(5). The battery pack shall meet the following criteria:]

*[(a) Contain rechargeable battery/batteries that can operate the receiver for at least 3.5 hr on a single (re)charge.;]

*[(b) Be *[either] *[internal] *[or] *[external] to the receiver;]

*[(c) Include all cables, hardware, etc., necessary to connect/install the battery pack. The batteries shall be water and dust tight and protected from damage and inadvertent shorting of the terminals.]

*[(6). For operation using *[AC] *[and] *[external DC] *[power].

*[(a) When operating under *[AC] *[or] *[DC] power, the unit shall be capable of simultaneously charging the battery pack. The battery pack shall power the receiver if the normal power supply is interrupted.]

*[(b) The AC power supply *[shall be internal] *[may be internal or external] to the receiver.]

*[(c) The power supply/battery charger shall provide all voltages necessary to operate the receiver and (re)charge the battery pack.]

*[(d) The power supply/battery charger shall be designed to automatically protect the battery pack from overcharging.]

*[(e) All cables and connectors needed to connect the power supply/battery charger to the power line *[and receiver] shall be included.]

*[(f) The AC power supply/battery charger shall operate from *[115-v] *[and 230-v] AC (±10 percent) *[50/] 60 Hz, single phase power.]

*[(g) The unit shall operate from external *[12-v DC] *[24-v DC] *[9- to 32-v DC] power.]

****

NOTE: Not all manufacturers provide a battery that is internal to the receiver. Moving the battery pack external to the receiver does not affect the functioning; it is a matter of design. For example, moving the battery pack external to the receiver could substantially decrease the size of the unit. The FOA is encouraged to define their requirements and proceed accordingly.

****

C.2.12. Manuals. At least two sets of complete operation and maintenance manuals shall be included with each receiver and shall cover all auxiliary components furnished with each receiver. *[Updates shall be furnished as they become available.]

C.2.13. Field Planning. The receiver shall have internal software that, as a minimum, is capable of computing the availability and positions of satellites for any given time and the current position of the GPS receiver using data gathered by the GPS receiver.

C.2.14. Dimensions. The DGPS receiver shall have no single dimension exceeding *[__] cm.

*[C.2.15. Weight. The receiver shall be transportable by one person. [One complete field station consisting of receiver, battery pack, antenna, and antenna cable shall not exceed *[__] kg (__ lbs).]

C.2.16. Data Format. The roving station receiver shall accept and apply correction data in radio technical commission for maritime services special committee 104 (RTCM SC-104), format version 2.1 and the U.S. Coast Guard Broadcast Standards. *[The reference station receiver shall generate pseudo range corrections for each satellite and transmit the corrections in the RTCM format, to be used by the roving station.]

C.2.17. Accuracy. Real-time positioning accuracy relative to the reference station shall be *[2]*[6] m *[2] sigma, or better, within a range of at least 300 km from the reference station.

C.2.18. Position Rate. The receiver shall be capable of providing output position fixes at rates within the range of [__] Hz to [__] Hz.

C.2.19. Velocity. The receiver shall be capable of determining *[velocity and] position while moving at speeds of up to *[__] knots.]

C.2.20. GPS Antenna Assembly.

(1) Antenna Mount. The GPS antenna shall be capable of being mounted on a standard surveyor's tripod with a 5/8 in. by 11-in. threaded stud *[or to a standard wild type tribrach].

(2) Receiver/Antenna Separation. The system shall allow the antenna to be located at least *[30] *[___] m from the receiver such that it can be operated remotely from the receiver with no system degradation.

(3) Antenna Cables. *[One] *[___] antenna cable(s) shall be furnished with each receiver. *[[One] *[each] of these cables should be at least *[__] m,] * [and the other cable should be at least *[__] m.] All appropriate connectors should already be attached to the cable ends. *[These cables shall be capable of being cascaded for a total length of *[___] m of cable for setup flexibility.]

*[(4). Antenna Assembly. The antenna assembly shall include the following criteria:

*[(a) A method to minimize ice and snow buildup.

*[(b) A method to reduce bird nesting capability.]

*[(c) The ability to withstand strong winds up to *[___] knots.]

*[(d) A method to orient (to north) after mounting.]

*[(e) A mechanical mark for height measurement with a known offset from the phase center.]]

*[(7) Be 100 percent sealed/watertight. *[One] *[___] GPS antenna shall be provided with each GPS receiver unit.]

*[(8). Antenna Pole. An antenna pole shall be provided for use during survey operations. It shall be *[a fixed- height pole of 2 m] *[extendable from a length of 1 m (±0.2 m) to 2 m (with a variance of ±0.5m)] and shall allow rapid attachment and detachment of the GPS survey antenna. The pole shall include a built-in leveling device and legs that are *[collapsible and attached] *[detachable].]

*[(9) Tribrach. A standard tribrach (with adapters) shall be provided with each antenna. The tribrach shall allow the antenna to be mounted atop the tribrach. The tribrach shall be able to be mounted on top of a standard surveyor's tripod with a 5/8-in. threaded stud and shall include adapters to allow mounting of standard target sets.]

*[(10) Vehicular Antenna Mount. A survey antenna mount that can easily be attached or detached from the vehicle shall be provided. This mount shall be designed so that it remains firmly in place at speeds of up to 88.5 kmph (55 mph) on a level roadway. The mount shall be designed so that its use does not require vehicle modification.]

C.2.21. Input and Output Ports.

(1) Standards. *[All I/O ports will be compatible with the RS-232 standard.] *[I/O ports shall be compatible with any remote station processor, data terminal or storage devices used in the positioning system.] *[The vendor shall provide complete documentation of the I/O ports including connectors, signal descriptors, connector pin outs, communications protocols, command and message descriptions, required to set up the receiver and extract and decode the observed data.]

****

NOTE: The following option, C.2.21.(2), would be used for differential code position interface to marine systems such as electronic charts or hydrographic survey systems.

****

*[(2) Real-time positional data out of the remote receiver will adhere to the National Maritime Electronics Association (NMEA) 0183 data sentences format and will be output over an RS-232 compatible port.]

C.3. Data Link for Real-Time Applications.

C.3.1. The data link shall be completely functionally integrated with the receivers and processors procured under this solicitation. This includes the incorporation of modems for the complete interface of radio to processor/receiver.

C.3.2. The data link shall provide data from the reference station to the "roving" station to allow the system to compute positions of the roving station using a pseudo range correction processing technique at a rate of at least one position per second, with no more than 1 percent loss of position data. The processing technique shall not be a function of the data link used. The data link shall transmit RTCM special committee 104 v2.1, as specified in Paragraph C.2. of this solicitation, to the other receiver used in the DGPS system. *[The data link equipment shall be identical at both stations to allow transmission from the "roving" station to the reference station.]

****

NOTE: There are several alternatives for the selection of a data link for the transmission of

pseudo-range corrections. Commercial service providers also charge a prescription and/or monthly fee for the corrections.

****

C.3.3. *[The data link system shall operate at the *[VHF frequency of _____]*[VHF frequencies of ___ ___ ___] and transmit power of *[___] w.]. *[The data link shall operate at a frequency and transmit power that does not require licensure for use.] *[The data link shall utilize a commercially available pseudo-range broadcast that follows the criteria found elsewhere in Section C of this specification. The proposal will include a fee schedule for prescription and monthly service.] *[The data link shall be capable of operation at a minimum of 9,600 baud, be minimum shift keying (MSK) demodulation, have a selectable bit rate between 100 and 200 BPS, be able to receive and select desired USCG Radiobeacon Signals in the range of 283.5 to 325.0 kHz, and operate in conditions similar to the GPS receiver specified in Section C.2.10.]

****

NOTE: The frequency used for a VHF broadcast must be coordinated with the FOA frequency manager. Modulation rates and/or channel bandwidth requirements also may have to be specified. The unlicensed frequency will also be low power, hence, very short range.

****

*[C.3.4. The data link shall have an omnidirectional broadcast range of *[8]*[16]*[24]*[32]*[40] km (*[5]*[10]*[15]*[20]*[25] miles) and maintain the positioning capability stated in Paragraph C.10.2.]

*[C.3.5. A mounting kit shall be included to mount the data link antenna to a mast or range pole.]

*[C.3.6. The data link antenna shall be *[suitable for installation on small hydrographic survey launches (less than 7 m)] *[and]*[have an antenna cable of at least *[____] m (___ ft)]].

*[C.3.7. Power Supply. The data link (including modem) shall operate on a *[standard 110-v AC power source]*[and]*[or]*[unregulated 12-v DC power source].]

*[C.3.8. Integrated GPS/Data Link Antenna Assembly. A combined GPS and data link antenna is desired.]

*[C.3.9. Receiver/Antenna Separation. The system, at the roving station, shall allow the antenna to be located at least 22.86 m (75 ft) from the receiver so that it can be operated remotely from the receiver with no system degradation.]

*[C.3.10. Antenna Cables. Two antenna cable(s) shall be furnished with each receiver. One of these cables should be at least 7.62 m (25 ft), and the other cable should be at least 15.24 m (50 ft). All appropriate connectors should already be attached to the cable ends. These cables shall be capable of being cascaded for a total length of 22.86 m (75 ft) of cable for setup flexibility.]

*[C.3.11. Integrated Antenna Mounting. A standard marine mount shall be provided for the integrated antenna to be mounted on top of a survey vessel.]

*[C.3.12. Antenna Assembly. The antenna assembly shall include the following criteria:

(1) A method to minimize ice and snow buildup.
(2) [A method to reduce bird roosting capability.]
(3) The ability to withstand strong winds up to *[100 knots.]

(4) Operation within the temperature range of -40 ºC to +65 ºC.]

*[C.3.13. Tribrach. A standard tribrach (with adapters) shall be provided with each antenna. The tribrach shall allow the antenna to be mounted atop the tribrach. The tribrach shall be able to be mounted on top of a standard surveyor's tripod with a 5/8-in. threaded stud and shall include adapters to allow the mounting of standard target sets.]

*[C.3.14. Vehicular Antenna Mount. A survey antenna mount shall be provided that can easily be attached or detached from the vehicle. This mount shall be designed so that it remains firmly in place at speeds of up to 88.5 kmph (55 mph) on a level roadway. The mount shall be designed so that its use does not require vehicle modification.]

*[C.4. Receiver Controller.]

*[C.4.1. A receiver controller shall be provided to allow DGPS receiver controls and settings to be modified or changed by the user. This controller may be integral to the GPS receiver and should have the following requirements:]

*[(1) Be capable of running the disk operating system (DOS) 5.0, or later, release date.]

*[(2) Have a minimum of a 486-dx (or equivalent processor) (which has the required math co-processor).]

*[(3) Have a clock speed of at least 66 mHz.]

*[(4) Have a minimum of 200 megabytes (mb) of hard drive, with 20 msec access speed or faster.]

*[(5) Have a minimum of 8 mb random access memory.]

*[(6) Have a minimum of 1 high density 3.5-in. disk drive.]

*[(7) Have a VGA graphics adapter.]

*[(8) Have a minimum of one parallel port and two serial ports.]

*[(9) Have an external monitor port that allows both internal and external monitor display simultaneously.]

*[(10) Be notebook computers.]

*[(11) Have an expansion port or module.]

*[C.4.2. Power. The controller must be able to operate from the same power sources as the receiver.]

*[C.4.3. Environment. The controller must be able to work in the same environment as the DGPS receiver.]

C.5. Software

C.5.1. All software must be provided to change setting and/or configure the GPS receivers.

C.5.2. All software must run on the platform as stated in Section C.4.

C.5.3. The software will allow the GPS differential code phase positions to be computed in a post mission processing mode.

C.5.4. Updates. All post-processing software updates shall be provided for a period of 4 years from the date of delivery.

C.6. Training.

C.6.1. Upon delivery, the vendor shall provide training of at least *[1] day at *[location] *[to *[4] persons] on the operation of all software and hardware delivered as part of this contract.

*[C.6.2. At a future date, determined by the contracting officer based on coordination with the vendor, and not exceeding 6 months after delivery, the vendor will give an additional *[1] day training at *[location].]

C.7. Miscellaneous Requirements.

C.7.1. All power cables, computer cables, and any other item not mentioned in these specifications needed to make this equipment fully operable shall be furnished as part of this contract.

*[C.7.2. Rugged shipping containers shall be furnished for all hardware delivered under this solicitation.]

*[C.7.3. Survey Planning. Survey planning software shall be provided that, as a minimum, includes the following: tabular and graphic SV rise/set times, elevations, and azimuths for user specified geographic locations and times; sky plots of satellite positions with provisions for plotting satellite obstructions on the screen; listing of GDOP, PDOP, HDOP, and VDOP; selection of specific satellite constellations to support in-depth kinematic survey planning; and selection of multiple satellite obstructions.

C.7.4. All hardware and software updates will be offered to the Government for a period of 1 year from the date of delivery, free of charge or delivery cost, or at a set rate as specified by the contract. The Government may, at its option, accept or reject the offered updates. The vendor shall support repair and maintenance of the Government owned configurations of hardware, firmware, and software for a minimum of 5 years after delivery.

*[C.7.5. The vendor shall provide repair and maintenance of all hardware delivered under this solicitation for a period of *[___ (--)] years, free of charge.]

****

NOTE: At this point, other unique items may be added to the requirements if called for and/or requiring specification in Section B.

Any specific vessel installation requirements for receivers, data links, or antenna should be added. As-built vessel drawings or installation sketches should be attached to the contract at Part III, Section J.

If DGPS is to be integrated with an existing navigation and/or survey system, manuals, drawings, etc. associated with that system should be referenced and attached at Section J. Both hardware and software connections and modifications to the existing system must be detailed if such effort is to be an item of work under this contract.

****

Section D Packaging and

Marking

D.1. Preparation for Delivery. The system shall be packaged for shipment in accordance with the supplier's standard commercial practice.

D.2. Packaging and Marking. Packaging shall be accomplished so that the materials will be protected from handling damage. Each package shall contain a transmittal letter or shipping form, in duplicate, listing the materials being transmitted, being properly numbered, dated, and signed. Shipping labels shall be marked as follows:

U.S. Army Engineer District, _____
ATTN: {include office symbol and name}
Contract No. _____
[Street/PO Box] {complete local mailing address}

Section E Inspection and

Acceptance

E.1. Acceptance Test. All equipment and related components obtained under these specifications shall be fully certified prior to contract award as meeting the performance and accuracy in Section C. *[any test previously performed for the Federal Geodetic Control Subcommitee (FGCS) will be acceptable for such certification by the vendor; otherwise the vendor shall be required to demonstrate, at the vendor's expense, the acceptability of the system in the manner prescribed in Paragraph E.2. If the FGCS test is to be used in lieu of a demonstration acceptance test, all results from the FGCS test shall be supplied to the contracting officer for evaluation by technical personnel.]

E.2. Final Acceptance Test. At the option of the Government, a final acceptance test will be performed to demonstrate total system conformance with the technical specifications and requirements in Section C.

E.2.1. The acceptance test will be conducted with the system operating in *[static] *[dynamic] *[both static and dynamic] mode(s).

E.2.2. The DGPS positional accuracy will be tested against the accuracy and ranges specified in Paragraph C.1. of this solicitation. The resultant DGPS accuracy will be evaluated with the 2 DRMS error statistic. Inaccuracies in the comparative testing network / system will be properly allowed for in assessing the test results.

E.2.3. The data link system will be tested over the operating distance specified in Section C.

E.2.4. Final acceptance testing will be performed at *[the point of delivery indicated in Section D] *[_____], and will be performed within *[____] days after delivery. The supplier will be notified of the results within *[____] days after delivery. If the equipment fails to meet the acceptance test(s), the supplier will be given *[____] days after notification thereof to make any modification(s) necessary to enable retesting. The supplier will be notified of the place, date, and time of testing and, at his/her option, may send a representative to attend such tests.

E.2.5. If after a second test, the system fails to perform in accordance with the technical specifications, the Government will *[_____]. {Reference applicable contract clauses/provisions}.

****

NOTE: The applicable contract clause and provisions must be referenced here.

****

E.3. Warranty Provisions. For 1 year after delivery by the vendor, all equipment failures, other than those due to abuse, shall be corrected free of charge. Equipment shall be repaired within 5 working days of receipt at the repair facility, or loaner equipment will be provided at no expense to the Government until repairs are completed and the equipment has been returned to the District. The cost of shipping equipment to the vendor for repair shall be paid by the Government while the vendor will pay for returning the equipment to the District.

Section F Deliveries or

Performance

F.1. Delivery and final acceptance of all equipment shall be made within *[___] days after contract award. Delivery shall be made at the USACE facilities at the address identified in Paragraph D.2. of this solicitation. Final acceptance will depend upon all equipment meeting all requirements specified in this contract.

F.2. The contractor shall deliver all material and articles for shipment in a manner that will ensure arrival at the specified delivery point in satisfactory condition and that will be acceptable to carriers at lowest rates. The contractor shall be responsible for and repair any and all damage until the equipment is delivered to the Government.

Section G

Contract Administration Data

Section H

Special Contract Requirements

Part II - Contract Clauses

Section I - Contract Clauses

Part III - Contract Clauses

Section J - List of Documents, Exhibits, and Other Attachments

Part IV - Representations and Instructions

Section K - Representations, Certifications, and Other
Statements of Bidders

Section L - Instructions, Conditions, and Notices to Bidders

****

NOTE: Add applicable contract clauses and provisions to the above parts/sections as required by the FAR and other supplemental regulations.

****

Part IV - Representations and Instructions

Section M - Evaluation Factors for Award

****

NOTE: The following clauses would be used if the solicitation requires an evaluation of proposals for award. See the introduction to this guide for the necessity of a formal proposal evaluation.

****

M.1. Price Basis. Bidders are advised that all bids are solicited on a firm fixed-price basis, and bids submitted on any other than a fixed-price basis will be rejected. Bids submitted on a basis other than free on board (FOB) destination will be rejected.

M.2. Evaluation Criteria.

M.2.1. Technical Factors. The technical part of the proposal shall clearly and fully describe the system to be furnished. Descriptive literature, manuals, and/or reports supplied by the Offeror will be the basis of the evaluation. They should clearly address all items found in the specifications. It is imperative that the Offeror respond to all items in the specifications in like language so the evaluation will compare all products from a common standard. Simple statements such as "conform," which indicate understanding of the requirements, are not adequate. Similarly, phrases which imply or state that the product meets or exceeds the specifications without providing adequate data for the evaluators to make comparisons with those specifications are not adequate.

M.2.2. Pricing Factors. The Offeror shall submit a lump-sum, firm, fixed price in accordance with Part I, The Schedule, Section B.

M.2.3. Preliminary Assessment Procedure. A preliminary assessment will be performed to determine if the Offeror's proposal is acceptable or can be made acceptable without major modification. (The basis for this assessment will be the descriptive literature as called for in Paragraph M.2.1. It is important that this literature be complete, clear, and concise.)

M.2.4. Evaluation Procedure. The evaluation will be based on the Offeror's compliance with a set of technical requirements consisting of the following items:

(1) System Operational Characteristics and Capacities. This includes; but is not limited to; accuracy, number of independent channels, data link system performance, ease of operation, and versatility.

(2) System Physical Characteristics and Capacities. This includes; but is not limited to; weight, energy requirements, ease of use, and protection from the environment.

(3) *[Post Processing Software] *[and] Field Planning Software. This includes; but is not limited to; adequacy of software for the specified task, ease of use, documentation, versatility, graphics capabilities, and support.

(4) Warranty, support services, and miscellaneous items.

(5) Proposals will be evaluated on the factors listed above by having assigned values that contribute to a total score. Baseline values will be established by the criteria found in the specifications. Weighting of the scores is in descending order of the above factors, with the most important listed at the top and the least important listed last. A technical team will evaluate each technical proposal and assign a point score. For those proposals that do not meet a pre-established minimum score as submitted, but that the Government decides could be made acceptable by the submission of more information, technical discussions may be conducted to obtain clarification or enhancement of any such proposals. After these discussions, a final point score will be assigned to each proposal by the team.

M.2.5. Proposal Completeness. Failure to submit all required information will result in the proposal not being evaluated.

M.2.6. Number of Technical and Price Proposals. *[One] technical and *[one] cost proposal(s) shall be submitted by each Offeror.

M.2.7. Final Acceptance Test. The system (equipment and/or software) may be required to undergo a final field acceptance test as described in Section E of this contract. Final award shall be contingent on this acceptance test.

M.3. Award Procedures.

M.3.1. The Government will select for contract award the best overall proposal whose final offer is the most advantageous to the Government considering the price and the technical factors included in the solicitation.

M.3.2. The Government may award a contract on the basis of initial offers received, without discussions. Therefore, each initial offer should contain the Offeror's best terms from a cost or price and technical standpoint.

M.4. Suggested Proposal Submittal Requirements.

****

NOTE: Select the appropriate items/options that should be provided by bidders to determine their capability in providing an adequate real-time positioning system. These items should be tailored to specific system requirements.

****

M.4.1 GPS Receivers.

Positional accuracy of system.
Signal levels .
Operation without cryptographic keys.
Observables.
    Measurement time tags.
    Code phase signals and accuracy.
Receiver output.
Receiver data rate.
PPS output.

Internal receiver testing.
Reinitialization.
Multiple satellite tracking.
Operating conditions.
- 5 deg SV acquisition.
- Humidity range.
- Temperature range.
- Waterproof.
- Corrosion resistance.

Power requirements.
- Surge protection.
- Power transfer from AC to DC and reverse.
- Low power warning.
- External power source.
- Battery pack.
- Charge/recharge capacity.
- Battery connections/cables.

Antenna.
- 5/8-in. by 11-in. mounting.
- Phase center stability.
- Cable length and quantity.
- Frequency reception.
- Environmental considerations.
- Waterproof.
- Antenna pole.
- Tribrach.
- Vehicle mount.

Manuals.
Field planning software.
Dimensions.
Weight.
RTCM output.
RTCM input.
Position update rate.
Velocity output.
Ports.
NMEA 0183 data string.

M.4.2. Data Link.
Functional itegration.
1 percent data loss.
Transmit/receive frequency.
Transmit/receive power.
Baud rate.
Prescription fee.
Service fee.
Antenna mounting.
Cables.
Power supply.

M.4.3. Receiver Controller.

Software/hardware compatibility.
DOS operating system.
Processor chip.
Clock speed.
Hard drive capacity and access speed.
Random access memory.
3.5-in. disk drive.
VGA graphics adapter.
Monitor.
Ports.
Power source.
Environment.

M.4.4. Software.

Compatibility with receivers and microcomputers.
Differential code phase processing, post mission.
Receiver control settings.
Field mission planning.

M.4.5. Training.

At delivery.
At future date.

M.4.6. Miscellaneous Requirements.

Cables, etc.
Shipping containers. Survey
planning software. Hardware
and software updates.
Maintenance and repair.

EM 1110-2-1003
30 November 2013

US Army Corps
of Engineers

ENGINEERING AND DESIGN

Hydrographic Surveying

ENGINEER MANUAL

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DEPARTMENT OF THE ARMY
U.S. Army Corps of Engineers
Washington, DC 20314-1000

EM 1110-2-1003

CECW-CE / CECW-OD

Manual
No. 1110-2-1003

30 November 2013

Engineering and Design
HYDROGRAPHIC SURVEYING

1. Purpose. This manual provides technical guidance for specifying requirements and performing hydrographic surveys of USACE river and harbor navigation projects, water control projects, and shore protection projects.

2. Applicability. This manual applies to all USACE commands having responsibility for civil works navigation, dredging, flood risk management, multi-purpose water supply/control, coastal storm damage reduction, hurricane protection, and hydropower projects.

3. Distribution Statement. This publication is approved for public release; distribution is unlimited.

4. Discussion. Hydrographic surveys are performed to provide underwater site plan data for nearly all USACE civil works activities. These projects primarily include channel condition, measurement, payment, and clearance surveys of coastal Federal navigation channels, inland river and intracoastal navigation projects, reservoirs, and underwater structural surveys at locks and dams. Also included are surveys for various coastal engineering projects, beach renourishment and restoration projects, shoreline protection structure construction (breakwaters and jetties), and river stabilization structures. Hydrographic survey systems developed during the past decade have become increasingly complex, requiring the integration of acoustic multibeam sonar systems with differential GPS positioning systems and inertial vessel orientation/alignment systems. Acoustic depth measurements now utilize sophisticated beam forming phase detection, interferometric, synthetic aperture, and backscatter signal processing methods. The quality control and quality assurance guidance in this manual is intended to increase the overall confidence in reported navigation project clearances and the measured elevations of water control and shore protection projects.

FOR THE COMMANDER:

18 Appendixes
(See Table of Contents)

R. MARK TOY, P.E
Colonel, Corps of Engineers
Chief of Staff

This manual supersedes EM 1110-2-1003, dated 1 January 2002.

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DEPARTMENT OF THE ARMY
US Army Corps of Engineers
Washington, DC 20314-1000

EM 1110-2-1003

CECW-CE/CECW-OD

Manual
No. 1110-2-1003

30 November 2013

Engineering and Design
HYDROGRAPHIC SURVEYING

TABLE OF CONTENTS

	Paragraph	Page
Chapter 1. Introduction		
Purpose	1-1	1-1
Applicability	1-2	1-1
Distribution	1-3	1-1
References	1-4	1-1
Discussion	1-5	1-1
Abbreviations and Acronyms	1-6	1-1
Hydrographic Survey Support to Corps Civil Works Activities	1-7	1-1
Use and Scope of Manual	1-8	1-3
Hydrographic Surveying Requirements during Project Phases	1-9	1-4
Geospatial Data Policy	1-10	1-4
Metrics	1-11	1-5
Trade Name Exclusions	1-12	1-5
Manual Development	1-13	1-5
Proponency	1-14	1-6
Chapter 2. Overview of Hydrographic Surveys for Civil Works Navigation and Water Control Projects		
Required Supplemental References	2-1	2-1
Section I: Overview of Hydrographic Survey Techniques		
General Hydrographic Survey Methods	2-2	2-1
Survey Coverage Options	2-3	2-2
Survey Line Spacing and Alignment Specifications	2-4	2-3
Horizontal Positioning Methods and Datum Specifications	2-5	2-5
Vertical Datum Specifications	2-6	2-6
Water Surface Elevation Measurement Specifications	2-7	2-6
Vessel Motion and Orientation Requirements	2-8	2-7
Quality Control and Quality Assurance	2-9	2-8
Miscellaneous Survey Requirements	2-10	2-8

	Paragraph	Page
Section II: General Planning Considerations		
General	2-11	2-9
Determining Project Accuracy Requirements	2-12	2-11
Determining Required Data Density	2-13	2-12
Section III: Vessel Selection Considerations		
General Considerations	2-14	2-13
Vessel and Equipment Acquisition	2-15	2-15
Section IV: Data Processing, Editing, Depth Selection, and Plotting Options		
Hydrographic Data Processing Flow	2-16	2-15
Initial Field Data Review and Editing	2-17	2-16
Office Data Editing and Processing	2-18	2-17
Depth Selection Options	2-19	2-18
Hard Copy Plot Options	2-20	2-20
Selecting Representative Depths on Plan Drawings	2-21	2-21
Terrain Modeling	2-22	2-22
Data Submittal to District Office Project/Design Engineer	2-23	2-22
Retention of Hard-Copy Depth Records	2-24	2-23
Section V: Estimating Costs for Hydrographic Surveys of Navigation Projects		
Factors to Consider in Estimating Survey Time	2-25	2-23
Plant Rental Rates	2-26	2-25
Crew Labor Rates	2-27	2-25
Effective Daily Field Survey Crew Rates	2-28	2-25
Survey Time and Cost Estimates	2-29	2-25
Section VI: Decision Matrix: Single Beam v Multibeam Surveys		
Chapter 3. Recommended USACE Accuracy Standards for Federal Navigation Projects		
Purpose and Scope	3-1	3-1
Discussion	3-2	3-2
Quality Assurance Performance Tests	3-3	3-2
Total Propagated Uncertainty Accuracy Estimates	3-4	3-4
Recommended USACE Depth Accuracy Standards for Engineering and Construction Surveys	3-5	3-4
Horizontal Accuracy Standards	3-6	3-7
IHO Standards for Hydrographic Surveys	3-7	3-7

	Paragraph	Page
Chapter 4. Single Beam Depth Measurement Systems		
General Scope and Applications	4-1	4-1
References	4-2	4-1
Section I: Principles of Acoustic Single Beam Depth Measurement		
Overview	4-3	4-1
Single Beam Transducer and Frequency Specifications	4-4	4-3
Echo-Sounder Control Settings	4-5	4-5
Single Beam Power and Receiver Sensitivity Effects	4-6	4-7
Section II: Single Beam Echo Sounders and Auxiliary Sensors		
Single Beam Echo Sounding Evolution in USACE	4-7	4-9
Single Beam Transducer Mounting Locations	4-8	4-10
Motion Correction on Single Beam Systems--Vessel Heave, Roll, Pitch, and Yaw	4-9	4-10
Section III: Single Beam Quality Control Calibrations		
Bar Check Calibration of Single Beam Echo Sounders	4-10	4-15
Depth Corrections Based on Bar Check Data	4-11	4-20
Velocity Meter Calibration	4-12	4-24
Squat and Settlement Calibration	4-13	4-27
Vessel Dynamic Draft Calibrations	4-14	4-29
Latency Calibrations	4-15	4-29
Section IV: Data Collection, Editing, and Processing		
Single Beam Survey Methods	4-16	4-30
Depth Collection Density and Bottom Coverage	4-17	4-30
Field Collection of Single Beam Survey Data	4-18	4-33
Editing and Processing Single Beam Data	4-19	4-34
Depth Selection and Thinning Options on Single Beam Data	4-20	4-34
Section V: Single Beam System Quality Assurance Performance Tests		
Depth Quality Assurance Techniques for Single Beam Surveys	4-21	4-36
Section VI: Summary of Quality Control and Quality Assurance Criteria for Single Beam Surveys		

	Paragraph	Page
Chapter 5. Multiple Transducer Channel Sweep Systems for Shallow Draft Navigation Projects		
General Overview	5-1	5-1
Background	5-2	5-1
Design of Channel Sweep Systems	5-3	5-2
General Survey Operation	5-4	5-4
Multiple Transducer System Quality Control and Quality Assurance.	5-5	5-5
Selecting Recorded Depths and Estimated Accuracies	5-6	5-8
Section I: Examples of Corps Multiple Transducer Survey Systems		
Mobile District Tuscaloosa Site Office Sweep Systems	5-7	5-9
St. Louis District Ross 875-4 Shallow Water Portable Sweep System	5-8	5-12
New York District Sweep System	5-9	5-13
St. Paul District Sweep System	5-10	5-13
Rock Island District Sweep System	5-11	5-15
Philadelphia District Sweep System	5-12	5-15
Jacksonville District Raytheon 719 CSS (Channel Sweep System)	5-13	5-16
Detroit District 120-Ft Strike Detection Systems	5-14	5-16
Section II: Recommended Quality Control Checklist for Multiple Transducer Sweep Systems		
Chapter 6. Acoustic Multibeam Survey Systems		
General Scope and Applications	6-1	6-1
Background	6-2	6-1
General USACE Applications	6-3	6-2
Section I: Principles of Multibeam Depth Measurement		
General	6-4	6-2
Depth Measurement Principles	6-5	6-2
Overall System Requirements	6-6	6-7
References	6-7	6-8

	Paragraph	Page
Section II: Multibeam Applications and Utilization on USACE Civil Works Projects		
General	6-8	6-9
Project Condition Surveys	6-9	6-9
Dredging Measurement and Payment Surveys	6-10	6-9
Shoal or Strike Detection Applications	6-11	6-10
Underwater Structure Investigation Surveys	6-12	6-11
Multibeam Sidescan Imagery	6-13	6-11
Miscellaneous Considerations	6-14	6-11
Section III: Configuring Multibeam Transducers on Corps Floating Plant		
General	6-15	6-12
Fixed Hull-Mounted Systems	6-16	6-13
Through-Hull Transducer Mountings	6-17	6-14
Bow-Mounted Transducers	6-18	6-14
Side Mounted Transducers	6-19	6-15
Stern-Mounted Multibeam Transducers	6-20	6-20
Section IV: Quality Control Procedures for Multibeam Systems		
Background	6-21	6-22
Initial Installation Alignment and Static Offset Measurements	6-22	6-23
Vessel Squat/Settlement, Draft, and Datum Variations	6-23	6-26
Patch Test (Residual Bias Calibration)	6-24	6-26
Velocity Measurements	6-25	6-30
Vessel Draft and Index Measurements (Bar Checks)	6-26	6-32
Beam Width Restrictions on Multibeam Systems	6-27	6-33
SectionV: Multibeam Survey Data Collection, Editing, and Processing		
Determining Coverage and Overlap	6-28	6-34
Editing and Processing Multibeam Data	6-29	6-36
Editing and Filtering Data	6-30	6-37
Thinning and Binning Multibeam Datasets	6-31	6-38
Recommended Bin Sizes and Depth Selection for USACE Navigation Surveys	6-32	6-38
Depth Selection Options from Binned Multibeam Data	6-33	6-39

	Paragraph	Page
Section VI: Quality Assurance Performance Tests on Multibeam Systems		
General	6-34	6-39
Performance Test Procedures	6-35	6-42
Multibeam versus Single Beam Performance Tests	6-36	6-45
Real-time Quality Assurance Tests	6-37	6-45
Sample Performance Test—Survey Vessel Shuman (Philadelphia District)	6-38	6-45
Fixed Calibration Barge (Louisville District)	6-39	6-46
SECTION VII: Summary of Multibeam QC and QA Criteria		
Chapter 7. GPS Positioning, Orientation, and Water Surface Elevation Measurement		
Purpose	7-1	7-1
Scope	7-2	7-1
Required References	7-3	7-1
GPS Background and Applications in USACE	7-4	7-2
GPS Accuracies	7-5	7-3
Reference Datums	7-6	7-3
Section I: Code Phase Differential GPS Positioning		
Real-Time Code Phase DGPS	7-7	7-3
USCG Code Phase DGPS Radiobeacon Navigation Service	7-8	7-4
Commercial Differential Navigation and Positioning Systems	7-9	7-5
Position Quality Control Tolerance Checks	7-10	7-7
Section II: Real-Time Kinematic Carrier Phase GPS Positioning		
Real-Time Kinematic (RTK)	7-11	7-8
RTK System Requirements	7-12	7-9
Real-Time Networks (RTN)	7-13	7-10
Inertial-Aided Post-Processed Kinematic (IAPPK) Position and Elevation Computations	7-14	7-10
Section III: RTK Water Surface Elevation Measurement		
RTK Surface Elevation Requirements in Coastal Navigation Projects	7-15	7-12
RTK Tide Corrections	7-16	7-13
Heave Correction Options from RTK Measurements	7-17	7-16
KTD File Generation from VDatum	7-18	7-16

	Paragraph	Page
Section IV: Vessel Motion and Orientation Measurement		
Motion Reference Units (MRUs)	7-19	7-17
Inertial Aided GPS Motion Measurement	7-20	7-18
Vessel Heave Corrections and Considerations	7-21	7-20
Recommended Quality Control Criteria for GPS Positioning Methods	7-22	7-22
Chapter 8. Coastal Navigation Project Channel Condition Surveys		
Purpose	8-1	8-1
Scope	8-2	8-1
References	8-3	8-1
Overview	8-4	8-2
Condition Survey Standards and Specifications	8-5	8-2
Topographic Feature Standards for Condition Surveys	8-6	8-3
Hard Copy Map Scales and Formats	8-7	8-4
Feature Content and Digital Data File Standards.	8-8	8-7
Internet Posting of Project Condition Surveys	8-9	8-7
Channel Framework Data	8-10	8-8
Channel Condition Survey Drawing Notes	8-11	8-8
Tabular Channel Condition and Controlling Depth Reports	8-12	8-10
HYPACK Channel Condition Reporter (CCR)	8-13	8-11
Chapter 9. Surveys of Navigable Inland Rivers, Locks and Dams, River Stabilization Structures, and Reservoir Surveys		
General Applications	9-1	9-1
Survey Equipment, Vessels, and Methods	9-2	9-2
Inland River Charting Surveys.	9-3	9-4
River Lock and Dam Investigation Surveys	9-4	9-6
River Stabilization Structure Surveys	9-5	9-8
Underwater Structure and Revetment Surveys	9-6	9-8
Levee Breech Surveys	9-7	9-9
Mississippi River Sand Wave Mapping	9-8	9-9
Section I: Hydrographic Surveys for River Hydraulics Studies		
Background	9-9	9-11
Cross-Sections for Hydraulic Studies	9-10	9-12
Hydraulic Engineering Guidance on Cross-Section Locations	9-11	9-16
Hydraulic Cross-Sections Adjacent to Bridges or Culverts	9-12	9-18
Required Accuracy of Hydraulic Cross-Section Data	9-13	9-20

	Paragraph	Page
Section II: Hydrographic Surveys of Reservoirs and other Impounded Areas		
Reservoir Surveys	9-14	9-22
Surveys of an Earth and Rockfill Dam	9-15	9-27
Section III: Summary of Recommended Accuracy and Performance Standards for Inland Surveys		
Chapter 10. Construction Dredging Measurement, Payment, and Clearance Surveys		
General Scope	10-1	10-1
Background	10-2	10-1
Types of Dredging Support Surveys	10-3	10-2
Dredge Contracting and Production Measurement Methods	10-4	10-4
Definitions of Dredging Grades	10-5	10-6
Factors Impacting Survey Coverage and Accuracy Requirements	10-6	10-8
Measurement, Payment, and Acceptance Survey Contract Specifications	10-7	10-9
Measurement and Payment Surveys Performed by Other than Corps Hired-Labor	10-8	10-11
Section I: Channel Clearance Surveys		
Definitions	10-9	10-12
Channel Clearance Bar Sweeps	10-10	10-13
Acoustic Evaluation of Clearances on Dredging Projects	10-11	10-16
Evaluating Clearance Grades in Unconsolidated Material	10-12	10-23
Side Scan Sonar	10-13	10-23
Combined Uncertainty and Bathymetry Estimator (CUBE)	10-14	10-23
Section II: Dredge Payment Volume Calculations		
Dredge Quantity Computation Techniques—Background	10-15	10-25
Average End Area Method	10-16	10-26
Surface Differencing Methods—“TIN Models”	10-17	10-27
Grid or Bin Vertical Projection Methods	10-18	10-27
Average End Area Computation	10-19	10-27
Reference Surfaces and Payment Templates used in Corps	10-20	10-28

	Paragraph	Page
Section III: Average End Area Computation Methods		
Background	10-21	10-30
Box Cut Allowance	10-22	10-31
Cross-Section End Area and Volume Computations	10-23	10-33
HYPACK Average End Area Dredge Volume Computations	10-24	10-36
Average End Area Computations on Irregular Channels or Non-Parallel Sections	10-25	10-41
SectionIV: Surface Differing Volume Computations (Triangulated Irregular Networks)		
Background	10-26	10-44
Computing Dredge Volumes from TIN Models	10-27	10-47
Overdepth Dredging Statistics (HYPACK DREDGESTATS)	10-28	10-57
Evaluation of Dredge Quantity Estimates Based on Depth Accuracy and Density	10-29	10-57
SectionV: Recommended Guidance for Dredging Surveys and Quantity Computations		
Recommended Dredge Quantity Computation Procedures	10-30	10-63
Contract Guide Specifications for Multibeam Measurement and Payment.	10-31	10-64
Chapter 11. Coastal Engineering Surveys for Beach Renourishment Projects and Shoreline Protection Structures		
Introduction	11-1	11-1
Required Supplemental Reference	11-2	11-1
General Procedures	11-3	11-2
Section I: Coastal Engineering Survey Techniques		
Differential Leveling Methods	11-4	11-7
Total Station Methods	11-5	11-9
Real Time Kinematic GPS Methods	11-6	11-10
Coastal Research Amphibious Buggy (CRAB)	11-7	11-11
Survey Sled Methods	11-8	11-12
Nearshore and Offshore Profile Acoustic Measurement Methods	11-9	11-13
LIDAR Bathymetry and Topography Methods	11-10	11-15
Section II: Coastal Project Applications		
Beach Renourishment Measurement and Payment Surveys	11-11	11-17
Offshore Jetty, Breakwater, and Groin Surveys	11-12	11-20
Subsurface Probings	11-13	11-23

	Paragraph	Page
Offshore Confined Placement or Borrow Area Surveys	11-14	11-26
Section III: General Guidance on Survey Requirements for Coastal Engineering Studies		
Coastal Engineering Studies	11-15	11-28
Accuracy Requirements for Studies	11-16	11-30
Data Density, Formats, Processing and Archiving	11-17	11-30
Coastal Processes Affecting Surveys	11-18	11-31
Overview of Coastal Processes	11-19	11-32
Profile Closure	11-20	11-35
Tides and Other Water Level Changes	11-21	11-35
Survey Planning Considerations	11-22	11-36

Appendices Page

A References……...A-1

B Manual Depth Measurement Techniques……B-1

C Contracted Survey Procedures and Cost Estimates…….C-1

D General Background on Hydrographic Survey Accuracy Estimates……...D-1

E IHO Standards for Hydrographic Surveys (S-44)……E-1

F Multibeam Quality Control and Quality Assurance Procedures
(North Atlantic Division Multibeam User Group)…….....F-1

G Terrestrial (Non-GPS) Positioning Methods…….……...G-1

H Kings Bay Entrance Channel Tidal Modeling for RTK Surveys
(Jacksonville District)…….……H-1

I Implementation of Inertial-Aided Post-Processed Kinematic GPS
Cape Canaveral, FL (Jacksonville District)……I-1

J Field Survey Report: Project Condition Survey
Tampa Harbor, Egmont Bar Channel and Mullet Key Channel
(Jacksonville District)……..J-1

K Channel Framework Data for Coastal Navigation Projects……K-1

L Almond Lake Reservoir Survey and Area Capacity Curves
(Baltimore District)…….…L-1

M 2010 Allegheny River Multibeam/Side Scan Sonar Scour Survey
(Pittsburgh District)……M-1

N Application Examples of Underwater Structural Investigation Surveys…….N-1

O Howard Hanson Dam Monitoring Survey Report-Seattle District…….....O-1

P Depth Measurement and Construction Payment in Unconsolidated
Material……....P-1

Q Navigation Project Object Detection--Side Scan Sonar……..Q-1

Glossary……...Glossary-1

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CHAPTER 1

Introduction

1-1. Purpose. This manual provides technical guidance for specifying requirements and performing hydrographic surveys of USACE river and harbor navigation projects, water control projects, and shore protection projects.

1-2. Applicability. This manual applies to all USACE commands having responsibility for civil works navigation, flood risk management, multi-purpose water supply/control, coastal storm damage reduction, hurricane protection, multi-purpose water supply/control, and hydropower projects.

1-3. Distribution. This publication is approved for public release; distribution is unlimited.

1-4. References. Referenced USACE publications and related bibliographic information are listed in Appendix A. Where applicable, primary source material for individual chapters may be noted within that chapter. Any required supplemental references are noted in each chapter.

1-5. Discussion. Hydrographic surveys are performed to provide underwater site plan data in support of nearly all USACE civil works activities. These support surveys include periodic condition assessments of coastal Federal navigation channels, inland rivers, intracoastal navigation projects, water control reservoirs, and underwater structural surveys at locks and dams. Also included are surveys that support various coastal engineering studies, beach renourishment and restoration construction, shoreline protection structure construction (breakwaters and jetties), and river stabilization structures. Hydrographic survey systems developed during the past decade have become increasingly complex, requiring the integration of acoustic multibeam (swath) sonar systems with carrier-phase GPS positioning systems and inertial vessel orientation/alignment systems. Acoustic depth measurements now employ sophisticated beam forming phase detection, interferometric, synthetic aperture, and backscatter signal processing methods. To reflect these newer developments, this manual establishes recommended accuracy and quality control standards to ensure uniform hydrographic surveying products; especially for construction dredging measurement, payment, and channel clearance assessment. The guidance in this manual is intended to enhance the equitability of contracted construction administration, and increase the overall quality and confidence in reported clearance or protection elevations in federal navigation and related shore protection or water control projects.

1-6. Abbreviations and Acronyms. Abbreviations and acronyms used in this manual are listed in the Glossary. Some abbreviations may be spelled out in each chapter for clarity.

1-7. Hydrographic Survey Support to Corps Civil Works Activities. Hydrographic surveying activities covered in this manual supports a wide range of civil works engineering and construction activities, ranging from federal navigation project dredging to surveys of wetlands.

This section describes some of the more common USACE activities or projects requiring hydrographic survey support.

a. Project condition surveys of federal navigation projects. The Corps is responsible for operating and maintaining over 900 federally authorized coastal navigation projects plus another 12,000 miles of inland and intracoastal navigation system channels. Periodic hydrographic surveys are performed over these authorized projects to determine the current condition and clearance of the navigation channels. These condition surveys are primarily used to determine if project conditions (e.g., shoaling) have changed enough to warrant maintenance dredging, if condition surveys are required at more frequent intervals, or if a greater survey coverage density is necessary. Drawings and/or project condition reports derived from these surveys are furnished to local sponsors, pilots, commercial navigation interests, and to other federal agencies, such as the U.S. Coast Guard (USCG) and the NOAA National Ocean Service (NOS). Condition surveys of inland navigation projects are used to modify project depth conditions for the monthly updates to the Inland Electronic Navigational Charts (IENC).

b. Construction dredging measurement and payment surveys. Dredge measurement and payment surveys encompass all work associated with dredging construction activities in USACE, most particularly those surveys performed to measure the amount of excavated, deposited, and/or placed material in subsurface or upland confinement areas. These surveys also include investigative studies used for preparing contract bid documents (estimated quantities) and for directly monitoring and measuring subsequent contract performance, payment, and acceptance. These surveys require a high level of accuracy in both positioning and depth measurement so that payments will be equitable and consistent with the actual work performed. A significant portion of the Corps' in-house hydrographic survey resources are engaged in direct support of dredging operations; in particular on coastal navigation projects. A wide variety of vessels and survey equipment are used, depending on water depth, inland or coastal location, payment method (in-place or daily rate), and the type of material being dredged.

c. Underwater obstruction and investigation surveys. Hydrographic surveys are performed to locate and assist in the removal of obstructions in Federal navigation channels. Surveys of jetties, breakwaters, locks, revetments, dikes, levees, and other river control structures are performed at regular intervals to assess the subsurface condition of the structures, such as scour, shoal build up, rock voids, etc. They are used to support a variety of engineering requirements. Side-scan sonar and multibeam sonar are typically used to detect obstructions or objects on the navigation channel bottom; in particular, after major storm events or during search and rescue operations. Magnetometer surveys are performed to detect buried pipelines, locate archeological remains, and trace buried cables. Underwater investigation surveys are also performed adjacent to bridge piers, locks, and below hydroelectric power plants to assess scour or other conditions. Both acoustic and visual (camera) methods may be deployed.

d. Coastal engineering surveys. Coastal surveys are performed for a variety of engineering purposes. These surveys are used to evaluate the condition of beach renourishment and hurricane protection projects or to support coastal engineering research studies. Coastal surveys

are performed to study the effects of offshore protection structures (jetties, breakwaters, and groins), harbor entrances, estuaries, and coastlines in areas of suspected accretion, erosion, or other material movement or transport. They are also performed to develop, evaluate, and calibrate physical and numerical models used for planning and design of projects. During beach renourishment or offshore structure construction, coastal surveys are performed to measure placement and estimate payment.

e. Dam and reservoir sedimentation surveys. Periodic underwater condition surveys are performed at many of the 600 water control/supply dams managed by the Corps, including 75 hydropower projects. Reservoirs behind these dams are periodically surveyed to assess sedimentation rates and update area-capacity curves.

f. Inland navigation charting surveys. Hydrographic surveys are performed to update maps and charts of the Corps inland navigation projects--about 7,500 miles of waterways. Corps-wide, these charts involve hundreds of drawings. These surveys also include periodic updates to Inland Electronic Navigational Charts (IENC). IENC updates are performed as needed when river conditions warrant. Hydrographic, topographic, and facility features along the river are updated.

g. Miscellaneous surveys. Various other marine surveys are performed to support civil works water resources activities. These include: environmental/HTRW surveys/studies of underwater areas, periodic disposal area monitoring surveys during placement of material, offshore drill barge location, subsurface probings (wash or dry), tidal boundary surveys (e.g., MHW demarcation), river hydraulic section surveys, river current measurements, wetland surveys, and underwater archeological surveys.

1-8. Use and Scope of Manual. This manual should be used as a "best practices" technical guide in performing hydrographic surveys with USACE hired-labor forces or contracted survey forces. It is also intended to support project managers, project engineers, or construction inspectors in preparing specifications for these surveys. It should be directly referenced in specifications for contracted construction, dredging, or Architect-Engineer services. This manual focuses on quality control calibration and quality assurance testing standards for acoustic single beam and multibeam survey systems. Field operation of particular hydrographic survey positioning systems and acoustic instrumentation are only minimally covered when reference can be made to more current NOAA manuals, data collection software manuals, or manufacturer operational manuals. The recommended quality control and quality assurance criteria in this manual should be considered in developing technical specifications for surveys supporting dredging measurement, payment, and acceptance functions. This manual may be referenced should hydrographic surveying functions be required as part of a USACE military construction or environmental restoration activity. It may also be referenced for surveys performed or procured by local interest groups under various cooperative or cost-sharing agreements.

a. Scope. Chapters 2 through 7 cover basic hydrographic surveying principles, to include: an overview of general survey planning, data acquisition, and processing techniques (Chapter 2),

recommended accuracy standards (Chapter 3), single beam systems (Chapter 4), multiple transducer systems (Chapter 5), multibeam systems (Chapter 6), and GPS positioning systems (Chapter 7). The remaining chapters, along with their associated appendices, describe specific applications to Corps civil works projects. These include coastal navigation project condition surveys (Chapter 8), surveys of inland waterways, river control structures, locks, dams, and reservoirs (Chapter 9), dredging construction surveys (Chapter 10), and coastal engineering surveys (Chapter 11).

b. Recommended guidance versus mandatory standards. Previous versions of this manual contained rigid prescriptive criteria for performing all aspects of hydrographic surveys, including mandatory plant and survey instrumentation, equipment calibration procedures, accuracy standards, data collection procedures, and data plotting criteria. These "mandatory" requirements have been largely eliminated--this updated version now provides only recommended depth accuracy, quality control, and quality assurance criteria—i.e., best practices. This change recognizes the fact that each District's navigation or water control project may have unique site conditions, and that no single accuracy, quality control, or quality assurance performance standard fits all Corps civil works projects. In addition, acoustic and satellite positioning improvements are expected to occur well before future updates to this manual are scheduled, potentially rendering some of the current guidance obsolete.

c. Instrumentation theory and principles. Theory of operation for various acoustic, GPS positioning, and inertial orientation systems is only briefly outlined in this manual—references are provided to other USACE engineer manuals or technical publications for more detailed information. Equipment configuration, calibration, operation, and procedural methods for performing and processing field hydrographic surveys are now sufficiently detailed in operation manuals provided by the various equipment and software vendors.

d. PROSPECT training. This manual is the primary reference document for use in USACE Learning Center (ULC) PROSPECT Course 056 (Hydrographic Survey Techniques).

1-9. Hydrographic Surveying Requirements during Project Phases. Hydrographic surveying support is required throughout most phases of civil works navigation and water resource projects. During the early phases of a project, a comprehensive program should be developed to integrate and fund hydrographic surveying requirements throughout the various stages of a project's life. Procedures for accomplishing this are contained in ER 1110-2-1150, Engineering and Design for Civil Works Projects. Hydrographic surveying support may be required during any of the five project phases outlined in ER 1110-2-1150: Reconnaissance phase, Feasibility phase, Preconstruction Engineering and Design (PED) phase, Construction phase, and Operation and Maintenance phase. Most survey support effort is required during the later three phases.

1-10. Geospatial Data Policy. ER 1110-1-8156, Policies, Guidance, and Requirements for Geospatial Data and Systems, details Army and Corps policies for processing, displaying, transferring, sharing, publishing, and archiving hydrographic survey data. This regulation applies to hydrographic survey data generated in Computer Aided Design (CAD), Site

Information Modeling (SIM), or Geographic Information System (GIS) file formats. Supplemental implementation guidance is in EM 1110-1-2909, Geospatial Data and Systems.

1-11. Metrics. The use of both metric and English systems of measurement in this manual is predicated on the common use of both systems in engineering practice, and the exclusive use of English units by the navigation industry. Although most, if not all, electronic surveying and satellite measurement systems now acquire data in metric units, these data are readily converted to English units by the processing software. In the Corps, engineering project coordinates are normally in English units and water depths are expressed in feet and tenths. Construction units are normally measured in linear feet, square feet (sf), or cubic yards (cy). Exceptions may exist on some OCONUS or military construction projects.

a. Metric-English conversions. Due to the variety of mixed metric and English measurements, equivalent conversions are not shown in this manual; the most common measurement unit is used for example computations. Unless otherwise indicated, metric conversions are based on the U.S. Survey Foot, which equals (exactly) 1200/3937 m (or 3.280833333333 ft/m). Note that OCONUS (and some CONUS) jurisdictions, and some software platforms, use the SI conversion (30.48 m /100 International Foot exactly) instead of the U.S. Survey Foot conversion.

b. Statistics. Accuracy or uncertainty statistics, standards, and tolerances specified in this manual are defined at the 95% Root Mean Square (RMS) level (95% = 1.96-sigma for 1D depth measurements), unless otherwise indicated. The terms "Accuracy," "Error," and "Uncertainty" are often used interchangeably in this manual even though their precise statistical definitions may differ.

1-12. Trade Name Exclusions. The citation or illustration in this manual of trade names of commercially available products, including supporting surveying equipment, instrumentation, and software, does not constitute official endorsement or approval of the use of such products.

1-13. Manual Development. The original version of this manual was developed in the 1980s and first published in 1991, then revised in 1994, 2002, and 2004 (multibeam systems). Most of the standards and technical guidance in the 1991 and 1994 versions were designed to support older analog depth recording instruments, mechanical, visual, or microwave positioning, and manual data processing and drafting methods. The 2002 version added newer technologies, such as acoustic multibeam swath survey systems and differential GPS positioning techniques. Much of the visual/mechanical survey procedural methods in earlier versions was either eliminated or moved to appendices in this current version. This update covers the use of more advanced multibeam systems and enhanced vessel positioning and orientation systems using carrier phase GPS and inertial measurement systems. Field survey activities throughout the Corps participated in the development and review of this latest version of the manual.

1-14. Proponency. The joint proponents for this manual in the HQUSACE Directorate of Civil Works are the Engineering and Construction Community of Practice (CECW-CE) and the Operations and Regulatory Community of Practice (CECW-CO). Technical development and compilation of the manual was coordinated by the U.S. Army Geospatial Center (CEAGC-GSA). Comments or recommended changes to this manual should be forwarded to HQUSACE (ATTN: CECW-CE). Technical issues dealing with dredging operations should be forwarded to HQUSACE (ATTN: CECW-OD).

CHAPTER 2

Overview of Hydrographic Surveys for Civil Works Navigation and Water Control Projects

This chapter provides a general overview of hydrographic surveys required for the engineering, construction, and maintenance of Corps civil works projects. It covers general survey planning, specification development, optional survey methods, vessel selection, reference datums, data processing and editing, and depth selection options. Time and cost estimating procedures are also outlined. The guidance in this chapter is primarily intended for USACE survey sections; however, portions are also applicable for use by project managers or design engineers specifying hydrographic surveys for civil works navigation or water control projects.

2-1. Required Supplemental References. The following reference manuals are required to supplement the material in this chapter.

a. EM 1110-1-1003, NAVSTAR Global Positioning System Surveying.

b. EM 1110-1-1005, Control and Topographic Surveying.

c. EM 1110-1-2909, Geospatial Data and Systems.

d. EM 1110-2-6056, Standards and Procedures for Referencing Project Elevation Grades to Nationwide Vertical Datums.

SECTION I

Overview of Hydrographic Survey Techniques

This section provides an overview of basic hydrographic survey techniques and systems used on Corps civil works projects. It covers both historical and current survey techniques. Details on these techniques are covered in the referenced chapters and appendices in this manual. The following paragraphs in this section contain general guidance on procedural and equipment options that must be considered in developing specifications for a hydrographic survey. These specifications will ultimately determine the required or resultant accuracy of a survey, as further detailed in Chapter 3.

2-2. General Hydrographic Survey Methods. Up until the 1960s, the primary method in USACE for measuring water depths utilized manual techniques. These included lead lines, sounding poles, and topographic surveys (levels and transits). Depth measurements were positioned using a variety of visual survey methods, e.g., transits, sextants, tag lines. Manual depth measurement procedures are described in Appendix B and visual positioning techniques in Appendix G. These manual and visual survey methods were gradually superseded when acoustic depth measurements (echo sounding) were implemented in the 1950s and GPS positioning in the 1990s. Echo sounders project a vertical beam from a single transducer to measure the water

depth. Single beam acoustic systems are described in Chapter 4. In the 1970s multiple transducer sweep systems were developed. These systems employ multiple single beam transducers on a boom array—see Chapter 5. Acoustic multibeam systems evolved in the early 1990s. These systems project an acoustic sweeping array beam from a single transducer. Multibeam system operation is covered in Chapter 6.

2-3. Survey Coverage Options. A primary survey specification must evaluate the density of bottom coverage required for a particular project. This specification affects the engineering use of the data and survey cost. There are two survey coverage methods that may be specified for a project: (1) Cross-Sectioning, or (2) Full Bottom Coverage. Cross-section surveys are performed by lead line, topographic survey methods, and single beam echo sounders. Full bottom coverage surveys are obtained by either multiple transducer systems or multibeam sweep systems. These different survey methods have advantages and disadvantages as outlined in the paragraphs below, and summarized in Table 2-5 at the end of this chapter.

a. Cross-Sectioning surveys. Surveys of navigation and other shore protection projects have traditionally been performed by running cross-sections at some predefined spacing, e.g., every 100 ft. Depths are measured using manual methods (lead line) or acoustic methods (single beam). Cross-section methods are most effective in shallow draft projects and in deep draft projects where the bottom topography in a channel is relatively uniform. Single beam cross-section surveys are typically the most economical method, requiring a minimal amount of survey instrumentation on the survey vessel. Smaller survey boats with low plant rental rates are used. Quality control calibration effort is usually minimal in comparison to multibeam systems. Data editing, processing, plotting, and volume computations are relatively easily and rapidly accomplished.

b. Full Coverage Surveys.

(1) Multiple transducer sweep systems. Multiple transducer boom systems provide full bottom coverage (technically ensonification). Multiple transducer sweep systems have application on shallow draft projects where full bottom coverage is required; thus, they are heavily used by USACE districts on inland navigation projects. The multiple transducer boom is designed to sweep a fixed width of the channel. Survey lines are run to ensure complete bottom coverage (or ensonification). See Chapter 5 of this manual for additional details on these multiple transducer sweep systems.

(2) Acoustic multibeam sweep systems. Multibeam systems can provide complete sweep coverage out to many times the depth of water. They have a particular application in deep draft projects where clearances are most critical, such as in new work or rock cut dredging. They are used in maintenance dredging surveys of deep draft projects and in underwater investigation surveys of underwater structures. Multibeam surveys are conducted on some shallow draft projects, particularly on some small, shallow rivers where bank-to-bank surveys are required to define the channel in rivers with moving sand beds. A full-coverage multibeam sweep will be more efficient than cross-sections in these environments. Multibeam surveys will generally cost

more than single beam methods due to the high-cost instrumentation required. Quality control calibrations and quality assurance testing are far more demanding (and time consuming) than for single beam systems. Multibeam systems require complex (and expensive) positioning and vessel orientation instrumentation. Not all projects require full bottom coverage—single beam cross sections are still adequate for many USACE projects. Therefore, project engineers must weigh the technical advantages of a full coverage survey versus sparser single beam cross-sections.

(3) In effect, multibeam systems are simply cross-sectioning systems. They can generate cross-sections of a channel many times a second, often generating a cross-section at 1-ft spacing along the channel. Hundreds or thousands of depths may be acquired each second. They can provide full-channel coverage surveys in near real-time, including on-board data processing, editing, color plots, and X-Y-Z "cloud" data files for direct import into a MicroStation or AutoCAD platform. Quantity computations using full digital terrain models acquired from multibeam data are significantly more accurate than average-end-area quantity take-offs from single beam cross-section surveys.

2-4. Survey Line Spacing and Alignment Specifications. A survey line spacing must be selected that will provide the necessary density of coverage--or overlapping coverage in the case of multi-transducer or multibeam sweep systems. On dredging projects, the survey line spacing will govern the amount of coverage over a given project area, regardless of whether lines are run as cross-sections or run parallel to the project alignment (profiles or longitudinal lines).

a. Single beam systems. For single-beam cross-section surveys run at a typical 100-ft spacing, the acoustic bottom coverage is typically less than five percent of the project by area. From this relatively low coverage density, quantity computations are estimated, the major assumption being uniformity of terrain between successive survey lines or sections. This is normally a valid assumption on many USACE navigation projects. It becomes invalid if abrupt changes occur between lines, in turn causing inaccuracies in quantity take-offs made using average end area methods. In areas undergoing construction, or where shoals or other irregularities occur, the line spacing should be made closer in order to detect and depict the full extent of irregularities. Far wider spacings are specified by project engineers for non-navigation surveys, such as river sections for hydraulic models, reservoir sedimentation studies, and coastal engineering transport studies. In general, cross-section spacing for navigation projects is 100 ft c/c and usually does not exceed 200 ft c/c.

(1) Alignments. Cross-sections are nearly always run normal to the project's centerline (baseline) alignment, a turning basin, or relative to a fixed baseline located ashore. These alignment references may also include levee baselines, beach construction baselines, or setback lines. Project alignments may be straight, circular curves, or transition curves--cross-sections are run normal to the line or curve tangent. Exceptions may occur in turning basins, wideners, or other irregular shaped areas. Figure 2-1 is an example of different cross-section alignments on a navigation project.

(2) Specifications. Most federal navigation projects have long-established (legacy) cross-section spacing and alignment specifications. Therefore, survey requests need only specify the overall survey limits and side slope coverage extensions.

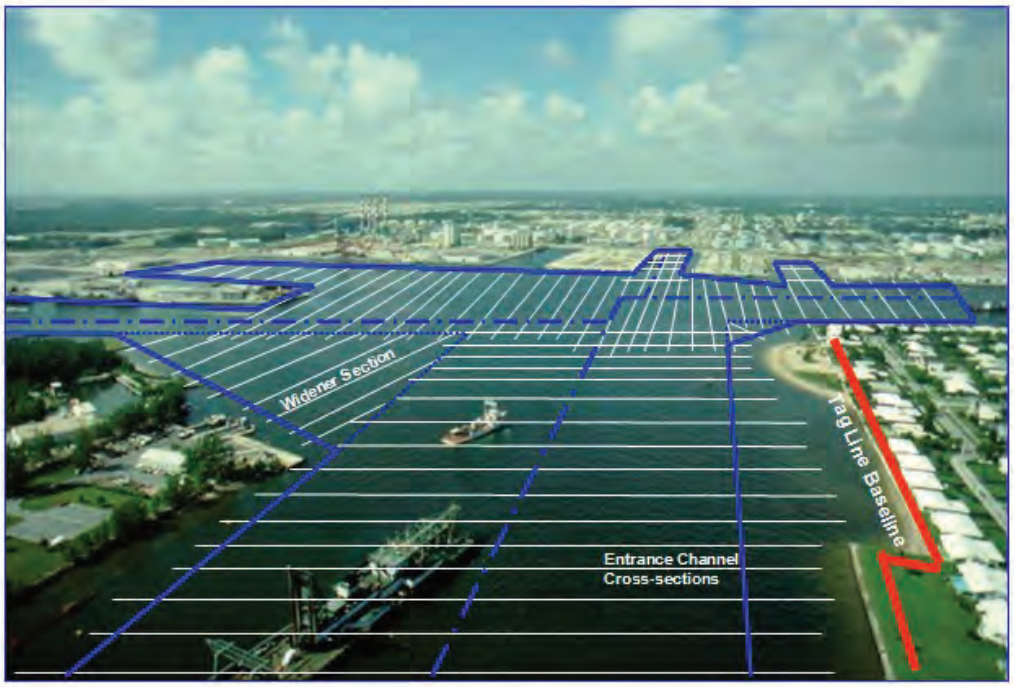

Figure 2-1. Cross-section coverage of a typical navigation project. Channel framework limits shown in blue. The red line on the right bank is a fixed baseline used on prior tag line surveys of the entrance channel. (Port Everglades Harbor, FL)

b. Multibeam systems. Acoustic multibeam systems generate a swath array from a single acoustic transducer. The coverage of this array on the bottom is dependent on water depth, manufacturer array limits, and outer beam quality degradation or loss. Some multibeam systems can be configured for over 180 deg coverage—"bank-to bank." However, due to loss of data quality on the outer beams, the coverage array is limited based on past performance testing. Thus, the array is typically restricted to ±45 to ±50 deg off nadir. This restriction will determine the line spacing. Usually, an overlap is designed into the line spacing. This overlap can range from 20% to 100%, or more in critical areas. Multibeam lines are usually run parallel to the channel alignment, as shown in Figure 2-2. In heavily trafficked projects, running parallel to the channel is an advantage over cross sectioning.

(1) As stated earlier, the primary application for multibeam systems is for surveys of deep-draft navigation projects--typically those projects over 10 to 15 ft in depth. Multibeam swath widths typically range from twice to seven times the water depth. Thus, for a 40-ft project, an 80- to 300-ft swath can be obtained with a single pass, depending on the array limits set. In

Figure 2-2, the five parallel lines will provide full coverage of the channel. Additional lines may be required to detail the upper side slopes.

(2) Specifications. When multibeam surveys are requested by a project manager, they should consult with the vessel Party Chief on the capabilities of the particular system. This mainly involves the recommended array limits based on past performance tests and the amount of desired overlap. This array limit and overlap criteria will, in turn, determine the line spacing and resultant survey time and cost. Details on determining line spacing and overlaps for multibeam systems are covered in Chapter 6.

Figure 2-2. Multibeam survey line coverage on a 40x300 ft wide deep-draft navigation project.

2-5. Horizontal Positioning Methods and Datum Specifications. Prior to the implementation of GPS positioning in the early 1990s, a variety of vessel horizontal electronic and manual positioning methods were employed. These included tag line, sextant, triangulation, trilateration (electronic), and total station.

a. Each of the above methods is described in detail in Appendix G. Two of these methods are still occasionally used on isolated projects—Total Station and Tag Line. GPS positioning techniques (differential code or carrier phase RTK) are now employed on all USACE hydrographic survey systems. RTK positioning is specified on navigation projects with critical clearance requirements, marine structure construction, and underwater structure investigation surveys.

b. Specifications. Project Managers developing survey requirements can generally assume code-phase DGPS positioning will be performed and should specify carrier-phase RTK on special projects requiring sub-meter horizontal accuracy. GPS positioning methods are more fully detailed in Chapter 7 of this manual and in EM 1110-1-1003.

c. Horizontal reference datums. All USACE projects should be referenced to the National Spatial Reference System (NSRS) maintained by the National Geodetic Survey (NGS). Primary control monuments (PBMs) must be directly connected to the NSRS. GPS geocentric coordinate systems are easily (and directly in software) transformed to a local coordinate system, i.e., a local State Plane Coordinate System (SPCS). Most construction and dredging projects also establish a local station-offset grid system which is directly related to the SPCS. Project or construction specifications must clearly state the required horizontal reference datum—both the regional NSRS and the local construction station-offset system. Primary NSRS control and/or calibration monuments at the project site must be clearly identified.

2-6. Vertical Datum Specifications. EM 1110-2-6056 provides detailed guidance on establishing primary control for all types of civil works projects constructed and maintained by USACE. Coastal, inland river, the Great Lakes, and OCONUS regions are covered in EM 1110-2-6056. It provides technical instructions for connecting project control with the NOAA National Spatial Reference System (NSRS) and the NOAA National Water Level Observation Network (NWLON). EM 1110-2-6056 supplements ER 1110-2-8160, Policies for Referencing Project Elevation Grades to Nationwide Vertical Datums, that requires "controlling elevations and local datums on USACE projects shall be properly and accurately referenced to nationwide spatial reference systems used by other Federal, state, and local agencies responsible for flood forecasting, inundation modeling, water control, flood insurance rate maps, navigation charting, and topographic mapping." In summary, survey specifications must indicate that the vertical reference datum can be related to the appropriate NSRS or NWLON system.

2-7. Water Surface Elevation Measurement Specifications. Hydrographic surveys measure depths relative to the local water surface and datum at the place of observation. The elevations on all federal navigation and water resource projects must be referenced to a specified tide or stage gage. This gage must, in turn, be referenced to an established vertical datum—hydraulic stage or tidal. Any variations between this gage datum and the project site must be modeled, interpolated, or extrapolated. Likewise, tidal phase variations must be modeled between the gage and the project site. Hydrographic surveys must be calibrated to this reference gage.

a. RTK surface elevation measurement. On projects with critical clearance grades, such as new work in rock cut channels, RTK elevation measurements should be specified in survey scopes of work. This requirement is also recommended for most construction dredging payment surveys. RTK methods are especially applicable to any navigation project where tidal phase differences between the reference tide gage and the project site are significant, as illustrated in Figure 2-3. RTK should also be used in scour surveys around locks, dams, and other structures.

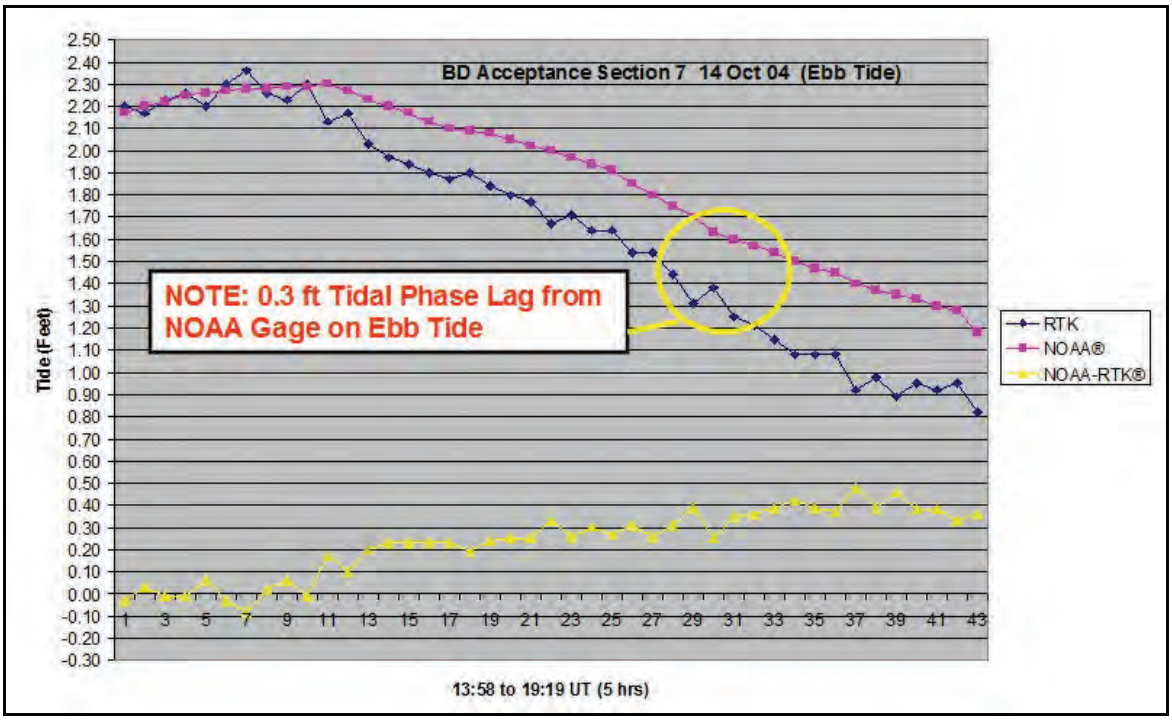

Figure 2-3. Five hours of water surface elevation differences between a NOAA tide gage at Key West, FL, and RTK surface measurements, 3 miles south in the main ship channel. This Pre-Dredge survey shows significant tidal phase differences that would be unaccounted for had only the gage been used. These constant phase differences (e.g., 0.3 ft) would adversely impact dredge clearance assessments and pay quantities if the NOAA gage were used rather than the on-site RTK surface elevations. On USACE projects with similar tidal phase and/or tidal range differences, use of RTK is essential to correct depths at the project site.

b. Specifications. Project or construction specifications should indicate the reference water level gage and datum parameters, along with any stage or tidal datum modeling requirements. RTK requirements should be specified on critical projects where direct gage data is inadequate.

2-8. Vessel Motion and Orientation Requirements. Most USACE survey vessels now are equipped with some type of motion compensation instrument. These inertial measurement instruments are generally referred to as "motion reference units," or MRUs. This instrumentation provides correction for vessel roll, pitch, yaw, and/or heave. The type, complexity, and cost of this equipment are dependent on the typical sea states encountered and specified data quality requirements for the survey. On shallow draft inland projects, motion compensation may not be required for single beam surveys. Motion compensation is essential for multibeam systems and single beam systems operating in high sea states. Motion compensation systems can exceed the cost of an acoustic depth measurement system. High-end (accurate) inertial-aided GPS motion

systems can cost up to $200,000. Basic motion compensation systems are less than $50,000. Details on MRUs are covered in Chapter 7 of this manual. Project engineers specifying survey requirements should be cognizant of their district's survey capabilities, and whether the lack of motion sensing equipment will adversely affect the resultant data quality.

2-9. Quality Control and Quality Assurance. QC and QA calibration and performance testing requirements are critical for all hydrographic surveys. Most of the guidance in this manual is focused on these requirements. Hired labor, A-E, or construction specifications should reference this manual for recommended QC and QA test requirements. Survey specifications should indicate whether formal Performance Tests are required in order to validate resultant accuracies.

2-10. Miscellaneous Survey Requirements. In house hydrographic survey vessels or A-E contractors may be required to perform ancillary data collection on some projects. Some of the more typical requirements are listed in Table 2-1. Project Managers developing specifications for one of these projects should contact the equipment manufacturers, data collection software venders, or other USACE districts for current applications and guide specifications. USACE district "subject matter experts," external contacts, or reference guidance are shown in Table 2-1.

Table 2-1. Supplemental Data Collection Requirements.

Data	Recommended Contacts
Side scan sonar	Manufacturer, Norfolk District, HYPACK 2011, NOAA
Current measurements (Acoustic Doppler Current Profilers-ADCP)	Manufacturer, HYPACK 2011, St. Louis District
Bottom classification or seafloor characterization	HYPACK 2011 (Geocoder) Norfolk District
Sub-bottom profiling	Manufacturer, HYPACK 2011
Sub-bottom probings (wash/dry)	Jacksonville District
Magnetometer surveys	Manufacturer, Jacksonville District
Biological surveys	Manufacturer, St. Louis District
Dredge system configurations	Measutronics, Inc.
Unconsolidated sediments	USACE ERDC (CHL), Mobile District New Orleans District, Stema Systems
Dredged Material Density (% solids)	Walla Walla District (Cost Engineering Branch); ERDC CHL, Vicksburg, MS

SECTION II

General Planning Considerations

This section provides additional guidance on some of the more critical factors that must be considered in planning and developing specifications for hydrographic surveys.

2-11. General. Most authorized USACE civil works projects have established survey methods and procedures; therefore, minimal planning is required for subsequent or recurring surveys. This section outlines some of the planning factors that should be considered in developing survey specifications for a specific project.

a. In-house (hired labor) or contracted options. Project/Study Managers or design engineers requiring survey support may need to evaluate whether to obtain this work from in-house crews of from contracted (A-E) forces. This evaluation may include the availability and capabilities of both options. Some districts may have no in-house survey capability or their crews are engaged on other priority projects. Use of an adjacent district's survey crew is another option to consider. Task order award turn-around time is always a major factor when considering the use of A-E forces. Geospatial (hydrographic) contracting procedures are outlined in EM 1110-1-2909 (Geospatial Data and Systems) and in Appendix C attached to this survey manual. Hydrographic surveying services are procured using Brooks A-E Act (PL 92-582) qualification-based selection methods.

b. Project schedule. Demanding construction advertise dates often impact survey planning schedules, and may necessitate reduced coverage densities or other actions to expedite completion.

c. Project funding. Funding limits will often dictate the survey scope of work for a project. Limited funds often necessitate a search for the most economical survey method while still obtaining sufficient data for engineering and construction purposes. Tradeoffs typically include increasing cross-section spacing or performing less frequent condition surveys.

d. Project location. Many dredge progress payment (acceptance section) surveys can be completed in one day with current surveying technology. Thus, it is not uncommon for mobilization and demobilization time to exceed the actual survey time. This is especially true if the survey crew has a long travel distance to the work site. Small-scope survey projects always cost more per unit than large efforts, due to mobilization and general overhead costs, among other factors. To reduce costs, it is always desirable to bundle geographically close projects if possible.

e. Survey performance and productivity capabilities. The survey crew (in-house or A-E) selected for a project must be capable of performing the work in accordance with the required accuracy and performance specifications. All in-house or contract survey forces have varying hydrographic surveying capabilities. Experience and capability must be demonstrated based on

past performance. Assessing such capabilities may be difficult for a study/project manager unfamiliar with the latest survey technology. Survey productivity rates have significantly increased over the past 30 years, especially in the last 15 years with the implementation of GPS positioning methods and multibeam systems. An example of productivity increases for a typical navigation project is shown in Table 2-2.

Table 2-2. Annual Project Condition Survey--Tampa Harbor 43-Foot Project
Gulf of Mexico to Port of Tampa--Field Survey Time Required to Perform Survey

Year	Positioning	Coverage	Crew-Days	Man-Days
to 1973	Visual (tag line)	200 ft O/C	360	1800
to 1993	Microwave 100 ft	O/C	40	280
to Date	DGPS	100 % (Multibeam)	8	24

(1) Table 2-2 indicates that survey productivity has increased by a factor of about 75 times since the 1960s and about 10 times since 1993. However, the data density, accuracy, and quality have also significantly increased since 1993 (and especially since 1973) given that a full-bottom coverage (multibeam) survey was obtained on the latest survey. This table also illustrates that 2- or 3-man survey crew today equals the output productivity of three to five crews in 1993. Table 2-3 is another comparable illustration of the gain in productivity due to improved positioning methods, especially DGPS techniques.

Table 2-3. Single Beam Cross-Sections per Day on a Typical Coastal Navigation Project. (Assumes a 400 ft channel width on a deep draft entrance project)

Year	Positioning	100-ft Cross-Sections Run	Crew Size
to 1973	Visual (tag line)	10 to 20	7 to 10
to 1993	Microwave	30 to 40	5 to 7
to Date	DGPS	75 to 200	2 to 3

(2) As a comparison between single beam and multibeam productivity, if the 200 cross-sections surveyed (i.e., 20,000 ft length of channel) with the DGPS single beam system area were surveyed with 4 to 6 multibeam lines, multibeam survey coverage could be accomplished in about 4 hours running time with the same crew size. Obviously, the major gain with the multibeam system over a single beam system is complete coverage of the channel bottom rather than isolated 100 ft c/c cross-sections. While productivity, accuracy and coverage have vastly improved, so have the costs of equipment. The purchase, installation, and initial calibration of a modern multibeam system may take several months, require a shipyard period with major modifications, and require extensive training of the crew.

2-12. Determining Project Accuracy Requirements. In general, accuracy requirements are more demanding for navigation projects where ship clearance and contract dredging payment issues are especially critical. Surveys for general hydraulic engineering studies, reconnaissance, planning, etc., usually do not require the same levels of accuracy. This distinction is not entirely rigid -- specific horizontal and vertical accuracy requirements should always be assessed and defined in the specifications for each project. Refer to Chapter 3 for more details on defining accuracy requirements.

a. Navigation and dredging support surveys. This classification applies to all surveys performed in support of the Corps navigation mission. It includes both deep-draft (> 15 ft) and shallow-draft (< 15 ft) navigation projects. Types of surveys include project condition surveys of navigation channels, dredging contract plans and specifications surveys, dredging measurement, payment, clearance, and acceptance surveys. A primary consideration involves the material characteristics of dredged material from the channel bottom.

(1) Hard bottom material and/or new work dredging. Examples include newly authorized navigation projects containing hard bottom material, such as rock or highly compacted material, or maintenance dredging of existing navigation projects containing hard bottom or otherwise hazardous material. Other examples might include navigation projects where low under-keel clearances are anticipated over potentially hazardous bottom conditions, hazardous cargo is transported, or where bottom sediment could adversely impact naval vessels transiting a project. A hard bottom classification does not require in situ bottom density sampling but should be based on a professional geotechnical opinion given local project knowledge, historical information, and project requirements. The most precise positioning and elevation measurement techniques are specified for these types of projects.

(2) Soft bottom material and/or maintenance dredging. These navigation projects include those containing soft sand/silt bottoms not judged to be hazardous to vessel hulls; or projects with soft, featureless, and relatively continuous channel bottoms where gaps in coverage between survey lines are unlikely to yield potential hazards/strikes. The vast majority of the Corps maintained waterways fall within this category. Survey accuracy and coverage specifications are usually less demanding for these projects.

(3) Unconsolidated sediments. The existence of unconsolidated sediments near the channel bottom can have a major impact on the accuracy specification for a survey, the equipment used, survey cost, and contract payment. Definitive survey specifications are required when these conditions are present. In many cases, a depth accuracy standard may not be applicable in these conditions. (See Appendix P for additional details.)

b. Underwater investigation surveys. These surveys include precise investigation surveys of/around locks, dams, power plants, abutments, piers, jetties, bulkheads, and other structures. Detailed investigation surveys of hazardous objects lying within the authorized navigation prism or project depth should follow (or exceed) the accuracy standards prescribed for navigation and

dredging surveys. General object detection may also be made using side scan or multibeam backscatter technology. Some 14 USACE districts report having this capability as of 2006.

2-13. Determining Required Data Density. The density of survey data to be collected is determined by a number of project-dependent factors. Some of the considerations used to determine the required data density, and the survey coverage needed to obtain that data density, may include:

- Type of construction project (dredging, rock placement, revetment construction, etc.) and related site investigation requirements.

- Survey data collection equipment (lead line, analog echo sounder, multiple-transducer sweep system, single head multibeam, automated data collection, etc.).

- Subsurface relief (rock, sand, silt, probability of intermediate pinnacles or shoals requiring development, etc.).

- Project economics (costs of surveys relative to engineering and design costs and estimated construction costs).

- Method of construction payment and/or computation thereof (in place, daily unit rate, average end area, triangulated irregular network, etc.).

a. In hard material, full bottom coverage may be obtained using any of the following methods: mechanical bar sweep, multi-transducer acoustic sweep, acoustic multibeam sweep, or side-scan sonar sweep. Double (200%) bottom coverage may be specified on critical navigation projects.

b. In soft material, single-beam acoustic systems are normally deployed, running cross-sections at some specified line spacing.

SECTION III

Vessel Selection Considerations

A wide variety and number of survey vessels are used throughout the Corps, as illustrated in Figure 2-4. These include conventional V-hull boats, catamarans, tugs, open skiffs, LARCs, pontoon boats, underwater sleds, air boats, surface-effect vessels, swamp tractors, converted barges, jack-up barges, and jet skis. Sizes of these platforms range from 14 ft up to 120 ft. This variety of floating plant is due to the different characteristics and depths of civil works projects surveyed. Many projects have unique environmental conditions and physical restrictions that require a particular type of survey vessel. This section provides a general overview of some of the factors to be considered when procuring a new survey vessel, or in evaluating the use of a type of vessel on a project.

Figure 2-4. Typical Corps survey vessels used in different project applications.

2-14. General Considerations. Since each district has unique project features and working conditions, these will primarily dictate the type of vessel used. These factors may include project depth, shallow-draft inland or deep-draft coastal navigation channels, geographical range of projects, dredging program size, and typical sea states encountered, to name a few. Selection of the most appropriate type vessel for the project conditions is critical to both production and cost. Larger vessels (greater than 26-ft) are generally more effective on open ocean entrance projects; however, their daily operating cost is high. Smaller, trailerable boats (less than 30-ft) are more efficient on inland navigation projects and coastal harbors. Smaller vessels also provide more flexibility to rapidly mobilize between projects. Their daily operating costs are significantly lower than larger platforms. However, smaller vessels are more subject to sea state motion, which can adversely affect data quality. Thus, a number of factors must be considered in selecting a survey vessel for a particular application. Some of the more important factors are discussed below.

a. Project depths. Vessel drafts must be small enough to obtain full coverage over a project, especially on shallow channel side slopes where material is excavated. If vessel drafts

are too deep, the inability to fully cover the side slope out to the required prism will impact quantity computations. In many cases, this presents a problem when large vessels with deep drafts attempt to perform cross-section surveys.

b. Splash protection. Fresh or salt water conditions will also dictate the type of vessel and survey equipment protection needed. Most hydrographic survey equipment is designed to be used in both environments. Open vessels may be used in fresh water environments where sea states are usually mild. On these open vessels only minimal equipment splash protection is needed. In salt water conditions, more care must be provided to protect the survey equipment from both splash and spray. Thus, a sealed cabin environment is usually essential.

c. Maneuverability. Water currents in rivers and tidal estuaries will affect the power requirements required on survey vessels. Maintaining headway against strong high-water river currents is essential. Likewise, vessels must have sufficient power to maneuver in coastal surf zones or near offshore structures. Generally, 23-ft to 30-ft vessels require at minimum 150-250 HP outboard engines.

d. Speed. Vessel design and power must provide for high running speeds to reach remote projects from their base or launch site. Typically, 20 kt to 35 kt transit speeds are required. Vessel survey speed is not an issue as these are normally well less than 10 to 15 kts.

e. Optimum hull designs for wave and sea state conditions. In the past, large survey vessels were required to reduce the affect of the heave, pitch, and roll created by heavy sea states. Now with state-of-the-art inertial motion reference units being able to correct for these sea state effects, smaller survey vessels can be used. The vessel hull design should provide as much stability as possible, especially minimizing roll. Pitch is difficult to control regardless of hull design. Various catamaran hulls appear to provide the best roll stability. In addition, they provide better multibeam transducer mounting options (see Chapter 6).

f. Daily operating costs. The daily operating cost is a function of vessel length, crew licensing requirements, and size of survey crew attached to the vessel. Larger (> 26 ft) survey vessels have significantly higher plant rental rates than small, trailerable vessels. This is due to the increased operation and maintenance costs, and requirements for USCG licensed operators on these vessels. Vessel utilization is another factor: there must be a sufficient deep-draft navigation project workload to ensure a 30-ft to 65-ft vessel can be effectively utilized (funded). Many survey vessels are PRIP funded and may be used for other non-survey applications, which increases their utilization. Whether the vessel is project or PRIP funded may also be a factor governing utilization and operating costs.

g. Data collection, editing, and processing enclosure. A comfortable, enclosed cabin is desired on most survey vessels, both for data collection and processing. A vessel with a sufficiently large cabin can be used to perform field-finish data editing and processing. This is often a desirable feature on dredge payment and clearance projects when same-day survey data

results are needed. Humidity control (air conditioning) should be included, especially in southern climates.

2-15. Vessel and Equipment Acquisition. Districts upgrading or replacing survey vessels should contact other districts that have recently made similar upgrades. Adjacent districts with comparable project conditions would be the best contacts. These other districts can provide vessel design drawings and, most importantly, any lessons learned after deployment of their new vessel or system.

a. Marine Design Center. The Corps of Engineers Marine Design Center in Philadelphia may be contacted for support in the design and procurement of larger (> 26 ft) survey vessels.

b. Community of Practice (COP). This web-based point can be used to query all USACE districts for recommendations on vessel and equipment upgrades.

SECTION IV

Data Processing, Editing, Depth Selection, and Plotting Options

All USACE hydrographic survey data are either collected by automated acoustic systems or converted from topographic survey observations into an automated format. Final data processing and plotting are accomplished using onboard or office-based computer systems. There is no prescribed USACE standard for hydrographic data collection, editing, graphic transfer, or plotting format. Each district has established methods and formats that support their varied projects and users of these projects. This section discusses some of the general data collecting and processing methods used throughout USACE.

2-16. Hydrographic Data Processing Flow. Figure 2-5 illustrates the general flow of data processing procedures generally representative of current hydrographic software acquisition and CADD processing systems used throughout the Corps. Field corrected data are transferred to the single beam or multibeam editors for subsequent correction and editing, usually performed in the district office. Cross-section files or matrix files are generated for use in hard-copy plots or volume computations. Final processed data are also exported to MicroStation, AutoCAD, or ESRI platforms for various engineering applications.

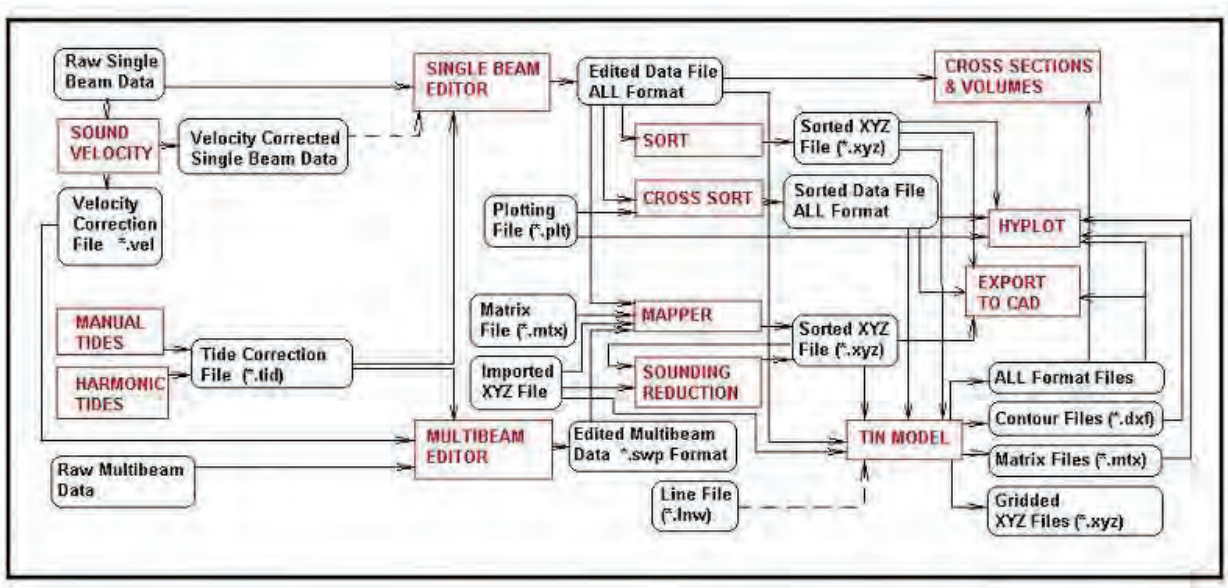

Figure 2-5. HYPACK post processing flow diagram for single beam and multibeam data. Other vendors (e.g., Trimble, CARIS) have software systems with similar functions.

2-17. Initial Field Data Review and Editing. After field data acquisition is complete, the data may be initially reviewed and edited in the field. In some districts, some initial processing may also be performed in the field. Editing is typically performed by manual processes described hereafter; however, software data editing algorithms have been developed to adjust, filter, smooth, edit, and thin hydrographic survey data.

a. QC and QA field processing. QC calibrations and QA Performance Tests are conducted, processed, and evaluated aboard the survey vessel. This includes real-time monitoring of motion sensors and sound velocity data.

b. Data anomalies. While editing the depth data, the field surveyor should also be alert for any unusual or questionable features indicated within the echo sounder data. For instance, a slight rise or depression on a normally flat bottom may be the indication of a side echo or scour hole associated with a nearby obstruction. Any echo sounder or multibeam features that cannot be adequately resolved or defined should be noted; additional data may have to be acquired in the areas immediately around these unresolved features.

c. Depth interpretation in unconsolidated or suspended materials. Other types of bottom conditions can also affect the extent to which the depth data must be reviewed and edited. In naturally soft bottom areas, or in dredged areas with unconsolidated materials, it may be difficult to detect or even define the "true bottom." A low-frequency transducer signal (e.g., 10 – 50 kHz) can usually penetrate a soft bottom layer and can help identify the first hard bottom return. However, even if a dual frequency echo sounder is used, it can still be a somewhat subjective decision as to what constitutes the true bottom. This can become a major point of contention

during dredge payment surveys and must be resolved in a consistent and equitable manner. Frequently, the surveyor must prove to the project manager and the dredge contractor that the depths they are using provide the "best" and most consistent representation of the bottom. In shallow water projects, random pole soundings or lead-line soundings can be obtained to verify the accuracy of the echo sounder depths. This is more difficult in deeper projects, though lead-line soundings may still be possible in ideal conditions. The surveyor can also highlight the comparisons of overlapping survey data outside of the dredged or disturbed areas to prove the consistency of the overall survey operations. Additional details regarding assessment of depth measurements in suspended materials or fluid mud are covered in Appendix P.

d. Final field review. After all necessary position, velocity, orientation, and depth edits have been completed, the surveyor should review the overall edited survey package to ensure that adequate and complete bottom coverage has been obtained. Ideally, this initial editing and review of the data should take place in the field so that any additional field work that may be required can be quickly addressed. This is particularly true for projects that are distant from the area where the survey party is based. During this data review, the surveyor should also check the consistency of the present survey data by comparing any overlapping sounding data. If the survey area is part of a dredging project, or has been surveyed in the recent past, then the current survey data can also be compared against any prior survey data to provide another measure of the reliability of this data. Any additional field data that are required to fill in coverage holes caused by rejected data, to better define a potential bottom feature, or to resolve some other discrepancy, should be acquired as soon as possible. This additional data should be edited and then combined with the prior survey data.

2-18. Office Data Editing and Processing.

a. District office review of incoming field data package. If the field performed some of the preliminary editing and/or pre-processing of data on board the survey boat, then the amount of district office review will be minimal, and will primarily be a quality assurance check on the adequacy of the field data editing. A cursory scan of cross-sections is usually adequate to pick up any editing deficiencies. Comparisons with any recent surveys may be performed as part of this QA process. For contract dredging surveys, pre- and post-dredge sections may be compared.

b. Editing depth data. Generally, bad depth data can either be rejected or edited, but should not be smoothed. During depth editing, the digital depth record should be compared to the analog echo sounder trace (if available). In addition to checking for incorrect or outlier digital depths (i.e., "spikes"), the editor should also ensure that the critical strikes or shoals have been digitized. For instance, if the peak of a shoal or obstruction was not digitized, then the editor must scale this depth from the analog record and then insert it into the proper location within the digital record. For single-beam cross-section surveys, there is usually not a lot of depth data editing or inserting that must be done. However, for multibeam surveys, and surveys conducted over irregular or varying bottoms, it may take a careful review of the records to ensure that the digital data accurately depicts the true bottom.

c. Data thinning routines. High-density data sets cannot be plotted in plan view due to overlapping depths. A number of methods are used in commercial data processing software to reduce the size of large data sets. These thinning routines typically use the TIN surface model to evaluate the terrain gradient in deciding which depths to eliminate. In flat areas, more depths can be eliminated without loss in overall model accuracy. In many cases, data reductions of 80% to 90% can be made in smooth terrain. Some software thinning routines use TIN contour density to eliminate data points in the TIN. Over thinning of data sets for dredge volume computations is not recommended. These data sets may be thinned for plotting/display purposes. Another method of data thinning uses a grid with an established origin point, azimuth, and grid spacing (HYPACK Matrix). Each gridded section is called a bin or cell. The bin size is determined when the matrix is built, e.g., a 5 ft x 5 ft matrix. This method is further described below.

2-19. Depth Selection Options. Once raw data points are collected within their given positional cell, the multiple depths within each cell may be thinned to a single representative depth for that cell. Binning or gridding routines provide options to thin multiple depths within a cell. Although designed for reducing the size of multibeam data, these binning routines may also be used for single beam data as well. Various representative depth outputs are possible with binned data:

- Minimum depth within the cell (e.g., "shoal biasing")
- Maximum depth within the cell
- Average (or mean) of all depths recorded within the cell
- Median of all depths recorded within the cell
- Shot depth closest to the cell center

Each of the above depth selection options has advantages and disadvantages. On dredge measurement and payment surveys where multiple passes are made, a small (e.g., 5 ft x 5 ft) cell could contain, say, 5 to 50 data points, from which a single representative (i.e. "thinned") depth must be selected. One of these points could be a noise "spike" that was missed during the editing process. The average of 50 depths within the cell may not be representative if the cell is too large and shoaler depths within the cell are obscured by the average. Likewise, the shot depth nearest the cell center (centroid) may not be representative. Therefore, selecting a bin size and representative thinned depth for a given project is a complex task and should be based on experience with specific project applications. Recommended bin sizes and depth selection options for multibeam surveys are outlined in Chapter 6.

a. Shot depth. For most applications, the "shot depth" closest to the cell center is used to best represent the terrain. This is because some of the other options can significantly bias the terrain representation if the cell sizes are too large, resulting in a false depiction of the true bottom condition (and dredged quantities). Statistically, a shot depth selection represents the best option for depicting datasets in that no inherent biases are produced in thinning the data. (Use of an unthinned raw dataset is, in effect, nearly unbiased; however, the size of the raw dataset may be too large for efficient quantity computations.) The position of the shot depth is typically shifted to the X-Y coordinates of the center of the cell.

b. Average (mean) depth. The "average depth" option can overly smooth the data if cell sizes are too large; however, this may be desirable in some instances. If cell sizes are kept relatively small, then the average depth can be a good representation of the bottom condition; and will represent a consistent, equitable payment method in dredging surveys. “Average” depths within a small, fixed bin size are recommended for computing dredged quantities. If bin sizes are set too large, then averaged depths may not be desirable on excavated slopes. (Visual interpolation of analog depth records on single beam surveys, in effect, averages the depths nearest the fix event mark. If single beam averaged depths are recorded, the system software may tag a position with the center of the depth series--requiring some form of on-line position interpolation.)

c. Median depth. The median depth of all depths in a cell will generally be nearly equal to the average depth when a large number of depths fall within the cell. The median depth may be superior to the average depth if noise spikes have not been adequately filtered out. For example, in a cell containing three depths (6 ft, 7, ft, and 17 ft), the median depth would be 7 ft but the average depth (10 ft) is biased due to the 17 ft spike. Selection of a median depth also provides use of an actually observed depth, as opposed to a resolved average depth. Although this distinction is not significant in a 1x1 ft or 3x3 ft cell, it may be justified for legal purposes. With large data sets in a cell, one of the observed depths nearest the average could equally be selected.

d. Shoal-biased or minimum depth. The minimum depth recorded within a given area has often been used for strike detection, dredge clearance, and controlling channel depth purposes. NOAA uses these minimum recorded or “shoal-biased” depths on nautical charts as a form of safety factor. Shoal-biased depths for Corps construction applications should be used with caution unless multiple "confirmed hits" are recorded within a bin, and/or between adjacent bins over a given area. Use of minimum shoal-biased depths can adversely skew dredge quantity computations and erroneously portray clearance depth data. Raw shoal biasing can also skew minimum clearance computations on Channel Condition Surveys or on tabular Channel Condition Reports. Shoals above project grade must be assessed based on multiple hits over successive passes--the least depth recorded in a bin is not necessarily the absolute elevation over an object. This is due to the relatively high variance in acoustic depth data--see discussions in this manual on data accuracy and confidence levels of assessing multiple hits. Automated software has been developed to perform this "multiple hit" analysis within each bin, and output bins containing depths with "confirmed" hits above a specified grade.

e. Maximum depth. Although this is a depth selection option, there are few USACE applications for processing maximum depths in a project.

f. Depths selection method for dredging volume computations. The "average depth" of all depths, or alternately the “median depth,” within each cell is recommended as the representative depth for the cell. The horizontal location of the representative average or median depth is the cell center or centroid. The representative average or median depths are then used to generate rectangular digital terrain models (DTM) or triangulated irregular network (TIN) models from

which dredge volume computations are computed in CADD routines using all the bins in the edited dataset matrix. If optional average end area volume (AEA) computations are performed in soft material by generating simulated cross sections through the full DTM or TIN model, cross sectional spacing shall be kept small so that AEA approximation errors are minimized. For example, a 5-ft cross-section spacing is far more accurate than a 100-ft spacing, and will better approximate the volume derived from a full TIN model computed using CADD differencing routines.

2-20. Hard Copy Plot Options.

a. Plan. A vast majority of surveys are plotted in site plan mapping format. Dredge plans & specifications surveys and subsequent payment surveys are usually plotted at scales of 100 or 200 ft to the inch, depending on the detail required. For more detailed construction work, larger scales (e.g., 1 in. = 40 ft and 1 in. = 50 ft) are commonly used. The recommended plan scale is 100 ft to the inch; however, 200 ft/inch or 400 ft/inch may be used where routine maintenance work is involved. A disadvantage of plan format is the inability to portray all the collected data at a reasonable character size. To increase data density requires a scale reduction, which increases the number of sheets covering a project and subsequent reproduction costs. Plan data are usually contoured relative to an absolute reference datum or an intermediate face above grade. Planimetric data may be added to the drawings depending on the nature and purpose of the survey. Some of the more advanced presentations can show contoured or color-coded depths of material above the channel template giving a clearer picture of where the dredging is needed and how much material is there.

b. Section. Section or profile views are often used to depict dredging cross-sections. They are extremely useful in comparing and evaluating various surveys performed over the same cross-section, a common requirement in dredging work. Such comparisons are difficult to perform using plan views. Section views of channels and other construction work are typically drawn at scales of sufficient size to adequately detail construction placement/excavation. Horizontal scales of 20 ft/inch, 40 ft/inch, and 50 ft/inch are common for navigation projects. Vertical scales are usually exaggerated to either 5 ft/inch or 10 ft/inch in order to depict low-gradient side slopes (and to provide a larger end area face when planimeters were used to measure end areas). Usually, all recorded elevation data points can be plotted in section; however, the numerical value must be scaled from the drawing. Two-dimensional section plots cannot portray any along-section vessel misalignment. Section views are rarely used for project condition surveys.

c. Profile. Profile sections from surveys run parallel (i.e., longitudinally) along the project alignment are typically used for project condition reports or centerline reconnaissance surveys/studies. Profiles of channel centerlines or quarter-points can depict an extensive amount of information in relatively compressed scales, and will readily portray critical, above project grade spikes or shoals. The use of profile format can significantly reduce the number of sheets required to cover a given project. For example, a project condition survey requiring a total of 10

to 15 plan sheets at 1 inch = 200 ft can be effectively shown in one or two profile drawings at 1 inch = 5,000 ft.

2-21. Selecting Representative Depths on Plan Drawings. When individual depths are plotted on a traditional plan drawing at some fixed scale (e.g., 1 in = 200 ft), the method by which a particular depth is selected from a dense multibeam data set is a difficult process. This was not a problem with older lead line or single beam survey methods--data were recorded at 20, 25, or 50 ft intervals and all the observed depths could be easily plotted on a 1 in = 100 ft or 1 in = 200 ft drawing scale. With multibeam data points being collected at 1-ft-sq footprints or smaller densities, it is impossible to portray the data at any reasonable or realistic two-dimensional hard copy drawing scale. The entire raw or binned dataset of individual depths, or equivalent three-dimensional terrain models, can be viewed on computer displays. However, as long as traditional hard copy drawings of plotted depths are required, then standardized procedures must be developed for plotting representative depths from the large multibeam database.

a. Drawing note on plotted depth selection. Plan drawings used in contract plans and specifications, dredging as-built surveys, disseminated project condition surveys, etc., should clearly indicate the thinning and depth selection option used.

b. Plotting selected depths on dredging and navigation surveys. For generalized plan drawing portrayals of a project condition, plans & specifications, or dredging progress survey, a "shot" depth taken from randomly selected bins provides the most unbiased representation of the pre- or post-dredged bottom condition. Shot depths are randomly selected from the edited bins. As outlined above, only a small percentage of the depths in the dataset matrix can be shown on typical plan drawing scales used in USACE (e.g.,, 1 in = 100 ft). Plan drawing CADD note block layers/levels should clearly state that the generalized plotted depths are not representative of the full dataset, and that the plotted depths shown should not be used for channel clearance or volume computations; and also noting that the original binned dataset should be (or was) used for such purposes.

c. Depth resolution and rounding. Depths should be rounded using standard engineering practice. Some districts round depths to the nearest even foot. In many USACE districts, it is a standard practice to record and plot corrected depths to a resolution of 0.1 ft. This implies an accuracy (i.e., ±0.05 ft) that does not reflect the uncertainties in acoustic depth measurements, especially on deep-draft navigation projects. Therefore, the estimated depth measurement uncertainties should be included in the metadata file for the survey project, and stated in the note block on any drawings or files furnished to the public or dredge contractors. Refer to the guidance on reporting depth uncertainties in Chapter 3.

d. Contour or color-coded plots. As an alternative to traditional 2D plan view plots of individual depths, contour or color-coded point 2D plots or 3D models may be used to better depict project conditions. This allows use of the entire edited (or binned) dataset.

e. Plotted depth options for single beam surveys. Single beam profile data may be thinned using intelligent data thinning software routines. Placing data points at evenly spaced distances (single-beam binning) along the cross-section track may corrupt the topography. Intelligent software is available to filter and thin data while maintaining integrity of the profile. When depth databases are thinned for plotting or other purposes, the random shot depth should be used. If databases are sorted to reduce the density of depths collected along a cross-section, then random depths along the section should be selected such that overplotting adjacent depths is avoided. Use of randomly thinned depths most correctly represents the original database and the accuracy of the individual observations.

2-22. Terrain Modeling. Most hydrographic data acquisition and processing software, and office CADD or GIS packages, now provide terrain modeling modules to allow input, modeling, editing, and analysis of 3D models. A user has direct interface necessary to build a non-uniform space point files (XYZ file) that can be used to create triangulated models and/or gridded models. Triangulated models can be created by two methods, Triangulated Irregular Network (TIN) and Topological Triangle Network (TTN). A TIN file is a surface model created from an XYZ file. It is defined by a set of 3D triangular facets, which are defined by lines drawn between the points that define the surface. The TTN file is a surface model created from an XYZ file and surface specific features, such as breaklines, obscure areas, faults and edges. These elements form an intelligent network that contains information about neighboring triangles. A grid file contains uniformly spaced data that can be derived from a number of sources including XYZ files, TIN and TTN files, digitized or scanned contours, or translated outside sources. After creating the appropriate files, the user can create and display the 3D model. To interpret the terrain models, the operator has a variety of procedures available, including:

- 2D and 3D contour displays
- 3D cross-sections
- 3D profile models
- 2D and 3D triangulated models
- Color-coded elevation displays
- Color-scaled contours
- Shaded relief (both color and monographic)
- Stereo displays (3D raised models)

The user also has the necessary procedures to edit the terrain model by adding, deleting, and moving points and inserting new profiles, area edits, noise removal, and arithmetic operations. Options are also available to perform analysis options, such as line-of-sight displays, intervisibility studies, volume calculations, and creation of slope or aspect models.

2-23. Data Submittal to District Office Project/Design Engineer. After review of the edited and processed data, the final data files and/or drawings are submitted to the district element that requested the survey. Generally, these submittals may include both raw and edited digital survey data, CADD files, echo sounder records, survey notes or field books, supplementary tide or GPS data, digital or regular photographs taken, metadata files, and any other relevant survey

information. Note also USACE spatial data policy requirements regarding Enterprise Geographic Engineering Systems (EGES), as outlined in ER 1110-1-8156, Policies, Guidance, and Requirements for Geospatial Data and Systems, and EM 1110-1-2909, Geospatial Data and Systems.

2-24. Retention of Hard-Copy Depth Records. Real time, hard copy depth profile records of navigation and dredging surveys are often used in the field to visually evaluate project condition and clearance. This may be done using hard-copy (paper) depth recordings or digital play-back recordings. Retention of real-time (or near real-time) profile depth records is required for contract measurement and payment surveys since these analog records contain bar check calibration data and Performance Tests as a continuous part of the record. These data can be retained either in hard-copy form or on a digital record that cannot be edited.

SECTION V

Estimating Costs for Hydrographic Surveys of Navigation Projects

2-25. Factors to Consider in Estimating Survey Time. The general guidance in this section is applicable to both A-E and in-house surveys. A-E survey cost estimates are covered in more detail in Appendix C.

a. Mobilization and Demobilization. This includes travel time to and from the vessel berthing location to the general project site. For USACE districts, the base location is the district office or an area office. A-E base locations are their home office. Cost estimates must allocate reasonable travel times to reach the project site. This includes both the survey vessel and survey crew.

b. Set up time at project site. Initial site preparation time can be highly variable, depending on whether survey control or gages need to be set. This may also include locating ramps or berthing. On projects with established control and gages, set up time will be minimal; basically checking existing control. If existing project control is inadequate, time must be allowed for establishing vertical control, setting staff gages, leveling and traversing baselines, and various other project-specific work. Since most authorized Corps projects have existing horizontal and vertical benchmarks and gages, preparatory set up time will be less than a half-day effort.

c. Travel time from berth to/from survey site. Cost estimates must include vessel travel time from a temporary berth or launch ramp to the survey site. This is also a highly variable time estimate, depending on the distance, vessel speed, and sea conditions. One to two hour travel times are not uncommon. Thus, a considerable portion of a productive survey day can be consumed just getting to and from the work area.

d. Quality control and assurance calibrations. Once underway to or at the work area, various quality control calibrations may be required, including horizontal position checks, RTK

gage calibrations, bar checks, velocity probes, Patch Tests, Performance Tests, etc. The time to perform these QC and QA is project dependant. On critical navigation projects, performing these calibrations may consume one to two hours each day. On less critical projects, these checks may entail only a half-hour per day effort.

e. Survey time. The amount of actual survey running time each day is dependent on the optimum vessel survey speed that provides acceptable data quality. In general, most surveys of Corps navigation projects are run at less than 15 kts, slower on more critical projects, and faster on high shoaling projects. Given a required survey scope of work (number and length of cross-sections or parallel multibeam lines), the total survey length (in miles) can be simply calculated; and given the optimum survey speed, the total survey time determined. Obviously, the number of hours per day of actual survey time is limited by the above travel times and calibration requirements. Thus, in a typical 8-hour work day, only 5 to 6 hours of effective survey time will be performed. On most projects, it is far more effective to authorize 10 to 14 hour workdays, to minimize these non-productive transits and calibrations, and maximize actual survey time. Those performing cost estimates may not have control over work and overtime authorizations; therefore, an 8-hour workday may have to be assumed. The number of hours of daylight may also need to be considered in northern regions.

f. Allowances and contingencies. Few surveys in marine environments are not impacted by equipment breakdowns, calibration problems, adverse weather, adverse sea states, and numerous other unforeseen problems. Estimating such contingencies is difficult and requires guidance from personnel with direct experience at the project site. Contingency estimates typically range between 5% and 20% of the overall estimated time.

g. Field data processing, editing, QA assessment. Usually, field survey crews perform preliminary QA assessments and data editing before sending survey data to the main office for final processing.

h. Office data processing, editing, QA assessment, plotting, and final deliverables. Time and cost estimates must include provisions for processing the raw survey data to the required final deliverable format. Depending on the data collection method, this is a highly variable estimate. Costs are based on burdened labor rates for a CADD or civil technician.

i. Office supervision and inspection. On A-E contracts for surveying services, an allowance is made for a PE or PLS to review the data prior to submittal to the District Office. The daily rate for this review is in the A-E contract schedule. USACE in-house supervision may be included in the technical overhead.

j. Potential resurveys-dredging projects. Allowances must be made for potential repeated clearance surveys on dredging projects, especially on new work or when rock cut channels are involved.

2-26. Plant Rental Rates. USACE daily plant rental rates are periodically computed based on vessel utilization. They usually include all vessel operating and maintenance charges, PRIP charges, and vessel operator charges. These daily rental fees vary significantly with the size of the vessel. They can range from less than $1,000/day for small vessels to upwards of $5,000 for 65-ft vessels. Rental rates can be obtained from Operations Division records. A-E plant costs are listed in the negotiated contract schedule. Various equipment, fuel, or other items may need to be combined to arrive at a daily rate.

2-27. Crew Labor Rates. Currently, survey crews consist of either two or three persons. Generally, only two survey persons are used on larger vessels--vessel operators are included in the plant rental rates. On smaller vessels (less than 26 ft) typically three persons are required, one of which is a boat operator. When staff gages must be manually observed, or local RTK base stations manned, either the third crew person or an additional person is required to perform this work.

a. A-E forces. Crew labor rates on A-E contracts are established in the negotiated contract schedule, typically a two or three person crew for smaller vessels. The A-E contract schedule will usually have a breakdown for a Party Chief, Survey Assistant, Survey Aid, and other personnel.

b. Hired labor forces. Crew rates for hired labor crews are available in USACE databases (e.g., CEFMS). These rates should include all direct and indirect overheads.

2-28. Effective Daily Field Survey Crew Rates. Most districts establish hired labor or A-E schedule crew rates on a lump sum basis, i.e., consolidating plant rental, equipment, surveyor labor, overheads, per diem, vehicles, etc. into a total daily survey rate. This simplifies computing time and cost estimates in that the time estimate need only be multiplied by the effective daily rate to arrive at a total survey cost. Alternatively, individually scheduled items can be accumulated to arrive at a total rate for a particular project. For example, the individual rates for the vessel, sonar system, positioning system, personnel, per diem, total stations, survey hubs, supplies, fuel, vehicles, etc. would be accumulated. Unless a unique project is involved, it is recommended that a lump sum daily crew rate be used.

2-29. Survey Time and Cost Estimates. The following cost estimate (Figure 2-6) illustrates the general factors that must be computed in developing time and cost estimates for hydrographic surveys. They are applicable to A-E or hired labor estimates. Assumed daily crew rates for single beam ($1,000) and multibeam ($3,000) systems are for illustrative purposes only, and are based on three-person crews.

REQUIRED:

Plans & Specifications Survey of a 40-ft x 400-ft deep draft navigation channel
10 mile (52, 800 ft) straight trapezoidal channel section with 3 on 1 side slopes

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SINGLE BEAM COVERAGE ESTIMATE

- 100 ft. C/C
- Extend 3 on 1 side slopes 200 ft outside toes
- Perform 4 QA cross-line check lines.

Number of cross-sections: 52,800 ft / 100 ft + 1 = 529 cross sections
Coverage along each section: 400 ft channel + 2 · 200 ft slope = 800 ft. Use 1,000 ft incl/turns.

Estimated survey coverage (nautical miles—nm):
529 x-tions x 1,000 ft ea / 6076 ft/nm = 87 nm
4 cross-lines x 52,800 ft / 6076 ft/nm = 35 nm
Total coverage distance: 122 nm

Assumed survey speed: 5 kts then 122 nm @ 5 kts … 25 hours running survey time

Assumed effective daily production rate: 5.5 hrs/day (includes transit, QC, QA, etc)

Estimated survey time: 25 hours survey time / 5.5 hours/day = 4.5 days … **use 5 days**

Estimated Survey Cost: 5 days at $1,500/day = **$ 7,500**

MULTIBEAM COVERAGE TIME ESTIMATE

- 90 deg limiting beam array (a)
- 10% sidelap coverage (s)
- one line on side slope outside each toe

From Chapter 6:
Line Spacing: $L = 2d \tan(a/2) \cdot (1-s) = 2 \cdot 40 \cdot \tan(45 \text{ deg}) \cdot (1 - 0.1) = 72$ ft
Number of lines: $N = |400 / 72| + 1 = 6$ [plus 2 for side slopes] Total: 8 lines

8 lines @ 52,800 = 422,400 ft or 69 nm x 1,000 ft ea / 6076 ft/nm = 87 nm

Assumed survey speed: 5 kts then 87 nm @ 5 kts … 14 hours running survey time

Assumed effective daily production rate: 5 hrs/day (includes transit, QC, QA, etc)

Estimated survey time: 14 hours survey time / 5 hours/day = 2.8 days … **use 3 days**

Estimated Survey Cost: 3 days at $4,000/day = **$ 12,000**

Figure 2-6. Survey time and cost estimate example.

a. Single beam versus multibeam survey time and cost estimates. The above example illustrates productivity differences between single beam and multibeam systems; i.e., 5 days for single beam versus 3 days for a multibeam system to cover the same project area. Any time advantage in the multibeam system will be offset by its added cost (rental rate) per day. However, this cost differential is offset by the added benefit of 100% bottom coverage with the multibeam system versus less than 5% for the single beam system.

b. Effective daily production rates. The assumed effective daily production rates (i.e., 5 or 5.5 hours per day) are a critical factor in the time estimate, and subsequently cost. In the above example, these rates are based on an assumed standard 8-hour working day and 2 or more hours of transit, set up, and QC actions. This standard 8-hour day is often assumed in developing A-E Independent Government Estimates (IGE) or in-house hired labor cost estimates. Ten hour, twelve hour, or longer workdays are more effective in minimizing transit times, and QC/QA calibrations; notwithstanding taking advantage of ideal weather or sea state conditions.

(1) Single beam. If a 10-hour workday is assumed, the total estimated survey time is reduced from 5 days (8-hour workday) to 3 days. If a 12-hour workday is assumed, then the survey could be completed in 2 days.

(2) Multibeam. The 10-mile project could be surveyed in 2 days with extended work hours per day; conceivably even in a 16-hour day.

(3) Vessel speed. The 5 kt assumed speed for the single beam survey is likely too conservative. Upwards of 10 kt survey speeds could be assumed; thus reducing the survey time considerably. The 5 kt multibeam speed is likely representative for a P&S quality requirement.

c. Mobilization and demobilization. Crew mob/demob from the home office to the field project site must be added to the overall cost estimate. These rates are typically the same as the daily crew survey rates (i.e., $1,000 and $3,000 in the above example).

d. Set up time. Additional crew time must be added for miscellaneous preliminary actions that must be performed prior to surveying. If this example were on an established project, with existing gages and control, set up time would likely be negligible. If not, then an additional crew day should be added.

e. Contingencies. An allowance for weather and mechanical breakdowns must be added to the overall field time/cost estimate. For a 3 to 5 day survey in the example, perhaps one day for contingencies might be added. These rates are the same as the daily crew survey rates (i.e., $1,500 and $4,000 in the above example).

f. Office data processing and QA review. In the above example, single beam processing to final deliverable would be less than one days labor; perhaps two days at the most. Since multibeam editing requires more effort (and is dependent on the data quality), two to five days

CADD labor might be allocated to this sample project. Any A-E or District Office QA oversight labor may also be added to the estimate—typically 4 to 8 hours.

g. Total cost estimate—single beam survey. Table 2-4 is a simulated example showing the estimated accumulations of all the survey cost factors, using the previous single beam example. (Rates shown are for illustrative purposes.)

Table 2-4. Total Survey Cost Example (Single Beam Survey)

Field Survey Cost:	5 crew days @ $1,500/day	$4,500
Mob/Demob:	2 crew days @ $1,500/day	$3,000
Set Up:	0.5 crew days @ $1,500/day	$ 750
Contingencies:	1 crew days @ $1,500/day	$1,500
Office processing:	2 CADD tech days @ 350/day	$ 700
Office PM Review:	1 Day @ $750/day	$ 750
	Total Estimated Cost:	$11,200

SECTION VI

Decision Matrix: Single Beam v Multibeam Surveys

The following table compares some of the applications and costs of single beam and multibeam systems.

Table 2-5. Decision Matrix: Single Beam v Multibeam Systems.

Evaluation Factor	Multibeam	Single Beam
Project depth, applicable	typically > 12 ft	any depth
Full bottom coverage	Yes (100%+)	No (< 5 % typical)
Dredging: new work	Recommended	Optional
Dredging: rock cuts	Recommended	Not recommended
Dredging: maintenance (soft matl)	Optional	Recommended
Dredging: payment	Recommended (TIN)	Recommended (AEA)
Beach renourishment surveys	Not recommended	Recommended

Reservoir surveys	Recommended	Optional
Underwater structure investigation	Recommended	Not recommended
Quality control requirements	Critical/demanding	Critical but less effort
Quality assurance test requirements	Critical/demanding	Minimal
Motion sensing required	Yes	No (optional)
Code DGPS positioning	Yes	Yes
Carrier RTK positioning	Recommended	Recommended
Cost: Acoustic system	$200k to $400k	$20k to $70k
Cost: Motion compensation system	$30k to $200k	$0k to $100k
Cost: Daily crew rate	$2,000 to $6,000	$1,000 to $2,000
Vessel hull modifications	Significant	Minimal
Field finish capability	Yes (more processing reqd)	Yes (rapid)
Office data processing time	Lengthy data editing	Rapid
Volume computations	Accurate	Interpolated

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CHAPTER 3

Recommended USACE Accuracy Standards for Federal Navigation Projects

3-1. Purpose and Scope. This chapter provides recommended accuracy standards for USACE hydrographic surveys of federal navigation projects. These standards are summarized in Table 3-1. This chapter, along with Appendix D, describes the Performance Test procedures and Total Propagated Uncertainty methods that are recommended to estimate and report the accuracy of observed depths on navigation projects; in particular, on evaluating the quality of contracted construction dredging clearance and payment surveys. These standards are intended to provide Corps-wide uniformity in specifying and reporting accuracies of surveys performed on navigation and other civil works water control projects.

a. Limitations on prescribed accuracy standards. The procedural and accuracy standards recommended in this manual are designed to reflect current survey positioning methods, acoustic instrumentation systems, calibration practices, and typical bottom conditions encountered at average USACE navigation projects. However, as noted in Chapter 1, it must be recognized that no single accuracy standard will be applicable to every USACE civil works project; therefore, USACE commands should tailor their survey procedures and required accuracies to each specific project. For example, more stringent accuracy requirements should be established for a deep-draft coastal entrance project with tidal influence than those needed for a shallow-draft inland navigation project, or a reservoir sedimentation survey. Likewise, more stringent requirements are typically needed for new work construction in a rock-cut navigation project with a high cost per cubic yard payment rate than for subsequent maintenance dredging of soft material. Underwater scour surveys adjacent to locks, dams, bridges, and hydropower projects will require the most demanding accuracy standards. Conversely, it is unlikely the nominal accuracy standards recommended in this manual will be achievable in projects containing fluid mud, suspended sediment, extreme tidal ranges, or with highly irregular topography and geomorphology. In summary, accuracy standards, and related quality control and quality assurance performance tests outlined in this manual, must be considered as only recommended guidance.

b. Standards for other civil works projects. Recommended accuracy and performance criteria for other types of civil works surveys (e.g., reservoirs, locks and dams, revetments, breakwaters, underwater structure investigations, beach renourishment, etc.) are detailed in chapters covering those projects. However, in most cases, the recommended standards for navigation surveys will be applicable to many of these other civil works projects.

c. Survey calibration and testing. Recommended quality control and quality assurance procedural methods for acoustic depth measurement and positioning are covered in separate chapters in this manual—e.g., Chapter 4 (single beam), Chapter 5 (multi-transducer), Chapter 6 (multibeam), and Chapter 7 (GPS positioning and inertial orientation systems).

d. Use of standards. USACE organizational elements requesting hydrographic surveys should utilize these standards in requesting and specifying in-house or contracted surveys. However, in-house survey sections should be consulted to ensure that the required accuracy specifications for a particular project are realistic and achievable; and whether or not these accuracies should be independently tested for compliance in the field. This chapter may also be referenced in Corps hired-labor or A-E survey specifications, and in construction dredging contracts.

e. Supplemental references. The following references should be consulted in conjunction with this chapter.

(1) EM 1110-2-6056. "Standards and Procedures for Referencing Project Elevation Grades to Nationwide Vertical Datums."

(2) "IHO Standards for Hydrographic Surveys—SP 44, 5th Edition." (IHO 2008).

3-2. Discussion. No measured depth is without error. Unlike visual topographic or construction survey measurements, acoustic depths are indirectly measured using various forms and combinations of time difference (amplitude detection), phase detection, or phase difference (interferometric) measurements. These measurement methods contain varying magnitudes of acoustic reflectivity and signal/noise that must be resolved into a "best estimate" of the depth. Spatial variations in bottom soil materials will also vary the recorded depth returns. Thus, an absolute "accuracy" of a depth measurement at a given point is rarely, if ever, known. In addition, hydrographic survey depth measurements are referenced to the local water surface, which will typically have tidal or river stage modeling uncertainties (biases) relative to a distant reference gage and datum. Vessel motion, orientation, and acceleration (i.e., velocity, roll, pitch, yaw, and heave) require corrections that include additional uncertainties. Also, numerous corrections must be applied to the resolved depth to account for often significant variables in the measurement system (e.g., latencies) and speed of sound or refraction variations in the water column. The total propagated magnitude of all the above random and systematic "errors" is termed "uncertainty," or "Total Propagated Uncertainty" (TPU). TPU is estimated using mean square error propagation techniques, resulting in a "±" root mean square (RMS) error estimate. This "best estimate" of a depth accuracy can have uncertainties ranging from ±0.2 ft in shallow-draft projects to more than ±1 ft in deep-draft navigation projects; the major uncertainty components being the water surface elevation measurement and geomorphological variations in the project area. The TPU of individual depth measurements is difficult to determine through any testing method; however, the Performance Test procedures described in this manual will often provide a general indication of the TPU.

3-3. Quality Assurance Performance Tests. The QA Performance Test is the primary USACE method by which the quality of a hydrographic survey can be estimated. This test compares depth measurements made over the same point (or many points) by two or more "independent" measurement systems. The test yields an estimate of the biases (i.e., repeatability) between the surveys, and the dispersion (i.e., standard deviation or approximate TPU) between the surveys, as

described below. A Performance Test is not an absolute accuracy or uncertainty assessment. Tests made by the same vessel are not truly independent. In addition, the bottom conditions of a separate Performance Test site may differ from the actual project site. Bottom soil material and topography may also vary within the test site and/or the actual project site. Performance Tests comparing surveys of the same test site by different vessels and measurement systems are more independent and provide better estimates of the statistical repeatability (or reproducibility) and standard deviations. The most representative Performance Test is comparisons between different vessels of entire surveys of the actual project area (e.g., a dredging acceptance section) where thousands of points can be compared—see example at Appendix F. Not all surveys require Performance Tests to estimate their accuracy. If no Performance Test is conducted, then the survey accuracy can be estimated and reported based on error propagation techniques (e.g., TPU)—see Appendix D. Procedures for conducting Performance Tests are covered in Chapters 4 and 6.

a. Performance Test repeatability. Repeatability is defined as the closeness of agreement between successive depth measurements carried out at the same point under similar measurement conditions. The QA Performance Test estimates survey repeatability by computing the mean difference in depths observed between overlapping datasets. Constant differences between surveys over the same point(s) is an indication of potential biases between the surveys. Repeatability or bias is specified and measured as either a "plus" or "minus" quantity, e.g., “+0.06 ft.” It is not a "±" dispersion statistic. In practice, survey "repeatability" provides an estimate of the resultant quality or accuracy of a survey.

(1) Repeatability is especially critical on dredge measurement and payment surveys. Resultant biases, if large, can adversely impact channel clearance assessment and construction payment. The repeatability measured in the QA Performance Test is, in effect, a quality control check. Repeatability results outside tolerances indicate site or system calibrations are inadequate and should be investigated.

(2) The recommended standards in this manual focus on assessing a survey's repeatability through the use of Performance Tests. It is important to reemphasize that repeatability estimates from Performance Tests are usually specific to a vessel, survey system, and the test site; in other words, they are not always statistically independent tests.

b. Performance Test Standard Deviation. Standard Deviation (or standard error) is a measure of dispersion when multiple depth measurements are made of the same point(s). Performance Tests typically compare the deviations between overlapping datasets (single beam and/or multibeam) in a large area—either over the entire project or in a separate test site. Standard deviation is expressed as a "±" deviation at the 95% level. Standard deviation statistics obtained from the same survey vessel should be used with caution in that these are not independent tests. Standard deviations from repeated Performance Test comparisons may often be used as estimates of Total Propagated Uncertainty over a test site or project area, assuming systematic biases have been either eliminated or properly minimized (randomized) through QC

calibrations. In addition, large resultant standard deviations do not necessarily indicate that a survey is "inaccurate"—numerous factors impact dispersions in Performance Test comparisons.

3-4. Total Propagated Uncertainty Accuracy Estimates. TPU is a statistical dispersion estimate based on the total propagation of all random and systematic errors present in a measurement system, from the reference tide/staff gage, through the vessel positioning and motion orientation systems, to the acoustic depth return from the bottom. It is based on a Mean Square Error estimation of the total error budget in a depth measurement, and is usually expressed as a "±" root mean square (RMS) error at the 95% level. TPU is broken down to its horizontal and vertical components—i.e., THU and TVU. Data processing software can estimate TVU and THU for each individual depth observation. Alternatively, an average TPU for a given project site can be estimated (e.g., from Performance Test results). These TPU estimates are dependent on the estimated accuracy of each error component.

a. Survey specifications and accuracy reporting. Since Performance Tests are not performed on most USACE surveys, TPU may be used as a criteria for specifying survey accuracy requirements. Such a specification entails consideration of the error parameters listed in Appendix D. Reported survey accuracies on published drawings would reflect these same estimates. (TPU is increasingly being recognized as a hydrographic measurement accuracy statistic by international standards organizations. Therefore, USACE districts are encouraged to utilize this reporting statistic on published survey drawings.)

b. TPU estimates from Performance Tests. The TPU (and TVU or THU) of a hydrographic survey usually cannot be tested in practice—it is estimated based on assumed error propagation. However, as noted above, Performance Tests may yield, over the long term, a good estimate of an average TPU at a project site. (Note that TPU deviation estimates do not provide survey bias assessments. These biases can only be evaluated by Performance Tests in the field.)

c. Examples for estimating TPU in navigation projects are shown in Appendix D. Refer also to Section 5 of "NOS Hydrographic Surveys Specifications and Deliverables" (NOS 2011) and Special Publication No. 44, "IHO Standards for Hydrographic Surveys," (IHO 2008) for additional discussions on TPU and error propagation estimates.

3-5. Recommended USACE Depth Accuracy Standards for Engineering and Construction Surveys. Table 3-1 contains recommended standards for hydrographic surveys of various types of navigation projects. These standards are based on typical project conditions and average results from USACE historical performance tests on coastal projects; therefore, they shall not be considered as absolute Corps-wide specifications. The standard deviations will likely be met on shallow draft projects in confined (calm) waters. They may not be easily met on deep-draft projects with adverse environmental or bottom conditions. As such, these standards should be considered as recommended guidance that may be modified to a specific project site condition. Additional accuracy and performance guidance for specific projects are outlined in other chapters and appendices in this manual. This additional guidance includes such items as quality control calibration requirements, vessel positioning and orientation criteria, acoustic return

assessment, data processing and bin sizes, representative depth selection, depth rounding, volume computation methods, and depth metadata reporting.

a. Specifying required survey accuracy. When specifying that survey depth measurements should meet a required "accuracy" to some "±" dispersion level, it is essential that the statistical measurement criteria be precisely defined, along with the process by which it will be confirmed or tested. If no confirmation tests of the resultant accuracy are performed (and these tests are not often performed in practice), then it can only be stated that the survey should be performed using quality control procedures that will "likely" or "probably" meet the desired (or intended) standard in Table 3-1, or alternatively an estimated TPU measure. On critical dredge measurement, clearance, and payment surveys, specifications should require that quality assurance Performance Tests be performed to assess the existence of any biases in the observations—i.e., "repeatability"—and the dispersion (standard deviations) in the measurements.

b. Unachievable accuracies. A desired (required) accuracy standard may or may not be achievable in practice due to varying or adverse project conditions. For example, a specified ±0.8 ft depth accuracy standard may be easily achievable on a federal navigation project in the Gulf of Mexico with a 1 ft tide range but is likely difficult to meet on the Pacific Columbia River Bar entrance channel with a 6-ft tide range and 10 ft swells. Thus, any nominal accuracy standard (such as those in Table 3-1) must be modified to meet "real-world" project conditions.

c. FGDC accuracy reporting guidance. Most traditional mapping accuracy standards, such as those prescribed by the Federal Geographic Data Committee (FGDC), require testing measurements against an independent source of higher accuracy. Independent sources of higher accuracy are rarely available for testing hydrographic surveys, other than in some inland districts with lock chambers. These FGDC standards do allow for reporting untested data accuracies if quality survey procedures were used that would likely meet the estimated accuracy. These FGDC standards state "regardless of whether the data was tested by an independent source of higher accuracy, or evaluated for accuracy by alternative means, provide a complete description on how the values were determined in metadata, as appropriate to dataset spatial characteristics." Performance Tests and TPU accuracy estimates would be considered as a FGDC "alternative means" evaluations.

d. Accuracy statements on drawings. Distributed drawings, plans, reports, studies, databases, and related metadata documents containing channel depth or clearance data should contain a statement (note) attesting to the tested (Performance Test) or estimated (TPU) accuracy of the survey data. On construction dredging projects, this accuracy statement will normally be based on results from actual or historical Performance Tests. If no Performance Tests were performed an estimated TPU may be indicated in the accuracy statement.

Table 3-1. Recommended Depth Accuracy Standards for Corps of Engineers Surveys of Federal Navigation Projects based on Performance Test Results. [1]

Project	Typical [2] Repeatability (feet)	Typical [3] Standard Deviation (± feet at 95%)
Coastal Deep Draft Projects (15>d<75 ft):		
Dredge measurement & payment surveys		
Channel clearance/acceptance		
Project condition surveys		
Maintenance Dredging (soft sand/silt bottom)	0.3 ft	±0.8 ft
New Work or Rock Cuts [4]	0.2 ft	±0.8 ft
Coastal Shallow Draft Projects (d<15 ft)	0.3 ft	±0.8 ft
Inland Navigation Projects (d<15 ft)	0.3 ft	±0.5 ft

NOTES:
1. These standards are recommended "target" tolerances that may be specified for the various navigation projects listed. They are primarily applicable to dredging measurement and payment surveys where Performance Tests are conducted. They are representative of "typical" or "average" USACE navigation projects, and should be modified to meet specific project conditions and survey capabilities; as such, they are not mandatory standards. Refer to the discussions and definitions in this chapter and in Appendix D.
2. Refer to Chapters 4 and 6 for performance testing procedures and survey bias assessment.
3. Standard Deviations are usually derived from Performance Tests. In certain cases, these standards may be considered nearly equivalent to Total Vertical Uncertainty; and, as such, they are an IHO "Special Order" standard.
4. These recommended tolerances may be difficult to meet on some single-beam system cross-line Performance Tests if an insufficient number of comparison points are tested.

If no Performance Test was conducted on a specific dredging project, then the drawing (metadata file) should note whether these target standards were likely met based on historical (long-term) repeated Performance Test capabilities of the vessel/system. Alternatively, for any dredging or project condition survey, an estimated TPU (or IHO Standard) may be noted.

Accuracy, QC, and QA performance criteria for coastal engineering and other civil works water control projects are found in their respective chapters.

3-6. Horizontal Accuracy Standards. Specifying that a hydrographic survey depth measurement meet some required horizontal accuracy standard is difficult in practice. The horizontal positioning uncertainty of a measured depth is a function of various factors, primarily the GPS positioning method (code DGPS or carrier RTK), multibeam outer beam array limits, acoustic footprint size, and vessel motion compensation employed. No specific Performance Test type procedure exists to quantify the resultant horizontal accuracy of a depth observation—positional uncertainties are buried within the error budget of the depth results in a traditional Performance Test, and any standards based on that test. Thus, horizontal accuracies can only be roughly estimated using TPU techniques described in Appendix D.

a. Reporting depth horizontal accuracy. Drawings and metadata files should indicate the positioning method used on the survey, including the estimated accuracy of that system (which may not necessarily be the horizontal accuracy of the propagated depth on the bottom). For survey drawings furnished to the public, or other federal agencies, estimated horizontal accuracies of depth measurements may be noted as meeting one of the IHO "Total Horizontal Uncertainty" (THU) standards. This untested estimate can be based on the type of project (e.g., IHO Special Order or Order 1a—a 2 m standard), the positioning system used, and outer beam footprint size on a multibeam system.

b. Topographic feature accuracy. Horizontal accuracy standards for topographic features near navigation or other civil works structures are specified in EM 1110-2-1005, Topographic Surveying. Topographic and planimetric features shown on USACE navigation drawings or charts should be located to accuracies consistent with the project drawings. Feature positional accuracies are estimated and reported at the 95% RMS level. Fixed planimetric features include dredging limits, rights-of-way, harbor lines, bulkheads, piers, etc. Fixed navigation aids are lighthouses, ranges, beacons, daymarks, etc. In general, code-phase DGPS accuracy is sufficient for positioning fixed navigational features; however, it is not applicable to design or construction of marine facilities or structures. Contract plans for such facilities should require conventional topographic mapping accuracies.

3-7. IHO Standards for Hydrographic Surveys. IHO hydrographic survey accuracy standards (IHO 2008) were developed specifically for nautical charting purposes. They do not necessarily apply to the engineering and construction (dredging) survey standards in this manual. IHO standards may be specified for (and reported on) coastal project condition survey drawings of federal navigation projects that are furnished to NOAA and the general public. IHO standards are based on TPU estimates, which, as noted above, may be difficult to test or substantiate.

a. IHO Special Order (areas where under-keel clearance is critical) and Order 1a (areas shallower than 100 meters where under-keel clearance is less critical but features of concern to surface shipping may exist) are most applicable to USACE surveys of shallow-draft and deep-draft navigation projects. Most USACE surveys of federal navigation projects fall within the IHO Special Order standard.

b. If an IHO standard is noted on a USACE drawing, then it should clearly indicate that a survey was performed to meet a particular IHO accuracy standard and that this was not proven by testing.

c. IHO standards have other Orders and specifications that may be of use in some USACE survey specifications for non-navigation projects. These other IHO Orders include specifications for total vertical uncertainty (TVU), total horizontal uncertainty (THU), bottom coverage (line spacing) requirements, and object detection requirements. IHO standards may also be referenced for surveys of deep-water disposal sites.

d. A complete copy of the current IHO S-44 Standard is at Appendix E.

CHAPTER 4

Single Beam Depth Measurement Systems

4-1. General Scope and Applications. Single beam acoustic depth sounding is the most widely used depth measurement technique in USACE for surveying river and harbor navigation projects. Single beam echo sounders were first used in the Corps back in the 1930s but did not replace reliance on manual depth measurement methods until the 1950s or 1960s. A variety of single beam depth measurement systems are used throughout the Corps, depending on project conditions and depths. These include single frequency systems, dual frequency systems, and multiple transducer channel sweep systems. Although multibeam systems are increasingly being used for surveys of deep-draft projects, single beam systems are still primarily used on shallow draft inland navigation projects. This chapter covers the principles of single beam acoustic depth measurement systems. It especially focuses on the critical quality control calibrations and quality assurance tests required for single beam echo sounding equipment.

4-2. References. This chapter only briefly discusses the theory and physical principles of underwater sound propagation, including transmission and reception characteristics of transducers. It only generally outlines the details in configuring single beam systems for data collection and subsequent data processing, editing, and thinning procedures. These topics are covered in more detail in the following technical publications that will be referenced throughout this chapter.

a. "Manual on Hydrography" (IHO 2005); Chapter 3, "Depth Determination."

b. "Multibeam Sonar Theory of Operation" (L-3 SeaBeam 2000).

c. "R2Sonic Operation Manual," (R2Sonic 2010).

d. "Odom Echotrac MKIII User Manual," (Odom 2008).

e. "HYPACK Hydrographic Survey Software User Manual," (HYPACK 2011).

SECTION I

Principles of Acoustic Single Beam Depth Measurement

4-3. Overview. Acoustic depth measurement systems measure the elapsed time that an acoustic energy pulse takes to travel from a generating transducer to the waterway bottom and back. This is illustrated in Figure 4-1 where the measured depth "d" is between the transducer and a point on the acoustically reflective bottom. The travel time "t" of the acoustic pulse depends on the velocity of propagation "v" in the water column. If the velocity of sound in the water column is known, the observed depth "d" from the transducer to the bottom can be computed from the measured travel time of the pulse. Given the vessel draft "d_r" and datum correction "r" the corrected depth "D" can be expressed by the following general formula:

Depth corrected to reference datum: $D = \frac{1}{2}(v \cdot t) + k + d_r + r$ (Eq 4-1)

where:

v = average velocity of sound in the water column
t = measured elapsed travel time from transducer to bottom and back to transducer
k = system index constant
d_r = distance from reference water surface to transducer (draft)
r = reference datum correction ("tide" or "stage" correction)

The above parameters must be periodically monitored for variations during a survey. This entails periodic calibration of the echo sounder, such as "bar checks" and "sound velocity casts."

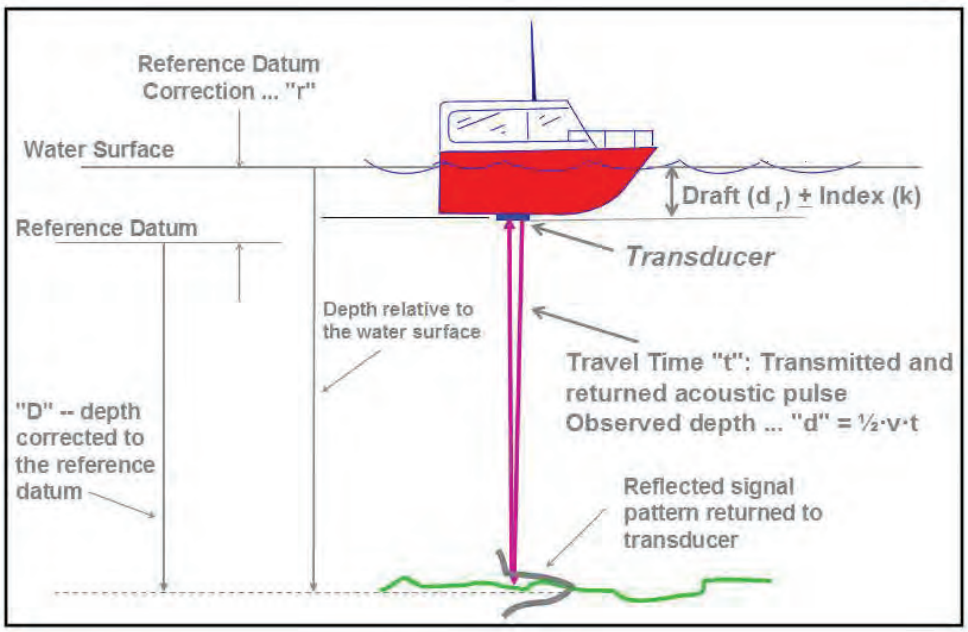


Figure 4-1. Acoustic depth measurement.

a. Travel time measurement. The travel time "t" of the sound pulse is measured either electronically in a depth digitizing device or mechanically (graphically) on an older analog recording type instrument. The accuracy of the absolute time measurement generally varies with depth. This is due to signal attenuation, noise, and the ability of the measurement circuitry to correlate the outgoing and incoming pulses. In addition, the acoustic reflectivity (impedance) characteristics of the target bottom soil material can significantly impact the sharpness of the returning pulse, and consequently the depth measurement accuracy. The irregularity of the reflected pulse causes uncertainty in the overall time measurement process. There is no practical calibration process for minimizing this error. The nominal “precision” (not accuracy) of echo sounding time measurement is usually rated by manufacturers at ±0.1 ft plus 0.1 to 0.5 % of the depth. This equates to a precision range of ±0.15 to ±0.35 ft in a 50-ft depth and is independent of the acoustic reflection characteristics of the bottom.

b. Velocity of sound in water. Determining the sound velocity "v" is perhaps the most critical factor in using acoustic depth sounders. [1] The sound velocity in water varies with the density and elastic properties of the water—see IHO 2005. These physical properties are, for typical river and harbor project depths, primarily a function of the water temperature and suspended or dissolved contents, e.g., salinity. Due to these effects, the sound velocity can range from 4,600 to 5,000 ft/sec. Since most river and harbor projects can exhibit large variations in temperature and/or salinity with depth, the velocity of the projected sound wave will not be constant over the distance from the boat's transducer to the bottom and back. The effect of this variation is significant. A temperature change of 10 deg F will change the velocity by as much as 75 ft/sec, or approximately 0.8 ft in 50 ft of water. A 10-ppt salinity change can vary the velocity by some 40 ft/sec, or approximately 0.4 ft in 50 ft. For practical single beam echo sounding work in shallow water, an average velocity of sound through the water column is usually assumed (by calibration). Use of an average sound velocity may not be valid in coastal projects subject to freshwater runoff, nor will it be constant over the entire project area surveyed. The sound velocity may be measured directly using a “velocity probe” or indirectly by a "bar check" calibration. A velocity probe can measure sound velocities at each point in the water column (e.g., every foot). These data can be used to compute an average velocity over the entire column or the recorded velocities at each increment can be used correct the observed depths. The bar check measures actual depths relative to the recorded depths on an echo sounder. Sound velocity determination is much more critical on multibeam systems--especially on the transducer face and for outer beam refraction correction.

c. Transducer draft and index constant. The transducer draft ("d_r") and index constant (k") must be applied to the reduced time distance to obtain the corrected depth from the reference water surface. The index constant contains any electrical and/or mechanical delays inherent in the measuring system, including return signal threshold detection variations. It also contains any constant correction due to the change in velocity between the upper surface level and that used as an average for the project depth range. For this reason, the apparent “draft” setting or reading on a digital or analog record is not necessarily the actual draft of the transducer, as would be obtained by physical measurement between the water surface and transducer. Also, the vessel draft is not the same as the transducer draft because the vessel draft may be measured relative to skegs or other points on the hull. The only effective method of determining the combined constants in Equation 4-1 is by a bar check calibration. The reference water surface datum correction "r" may need to be further adjusted based on real-time river/lake stage, pool, or tidal observations. The various corrections required in an acoustic depth measurement are discussed in subsequent sections in this chapter.

4-4. Single Beam Transducer and Frequency Specifications. A transducer converts electronic energy to acoustical pulses and vice versa. They operate by converting electrical energy into mechanical energy, i.e. transducers convert electrical pulses from a signal generator to

[1] Sound velocity is more correctly a scalar quantity (speed), but the term "velocity" is more commonly used in practice. Most single beam echo sounders have “speed of sound” controls to set an average sound speed/velocity.

longitudinal vibrations which propagate into the water column as a pressure wave. During the reception, reciprocally, the pressure waves are converted into electrical signals (IHO 2005).

a. Frequency selection. The type of transducer used is a major determining factor in the adequacy of a depth measurement. The optimum transducer frequency is highly project- or site-dependent. Throughout USACE river and harbor projects, a variety of frequencies have been used. These frequencies generally range between 20 kHz and 1,000 kHz. Each frequency/transducer has physical characteristics that particularly suit it to an individual application or project site. In general, higher frequency transducers (100 kHz to 1,000 kHz) will provide more precise depth measurement due to both the frequency characteristics and more-concentrated (i.e., narrow) beam widths. However, lower frequencies are less subject to attenuation, which allows greater depth measurement and penetration of suspended sediments. Although greater depth measurement is not required for river and harbor projects, the ability to penetrate suspended sediment is a decided asset, especially in performing surveys for dredging projects. A major disadvantage of higher frequency transducers is that there is high signal attenuation with depth, and low specific gravity suspended sediments (fluff) or bottom vegetation will readily reflect the signal. High frequency transducers are not recommended in areas where suspended sediment layers commonly occur, or where bottom vegetation may obscure the desired “pay” grade. In such areas, frequencies ranging between 20 kHz and 50 kHz are typically employed for payment determination.

b. Beam width selection. Transducers are designed with varying beam width patterns—see Figure 4-2. Most USACE applications require narrow beam widths in that the array is more focused, resulting in a smaller footprint and better resolution. Narrow beam transducers (i.e. less than 8 deg) may require roll and pitch correction since the more-focused beam will measure a slope distance at non-vertical points. Narrow beam transducers should be obtained with minimum side lobes. Lower frequency transducers (below 40 kHz) tend to have larger beam widths, which can cause distortion and smoothing of features in irregular bottoms or on side slopes.

c. Shoal or object strike detection. Far more complex is the effect of transducer frequency on the detection of certain-size objects on the bottom. Detection of blasted rock fragments or other hazardous objects above project grade is a difficult process with traditional single-beam echo sounders, regardless of the frequency used. Generally, wider-beam transducers may be more suited for strike detection than narrow-beam transducers. However, the sounding system's threshold detection settings, gate settings, display methods, etc., are also critical to strike detection. Vertically mounted, narrow-beam transducers (either single hull-mounted or boom multi-transducer “sweep” systems) may not be the best configuration for providing optimum energy return from small underwater strikes; notwithstanding their small acoustical footprint. Side-looking multibeam systems and side-scanning sonar will often provide better returns from such stealth-type objects.

d. 200 kHz narrow beam transducers. The most commonly employed transducer frequency recommended for use on typical Corps river and harbor navigation projects is 200-208 kHz. Transducers operating at this frequency are usually narrow-beamed (between 1.5 deg and 8

deg at the -3 dB points) to provide more accurate bottom detailing. A 3-deg beam width is most commonly used in USACE. Narrower beam widths are recommended for projects with relatively hard, smooth grades, such as rock cuts or sand bottoms. The 200-208 kHz (± 10%)

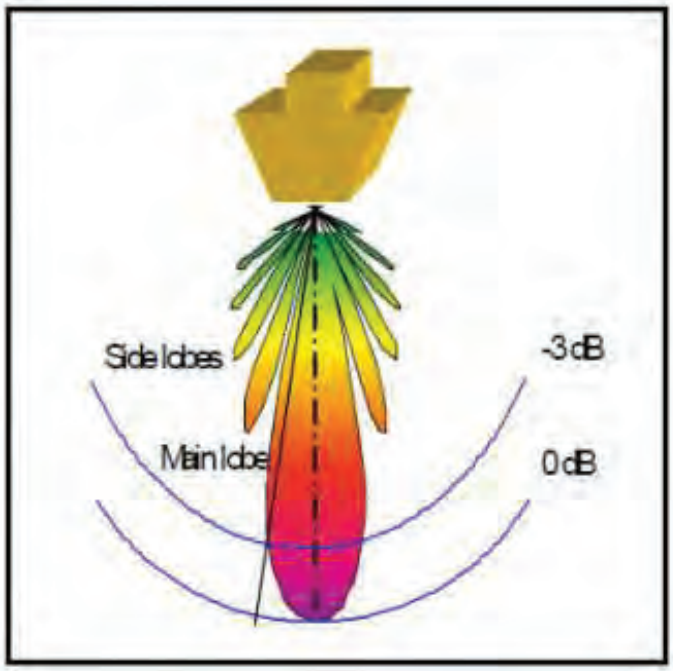


Figure 4-2. Transducer beam pattern. Sensitivities are normally measured at the - 3 dB half-power points. (IHO 2005).

frequency is not a mandatory USACE frequency standard, nor is any particular beam width. Local conditions and unique project requirements will dictate the optimum type of survey system and frequency to be used. However, for navigation and dredge payment surveys, the acoustic survey system and/or transducer frequency should be constant throughout the project duration—and clearly identified in construction contract specifications. Multiple frequency systems may be used for analyzing sediment layers of varying densities-- typically using 200 kHz and 28 kHz dual frequency sounders.

4-5. Echo-Sounder Control Settings. Single beam echo sounders have power, gain, and other signal amplitude detection processing adjustments that need to be tuned to the local project conditions. It is important to understand these settings on echo sounders—in particular, how their adjustment can alter the measured depth. The following section explains some of the common controls found on many echo-sounders—it is primarily excerpted from portions of IHO 2005 (Manual on Hydrography) and from ODOM 2008 ("Odom Echotrac MKIII User Manual"). Not all of the controls listed below are available on every echo sounder.

a. Transmitted power. The operating range of the echo sounder depends on pulse length, frequency, and transmitted power. To optimize the use of the echo sounder, the transmitted

power should be kept at the lowest values consummate with adequate detection. Increases in power will result in high levels of echoes but also in higher reverberation levels, creating a poor record. Most echo sounders have a power setting control that can be adjusted depending on the project depth and bottom condition. The Odom Echotrac MKIII also has an automatic transmit power setting ("Tx") that varies the power based on a maximum depth setting.

b. Gain and Automatic Gain Control (AGC). Gain is the amplification of the return echo signal. On older analog echo sounders gain was synonymous with the "sensitivity" control. The amplification of the signal also amplifies the noise and consequently the data record may be confused. It is recommended that the receive gain be adjusted according to the seabed type and to the transmission power (IHO 2005). For example, the Odom MKIII echo sounder has a receive gain control ("Rx Gain") that adjusts the amount of attenuation or amplification applied to the return echo. Covering a range of approximately -20dB gain (20dB of attenuation) at the minimum position to +40dB gain at the highest position, the selected amount of gain or attenuation is applied in addition to the internal automatic TVG (time varied gain). In the "Automatic" position, the amount of amplification or attenuation applied to the return signal is determined by the Digital Signal Processor (DSP). Located inside each transceiver module, the DSP attempts to keep the bottom return at between 80 and 90 % of full scale without allowing the signal to be over amplified and to saturate the receiver. Thus, AGC adjusts the differing signal intensities returned by echos from hard rock and soft silt. The 20Log Time Varied Gain curve is the generally accepted standard in single beam vertical echo sounders and the default value for the Odom MKIII. The 20Log curve includes compensation for both spherical spreading loss and absorption losses. (Odom 2008).

c. Time Varied Gain (TVG). The received signal is amplified as a function of time (depth) such that similar echos are generated and digitized for varying depths. TVG removes transmission loss from acoustic absorption and beam spreading.

d. Pulse length. The pulse length is usually selected automatically as a function of the operating range. The pulse length determines the vertical resolution of the echo sounder--short pulses are necessary for a better resolution. It may be necessary to increase the pulse length in areas with poor reflectivity or with steep slopes. In shallow waters, where resolution is more important, short pulses must be used. This will reduce the probability of false echoes due to strong reverberation. Larger pulse lengths have poorer object resolution. Two objects inside a narrow beam will be recorded as a signal target if they are less than half a pulse length apart; they will be resolved as two separate echoes if they are more than half a pulse length apart.

e. Velocity/Speed of Sound control. This is the nominal value of sound velocity that normally will be set to the average on the recorder's "speed of sound" control, as obtained from a Velocity Probe cast or a Bar Check. Usually this average speed of sound will be used in subsequent processing. If there are large velocity changes in the water column, an average velocity of sound is not recommend to correct the depths at varying elevations—use a table of measured velocities in the data acquisition software. When significant water velocity changes were observed, during post-processing the depths can be corrected by applying the actual sound velocity profile obtained from the cast or the recorded bar check differences at varying depths.

f. Resolution. This is the ability to separate returns from two or more objects close together; it is generally expressed as the minimum distance between two objects that can be separated.

g. Ping rate. On an Odom MKIII this parameter refers to the pulse repetition rate of the sounder. The default is "AUTO," that is, the sounder "pings" as rapidly as possible as dictated by the end of scale value, the velocity of sound, and a certain amount of processor overhead time. Selection of a fixed number of soundings per second from a minimum of 1 per second to a maximum of 20 per second is also possible (Odom 2008).

h. Maximum and minimum depth gates. Gate controls can be set to blank out signal returns outside the working depths, due to noise or other sources. Additional noise and gate filters can be applied during post-processing—e.g., in the HYPACK Single Beam Editor.

i. Threshold settings. This parameter sets the digitizer threshold, or the time (i.e., depth) on the return signal where the return is registered—see Figure 4-3. Many single-beam manufacturers have a fixed threshold that is internally calibrated such that the recorded depth represents a fixed 60% (±10%) of the maximum return echo voltage available for a saturated echo. The transmitted power and/or received sensitivity settings can also vary the shape of the signal, and thus the measured depth. The Odom MKIII provides a variable threshold option where the digitizer will only detect the signal at the point it exceeds the percentage entered. The Odom MKIII default of 25% is the threshold that can be seen on the paper chart. A higher percentage threshold should be used to detect a hard bottom in sea grass conditions. When the Odom MKIII threshold is set to "none" the digitizer will detect the signal with the highest energy--use this setting only in very deep depth conditions. (Odom 2008).

4-6. Single Beam Power and Receiver Sensitivity Effects. The proper setting of the echo sounder's power and receive gain (or sensitivity) controls (Figure 4-4) must be maintained when conducting single beam hydrographic surveys. In soft or unconsolidated material, depth biases upwards of 1 ft can be induced by varying these settings. The adverse impact of such constant depth errors on channel clearance and payment is obvious. Thus, it is critical to maintain constant power and gain settings throughout the survey; including the bar check calibration. In practice this is usually not possible—especially on channel cross-sections where the upslope depth is significantly shallower that the channel depth, or in varying hard and soft material along the section. In these cases, the power and/or gain may have to be adjusted to ensure a valid depth is recorded throughout a cross-section of varying side slope and channel depths. When these adjustments must be made, this fact should be noted in the field book or survey log.

a. Typically, survey sounders take a point for the sounding depth that is at 60% of the maximum return echo voltage available for a saturated echo (Figure 4-3). If the return echo is nearly vertical, there will be no time or depth delay from the point where the received echo starts to return from the bottom and the point where it reaches the 60% of maximum which is the digitized depth point on the echo. If the receiver gain setting is too low, the received echo will have a more rounded shape. If the gain is quite low, the slope of the echo can induce a

significant difference in time between when the echo is first being received to when the 60% point is reached, resulting in a depth error showing a deeper depth than the true bottom.

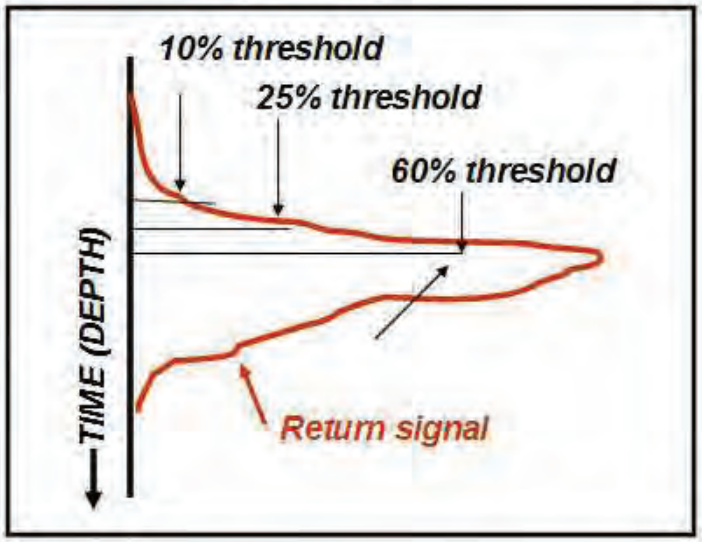


Figure 4-3. Digitizer receive gain and threshold settings. The sharper the return signal the less impact the settings have on the digitized depth. Transmit power variations may also modify the shape of the return signal, and depth measurement.

Figure 4-4. Odom MKIII transmit (TX Power) and receive power (RX Gain) adjustments. Maintaining consistency in these adjustment settings is critical in ensuring survey repeatability in soft material.

b. The correct gain setting is reached when the top most color of the echo trace on the sounders display is at its maximum, typically red on some digital screen displays. It should stay at this color without breaking up or changing to the next color in the palette—approximately one third of the total echo trace. If a bottom tracking line is displayed, the line should be fairly stable without jumping up and down while on a flat bottom. This can also be an indicator of a weak echo as the slope of curve is changing as the weak echo fades, causing the 60% point and resulting depth indication to move around. Digital signal returns can be viewed on graphical displays as shown in Figure 4-5.

c. Caution must also be used in not setting the gain too high, as this results in false soundings from fish targets, vegetation, suspended sediments, and noise in the water column, which can reach a 60% level and become erroneous depths—i.e., shallower than the grade.

d. In soft material, varied power and gain settings should be tested in the deeper part of the channel to determine if significant depth differences result from small setting changes. If so, then maintaining records of these settings will be critical for survey measurement & payment repeatability in these areas. In these soft bottom areas, obtaining repeatability between two different survey vessels (echo sounders) will be difficult, at best. Different echo sounders with different power/gain settings will yield constant depth biases over the same area, resulting in differing clearance assessment and pay quantities. In these problematic soft sediment channels, it is recommended that the same vessel (echo sounder) be used for all payment and clearance surveys.

SECTION II

Single Beam Echo Sounders and Auxiliary Sensors

4-7. Single Beam Echo Sounding Evolution in USACE. Prior to the 1970s, most USACE districts employed mechanical analog depth recorders. The most common models used were Bludworth and the Raytheon DE 719 (Figure 4-6). These devices marked the continuous depth profile on a pre-printed graph paper using a rotating stylus mechanism. The speed of the rotating mechanical stylus was a function of water depth and velocity of sound. Unfortunately, the rotational speed of the mechanical recorders was often unstable and required constant calibration and realignment. Few, if any, of these mechanical analog recording systems are still used in the Corps.

a. In the 1970s, USACE districts began to acquire digital depth recording systems. These systems marked analog (profile) depths directly on blank thermal recording paper; thus eliminating most of the alignment errors common in mechanical recorders. Digital depth data could also be sent to a data logging device where it was correlated with positioning data input. All modern depth measurement systems are now configured to output measured depths to data recording software where they can be time tagged with position, water level, and motion sensing data. Options available for real-time (or post-processed) cross-section display include both digital and hard copy.

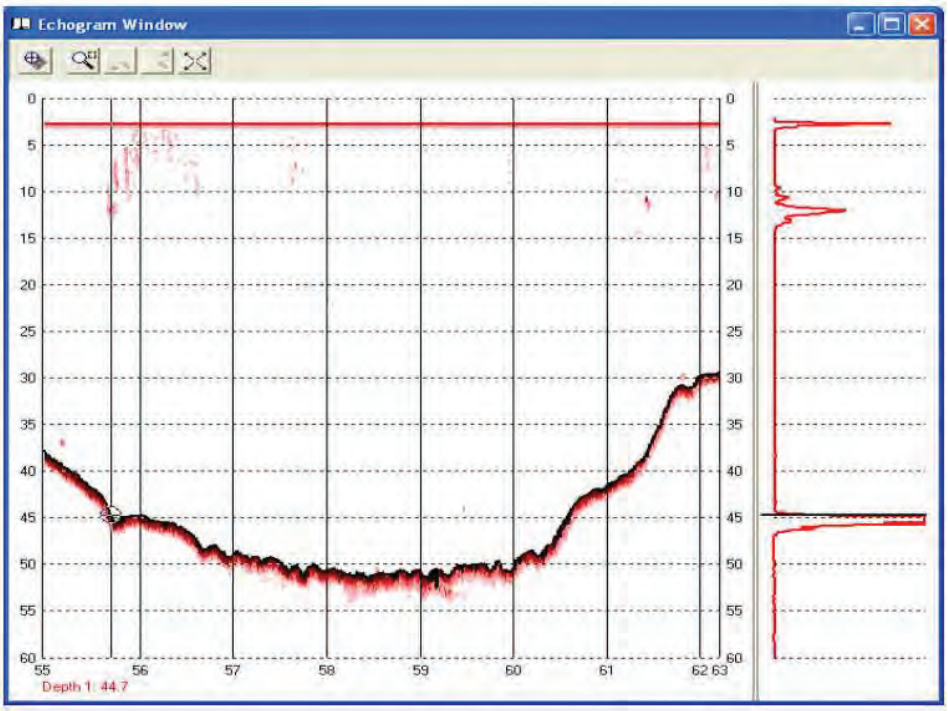


Figure 4-5. Digitized depth signal return display at a selected point along a cross-section.

b. Figure 4-7 depicts some of the more common digital sounding units used by Corps districts. Detailed descriptions and specifications for these (and newer) units may be obtained from the manufacturer's operating manuals and/or other literature.

4-8. Single Beam Transducer Mounting Locations. The transducer for a single beam echo sounder should ideally be mounted in the hull nearly amidships and as near as possible to the vessel's fore and aft center of rotation. The transducer should be permanently located in a frame or transducer well adjacent to the vessel's keel. Over-the-side, bow, and stern mounts are acceptable but not recommended. These external mounts may exhibit significant dynamic motion on small vessels and may require heave-pitch-roll motion correction. The positioning system's GPS antenna should preferably be located directly over the transducer--any X-Y-Z offsets (lever arms) must be accurately measured and input into processing software. Requirements for inertial motion correction will be determined based on the type of vessel and typical sea conditions encountered. These motion corrections may not be significant in relatively calm inland navigation projects; however, in coastal projects, motion correction may be essential.

4-9. Motion Correction on Single Beam Systems--Vessel Heave, Roll, Pitch, and Yaw. Correcting observed depths for the superimposed effects of vessel roll, pitch, yaw, and heave was once perhaps the most difficult aspect of hydrographic surveying. Along with tide/stage,

these effects are a major error component in hydrographic surveying. Since vessel roll, pitch, yaw, and heave conditions can occur simultaneously and at different periods, either visual or automated interpretation of a single beam analog profile record to reduce these errors is an

Figure 4-6. Raytheon DE 719 analog-recording portable echo sounder ca 1978. (Jacksonville District)

imprecise process, at best. Vessel heave is the major error component of the four listed motions. (Yaw is usually not significant—and not corrected—on single-beam installations if the positioning antenna is located vertically inline with the transducer.) Since the mid 1990s, affordable and accurate motion compensation sensors have significantly reduced (but not eliminated) these errors. Many districts have now incorporated motion compensation into single beam systems. Motion compensation (heave-pitch-roll) is essential on critical dredging measurement and payment surveys and strongly recommended for all other surveys where adverse sea conditions can affect the quality of the recorded data.

a. Interpretation of single beam recorded depths without motion compensation. The impact of lateral vessel roll and fore-and-aft pitch of the vessel are more pronounced when narrow-beam transducers are employed because the sounding cone becomes non-vertical and measures a longer slope distance. Up and down vertical heave reflects the wave height. Heave is superimposed with roll and pitch on the observed depth. Heave values typically can range up to 2 to 4 ft whereas roll/pitch depth errors are much smaller--e.g., less than 1 ft. Interpretation of the effects of all three potential motions on an analog recording requires skill and experience with the vessel motion at the time of the survey. The apparent smoothing of undulations on the graphical record are not always interpolated correctly, depending on the vessel's course relative to the seas, vessel size, vessel characteristics, and wave height. On an irregular bottom, it is extremely difficult to separate vessel motions from the bottom undulations. Digitally recorded depths do not allow for any human interpretation or smoothing of undulations due to heave, pitch, and roll.

Figure 4-7. Typical single-beam echo sounders used on USACE projects ca 2002.

(1) Unless reliable motion compensation devices are used, the only practical method of minimizing vessel motion effects is to limit the maximum allowable sea states under which a particular type of survey may be performed. Such limitations are highly subjective and can have significant economic impacts, due either to delayed survey work or to inaccurate payment when a survey is performed under adverse conditions. Maximum sea state limitations must also factor in the size and relative stability of the survey vessel, along with the effects of the prevailing wave direction relative to the survey lines or cross sections. Procuring larger vessels to minimize roll, pitch, and heave is likewise no longer economically justified given the small cost of motion compensators. Thus, a simple maximum allowable wave height criterion is difficult to definitively specify.

(2) An on-site assessment of the potential data adequacy must be performed since so many variables are involved. If the effects of vessel motion appear to be degrading the desired (and acceptable, from a contract performance measurement standpoint) survey quality after the on-site assessment is performed, the on-site survey party chief should make the decision to postpone the survey.

(3) A subjective judgment on the effects of excessive vessel motion to a survey's adequacy must also consider the type of survey. One-half foot seas may be the maximum tolerable limit for performing a final acceptance survey or sweep on high-unit-price rock excavation work, whereas 1-ft seas or larger might have been tolerable for the initial pre-construction survey of this same project. Any workable sea state may be tolerated for an intermediate progress payment survey of this project. No maximum sea state limits need be imposed on performing less critical non-navigation surveys--the only tolerance to be considered is the ability of the vessel, equipment, and personnel to collect reliable data.

(4) The NOAA Office of Coast Survey (OCS) "Field Procedures Manual" (OCS 2011) provides the following guidance regarding the need for motion compensation equipment:

> "[If] the magnitude of vessel roll and pitch is less than the sonar beam width, these attitude characteristics will have little effect on sounding accuracy and their application to vertical single beam data is not required by OCS. However, to maintain data quality in sea states where vessel roll and pitch angles exceed sonar beam width, OCS recommends that an external sensor be used to record heave data for application during post-processing. If a heave sensor is not employed, the vertical single beam system should be used only when conditions are favorable for minimizing heave bias and data must be scanned for heave artifacts during post-processing. If heave artifacts can be reliably interpreted, they shall be manually removed from the depth data. Data acquisition should be suspended if the heave signature exceeds 0.5 m and a heave sensor is not being used."

(5) Based on the above discussion, use of motion compensation instruments for single-beam surveys is usually recommended in order to maximize data quality and production.

b. Motion stabilization for single beam systems—dredging surveys. To best minimize the adverse effects of vessel motion, single beam systems used for dredging and navigation surveys in rough sea states should be equipped with automated motion compensation—e.g., MRUs, IMUs, and/or POS/MV. Motion compensation is often recommended if the effects of heave, roll, or pitch generate depth errors exceeding ±0.2 ft. (Note that maintaining heave corrections at the ±0.2 ft level may be difficult to achieve in heavy seas.) Yaw compensation may or may not be required. Motion compensation may not be necessary in confined, calm waters, such as inland rivers or reservoirs; presuming these corrections are less than ±0.2 ft. Motion compensation systems are configured to operate in line directly with depth recorders or independently as a real-time input to the survey data acquisition and processing system. Nearly all systems display heave, pitch, and/or roll information in real-time; allowing for operator assessment of the data quality. Motion compensation is then applied either in real-time or during post-processing of data—e.g., in the HYPACK Single Beam Editor software. Raw observed data can be independently corrected for heave, roll, and/or pitch, depending on the magnitude of these correctors.

c. Heave compensation. The major depth error component is heave--the long period up and down motion of the vessel due to wave motion, other vessel wakes, etc. Heave is basically a

function of wave swell and period. Heave errors are normally excessive at coastal entrances and on offshore approach channels--large 65-ft survey boats can typically work in swells up to 3 or 4 feet. Modern heave compensators can effectively record heave movement and smooth out these effects. Heave compensators require internal alignment and stabilization calibrations specified by the manufacturers. Since heave compensators can be subject to constant drifts and "hang ups," continuous monitoring during surveys is required—refer to Chapter 7 in this manual for details on heave compensator operation, minimization of heave drift, true heave, induced heave, and use of inertial-aided RTK heave measurements.

d. Single beam position correction for roll and pitch. The transducer measures depth from the first echo return. The wider the beam, the less effect vessel roll or pitch will have since the transducer beam width falls within the vertical. For narrow beam transducers a slope rather than vertical distance is measured. If roll and pitch is severe--e.g., a 10- to 15-deg roll--the recorded depth will be a longer slope distance. This measurement should either be rejected due to excessive roll/pitch or corrected for slope-to-vertical given the observed roll/pitch angle from a motion sensor. Excessive roll and pitch can also inject position errors in the measured depth. This is caused by the motion of the positioning system antenna relative to the transducer. If the distance between the units is large, roll and/or pitch displaces the transducer. This is usually not significant for most applications but can be corrected with roll/pitch and antenna-transducer offset data. Processing software can provide pitch/roll slope-to-vertical depth correction in addition to correcting for the positional (X-Y) eccentricity or the transducer relative to the positioning antenna.

(1) Roll-pitch effects. On larger vessels--i.e., greater than 26 ft--roll and pitch are usually not excessive under normal working conditions--typically less than 5 deg. However, on smaller vessels (e.g., less than 26 ft) roll or pitch can easily approach or exceed 10 deg in rough seas. The correction for roll and pitch varies with the angle of rotation and depth. However, the beam width of the transducer may be greater than the overall roll or pitch, resulting in the first return still being near vertical. Corrections for roll-pitch may be applied for high frequency narrow beam transducers--similarly to that applied to narrow beams formed by multibeam arrays.

(2) Roll-pitch position displacement correction. Single beam processing systems correct for depth and position variations due to roll or pitch. Using roll-pitch data, the software will correct the depth's X-Y position due to rotation of the antenna-transducer axis, and optionally to compute the X-Y coordinate of the center of the projected (i.e., steered) beam on the bottom. On a large survey vessel with an antenna located 30 ft above the transducer subject to a 10 deg roll or pitch, this would amount to a 5 ft horizontal displacement of the transducer. In a 30-foot project, the center of the beam on the bottom would also be displaced by another 5 ft (approximately) relative to the transducer. The total horizontal displacement of the depth relative to the antenna would then be about 10 ft. A smaller survey boat would normally have a much smaller antenna height (< 10 ft) so the horizontal displacement between the antenna and beam-steered bottom depth would be smaller.

(3) Roll-pitch slope to vertical depth correction. In addition to the antenna-transducer-bottom depth positional displacement correction, the slope-to-vertical correction to depth may

also be computed and applied to the observed depth. The slope-to-vertical depth correction is usually small for typical roll-pitch conditions. Full roll and pitch corrections for single beam systems are performed in the processing software (see HYPACK 2011).

(4) Roll-pitch tolerances for single beam systems. Ideally, roll-pitch depth errors should be kept within tolerable limits--say not greater than 0.2 ft. This can be achieved if maximum allowable roll or pitch is kept less than 10 deg when using a typical 8 deg beam width transducer. On critical deep-draft projects, 5 deg roll-pitch limits would be recommended. In general, roll-pitch exceeding 10 deg is a degraded working environment and overall acoustic data quality is marginal.

e. Yaw. Yaw (or vessel heading) rotation error is not significant for vertical single beam systems if the transducer and positioning system antenna are co-located vertically. If these units are not located vertically, then offset corrections must be applied using vessel heading information. This translates the position to the transducer--it has no effect on the measured depth other than position. A variety of techniques can be used to measure real-time heading: magnetic fluxgate compasses, fiber optic gyrocompasses, inertial systems, and carrier-phase POS/MV.

SECTION III

Single Beam Quality Control Calibrations

Calibration of acoustic sounding instruments is absolutely critical in maintaining quality control of depth measurements. This is primarily due to instabilities or variances in the sound velocity, or to a lesser extent, in the equipment. Failure to perform adequate calibrations, including documentation/certification thereof, can lead to total unacceptance of the survey and any payment associated with it. This section describes the various methods used to calibrate single beam depth measurement equipment. The calibration procedures in this section also apply to multiple transducer sweep systems and, in part, multibeam systems.

4-10. Bar Check Calibration of Single Beam Echo Sounders. The primary echo-sounder depth calibration procedure in USACE is the "bar check." The bar check is recognized throughout the Corps and dredging industry as the standard calibration method for all acoustic depth measurements. The bar check is a quality control procedure. It is not a quality assurance procedure. The bar check is used to minimize the following systematic errors inherent in depth recording systems: instrumental errors—index, mechanical, and electrical; velocity of sound errors due to temperature, salinity, or other suspended or dissolved sediment variations; and dynamic draft fluctuations resulting from varying vessel displacement caused by fuel and personnel loads. The bar check is a flat bar or plate suspended by precisely marked line(s) to a known depth below the water surface and under the transducer. The effect of a varying velocity of sound in the water column is observed by performing a bar check. A series of depth intervals are observed during a bar check, down to the project depth. Any difference between the reference bar depths and the recorded depths represent corrections to be made to any subsequently recorded soundings. The bar check represents the only recognized check on the

quality of a depth recording system. Draft and index variations are also compensated through the use of a bar check calibration. However, in reality, the bar check is not an "absolute" calibration device. It has inherent errors and biases, and may not exhibit the same acoustic reflective properties as the bottom. This primary reference device is also used to periodically check secondary calibration devices, such as a sound velocity meter and a Ross ball check.

a. General procedure. Figure 4-8 characterizes the operation of suspending the bar a known distance below the waterline using calibrated chains. Both a single line calibration plate and a dual line (full beam) bar check device are shown. The bar check must be taken at sufficient intervals to correct any variations in the velocity of sound. Normally, intervals of 5 to 10 feet are adequate, unless the velocity of sound is highly variable. It is again emphasized that a bar check will not correct for variations in acoustic reflectivity, either between the bar and bottom material or between different bottom materials within a project area. The bar check is also not a totally independent reference in that it may contain errors within itself--e.g., wave action interpolations and line marking errors.

b. Bar check apparatus. The suspended bar is constructed of flat stainless steel or aluminum plate welded or bolted to any supporting crosspiece section. The plate should be of sufficient width (typically 8 to 12 inches) to provide an adequate return down to project depth. If the bar length is longer or shorter than the vessel beam (on the measuring deck), a slope line distance error may be present in the cable tagging. Generally the bar should be approximately 1 ft longer than the vessel beam (at the measuring deck point). The reflecting plate need not extend the full length of the bar. Both ends of the bar are rigged with universal-type swivel joints to attach the supporting lines. Each line is zero-referenced from the top of the plate and is marked at either 1- or 5-ft increments. The top surface of the bar plate may optionally be coated with foam, rubber, or other like material that better simulates the acoustic reflectivity properties of the channel bottom. A small (12-in.-diam) steel plate can be used to calibrate over-the-side mounted transducers. The plate is suspended by a single bar check line or lead line. Calibration and/or adjustment are performed in a manner identical with that used for bar check. Special caution must be taken not to change the vessel draft when performing a check on one side or end of the boat.

c. Bar weight. The weight of the bar will be dependent on the types of currents experienced, project depths, and beam of the vessel. A typical bar will range between 40 and 100 lb. In deep-draft projects with large currents, a heavy bar is essential because subsurface currents will pull too light a bar away from the transducer's vertical plane, causing loss of acoustic return or slope error in the check lines. Provisions for adding additional weight to the bottom base of the bar ends may also be needed in strong currents. Increased bar weight may necessitate additional personnel to perform the bar check.

d. Bar check procedures on large vessels. On a larger vessel, the bar is usually deployed off the bow and each end walked aft until abeam of the transducer. Both lines are held at the desired fixed depth increment (visually meaning vessel and water surface motion), and the depth recorder is simultaneously observed, annotated, and/or recalibrated. Vessel alignment should be

held toward the sea to minimize roll. Under adverse wind and current conditions, coupled with a narrow-beam transducer, maintaining vertical alignment of the bar and lines becomes extremely

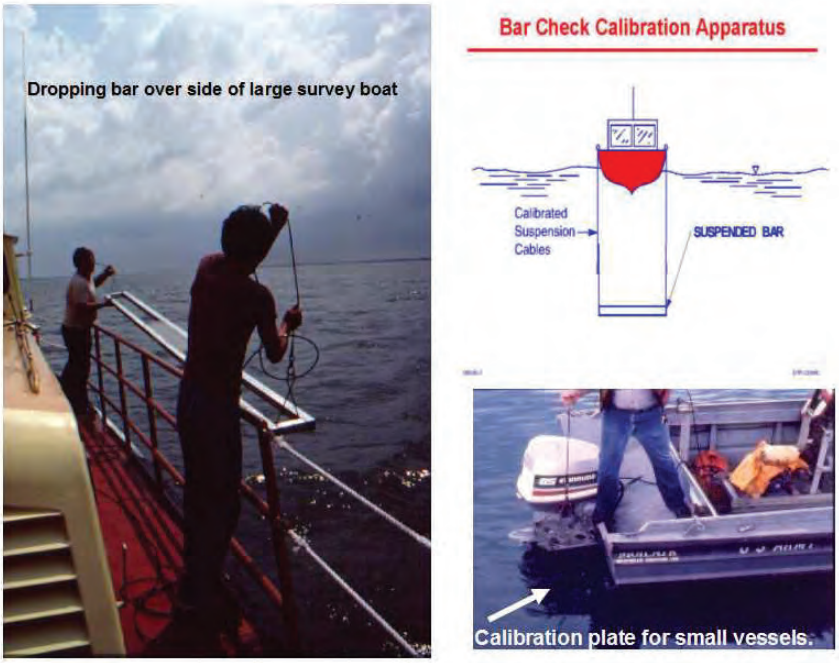


Figure 4-8. Bar check calibration.

difficult, especially at greater bar depths. In such cases, the skill and experience of the boat operator to maneuver the vessel over the suspended bar becomes critical to the process. On smaller vessels, personnel movement during a bar check may affect the nominal (underway) trim of the boat—also known as the "Bubba Effect." Care must be taken to ensure that this variation is minimized.

e. Calibration increments. Static bar comparisons should be taken at 5-ft intervals throughout the project or dredging excavation range. If the recorder is adjusted to display actual bar depths, subsequent bar check readings need to be taken only at the upper, intermediate, and lower project levels to verify stability. A sample bar check observed on an older analog echo sounder is shown in Figure 4-9. The 5-ft incremental bar readings are recorded throughout the dredging range, where in this case, an average velocity of sound in this depth range was obtained.

f. Data corrections. Stage/tidal corrections, vessel squat corrections, draft loading variances, calibration line graduation errors, or any other correction should normally not be “dialed” into the echo-sounder but should entered as separate corrections in a log or the data acquisition software. Recorded depth data must be “original” relative to the subsequent corrections. Adding depth corrections directly into the depth sounder makes reconstruction of

original survey data difficult -- and indefensible in the case of a contractual dispute or claim over the data adequacy.

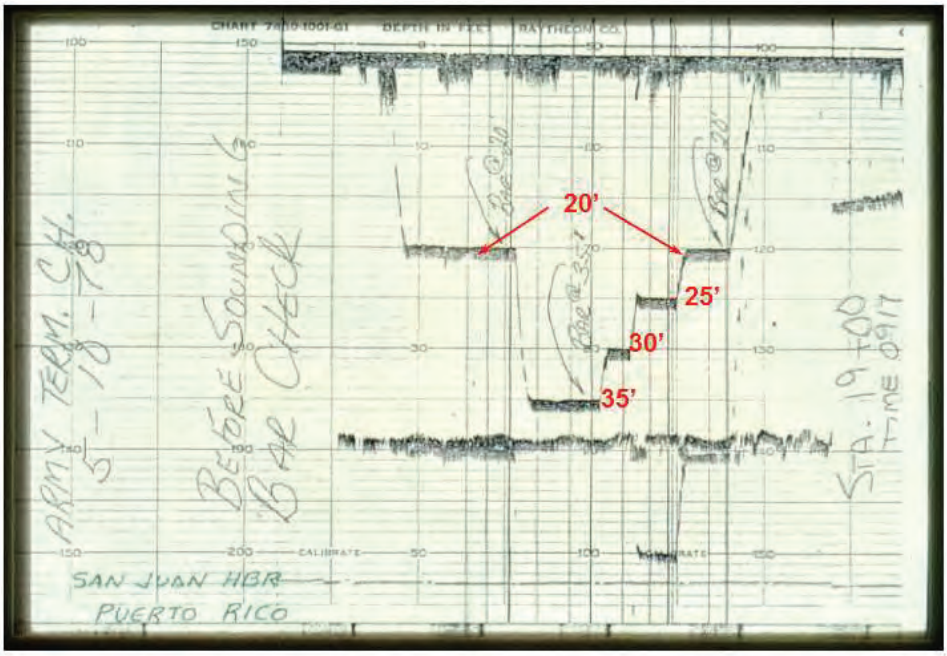


Figure 4-9. Example of bar check in deep-draft navigation project. Bar increments are at 5 ft increments through the dredging excavation limits—20 ft to 35 ft depth. (Jacksonville District)

g. Frequency of bar checks. For critical navigation and dredging support surveys, two bar checks were once recommended each day--one before work and one after completing a day's activity. In a given project or dredging area, the frequency of bar checks may be reduced if repeated bar check indicate a stable draft correction, repeatable average velocity of sound corrections, and repeated agreement with velocity cast data. For example, if repeated velocity casts show the average velocity of sound is 4,905 ft/sec and this agrees with the velocity of sound on the echo sounder obtained by repeated bar checks, then more reliance on velocity cast data would be warranted, and bar checks performed only periodically; weekly or monthly. The "periodic" time span is a judgment call by the surveyor, based on the stability and repeatability being obtained between past velocity casts and bar checks. (These comparisons should be well documented in a log book before bar checks are reduced.) A critical dredging measurement and payment survey (e.g., in a high cost/cy rock cut) may dictate more frequent bar checks during the course of the project. However, if there are ever any concerns over vessel draft changes, only a bar check will be able to measure this.

h. Location of bar checks. Due to the high potential for local temperature and/or salinity variations in typical USACE river and harbor projects, the resultant effect on the velocity of sound must be measured directly at the work site. This is an essential requirement for payment surveys. If an area is known to be subject to extreme temperature/salinity variations, additional

bar checks in these areas may be warranted. In extremely adverse conditions where it is physically impossible to perform a bar check at the project site (due to high winds, currents, and/or sea states), a velocity probe may be used to determine the sound velocity at the project site. However, on critical projects, both a bar check and velocity probe should be simultaneously performed in a protected area near the project vicinity. The sound velocity derived from the bar check should agree within 10 fps with the probe's average velocity in the protected area. The echo sounder draft would be set from the bar check and the echo-sounder "speed of sound" setting would be readjusted based on the probe velocity measured later at the actual project site.

i. Bar check recording. As shown in Figure 4-10 bar check observations may be digitally recorded. Bar check data for digital echo sounders may be optionally recorded in a field survey book or on a survey log form. For dredging payment surveys in which analog backup recordings must be maintained, digital bar check data may be recorded on the analog record for comparative purposes. It is a recommended practice to maintain a continuous record of all bar check calibrations in a bound survey field book aboard the vessel. This record should include draft and speed settings, transmit power and receive gain settings, along with other instrumentation calibration and alignment records, including velocity probe results.

j. Agreement between successive bar checks. If two bar checks are performed each day, they should be compared for excessive differences. Adjustments are never made to the final (end-of-day) bar check. Results are logged at the same check increments used during the initial calibration. Any known draft variation due to loading should be applied to the final readings before comparison. Otherwise, the draft variation may be taken from markings on the vessel hull. Failure to obtain consistent agreement between successive bar check calibrations may be due to any number of physical or electronic causes, and must be located. The frequency of calibration may have to be increased. The mean value of the calibrations may be used to correct the recorded data.

k. Calibration of bar check lines. The bar check suspension lines must be periodically checked to ensure the accuracy and stability of the graduated marks on the lines. Periodic calibration data shall be recorded on a worksheet or in a field survey book. Any errors in the graduated marks must be physically corrected (removed) at the time of calibration.

l. Ross Ball Check calibration. As a substitute to a full-beam bar check, many districts use a center-mounted, spherical calibration ball with a flattened radar reflector type top. This device was designed and developed by Wayne Ross of Ross Laboratories. The ball is suspended on a cable from the interior of the boat by a hand crank-lock mechanism. The line is marked and calibrated in a manner similar to that used for a bar or lead line. An interior water level gage may also be used to measure/monitor the line indexes. Details regarding installation, maintenance and operation of this calibration device can be obtained from the manufacturer (Ross Laboratories, Inc.).

m. Alternate lead line or sounding pole calibration. On shallow draft projects (< 15 ft) with hard sand or rock bottoms, a lead line may be employed to calibrate the echo sounder at or near the project depth level. This "check" does not calibrate the draft or velocity of sound, so it

is only valid around the calibrated depth—say ±5 ft from that depth. Therefore, do not use this calibration method if depths vary by more than ±5 ft. This assumes the estimated vessel draft and velocity of sound entries in the depth recorder are relatively close to reality. If so, small

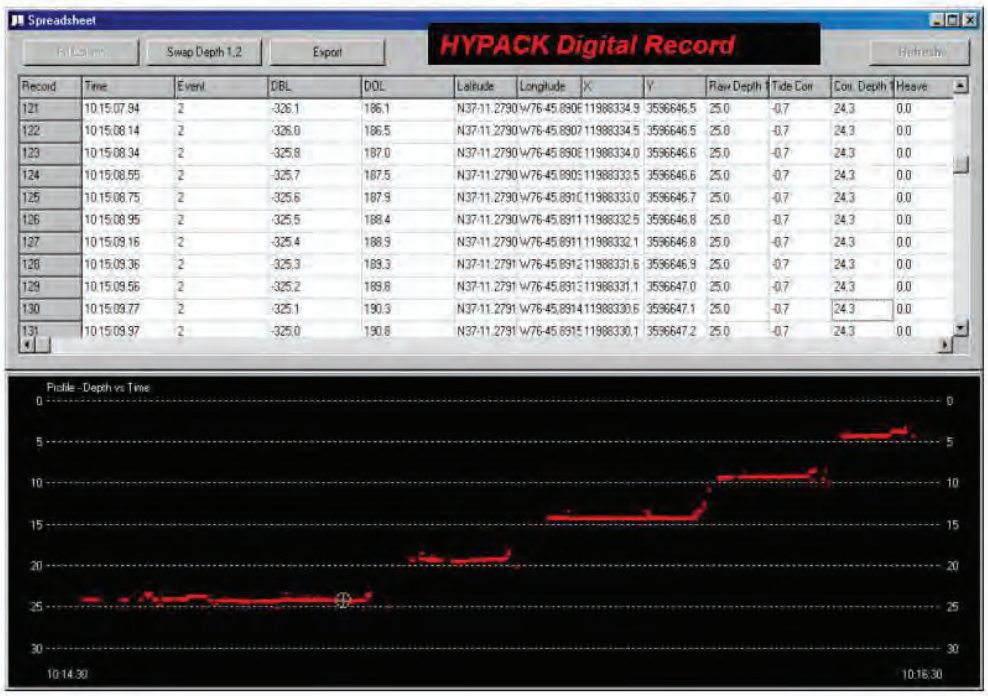


Figure 4-10. Digital record of a bar check.

errors in the draft or velocity of sound will not significantly impact the depth measurements at the calibrated depth. (This method also assumes that the lead line can be placed over the transducer and/or the bottom is flat. If a lock chamber is available, then this is a good place to check calibration.)

4-11. Depth Corrections Based on Bar Check Data. There are several methods of performing bar checks and arriving at corrections to apply to observed depths. (This section assumes no velocity probe data was available and corrections are based strictly on bar check calibration data.) Three methods are commonly used in USACE as outlined described below. Each of these methods is acceptable on any type of survey. Results from a typical bar check calibration are shown in Table 4-1 below. No adjustments to the speed of sound or draft settings were made during this calibration—the bar was dropped at 5-ft intervals and the echo-sounder depth recorded as read. The differences between the bar depth and recorded depth indicate the presence of both a constant index error and a velocity error in the recorded data. The velocity change is exhibited by the increasing differences below 20 ft where a change in the water's sound velocity has occurred. The constant 0.2-ft index error indicates that the presumed 3.0-ft draft measurement must be independently checked. Three different methods for correcting soundings are described below.

Table 4-1. Sample Results from a Bar Check Calibration.

Initial speed set at 5,100 ft/sec Initial draft = 3.0 ft Project depth range: 20 to 40 ft

Depth of Bar	Recorded Depth	Difference	Notes
5 ft	5.2 ft	0.2 ft	0.2 ft index error indicated
10	10.2	0.2	
15	15.2	0.2	
20	20.2	0.2	
25	25.3	0.3	Change in water column velocity occurs
30	30.4	0.4	
40	40.6	0.6	
45	45.7	0.7	
50	50.8	0.8	

a. Correction Table Formula. This is the depth-velocity correction method used by most processing software and many survey organizations. It is the preferred depth correction method. It is the only correction method that will work when the velocity profile is not linear in the water column—i.e., an average "speed of sound" setting on the recorder should not be used. Recorded depths may be directly and individually corrected mathematically without making any adjustments to the draft or speed settings on the recording device. Some survey organizations will put a nominal speed of sound (e.g., 4,800 ft/sec) and assumed draft (0 ft) in the echo sounder and let the software make all the depth-velocity corrections. All recorded depths are adjusted according to the bar check data, such as that recorded in Table 4-1. This reduction can be made on-line when an automated data acquisition system is used or off-line during the post-processing phase. The results of a sample calibration shown in Table 4-1 are used directly for this process; however, a table combining the before and after survey bar checks may also be used. A corrected depth is then computed by:

$$d_c = [\,[\,(\,bar_i - bar_{i+1}\,) \div (\,rec_i - rec_{i+1}\,)\,] \cdot (d_0 - rec_i\,)\,] + bar_i \qquad \text{(Eq 4-2)}$$

where:

d_c	=	corrected depth
d_o	=	any observed/recorded depth to be corrected for sound velocity and index
bar_i	=	bar depth at checkpoint i
bar_{i+1}	=	bar depth recorded at point i+1
rec_i	=	recorded depth at bar depth i
rec_{i+1}	=	recorded depth at point i+1
i, i+1	=	any two successive calibration depth points and $rec_i > d_o < rec_{i+1}$

An observed depth is corrected between its closest range of calibration data. For example, if a 43.5-ft sounding is recorded, it is corrected relative to the calibration data in Table 4-1 at the 40- and 45-ft levels. From the calibration table:

bar_i	=	40	rec_i	=	40.6
bar_{i+1}	=	45	rec_{i+1}	=	45.7

From Equation 4-2,

$$d_c = \frac{(40 - 45)}{(40.6 - 45.7)} \cdot (43.5 - 40.6) + 40$$

$$d_c = \frac{(-5)}{(-5.1)} \cdot (2.9) + 40$$

$$d_c = 0.9804\ (2.9) + 40 = 2.8 + 40 = \underline{42.8}$$

Given a bar check calibration table, all subsequent observed depths may be corrected using the above described procedure. Such a procedure may be performed either on-line or in an off-line mode. Correcting non-digital depth data by this method is obviously not very practical unless that data can be digitized into a database. This Correction Table/Formula method works well in areas of salt wedges or places where the water has distinct temperature differences.

(1) This method may be preferred in the vicinity of power plants where the plant cooling water effluent has a much higher temperature than the surrounding water. This will cause the velocity of sound to increase slightly if the water is turbulent and thoroughly mixed. In most cases the effluent will not thoroughly mix with the surrounding water. This will cause the temperature to be different through the depth layers. The result to the surveyor will be a significant increase in the velocity of sound in these depth layers (shallow soundings). If the bar check table does not reflect this phenomenon, the survey may erroneously indicate extreme shoaling in the area of the power plant outfall. A separate bar check should be recorded in these areas.

(2) Since the velocity of sound is normally fairly stable over most river and harbor projects, it is usually desirable and more practical to base the above-described correction over a wider interval than 5 ft. Given the sample project data in Table 4-1 with excavation depths ranging between 20 and 40 ft, a single correction factor may be computed over that range, since the differences over that 20 to 40-ft range in Table 4-1 are linear.

For example:

bar_i	=	20	rec_i	=	20.2
bar_{i+1}	=	40	rec_{i+1}	=	40.6

From Equation 4-2,

$$d_c = \frac{(20 - 40)}{(20.2 - 40.6)} \cdot (d_0 - 20.2) + 20$$

$$d_c = 0.9804\, d_0 + 0.2$$

The above factor may be used to correct any depth ranging between 20 and 40 ft and may be practically extended to a range of 15 to 45 ft. Such a correction procedure is valid as long as the calibration data are linear over this range.

(3) The constant term (0.2 ft) represents the index correction. The ratio (0.9804) represents a velocity correction between that set in the recorder (5,100 ft/sec) and that actually occurring in the water medium over this range, or approximately (0.9804) · (5,100 ft/sec) = 5,000 ft/sec. Readjusting the recorder to 5,000 ft/sec and modifying the draft line to 2.8 ft (3.0 - 0.2 ft) will not graphically correct the depths over this range.

b. Graphical bar check calibration method (Jacksonville District). The computational method described above may not always be suitable in practice, since the displayed depth cannot readily be related (i.e., on-site) to a required excavation grade. Performing the computations and then applying other required corrections (squat, draft loading variances, and stage/tide corrections), requires automated processing capabilities. Such equipment may not always be available aboard small workboats. Since most construction payment/acceptance work depends on immediate on-site assessment of the recorded data, the computations must be minimized. This may be accomplished by visually/graphically changing the speed of sound and draft settings in the analog/digital echo sounder such that the recorded depth equals that calibrated during the bar check. In essence, the recording mechanism is reoriented and rescaled by appropriate adjustment of the speed of sound and index/draft settings. This procedure is performed only during the initial bar check of the day, never during the final check. This so-called "Jacksonville District" method only works when the sound velocity profile in the water column is linear. If it is not linear, this "trail and error" adjustment method will never "converge." This would be the case in the velocity profile in Table 4-1 where there is an abrupt change at 20 ft. However, if the excavation depths range between 20 ft and 50 ft, then a linear velocity profile can be obtained, disregarding depths shallower than 20 ft. The procedure for making these graphical adjustments on an echo sounder is described below.

(1) Calibration is a sequential process performed by trial and error so that the index/draft and the sound velocity errors are simultaneously minimized. Two depths, for example, 20 and 40 ft, are chosen that correspond to the maximum and minimum project depths. The bar is lowered to the lesser depth, and the depth recorder display is adjusted with the index controls to read that depth value. The bar is then lowered to the greater depth, and the reading is adjusted to that depth using the speed of sound control only. When the bar is returned to the first depth, the reading is observed. If the display reads low or high, the display should be adjusted to the proper reading with the index control The entire process is then repeated by lowering the bar to the

greater depth, and adjusting the speed of sound control, and then back to the first depth for inspection of the display until the correct reading is produced at all three steps (within ±0.1 ft). Intermediate readings should then be checked to compare displayed value with the known length of bar lines.

(2) Once set, the speed of sound and draft settings will usually remain fairly stable for a given project area. The primary advantage of the method described above is that a recorded depth can be easily referenced to a required excavation grade. If the velocity of sound is not relatively constant throughout the working depth range, it will not be possible to adjust the instrument so that it reads equal to the bar check at each depth increment. In such cases, the data will have to be corrected by linear interpolation as described previously.

c. Modified graphical bar check calibration method. This method is similar to the above graphical method except that the draft setting on the recorder is not modified. The bar is placed close to the maximum project depth (40 ft in this example), and only the speed of sound control is adjusted so that the observed bar equals the actual bar depth. The bar is then raised at 5-ft intervals throughout the range of project depths, and observed bar readings are recorded. Any significant variation will be corrected in the office data-processing program using the computational procedures described previously. This method only minimizes the error near the lower level at which the sound speed control was adjusted. The recorded values at other depths will be proportionately in error. In the sample data from Table 4-1, at the 20-ft bar check level the recorder will read 19.9 ft, a 0.1-ft error. Near the project excavation grade the instrument is adequately calibrated. However, this is not true up the side slopes.

4-12. Velocity Meter Calibration. A velocity meter (or "Velocity Probe") is a portable, hand-deployed instrument that directly measures sound velocity at intervals of depth in the water column—Figure 4-11. Observed depths are directly corrected based on the velocities obtained from the probe. These corrections are performed in the data acquisition software in real-time. A velocity meter may be used to correct sounding data in lieu of a bar check provided historical comparisons between the velocity probe and the bar check have been performed, and consistent and repeatable results are obtained. Velocity measurements are always taken at the project work site. A velocity meter must still be periodically calibrated, both internally and externally. A periodic bar check is still necessary to calibrate the draft correction.

a. General description of velocity meters. Velocity meters generally consist of a probe attached by cable to a waterproof, hand-held control unit powered by internal batteries. The cable is numerically labeled at 5-m intervals and marked in 1-m intervals, or labeled at 10-ft intervals and marked at 5-ft (or more frequent) intervals. Some models use a pressure sensor for depth determination, thus minimizing cable slant range errors. Velocity meter output is typically velocity of sound as a function of water depth. Sound velocities should be recorded at 1-, 5-, or 10-ft depth intervals, depending on the variability of the velocity readings and project depth. Readings should be made to the nearest 1 foot per second (fps). Where velocity of sound is not constant over the water column (e.g., Table 4-1) a correction table should be developed in the processing software. This is especially critical for multibeam systems where velocity variations can refract outer beams. Software processing systems provide a sound velocity correction table

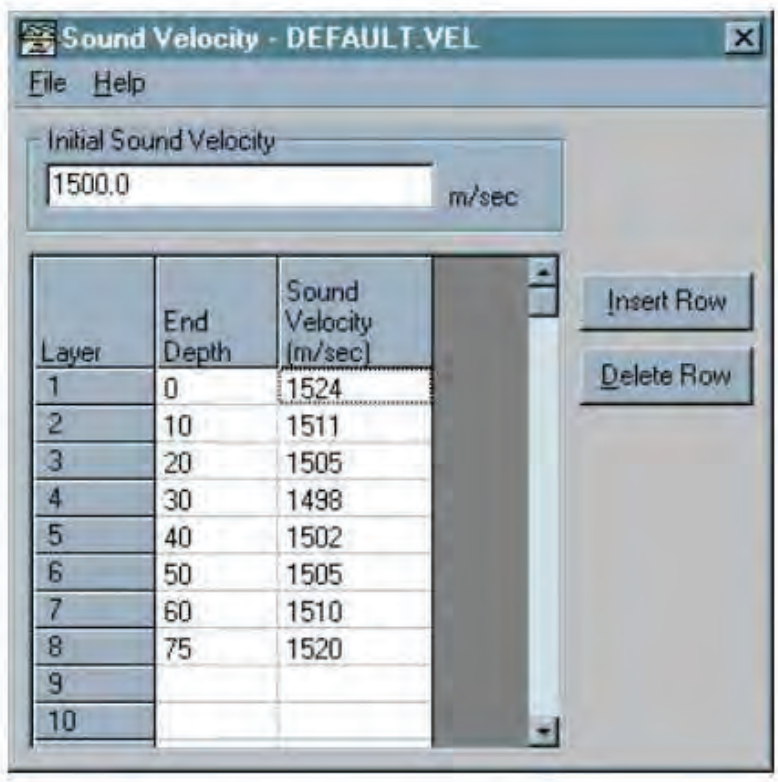
based on velocity readings at incremental depths (Figure 4-12). It is essential that velocity meter data be periodically compared to a bar check.

Figure 4-11. Odom DigiBar Pro Velocity Profiler.

b. General description. An Odom DIGIBAR-PRO is a velocity meter used in many USACE districts. It employs a sing-around method of sound velocity determination. Mounted near the end of the sampling probe is a high frequency "sing-around" transducer and its associated reflector. This precisely spaced pair is used to measure the velocity of sound in water by transmitting and receiving a signal across their known separation distance. After the first transmission, the received echo is gated and introduced into the feedback loop of an oscillator that re-triggers the transmitter and begins the cycle again. The frequency resulting from this regenerative feedback loop is determined by the distance the signal travels (transducer to reflector and back) and is directly proportional to the velocity of propagation of the sound pulse through the measured medium. This method of direct sampling means that all factors that influence the velocity of sound, including salinity, pressure, and temperature, are taken into account. The average velocity value of each cast can be calculated, or the entire velocity profile of the cast can be up-loaded to a computer, in spreadsheet format, for subsequent use in depth or ray-bending calculations. The unit not only samples, displays, and stores values for the velocity of sound in water, but it also ties each collected value to a precise depth. The meter has a pressure sensor to determine depth of the probe.

c. Velocity probe quality control test. The operation of the velocity probe should be periodically calibrated. The frequency of these tests may vary depending on the manufacturer's recommendation. The following equipment is typically needed for data quality assurance tests of velocity probes:

(1) Calibrated thermometer
(2) Clean fresh water
(3) Clean vessel (plastic bucket) large enough for the probe.



Layer	End Depth	Sound Velocity (m/sec)
1	0	1524
2	10	1511
3	20	1505
4	30	1498
5	40	1502
6	50	1505
7	60	1510
8	75	1520
9		
10		

Figure 4-12. Sound velocity correction table entered into a data collection system (HYPACK).

Fresh water is needed because its salinity (parts per thousand) is less than that of seawater. In some cases the fresh water salts, pollutants, or other particles in suspension may affect the water density. Distilled water should be used if this is the case. Using the manufacturer's calibration chart, the propagation velocity can be computed with known temperatures.

d. Velocity meter corrections/calibrations. The velocity probe measures the actual sound velocity over the entire depth measurement range. From these data, a correction algorithm can be devised for on-line or post-processing data reduction. If velocity probe data are used to obtain an average sound velocity over a given range, then this average velocity may be used to adjust the digital or analog recording echo-sounder as is done with a bar check calibration. The average velocity determined from a velocity cast should be within 10 ft/sec from the indirect average velocity determined by a bar check. A velocity probe calibration does not confirm/check the index/draft setting on the analog/digital recorder. This must be done with a bar check.

e. Velocity probe v. Bar check. A major advantage of a velocity probe check over a bar check is the ability to perform rapid calibrations in heavy seas or currents. Calibrations are thus more easily (and frequently) performed directly at the project site. If repeated comparisons between the velocity probe and bar check yield consistent velocity measurements, then the velocity probe can be used with confidence.

f. Velocity computation from measured water samples. If the velocity of sound is required in an area beyond the reach of a tethered velocity probe (such as in a deep offshore disposal site), then alternative methods are needed to measure the velocity. If water samples are obtained at the lower depths, then the velocity of sound at that depth can be computed from the following formula:

V = 1448.96 + 4.591 T - 5.304 x 10-2 T2 + 2.374 x 10-4 T3 + 1.340 (S-35) + 1.630 x 10-2 D + 1.675 x 10-7 D2 - 1.025 x 10-2 T (S - 35) - 7.139 x 10-13 T x D3 (meters/sec) (Eq 4-3)

where,

T = temperature in degrees Celsius

S = salinity in parts per thousand (ppt)

D = depth in meters

In practice, a CTD (Conductivity-Temperature-Depth) instrument is deployed through the water column, from which the above parameters can be computed.

4-13. Squat and Settlement Calibration. As a vessel's speed increases, it generally settles (draft change) or squats (pitch change) into a lower profile in the water or planes into a higher profile, causing an error in depth measurement that must be corrected. This combined vessel draft and pitch motion correction is field calibrated and typically entered into the data collection system as a "Squat Correction Table." A “Squat Test,” calibrating underway combined squat and settlement, should be performed at least annually to determine the relation between boat speed and transducer height above or below the static sounding reference plane. Report results of this calibration test in a field book. Squat correction tables/curves should be maintained aboard the vessel--see example in Table 4-2. RTK systems which provide direct (absolute) antenna-water surface-transducer elevations eliminate the need for the squat correction, as the RTK ellipsoidal antenna height will record the vessel trim variations in real-time.

a. Conventional differential leveling techniques are used to measure the required calibration constants under normal loading (fuel/personnel) conditions. A level is set up on a pier or bulkhead with the boat in a static position in calm water, and elevations are taken at a point on the boat directly over the transducer, i.e., amidships. With a stadia board or level rod held at this point, the boat is driven past the instrument at various speeds, and elevation differences are noted at each speed. In moving bodies of water (wind and/or current), this procedure must be run both up and down current to obtain the mean speed/squat. Boat speeds

(actually RPMs) and observed rod readings are recorded on the form. A subtraction of rod readings after due correction for tide differences gives the squat corrections at each speed.

Table 4-2. Squat and Settlement Calibration (65-ft Surveyboat Florida, Jacksonville District).

Conducted 29 May 1998, St. Johns River, Jacksonville, FL

Engine RPM	Upstream Rod	Downstream Rod	Tide	Squat	HYPACK Entry
Dead in water	0.70	--	1.12	0.00	
800	0.73	0.73	1.19	-0.10	+ 0.10
1000	0.65	0.63	1.33	-0.15	+ 0.15
1200	0.62	0.58	1.43	-0.21	+ 0.21
1500	0.58	0.58	1.50	-0.26	+ 0.26
1800	0.43	0.41	1.60	-0.20	+ 0.20

b. General solution for determining vessel settlement and squat on each pass (Differential Leveling Method).

Settlement and Squat Correction = (T1 - T0) + (R1 - R0) (Eq 4-4)

where

T0 = tide reading dead in water
R0 = rod reading dead in water
T1 = tide reading at underway RPM
R1 = rod reading at underway RPM

(If RTK observations are used instead of differential leveling, simply insert the RTK "R0" and "R1" elevation readings in the above formula.)

c. Squat/Settlement measurement using RTK. An alternate method for determining squat/settlement makes use of carrier-phase GPS elevation difference measurements.

(1) Position the RTK antenna near the center of the vessel and measure the vertical and horizontal distance from the antenna to the vessel's reference point with steel tape.

(2) Use data from a nearby tide gage to provide a datum from which to measure the elevation. The gage should be in the survey area and if the area is large, two gages should be used.

(3) Run the same survey line at different speeds. Also, run the line under different loading conditions.

(4) Record the RTK elevations, heave, pitch, roll, vessel speed, and water levels at common times. The sampling rate should be at the highest for RTK and MRU (IMU) sensors (10 Hz and 100 Hz, respectively) while the water levels can be recorded at approximately 5- to 10-minute intervals.

(5) Record the antenna height while stationary.

(6) All data should be synchronized and interpolated if necessary.

(7) Use the RTK antenna offsets and attitude data to compute the roll and heave, and correct the antenna elevations. Subtract water level data and heave data from GPS antenna elevation.

(8) With these corrections for motion and water levels, compute the average speed in the water and the average antenna elevation with respect to the ellipsoid. Produce a look up table for the transducer draft correction.

d. Corrections are added to the soundings to refer them to a static state. Squat corrections are therefore considered positive quantities as the transducer depresses (squats) deeper into the water at increased speeds. In this case, a positive squat is added to the raw observed/recorded depth. A negative squat may occur with high-speed planeing, surface effect, or hovering type vessels. For these types of survey vessels, a squat test is especially critical and must be performed more frequently.

4-14. Vessel Dynamic Draft Calibrations. Boat loading variances during the course of a survey will affect transducer height. Short-term variations in the draft due to fuel usage may be observed directly from scribe marks on the hull abeam of the transducer. Any such variation should be evidenced directly in subsequent bar checks. The actual draft/index setting on the recorder/digitizer may optionally be changed to reflect a draft variation; however this practice is not recommended. These dynamic draft variations should be entered as separate depth corrector in the real-time software. Data from bar check draft calibration observations should be compared with the water line mark readings to establish a record of draft variations, from which corrections may be directly applied to recorded depths based solely on hull waterline-mark elevations.

4-15. Latency Calibrations. Latency is the time difference or lag between the time positioning data are received and the time the computed/processed position reaches the data logging module and is time-tagged. Latency typically results in a negative along-track displacement of the depth measurements--i.e., the time-tagged observed depth is acquired during the positioning system reading cycle whereas the output position is time-tagged when the computation cycle has been completed. While surveying at slow speeds, this displacement will be small. At higher speeds,

the displacement increases--i.e., it is proportionate to the speed. Position-depth latency distances of up to 40 ft have been observed--an intolerable systematic error that must be corrected and periodically calibrated. The impact of a latency error is illustrated in Figure 4-13 where a saw tooth contour results at each cross-section. Latency displacements are also a function of the type of positioning system used. For code DGPS systems, the processing time for the position will vary with the number of observations used in the final GPS solution--thus causing small variations in the latency itself. Use of the "T0" pulse from the GPS receiver minimizes this error. If the time imbedded in the GPS message is used, then the correct synchronization between this time and the transducer or signal processing clock must be assured. The latency delay is computed by measuring the along-track displacement of soundings from the pair of coincident lines run at different speeds over a steep slope or other prominent topographic feature. Details on performing latency time bias tests are found in the multibeam systems chapter of this manual. Procedures for internal time-tagging GPS messages and applying latency corrections (in real-time and/or post-processing corrections) are contained in the HYPACK Software User Manual (HYPACK 2011)--typically under hardware setup sections where various positioning equipment offsets are entered. Latency bias calibration tests and synchronization of time-tagging correctors are absolutely critical and must be periodically performed and monitored.

SECTION IV

Data Collection, Editing, and Processing

4-16. Single Beam Survey Methods. Single beam surveys are run either normal to (i.e., cross-sectioned) or parallel with the channel or river alignment. Cross-sections for dredge payment surveys are usually spaced between 50 and 200 ft, depending on the bottom consistency between sections and need for shoal or strike detection. Cross-sections are extended up the channel sides to ensure the dredging template is fully covered for payment. Cross-section spacing for general Project Condition surveys is typically 100 ft c/c; however, 200 ft to 500 ft spacing is performed on some projects where less density is required. Project Condition Survey lines are sometimes run parallel with the channel or river alignment—usually inside the channel toes. The spacing of parallel lines is typically between 50 and 250 ft, again depending on channel/river dimensions and shoaling patterns.

4-17. Depth Collection Density and Bottom Coverage. Single beam echo sounders typically collect depth data at a rate of 1 to 20 soundings per second, usually depending on depth. Data acquisition systems can be set to acquire some or all of these data points each second. If continuous bottom coverage along the cross-section is required, then the update rate should be adjusted such that each portion of the cross-section is ensonified. This update rate is a function of the average or project depth, vessel speed, and transducer beam width. An approximate computation of this update rate can be made from the following equation:

$$\text{Update rate (milliseconds)} = 1185 \cdot (D / v) \cdot \tan(a/2) \qquad \text{(Eq 4-5)}$$

where

D = Average or project depth

v = Speed in knots and a = Transducer beam width

a. Since all these parameters can vary during a survey, the minimum practical update rate should be used. For example, given a project depth of 43 ft and an 8-deg transducer, the required update rate would be 400 millisecs at 5 kts, and 200 millisecs at 10 kts. Thus, a 200 millisec rate (i.e., 5 depths/sec) would be adequate for all speeds less than 10 kts. However, if the project

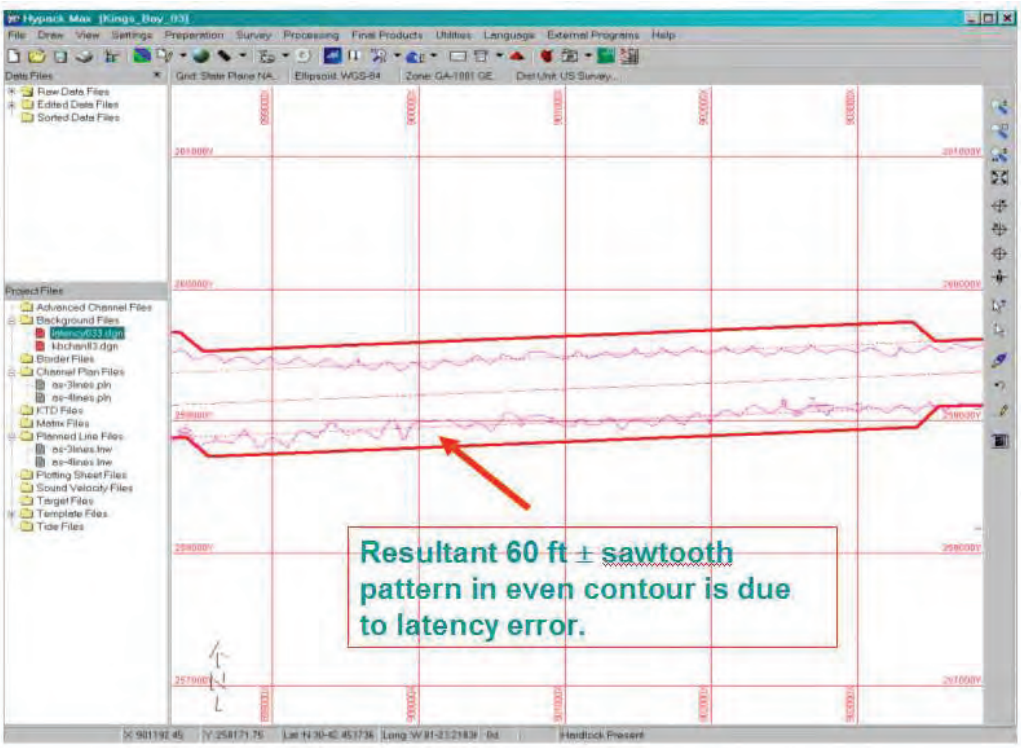


Figure 4-13. Effect of latency error in data contours as shown in plan view of channel.

depth were only 20 ft, a 100 millisec collection rate would be needed to obtain full along section coverage if the vessel runs up to 10 kts. In general, a 100 millisec update will be adequate for most surveys. Setting too large an update rate could leave data gaps. Higher densities (i.e., every 50 to 100 milliseconds) might be collected in rock-cut channels to give a more accurate representation of the bottom and to detect strikes above grade. A high density of depths may also be needed to confirm multiple hits on strikes. Data collection software allows input of the desired depth collection rate. As high-density depth data is recorded, it is time tagged to interpolated positions taken at a lower update rate. Dredging contracts should specify depth data collection density used in payment computations, and distinguish the process by which depths are thinned or generalized for plotting purposes (i.e., sorting, binning, or gridding techniques).

b. Ensonification coverage on bottom. Each transducer ping ensonifies an area of the bottom. The size of this ensonified area is a function of the transducer beam width and transducer characteristics (i.e., side lobes). The narrow beam transducers used in the Corps

ensonify a smaller area of the bottom; resulting in less distortion or smoothing of bottom features within this area. However, only a small portion of a channel is ensonified by narrow beam transducers. Table 4-3 illustrates the lineal coverage for typical USACE transducers. Table 4-4 depicts the resultant footprint coverages.

Table 4-3. Approximate Lineal Coverage for Different Beam Width Transducers.

	BEAM WIDTH			
Project depth	1.5 deg	3 deg	8 deg	20 deg
10 ft	0.3 ft	0.5 ft	1.4 ft	3.5 ft
25 ft	0.7 ft	1.3 ft	3.5 ft	9 ft
50 ft	1.3 ft	2.6 ft	7 ft	18 ft
75 ft	2 ft	4 ft	10 ft	26 ft

Table 4-4. Approximate Footprint Coverage for Different Beam Width Transducers.

	BEAM WIDTH			
Project depth	1.5 deg	3 deg	8 deg	20 deg
10 ft	< 1 sq ft	< 1 sq ft	< 2 sq ft	10 sq ft
25 ft	< 1 sq ft	< 2 sq ft	10 sq ft	60 sq ft
50 ft	< 2 sq ft	5 sq ft	40 sq ft	250 sq ft
75 ft	3 sq ft	10 sq ft	90 sq ft	550 sq ft

(1) Table 4-4 clearly indicates that bottom coverage is small for narrow beam transducers. Thus, when cross-section surveys are performed, only a very small portion of the channel is ensonified. The total amount of ensonified coverage for typical cross-section surveys at 100-ft and 200-ft spacings is shown in Table 4-5.

(2) Table 4-5 indicates that only 1% to 5% of a channel bottom is typically ensonified by single beam cross-section surveys. From this small data sample, shoaling conditions are projected and material quantities are estimated using end area projection methods. In effect, quantity take-off computations and shoaling estimates are "extrapolated" over 95-99% on the channel that is not surveyed. These estimates have traditionally been adequate for engineering and construction purposes, and they were deemed practical given the high cost of data collection per cross-section.

Table 4-5. Approximate Percent Bottom Coverage for Cross-Section Surveys.

	100-ft Cross-Sections			200-ft Cross-sections		
Project depth	1.5 deg	3 deg	8 deg	1.5 deg	3 deg	8 deg
10 ft	0.3%	0.5%	1.4%	0.1%	0.2%	0.7%
25 ft	0.7%	1.3%	3.5%	0.3%	0.6%	2%
50 ft	1.3%	2.6%	7%	0.6%	1%	4%
75 ft	2%	4%	10%	1%	2%	5%

4-18. Field Collection of Single Beam Survey Data. Most USACE districts collect and process single beam data using commercial hydrographic survey software platforms, the most common being the HYPACK software platform which is currently used by nearly all districts. A brief description of the current (2013) process in HYPACK is outlined below. (Note that these field collection methods and software modules will evolve over time; thus, the following should be considered current guidance only.)

a. Establishing survey line files. Prior to surveying, the desired cross-section coverage is set into the survey acquisition system. Data acquisition packages have a variety of features to set up survey lines relative to a project or channel alignment. These are found in the "LINE EDITOR" and "CHANNEL DESIGN" programs. Either straight or curved survey lines can be generated. Survey lines can be set up to cover turning basins--see example at Figure 4-14. Included with the cross-section alignments are the channel turning point coordinates along with side slope grades. This line file data may also be used for subsequent end-area volume computations.

b. Irregular channel cross-sections. Line Files can also be configured to optimize spacing of cross-sections through varying channel baseline alignments (Figure 4-15). This so-called "SMART CORNERS" option can be used to improve average-end-area volume computations in these irregular areas; however, in this example, a TIN model might be an easier method of computing dredge quantities.

c. Field data collection. The "SURVEY" program collects continuous data from the various depth, motion, and positioning sensors. Parameters for all these sensors are set up in the "SURVEY" program, along with applicable depth corrections (e.g., tide, draft, squat, etc.). The real-time software provides windows for the system operator and boat helmsman, such as left-right guidance, planned survey line maps, motion sensor status, position and depth alarms, etc., as illustrated in Figure 4-16.

d. Marking position events on hard-copy depth profile records. Real-time horizontal positioning event marks (or fixes) are typically made on analog or digital hard-copy recorders. The vertical event line in the recorded profile may be manually “fixed” or automatically

generated from the positioning system. Event marks are usually tied to the channel station-offset coordinate system.

4-19. Editing and Processing Single Beam Data. The HYPACK "Single Beam Editor" processing software flow is shown in Figure 4-17. The “raw” observed depth data was time-tagged during the survey collection, as were inputs from other peripheral devices (GPS, IMU, tide, etc.). Single beam depth sounders are capable of recording depths at rates of 10 or more per

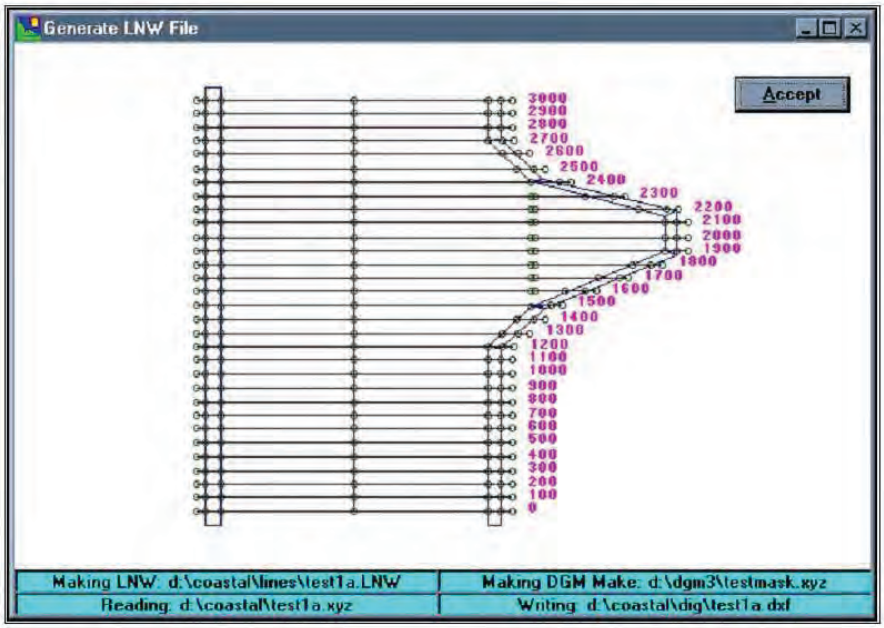


Figure 4-14. Planned survey lines covering channel and adjacent turning basin including channel limits and side slope parameters.

second; however, GPS positional updates are typically input every second. Thus, the processing software must interpolate and time-tag positions for the intermediate depths. Likewise, any observed roll, pitch, heave, and heading sensor data comes in at varying times and must be time-tagged to each depth. Based on the time of the depth measurement, the Single Beam Editor correlates the position, tide, stage, vessel draft, sound velocity, and motion corrections. Manual (visual) editing may be performed on each cross-section, verifying depth corrections and removing outliers or anomalies. Automated filtering options may also be applied. Each “edited” depth is then saved with all corrections made to the original observed (raw) depth. A variety of depth sorting and selection options are available depending on the intended final product—plan or section plots, volumes, channel condition report controlling depths, modeling, TINs, etc. (See the HYPACK User's Manual (HYPACK 2011) for complete details on the editing and processing options available in the "Single Beam Editor.")

4-20. Depth Selection and Thinning Options on Single Beam Data. Single beam depths recorded along a cross-section are too dense to plot on plan documents (maps and charts). The

dense soundings are thinned (i.e., "sorted") to conform to the desired final plan plot scale, e.g., between 4 and 8 soundings per inch at the scale of development. Higher densities (or all recorded depth data) may be plotted in profile section views, or plotted as color coded pixels in plan view. The sorting options shown in Figure 4-17 provide various options for thinning depths along a cross-section and removing overplots.

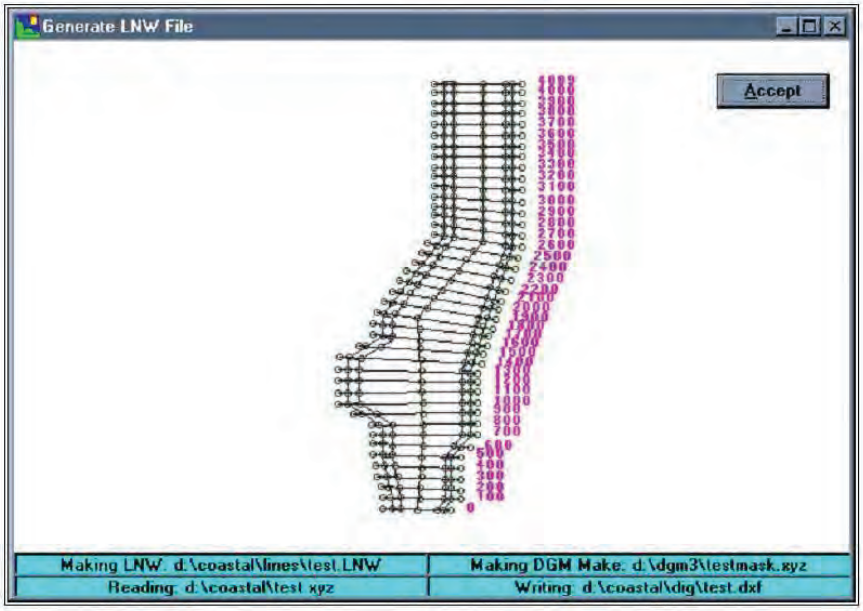


Figure 14-15. "Smart Corners" generated planned survey lines covering irregular channel alignments--cross-section alignment varies over channel intersections.

a. Representative depth selection. The selection of a representative output depth (e.g., shot, minimum, strikes, confirmed hits, etc.) is dependent on the survey purpose and/or intended plan scale—see details in Chapter 2. Observed ("shot") depths are often just randomly selected (sorted) to fit the available plot region along a cross-section—e.g., "select the next depth in the cross-section file that won't overplot the previous depth." Minimum depths over a cross-section or channel region may also be sorted out for controlling depth reports—see Chapter 8.

b. Dredge volume computations. All the recorded and edited observed depths along a cross-section should be retained for volume computations. These depth values may be plotted at points on a section view of each cross-section. Shot depths shown on plans and specifications surveys, and on pre- and post-dredge plans, should be randomly sorted as outlined above. Drawing notes should clearly indicate that quantity estimates were based on the total datafile, not the sorted (thinned) plotted version.

SECTION V

Single Beam System Quality Assurance Performance Tests

4-21. Depth Quality Assurance Techniques for Single Beam Surveys. This section describes various procedures used to test quality assurance (QA) on a single beam hydrographic survey. These techniques are especially applicable to critical navigation and dredging payment surveys. The primary (and most critical) reason for conducting QA Performance Tests is to detect a systematic bias (or lack of repeatability) in the data--e.g., tide, velocity, squat, etc. Single beam Performance Tests generally rely on comparisons of depth measurements observed from two surveys of the same area by the same survey vessel. Where possible, comparisons should be made against different vessels over an established test site. The adequacy of these comparisons depends on the number of depth comparisons made and the independence of the comparative surveys; in many instances, the number of comparison points may not be statistically valid and

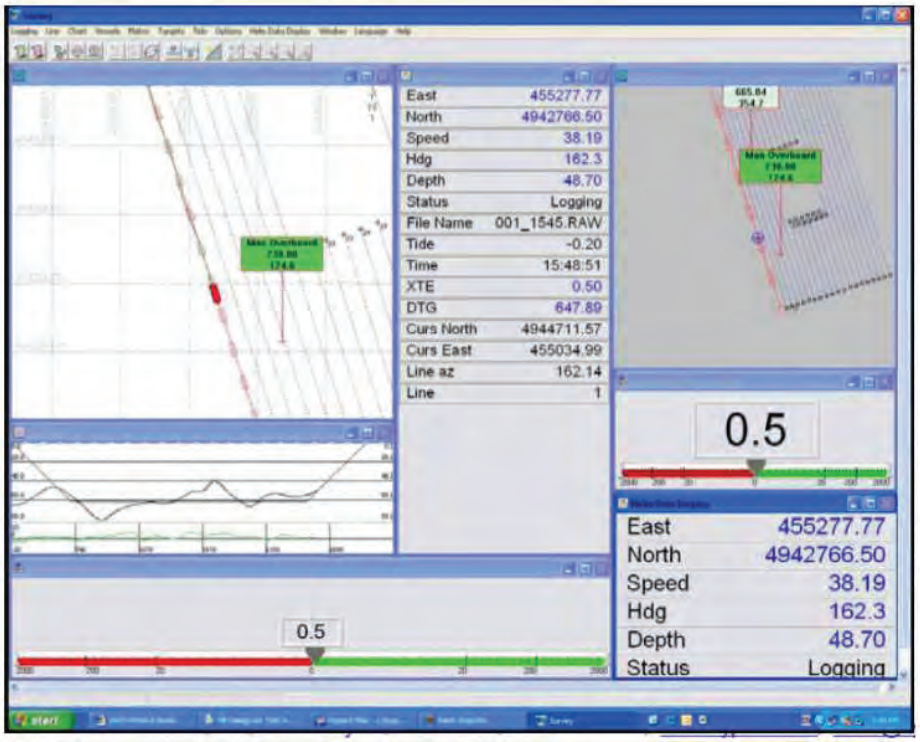


Figure 4-16. "SURVEY" program for single beam data collection—sample real time system operator and helmsman display options.

the surveys are not truly independent if comparing data collected by the same vessel. From a rigid statistical sense, the results of non-independent comparisons (same survey vessel and echo sounder) are only an estimate of the internal precision, not “accuracy” or "TPU." Therefore, comparative data derived from non-independent tests cannot be considered as an absolute quality check.

a. Cross-line check method. On typical channel cross-section surveys, a number of parallel lines (3 to 5) are run along and within the channel, to intersect with the cross-sections. Comparisons are made of depth differences at the intersecting points between the cross-sections and the parallel lines. Preferably, these check lines are run at different tide/stage levels and after recalibration of depth sounding equipment. Depth differences at the intersecting points are tabulated and statistically analyzed. The mean difference and standard deviations of crossing elevations should generally fall within acceptable tolerances for the type of survey (Chapter 3). At least 100 cross check comparisons should be obtained, and preferably many more. The mean difference or bias between the two separate surveys is the more critical test than the standard

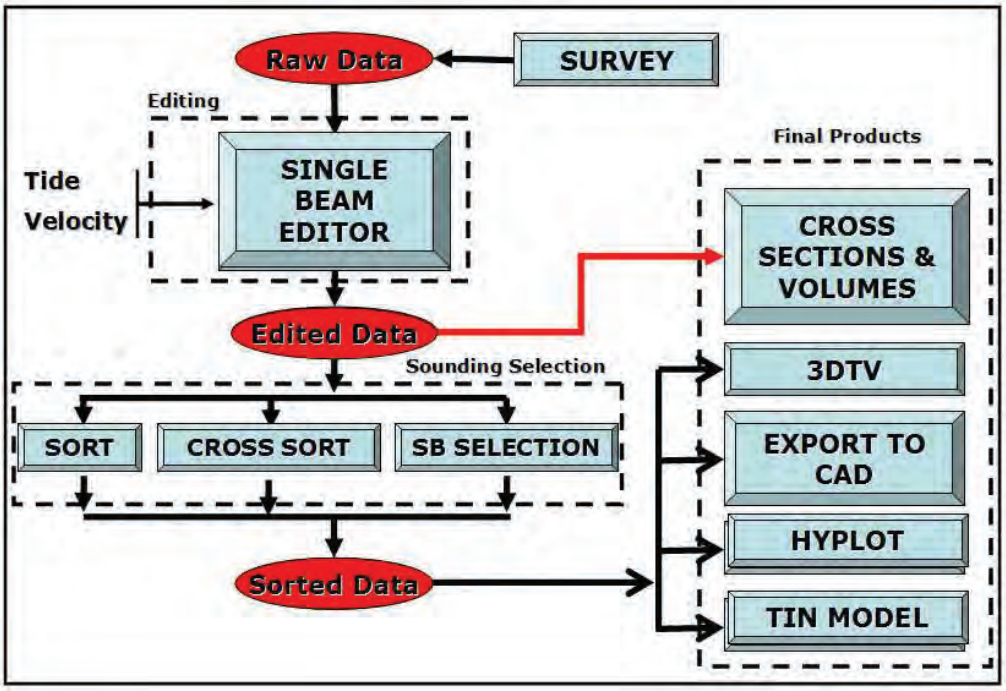


Figure 4-17. Single beam editor data processing flow. Depth sorting options are dependent on final use of the data (plots, volumes, TIN, etc. (HYPACK 2011)

deviation result. The results of such a cross-line check analysis should be noted on all plots, drawings, metadata files, maps, or charts; as an indication of the data consistency (actually repeatability) obtained. As such, when performed by the same vessel, this cross-line check method is not an independent test. Software can perform the cross-line check comparisons, tabulate the differences, and the statistics of the results. Examples of cross-line test examples are shown in Figure 4-18 and Figure 4-19.

b. External check line comparisons. Another single-beam quality assurance technique involves the establishment of external check lines. This QA test was developed by the Norfolk District to test for tidal modeling variations in offshore regions in Chesapeake Bay. Check lines are established parallel with the channel and outside of it far enough that any activity in the

channel will not affect the natural lay of the bottom covered by the check line. The check line location is selected in an area that is relatively devoid of any abrupt changes in elevation. Depending on the length of the survey there may be several lines, i.e. one in each tidal zone. These same lines are run each time the project is surveyed. Mean differences are computed—primarily to check for biases due to tidal variations. Since past surveys and different vessels are used, this method does provide an independent check.

c. Averages of Extended Cross Sections. Extended cross sections into undisturbed areas well outside the channel is another single-beam quality assurance technique that provides an independent check on the survey adequacy. These extended sections provide a means for comparing successive surveys of a given cross-section. As with external check lines, these extended cross-sections will provide an indicator of biases between different surveys. Resolving the source of any recorded biases is the difficult part of the process.

(1) The use of extended cross sections for comparing successive surveys requires that four conditions be satisfied. First, the number of extended cross sections needs to adequately represent the survey area. Second, each cross section must be extended beyond the area affected by dredging, since the comparisons could be made between surveys conducted before and after dredging. Third, the bottom outside of the dredging area must be relatively flat; otherwise it will be difficult to distinguish between the natural bottom and a survey discrepancy. Finally, the bottom must be relatively stable outside of the dredging area.

(2) The primary purpose of extended cross sections is to compare two given surveys by computing the average depth along the extended portion of each cross section. This is repeated for each successive survey of a given cross section. The algebraic difference between the average depth of each of the two surveys is computed. Then the average algebraic difference of all the cross sections is computed. The result of this analysis will be a measure of how well two given surveys at a given cross section repeat each other and how well the two surveys of the entire group of cross sections compare overall.

e. Cross-section overlay comparisons: Real time or Post-Processed. During dredging operations it is advantageous to compare a current survey with previous surveys of the same area/cross-section. This can serve as a "blunder check" when performed real-time aboard the survey boat. An example of such a comparison is shown at Figure 4-20.

SECTION VI

Summary of Quality Control and Quality Assurance Criteria for Single Beam Surveys

The following table summarizes recommended QC and QA criteria for USACE single-beam surveys. These criteria are critical for surveys supporting dredging and navigation.

Table 4-6. Recommended QC and QA Procedures for Single Beam Surveys

Procedure	Recommended Application
Bar Check Calibration	Perform periodically. Frequency of bar checks can be reduced if average velocity repeatedly correlates with velocity cast data. Perform at beginning of critical dredging projects. Correlate with dynamic draft variations.
Dynamic Draft Corrections	Monitor every 0.1 ft trim change.
Velocity Cast Calibration	Perform, at minimum, twice daily. More often in highly variable waters. Correlate with bar check velocity.
Squat/Settlement Calibration	Perform annually over different vessel speeds and loading conditions.
Latency Calibration	Perform periodically to obtain average correction over time. Perform at beginning of any critical dredging survey.
Horizontal Position Check	Daily on dredging projects (RTK v Code DGPS adequate)
Vertical Calibration (RTK)	Perform twice daily at project reference gage or tidal bench mark.
Motion Compensation	Apply if river or sea conditions warrant correction.
Vertical Datum Verification	Refer to EM 1110-2-6056 for periodic requirements to ensure coastal tidal datums are consistent with NOAA reference datums; including periodic checks of tide/staff gages.
Survey Coverage (Density)	On maintenance projects, single beam cross-sections should generally not exceed 200 ft c/c. (Full multibeam survey coverage is recommended for deep-draft projects with critical under keel clearances over rock.)
Quality Assurance Performance Tests	Perform periodically against other vessels at constant test site. Perform internal repeatability check daily on critical dredging surveys.

The following matrix is an example of a "Single-Beam Standard Operating Procedure" developed and used by Buffalo District for a specific type of depth recorder. This "best practice" example illustrates the typical quality control and quality assurance checks performed during a field survey.

Table 4-7. Single-Beam Survey Standard Operating Procedure (Buffalo District).

Equipment Set-up:

Attach depth sounding unit to the 12-volt batteries via power cable.
Attach power cable to differential GPS unit.

Attach GPS antenna to differential GPS unit.
Attach VGA cable (boat operator driving screen) to depth sounding unit (via cable).

Attach transducer cable to depth sounding unit.

Equipment Calibration:

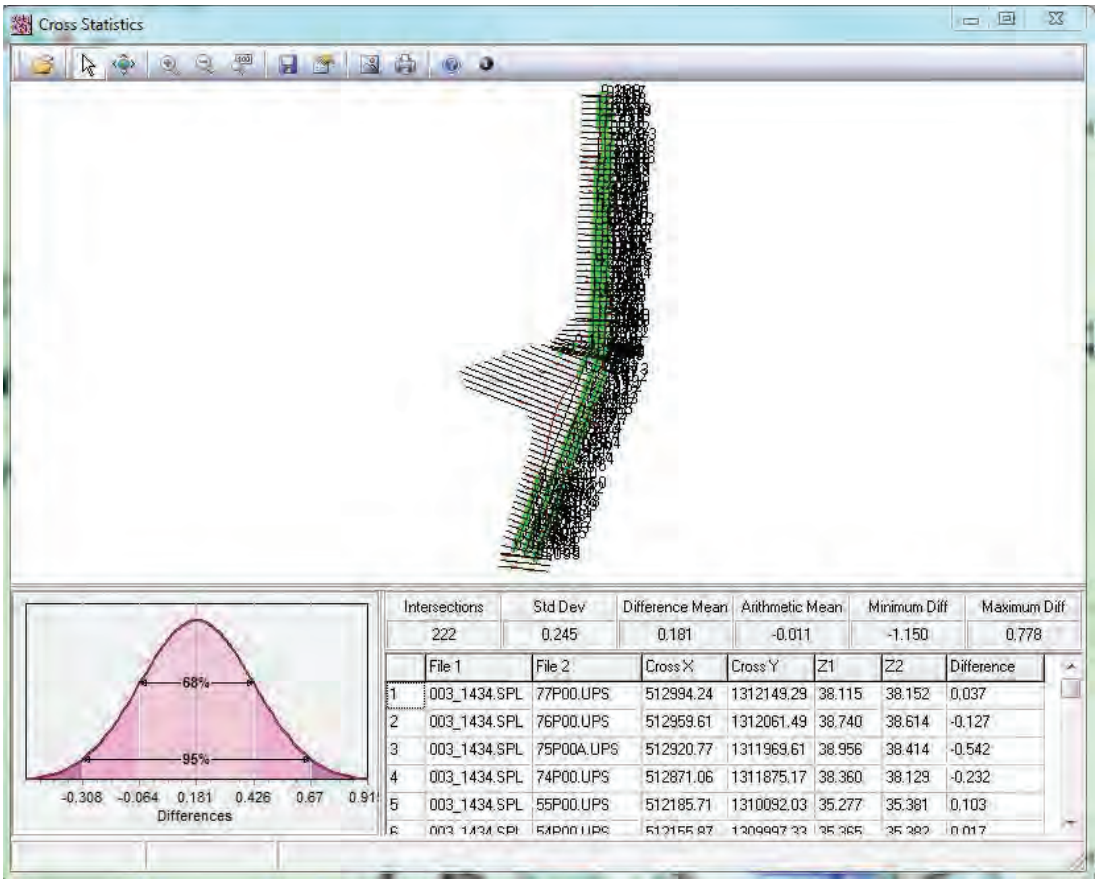
Turn on depth sounding device (not transducer).
Open Depth computer program. Create new folder and link Depth data so the .BIN and .TXT files are saved to said folder.
Turn transducer on.
Download .BIN data to external drive.
Drop check bar to required depth (depending on survey data needs).
Within computer program, adjust speed of sound to the project depth.
Minimize computer program and open HYPACK to begin to survey.

Survey Data Collection:

Obtain a gage reading.
Open HYPACK and create new project.
Enter project information.
Check geodetic parameters for area.
Activate appropriate line file for work area and navigate to area.
Run a latency line within HYPACK.
Use log sheets to document the Time, Gage, Speed of Sound, and Notes for each line that's run. Document the Cross Section (e.g., 100+00), line file #, Direction, Speed, Line Good vs. No Good, Pertinent Data, etc.
Obtain a gage reading depending on crew availability, weather conditions, and USACE engineering manual regulations. A minimum of 2 gages is required (before and after survey) if limited to 2 man crew in a small harbor and weather is calm.
Obtain a horizontal position check.

Equipment Breakdown:

Download .RAW data files to external data device.
Download .BIN data from the SDI folder. If desired, rename appropriate .BIN file with the cross section included with the associated file.



Intersections	Std Dev	Difference Mean	Arithmetic Mean	Minimum Diff	Maximum Diff
222	0.245	0.181	-0.011	-1.150	0.778

	File 1	File 2	Cross X	Cross Y	Z1	Z2	Difference
1	003_1434.SPL	77P00.UPS	512994.24	1312149.29	38.115	38.152	0.037
2	003_1434.SPL	76P00.UPS	512959.61	1312061.49	38.740	38.614	-0.127
3	003_1434.SPL	75P00A.UPS	512920.77	1311969.61	38.956	38.414	-0.542
4	003_1434.SPL	74P00.UPS	512871.06	1311875.17	38.360	38.129	-0.232
5	003_1434.SPL	55P00.UPS	512185.71	1310092.03	35.277	35.381	0.103
6	003_1434.SPL	54P00.UPS	512155.87	1309997.33	35.365	35.382	0.017

Figure 4-18. Automated cross line check software. Statistics output from 222 intersections are standard deviation (±0.245 ft one-sigma), mean difference (+0.181 ft), absolute difference (-0.011 ft), and minimum/maximum differences (-1.15 ft and +0.77 ft). The 95% standard deviation from the test is ±0.5 ft. (Ybor Channel, Tampa Bay, Jacksonville District)

Kings Bay Navy Base Entrance Channel (Cut 1N) Cross-Line Comparisons
Surveyboat Florida, Jacksonville District
1-2 August 2000
RTK GPS positioning and elevation. Heave compensation active.
Search radius set at 10-ft
Single beam cross line check differences in feet

+1.16	-0.72	-0.19	-1.47	-0.41	-0.07	-0.71	+0.43
-0.14	+0.86	-1.52	-0.50	-0.41	-0.61	+0.98	+1.71
-0.89	-0.29	+0.60	-1.95	+1.26	+0.02	-0.05	-0.26
+2.04	-0.24	-1.17	-0.79	+0.19	+0.88	+0.99	+0.38
+0.55	-0.16	-0.28	-0.89	-4.05	-0.46	-0.45	+0.56
+0.82	-0.69	+0.36	-0.43	-0.67	-0.35	-1.6	+0.17
-0.53	-0.24	+0.45	-0.12	-0.86	+1.77	+0.45	-1.65
+1.95	-0.04	+0.57	+0.00	+0.61	+0.91	+0.88	-0.80
+0.33	+0.09	+1.15	-0.08	+0.03	+0.38	-0.14	
+1.08	-0.06	+0.17	-1.18	+0.10	-0.07	-0.05	

Total number of cross-check observations = 78

Mean of Differences	**= (-) 0.043 ft**
Confidence of computed mean (95%)	**= ± 0.21 ft**
Standard Deviation (67%)	**= ± 0.944 ft**
95% Estimated Accuracy	**= ± 1.85 ft**

Figure 4-19. Single beam Cross Check Line Performance Test. (Jacksonville District)

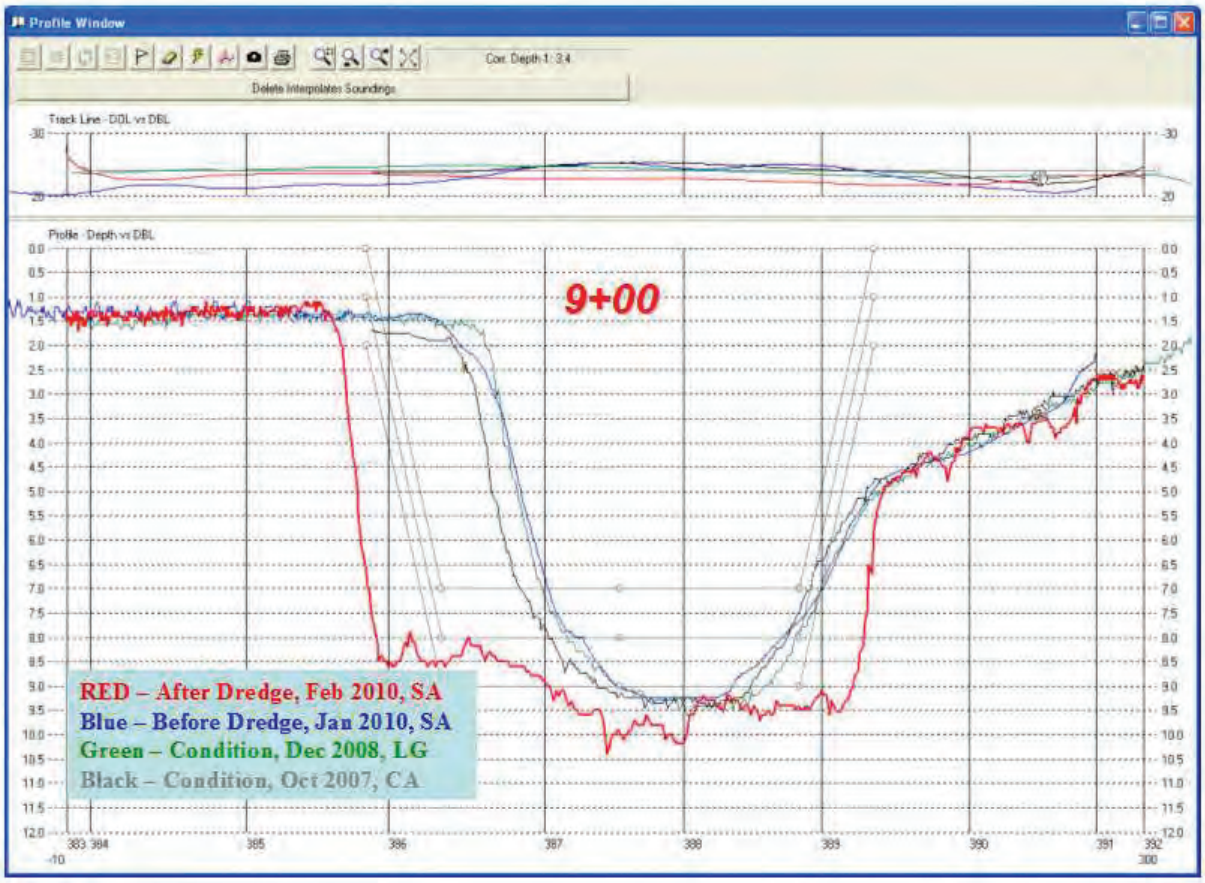


Figure 4-20. Post-Processed comparisons of four successive surveys at Station 9+00, Broad Creek Channel. (Norfolk District)

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CHAPTER 5

Multiple Transducer Channel Sweep Systems for Shallow Draft Navigation Projects

5-1. General Overview. Multiple transducer sweep systems are simply an array of single-beam transducers spaced provide 100% ensonification coverage of the bottom (Figure 5-1). The Corps deploys a variety of multiple-transducer channel sweep systems, mainly on inland navigation shallow draft navigation projects. They are primarily used for periodic project condition surveys; however, they may also be used for construction measurement, payment, and clearance work. These sweep systems are also useful in searching for (and evaluating clearance of) hazards to navigation. Multiple transducer systems are also used on some coastal shallow draft projects where multibeam systems may have limited swath coverage. Their prior use on deep draft coastal projects is declining due to increased reliance on multibeam technology. Since multiple transducer systems are similar in operation to single beam systems, most of the quality control and quality assurance procedures covered in Chapter 4 are directly applicable to multiple transducer operations. This chapter provides guidance on the design and operation of multiple transducer systems. Section I contains examples of typical systems used in the Corps. A quality control checklist is at Section II.

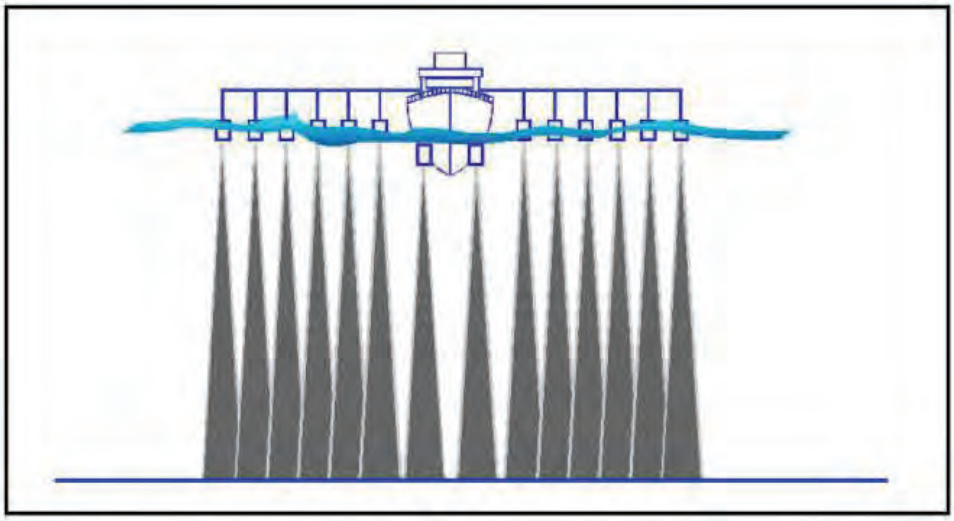


Figure 5-1. Generalized multiple transducer sweep array. Transducers are configured for maximum coverage and bottom ensonification at the project depth.

5-2. Background. Multiple transducer systems were first deployed in the Corps during the early 1970s. These systems were originally designed and developed by Raytheon, Ross Laboratories, Innerspace Technology, and Odom. The primary goal during that time was to obtain 100% ensonification coverage in a channel. These systems replaced the mechanical bar sweeps used

by some districts for project clearance and acceptance—both in shallow- and deep-draft projects. Over the years many inland USACE districts have contracted with Ross Laboratories (Seattle, WA) to develop multiple transducer systems on side-mounted booms. Currently (2013), districts operating multiple transducer systems include: St. Louis, St. Paul, Rock Island, New York, and Mobile.

5-3. Design of Channel Sweep Systems. Channel sweep systems are simply a series of standard single beam transducers mounted vertically on a survey boat, barge, or other stable platform. The transducers are typically mounted on deployable booms attached to the vessel. The number of transducers in a sweep ranges from three up to 32. Resultant bottom coverage is a function of transducer spacing, beam width, and channel depth. Due to high potential motion at the far end of each boom (from vessel roll), boom-sweep systems are normally effective only on calm, restricted inland waterways; unless motion compensation is used. Boom-mounted sweep vessels normally run survey lines parallel to the channel alignment.

a. Sweep width. The sweep width is determined by the type of vessel deployed and project (channel) characteristics. Multi-transducer weep systems have been designed to cover swaths ranging from 15 ft to over 120 ft. Optimizing sweep width with vessel maneuverability is often difficult--large sweeps using boom-mounted transducers being more difficult to control. Optimizing sweep width requires consideration of vessel characteristics and local conditions.

b. Transducer configuration. One or more transducers may be mounted permanently in the vessel hull. Additional transducers may be mounted on “over-the-side” outriggers or, more commonly, from hinged, retractable booms deployed to port and starboard. The more common systems used today deploy between 5 and 12 transducers on combinations of hull and retractable boom mounts. Figure 5-2 depicts a typical sweep system with transducers mounted in the hull and on port and starboard retractable booms.

Figure 5-2. Survey Vessel Moritz Multiple Transducer Sweep System—54-ft swath with transducers spaced 6-ft c/c. Retractable boom fits flush with hull as shown in left photo. (New York District)

(1) A normal installation for a boom system would include one or more transducers mounted in the hull and two or more transducers mounted on each boom. On smaller vessels typically a five-channel system is used (1 hull, 2 port, and 2 starboard). For most Corps projects, transducers are selected at a 200 kHz frequency (±10 kHz) and with a wide 8-deg beam angle. Some systems have wider beam widths (e.g., selectable 10 deg or 22 deg). Each channel has its own transmitter, receiver, and depth digitizer board. Both analog and digital depths may be recorded by the operator. The Ross system uses one transmitter common to all channels. By firing all transducers simultaneously from one source, cross talk or timing issues with multiple transmitters is eliminated. The return echoes are then sent to individual receivers and A to D channels.

(2) The port and starboard booms are retractable via hand or hydraulic winch. The stored position is usually vertical--usually against the side of the boat cabin. Some designs have horizontal storage along the hull. The boom assemblies can be totally removed in some designs. The individual struts mounting the transducers are designed with a breakaway feature should the strut strike a floating obstacle. The Ross system also utilizes a custom designed rubber boot that minimizes turbulence around the transducer and protects it when striking the bottom or objects in the water.

c. Transducer beam width and spacing. Transducer spacing is determined by the nominal project depth, transducer beam angle, and desired side overlap between transducers. Transducer spacing typically ranges between 3 and 10 ft, depending on channel/project depth. Ideally, this spacing could be varied for given project depths; practically, however, the spacing is usually set for an optimum minimum depth in most projects. Transducer spacing can be computed by the following:

$$\text{Transducer Spacing} = 2 \cdot (d) \cdot \tan(b/2) \qquad \text{(Eq 5-1)}$$

where,

d = design project depth
b = transducer beam width

(1) Table 5-1 below details transducer spacing (in feet) for 8 deg and 16 deg beam widths for various project depths (at 100% coverage--i.e., no overlap) are shown below.

(2) From the above, a five-transducer system operating in a 10-ft inland navigation project will cover about a 15-ft swath if a 16-deg beam width is used. Larger beam width transducers may be obtained to increase coverage. Full 100% coverage is not always required on shallow-draft inland projects; thus the spacing can be adjusted for 50% to 75% coverage. Spacing may also be reduced to provide overlapping coverage (i.e., > 100%) for critical strike detection. Coverage is monitored in real-time as shown in Figure 5-3.

Table 5-1. Transducer Spacing for 8 and 16 deg Systems.

	Depth (Ft)							
Beamwidth	10	15	20	25	30	40	50	75
8 deg	1.4	2.1	2.8	3.5	4.2	5.6	7.0	10.5
16 deg	2.8	4.2	5.6	7.0	8.4	11.2	14.1	21.1

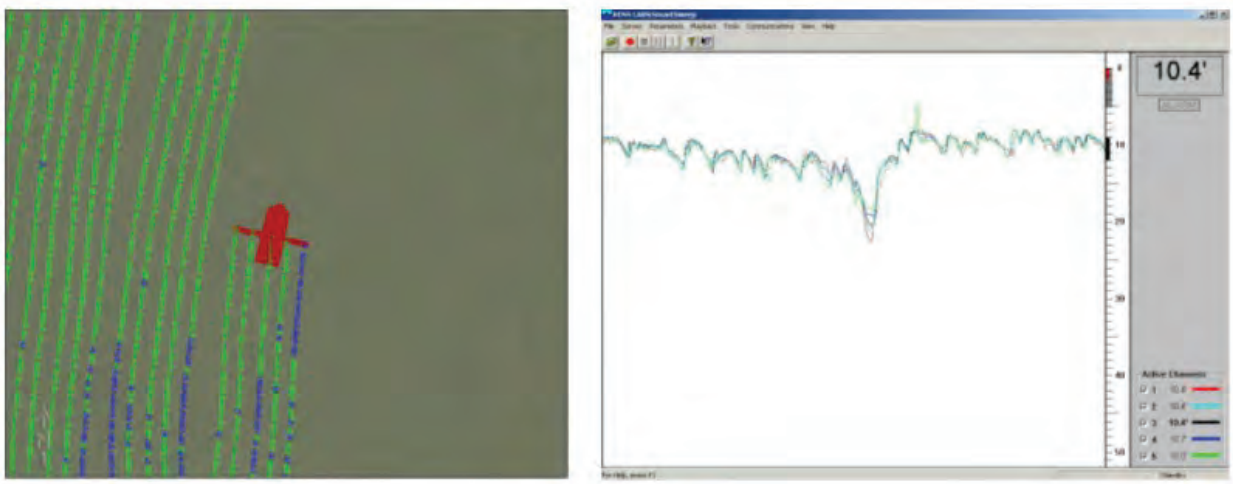


Figure 5-3. Real-time track line plots (“paintings” or "mowings") from each transducer on a 5 transducer 24-ft boat. A swath width of approximately 25 ft is obtained. Soundings shown in blue were coded for real-time shoal detection purposes. Screen capture on right depicts color-coded superimposed profiles from each transducer. (Mobile District and Ross Labs)

5-4. General Survey Operation. Multiple transducer sweep systems are operated similarly to single beam or multibeam systems. Collected depth, positioning, and motion sensor data are input to a hydrographic software system for real-time navigation, display, and storage for subsequent processing.

a. Data collection. Analog and/or digital data recording are available on multi-transducer systems. Digital display modeling techniques are used to assist in interpretation of the large amount of recorded data, especially when 8, 12, 16, or 32 transducers are simultaneously operating. Automatic alarms can be set to indicate strikes above a defined channel clearance grade. Vessel guidance, tracking, and data storage is now performed using standard software

packages (e.g., HYPACK) containing modules for multiple transducer systems. Complete bottom coverage is assured by screen painting swath tracks similar to multibeam systems.

b. Positioning methods. Code phase DGPS (1 to 2 meters) is normally an acceptable positioning method. Total Station positioning may be employed in obstructed areas. Carrier phase GPS (RTK) should be employed when positional or vertical accuracy is more critical—e.g., at the sub-decimeter level. Outer boom yaw alignment correction may be needed if currents excessively crab the survey vessel. This correction can be made using simple flux gate compasses, gyros, or POS/MV systems.

c. Strike detection with sweep systems. The capability for strike (or shoal) detection using channel sweep systems is highly dependent on the operating characteristics of the transducers and the acoustic signal processing system, along with coverage patterns, floating plant maneuverability, and sweep overlap. Optimum transducer spacing and beam angle are essential for strike identification given a nominal project depth. Object detection is best when operating at slow speeds to ensure multiple hits. Repeated passes are recommended for confirmation or assured clearance. Obtaining 100% coverage with an acoustic sweep system may not provide full assurance that all potential strikes have been observed. Many objects can deflect acoustic energy such that they are below the detection threshold of the echo sounder. Some large rock fragments can exhibit "stealth-like" acoustic characteristics to vertically mounted transducers, and thus avoid acoustic detection. In such cases, it is best practice to run overlapping swath runs that will provide 200% (or more) bottom coverage. On critical investigations, side scan survey methods should also be considered.

5-5. Multiple Transducer System Quality Control and Quality Assurance. Multiple transducer quality control requirements are essentially identical to those for single beam surveys (Chapter 4). Multiple transducer quality assurance Performance Tests can be performed similarly to single-beam and multibeam Performance Tests covered in their respective chapters. The following paragraphs amplify some of the criteria that are unique to multi-transducer systems.

a. Velocity and draft calibration. Multiple transducer system sound velocities are calibrated identically to single beam systems—i.e., periodic bar checks and velocity probes. In shallow water, velocity changes are normally not as critical. Maintaining and monitoring transducer draft and alignment throughout the booms is especially critical. Calibration of the multi-transducer system is performed similarly to that of single transducer systems. Index and/or draft errors of the boom transducers are individually stored in the hydrographic survey processing system as corrections. Removal of any one of the boom transducers for any reason (cleaning, etc.) constitutes a re-installation/boom calibration procedure.

b. Boom calibration procedure after installation. The survey vessel must be in protected calm water for this procedure. The booms are lowered and leveled by the best possible means available. Roll motion must not be allowed at this time. A bar check is performed on the hull transducer. This will minimize the index and draft errors and establish the same speed of sound

for all transducers. Next the bar (or plate) is moved outward from the hull transducer (using a separate boat) to the nearest boom transducer on one side of the survey vessel. The hull transducer soundings are compared to the sounding values recorded at the hull transducer. Any discrepancy found is recorded as a combination of draft and index error. The opposite (negative) of this recorded value will be applied to all soundings from this particular transducer until the transducer is physically moved from the fixed position in the boom. All boom transducers are compared to the hull transducer by the same procedure. The area selected for the boom calibration should be where no changes in temperature or salinity could change the speed of sound during this calibration. Clearly noticeable particles in the water column may also affect the speed of sound.

c. Periodic calibration of Ross Dolphin Sweep System (Philadelphia District Method). Periodic calibration of Ross Dolphin sweep systems is performed using basically the same criteria required for a single transducer system. Once a month, all transducers in the hull are calibrated, utilizing a standard bar lowered to the project depth directly under the vessel. Transducers in the port/starboard beams are calibrated on an annual basis. On a daily basis, a Ross ball check device, which is mounted as part of the referenced transducer pod, is utilized to calibrate the average speed of sound utilizing a 3½-deg transducer. The 3½-deg transducer is used to assure that the depth reference is as close to a true vertical distance as possible. A sound velocity profiler is also used daily to verify the ball check calibration procedure. Maintaining and monitoring the transducer draft(s) is especially critical. Each transducer channel in the sweep is adjusted similar to the procedure used in the single transducer systems.

d. Lock chamber calibration. When a lock chamber with a clean, smooth floor is located in the district, multiple transducer sweep systems may be simultaneously calibrated. Calibration can be performed at varied surface elevations by drawing down the lock to desired intervals—i.e., the project depth. The lock chamber affords a stable water surface that eliminates sea state effects on outer boom transducers. Individual transducer channels are calibrated and adjusted to read true depths.

e. Motion compensation requirements. Boom sweep systems are normally used on shallow draft inland projects where sea state conditions are typically calm. Thus, full X-Y-Z inertial motion sensors are rarely added to these sweep systems unless sea states cause excessive errors. Roll correction is especially critical if there is excessive motion at the outer transducers. Physical movement of the outer transducers will determine whether surveys should continue under adverse sea conditions, or whether POS/MV and IMU systems are required. Small roll errors can significantly affect depth readings on long boom systems--e.g., a 1-deg roll on a 25-ft boom causes approximately a 0.4-ft error in the sounding. Excessive heave should not be a problem on calmer inland navigation projects where sweep systems are deployed.

(1) Roll compensation. Roll should be compensated for and corrected in the processing software if the outer transducer on a boom experiences movement in excess of allowable tolerances for the project. Smaller boat systems with short outriggers would be less subject to

roll errors, so compensation would not be required. Beam steering position and slope corrections due to excessive roll and pitch are usually negligible for shallow-draft projects when wide beam transducers are used; thus the need for these corrections would be minimal. Typically Flux gate compass corrections are used with smaller sweep systems for roll correction input.

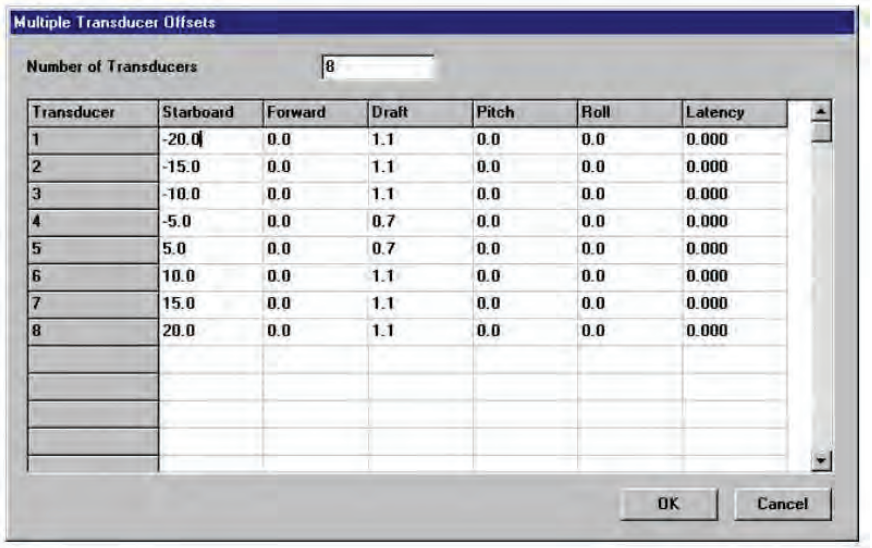
(2) Yaw correction. Most multi-transducer sweep vessels surveying at slow speeds in river currents will exhibit yaw in order to maintain heading. Therefore, yaw correction is usually necessary. Boom alignment due to vessel yaw is controlled using a flux gate compass, a gyrocompass, or inertial-aided POS/MV techniques. Software must correct each transducer offset (lever arm) relative to the positioning antenna in addition to correcting eccentricities due to yaw. This is done using similar techniques covered under the chapter on vessel orientation systems. Full yaw correction is critical.

(3) Heave correction. Only required in excessive sea states.

(4) Pitch bias. Usually negligible given slow sweep speeds on inland projects.

(5) Latency. Latency between the positioning system and the multiple transducers is calibrated similar to single beam or multibeam systems.

(6) Fixed lever arm offsets. Horizontal lever arm offsets of individual transducers are measured relative to the vessel center of mass--the point where an inertial MRU unit should be located. Vertical offsets (draft) are relative to the water line and are determined from a bar check. Parameters for multiple transducer systems are entered in processing software in a variety of methods--Figure 5-4 depicts a typical multiple transducer system offset table.



Transducer	Starboard	Forward	Draft	Pitch	Roll	Latency
1	-20.0	0.0	1.1	0.0	0.0	0.000
2	-15.0	0.0	1.1	0.0	0.0	0.000
3	-10.0	0.0	1.1	0.0	0.0	0.000
4	-5.0	0.0	0.7	0.0	0.0	0.000
5	5.0	0.0	0.7	0.0	0.0	0.000
6	10.0	0.0	1.1	0.0	0.0	0.000
7	15.0	0.0	1.1	0.0	0.0	0.000
8	20.0	0.0	1.1	0.0	0.0	0.000

Figure 5-4. Multiple transducer lever arm, latency, and draft Offsets input into the survey data collection system. (HYPACK, Inc.)

f. Squat tests. At typical slow sweep speeds vessel squat and settlement should be minimal. However, this should be checked by performing a Squat Test"—see Chapter 4.

g. Vessel speed and shoal/strike detection hits. Vessel speed should be controlled such that objects or shoals above project grade receive at least three solid acoustic hits during a pass, or accumulate on overlapping passes. The depth update rate for each transducer channel must also be factored into the maximum speed determination. For dredge payment surveys, the maximum update rate shall be used in recording depths from each transducer channel. Data gaps can result if too high a velocity is maintained and individual channels do not update at a rapid enough level. Depths should be recorded at the maximum rate possible with the recording and processing system.

h. Quality assurance Performance Tests. Performance Tests are not required on all surveys; however, they should be periodically run during maintenance periods or other available opportunities (lay days). The frequency which Performance Tests should be performed is vessel/system dependent, and largely rests on the judgment of the system operator. The stability (repeatability) of results from past tests will provide an indication of the continued reliability of the data. If repeated tests yield stable results, then only infrequent (monthly or quarterly) tests would be indicated. Performance Tests are recommended for dredge clearance or payment surveys.

(1) QA Performance Tests with multiple transducer systems may be performed similar to single beam and multibeam systems, i.e., comparisons between two independently collected full data sets over the same area. The Reference Surface may be developed using data from only the hull-mounted transducers, thus minimizing yaw and roll effects. Alternatively, and a preferred option, comparisons with Reference Surface datasets from other survey vessels may be used. If available, tests within a confined lock chamber can be made. Follow the QA Performance Test software and analysis procedures described for multibeam systems in Chapter 6.

(2) Performance Test results will include an assessment of biases on the outer boom transducers, along with 95% standard deviation results. Any overall large biases between the test datasets should be investigated and resolved.

5-6. Selecting Recorded Depths and Estimated Accuracies. Selecting representative depths should follow the same guidance used for single beam and multibeam surveys—see the guidance at Chapter 2. Depths can be displayed in numerical values or color-coded to various ranges. Contour depth display options may also be used. If depths are binned for plotting purposes, the shot depth nearest the bin centroid should be used. Shoal biased (i.e., minimum) or average depths should not be used to evaluate dredging progress or payment—the average or median depth within a bin is recommended. Data thinning should be kept to a minimum for payment surveys. Therefore, bin sizes should be kept as small as possible.

a. Estimated depth accuracy results. Depth measurement relative accuracies in shallow draft projects (<15 ft) on firm bottoms are usually around the ±0.2-ft level with a properly

calibrated and operated system. Accuracy will degrade in deeper depths, or if sea or river wave conditions impact the vessel stability or motion corrections. If quality assurance Performance Tests are performed, then statistical data from those tests will yield an indication of the internal accuracy (i.e., standard deviation and repeatability) of the system. Actual or historical Performance Test results should be noted on the survey drawings and metadata files.

b. Reporting the estimated accuracy of measured depths. As noted in Chapter 3, determining the uncertainty of a depth measurement is difficult, and only an estimate is possible. In many inland applications, the uncertainty of a depth observation will be primarily dependent on the accuracy of the water surface elevation measurement. River stage interpolations over 10 to 30 miles between gages may result in stage uncertainties exceeding ± 1 ft. If local RTN/RTK elevation methods are observed from nearby primary gage benchmarks, then the uncertainty of observed depths in a shallow draft project may approach the ±0.3-ft level, given the likely ±0.2-ft accuracies achievable from the depth measurement system. Noting the estimated TPU is recommended on final survey products; especially those furnished to the public.

c. IHO standard. Surveys performed for nautical charting purposes should note the intended IHO SP-44 they were performed to meet. In general, most USACE navigable waterways should be surveyed to meet the IHO Special Order category.

SECTION I

Examples of Corps Multiple Transducer Survey Systems

This section contains descriptions of multiple transducer sweep systems currently operated by USACE districts. Some of these systems may have been subsequently modified or replaced. Descriptions of superseded systems are retained should these designs have application in future work.

5-7. Mobile District Tuscaloosa Site Office Sweep Systems. The Mobile District Tuscaloosa Site Office operates four multiple-transducer automated sweep survey systems utilizing depth sounding hardware manufactured by Ross Laboratories and HYPACK data collection and post processing software. The systems are used to provide data collection for Inland Electronic Navigation Chart (IENC) update and support for dredging activities and project conditions along over 700 miles of the shallow-draft 9-ft x 200-ft navigation channels of the Black Warrior–Tomigbee and Alabama River Systems. Following are descriptions of the systems.

a. General description. The Tuscaloosa Site Office operates three (3) trailerable 24-ft sweep survey vessels and the 60-ft sweep survey vessel E.B. WALLACE (see Figure 5-5). The three 24-ft small-boat systems have a total of five transducers with four being attached to hydraulically operated, retractable booms and strut assemblies and one being mounted amidships through the hull. The small boat systems provide full 25-ft swath coverage of the bottom with no gaps at water depths of 17 ft while performing data collection survey operations. The E.B. WALLACE has a total of 12 transducers with 10 being mounted on spring-loaded struts attached

Figure 5-5. Tuscaloosa Multi-transducer sweep boats. E.B. WALLACE on left and one of three 24-ft vessels on right. (Mobile District)

to two 30 ft hydraulically operated retractable booms and two being mounted amidships through the hull. The E.B. WALLACE provides a complete 70-ft-wide swath of the river bottom with each pass of the vessel. All transducers are spaced at 5-ft intervals along the boom and operate at frequencies of 200 kHz. The E.B. WALLACE has dual beam selectable angles of 10 and 22 deg and the small boats have a beam pattern of 10 deg at the 6db level. All the vessel's electronic components are rack mounted in custom cabinets and located in climate controlled cabin areas. (Note: The E.B. Wallace is being updated to 10-deg. Low "Q" transducers identical to those on the three small boats for better shallow water operation. These transducers allow sounding to within one foot from the face of the transducer.)

b. Survey procedures. Data collection is performed for each assigned surveying effort by running sweep lines that are parallel to the navigation channel. This method is also known as "mowing the lawn" or "painting the screen," and provides data coverage of the entire navigable water area or river "bank to bank" survey.

c. Transducer calibration and quality control. Transducers are calibrated with daily "ball checks" using the Ross Labs lead ball check assembly. Traditional monthly bar checks are also made using steel angle iron and a calibrated chain to verify the transducer drafts. Checks are also performed over fixed objects such as lock and dam miter sills to provide additional assurance of depth accuracy. Independent verification is also made by comparisons of hydrographic data produced with the sweep system with simultaneous collected data produced by A-E contract survey vessels.

d. Vessel positioning. Positioning is provided through a Trimble SPS 461 GPS system with dual antennas providing differential correction signals from USCG broadcast sites. In addition, the Trimble SPS 461 GPS receiver is equipped with a real-time kinematic (RTK) positioning system module for both horizontal and vertical positions. The RTK module uses an

Intuicom cellular bridge to receive a vendor-supplied network of corrections from a series of reference stations across four southeastern states: Georgia, Alabama, Tennessee, and Mississippi. The service provides network corrections that include data from both the US NAVSTAR and Russian GLONASS satellite systems. Each vessel incorporates a digital compass and a Honeywell HMR3000 roll and pitch sensor equivalent to a Micro Strain model 3DM-GXI.

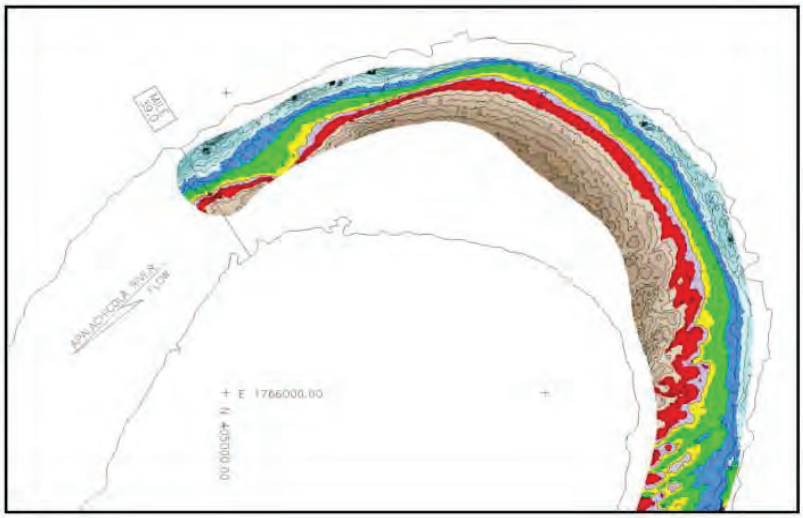


Figure 5-6. Color filled contour map plot near Mile 39 of the Apalachicola River. (Mobile District)

e. Data processing. Sweep data in digital format is recorded and stored onto CDs and DVDs and is either transmitted via email, FTP, or delivered to the office for editing and post-processing using HYPACK software. The data is processed into full color 30- x 42-in plan-view drawings of each survey area. The finished plots consist of color filled depth contours with elevation labels—see example at Figure 5-6. All data points collected during the sweep survey are used in the post-processing effort with various levels of data thinning being performed to achieve desired bottom mapping results.

f. Data distribution. End use of the processed data consists of not only hard copy plots but also digital dredging files and publicly available X-Y-Z data points. Contract rental dredges are given digital plans and detailed cut boxes that are displayed using government-furnished DREDGEPACK software from HYPACK, Inc. Digital X-Y-Z data is also made available via the Tuscaloosa Homepage Internet site for FTP download by vendors desiring to produce electronic charting products as well as display in a publicly accessible, on-line, interactive GIS system. The available data set consists of edited ASCII X-Y-Z format sounding points from which the electronic chart vendor will utilize to produce contour maps. Such contouring will be incorporated into charts depicting the shoreline and other physical features of the river system. Vendors providing electronic charting systems will be responsible for providing the finished chart that will ultimately be displayed on a vessel by the end-user.

g. On board equipment. Table 5-2 lists the survey instrumentation on the 24-ft vessels and the 60-ft E.B. WALLACE:

Table 5-2. Ross Model 4810 Sweep System Components.

Ross 962 controller (5-channels 24-ft boats and 12-channels E.B. WALLACE)
Ross Transducers - E.B. WALLACE, 12 @ 200 kHz, dual beam (10 and 22 degree beams)
Small Sweep Boats, 5 @ 200 kHz, 10 deg beam width
Ross 5150 one-man bar/ball check and underwater housing
Ross 9750 roll, pitch, and heading sensor. (Honeywell HMR 3000 series)
Trimble SPS 461 GPS with RTK module and Intuicom cellular bridge
Small-HP desktop color printer
Panasonic Tough Book 30 data collection computer with docking station. Consists of a 1.8 GHz Pentium processor with 2 GB of RAM, 160 GB hard drive
Dell 17-in ultrabright helm monitor
Dual ICOM model IC-M422 marine radios, integrated MXA-5000 AIS commercial vessel receiver with display from GARMIN GPS Model 430
Satellite telephone

5-8. St. Louis District Ross 875-4 Shallow Water Portable Sweep System. The Ross Laboratories 875-4 shallow water portable sweep system consists of four transducers on a lightweight 18-ft portable boom, which can be temporarily mounted on small skiffs or john boats (Figure 5-7). The watertight system operates on 12v DC. It has four to eight channel data collection options, can work in shallow water (to 1.5 ft), and operates with narrow beam 200 kHz transducers.

a. Real-time display. The multi-channel depth sounder system is able to display all channels on the system's 10-in color CD display; with each channel being represented by its own unique color. It also has adjustable tracking gates for each depth channel that can continuously track a changing seabed without user input.

b. Transducer specifications. The depth sounder operates at a frequency of 200 kHz, using four transducers (either 8-deg @ -3dB or 12-deg @ -6dB) with a six (6)-ft nominal spacing. The depth sounder system outputs a custom NMEA 0183 string to HYPACK software.

c. Data storage and display. The depths are stored on the internal hard drive media for future playback and printing. This data is downloaded and transferred to an office PC running Ross Multi-Channel Playback software using a USB Memory Card.

d. Accuracy. The depth sounder subsystem is based on a crystal-controlled clock. Depth measurement accuracy is a function of bottom type, bottom slope, and transducer beam angle. An echo detection algorithm is used to first determine that an echo has adequate echo strength to

be digitized and then calculates the digitized depth from the leading edge of that same echo signal. This algorithm is designed to reduce the type of errors related to echo signal rise time.

Figure 5-7. Ross 875-4 sweep system surveying the London Avenue Canal in New Orleans, LA, after Hurricane Katrina (2005). (St. Louis District)

e. Processor software. The main task of the processor software is to sample the four (4) channels of analog information at a rate of 50,000 samples per second for each channel. It then calculates the depth for each channel. The software is also responsible for recording the raw sounding data to the internal hard drive, displaying the data to the screen, and responding to user commands.

5-9. New York District Sweep System. Figure 5-8 shows the 25-ft survey vessel NYSB1 operated by the New York District. This boat is equipped with a multiple transducer sweep system (Ross Mini-Sweep Transceiver). The original system was developed by Ross Laboratories and is used to determine clearance during the rock excavations in New York Harbor deep-draft channel deepening projects.

5-10. St. Paul District Sweep System. This section describes two multi-transducer sweep survey systems operated by St. Paul District on the Upper Mississippi River. Both systems are boom-

mounted systems with a five-transducer array, mounted on 25-ft Sea Ark workboats. The systems were designed and installed by Ross Laboratories Inc. The systems are primarily used

Figure 5-8. Survey Vessel NYSB1 Multiple Transducer Sweep System. (New York District)

on project condition and dredge payment surveys of shallow-draft projects in the Upper Mississippi. (Note: the St. Paul District is currently (2013) replacing the five-transducer system with a six-transducer system mounted on a 24-ft aluminum catamaran vessel supplied by Armstrong Marine of Port Angeles, WA.)

a. Five-transducer system. The five-transducer vessel is boom mounted on a 24-ft Sea Ark boat powered by twin 150-HP outboard engines (Figure 5-9). The survey system is a complete 12-volt system with DGPS, roll sensor, and fluxgate compass all integrated into HYSWEEP data collection software. The five transducers are interchangeable from 10-deg to 20-deg beam angles for shallower water. All surveys are accomplished longitudinally and usually at speeds of under seven knots. Sweep data is edited in HYSWEEP software and then e-mailed to the Fountain City Project Office for plotting and analysis.

b. Lock chamber calibration procedures. The electronics are calibrated monthly using an aluminum bar check inside a lock chamber with the gates closed. The lock floor chamber depths are checked using a lead line or pole. A bar check is then used to calibrate the sounders with the depths at 5, 10, 15, and 20 ft. All transducers are then forced to read the same depths on the data collection computer. A predetermined survey line is set up in the lock chamber and the boat then runs this line. The recorded depths are compared with the chamber depths. The Ross ball check

is then calibrated at the same time for future daily or job specific use for project condition and /or payment surveys.

Figure 5-9. St. Paul District Five-Channel Ross Mini Sweep System on a 24-ft boat.

5-11. Rock Island District Sweep System. The Rock Island district currently operates two Ross Sweep Systems; one mounted on the MV Holling, a 34-ft catamaran vessel utilizing 10 transducers, the other a 9-channel system installed on the MV Heinz, a similar sized cathedral hull vessel.

5-12. Philadelphia District Sweep System. The Philadelphia District operated a ten-transducer boom-mounted Ross sweep system aboard the S/V Shuman until 1999. It was used for clearance and dredge payment on deep-draft navigation projects in the Delaware River, Delaware Bay, C&D Canal, and Chesapeake Bay. It was replaced with a RESON 7101 multibeam system currently in use today.

a. Four of the 10 transducers are mounted directly to the hull of the catamaran-type survey vessel. Six transducers are boom mounted, three to port side and three to the starboard side boom. Transducers are calibrated with a bar check monthly. Daily, a Ross ball check was performed to monitor the drafts of the hull-mounted transducers. A sound velocity profile was also used calibrate water sound velocity changes.

b. Vessel sweep speed was normally between 3 and 6 knots. Sweep data from all transducers was collected by time, not distance along the track line. Therefore, vessel speed must be controlled to avoid gaps. A fluxgate compass (or gyroscope) was interfaced with the data collection system to correct for yaw of the vessel and boom assembly--allowing for direct coordinate computation on each transducer. Both microwave and later code DGPS positioning were used.

(1) Sweep line spacings were designed for 20% side overlap. Cross-line checks were optionally run in order to monitor quality control of the sweep data. Comparisons were made using either a single transducer or full terrain models.

(2) Sweep data was edited though use of the system monitor aboard the vessel. Editing and review were made in plan or section format and the database corrected as required. Final plot scales and densities were selected depending on the nature of the project. In most instances, depth data must be selectively "thinned" for plan view plots at normal scales. Other options allow for selecting fixed cell (window) sizes for site plan plots or filtering out and plotting strikes above a preset grade.

(3) Cell/window size can be automatically determined -- typically 5-ft or 10-ft square. Since one or more depths may have been recorded within a cell, different techniques were used in determining the final value displayed or in material quantity computations. Normally, either the least depth or average depth within a cell was used. This value was then shifted to the cell centroid for plotting purposes. This process for selecting, thinning, and shifting of data must be thoroughly understood by those evaluating the data relative to contract performance.

5-13. Jacksonville District Raytheon 719 CSS (Channel Sweep System). One of the original Raytheon multiple transducer systems developed in the 1970s was designed without boom arrays. Side transducers were temporarily mounted to the hull of the boat, as shown in Figure 5-10. With only three transducers, sweep coverage was limited based on the beam width of the vessel; however, higher vessel speeds could be attained without boom restrictions. Depth data was recorded on stylus sparked paper, with offsets for each transducer. This system was used for visual (real-time) dredge clearance estimates. Figure 5-11 shows an analog representation from three transducers. Each transducer is offset by a fixed amount on the same graphical record. Visual interpolation of these analog records for strikes above grade was difficult. Interpretation becomes even more difficult as the number of transducers increases. This system's use was discontinued in the 1980s.

5-14. Detroit District 120-Ft Strike Detection Systems. This section describes multiple transducer sweep systems that were deployed on 100-ft vessels by the Detroit District during the 1980s and 1990s. The district deployed two such systems--one in Detroit and another at Sault Ste. Marie, MI. They replaced the manual sweep rafts previously used for strike detection. These systems have since been replaced by multibeam systems on small 26-ft survey vessels. The design and operation of these systems was unique and warrants description in this chapter.

Figure 5-10. Raytheon 719 CSS three-channel hull mounted sweep ca 1970s. (Jacksonville District)

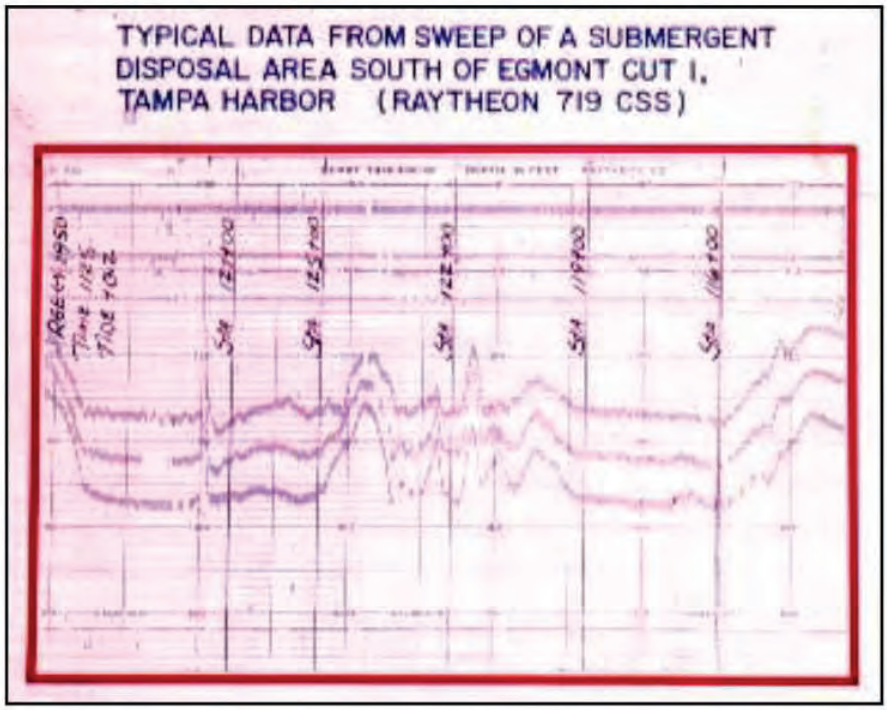


Figure 5-11. Raytheon 719 CSS multiple transducer analog record ca 1980. (Jacksonville District)

a. An Odom Echoscan multiple transducer channel sweep system was deployed from a 200-ton, 100-ft long by 30-ft beam by 7-ft draft, self-propelled barge containing 32 separate

transducers spaced 3.75 ft O/C (Figure 5-12). The transducers were mounted along a catwalk that extends 10 feet beyond each end of the vessel. This provides for a 116.25 ft length or about a 120-ft swath at typical project depth. These systems were used for strike detection in rock cut channels. Obstructions may be caused by ice jams, propeller wash, or large vessels dragging anchors that lifts and loosens rock material within the channels. Each transducer had a large enough beam width to provide overlapping coverage in typical 25- to 30-ft project depths found in the Detroit, St. Clair, and St. Marys river channels. The operating frequency was 214 kHz with pulse duration of 0.1 msec. The transducers are small ceramic discs 1.55 inches in diameter. The transducer beam width is 12 deg at -3dB and 17 deg at the -6 dB power points. Transducers were individually calibrated using standard bar check devices supplemented with velocity probe data and ball-check methods. A 32-ft calibration bar was employed in order to check every transducer. Calibration was also performed in a lock chamber at the Soo Locks where 30-ft depth can be obtained. Each transducer had separate draft and sound velocity settings. This type of vessel usually worked in conjunction with a crane barge (derrick boat) for removing loose rock and other debris within navigation projects.

b. The vessels were propelled by two Schottell, 360-deg, hydraulically operated rudder propellers, one at each end of the vessel. They were driven by 240 HP engines. The vessels have no keel so all direction and movement is dependent on the rudder-propeller system. The vessels were controlled by the direction and amount of thrust from the rudder-propeller. The vessel was navigated to work sites as any 130-ft long vessel. The rudder was manually controlled and a handwheel from each rudder-propeller with arrows indicating thrust direction allows the boat operator to direct the engine's output. Throttles located in the center of the handwheel provide the thrust controls. Auxiliary power was obtained from two 30 kW generators operating at 3 phase and 480 volts.

c. The vessels were operated sideways while sweeping. The boat operator controlled the vessel's speed and direction with a single handwheel and throttle. The Schottell unit's actual direction and amount of thrust was controlled by a computer interfaced to a gyrocompass and autopilot. The computer maintained alignment of the vessel at 90 deg to the direction of survey.

d. The sweep vessels were originally positioned using Del Norte microwave range-range and range-azimuth modes. In the 1990s positioning was converted to differential GPS. Data acquisition was originally performed using Comstar Echo Scan software running on a HP 9000 computer. Processing originally required 16 hours for each 8 hours of survey data collected--requiring a 24-hour processing operation. Once PC-based HYPACK software was added in 1994, data processing time was reduced substantially. Since only "strikes" above grade are significant, processing and/or plotting of data below grade could be eliminated.

e. Original staffing on the sweep vessel in 1986 was nine persons: three (3) Wage Grade vessel operators and six (6) GS survey technicians. With DGPS positioning and enhanced acquisition software, this staffing was reduced to four (4) persons by 1995.

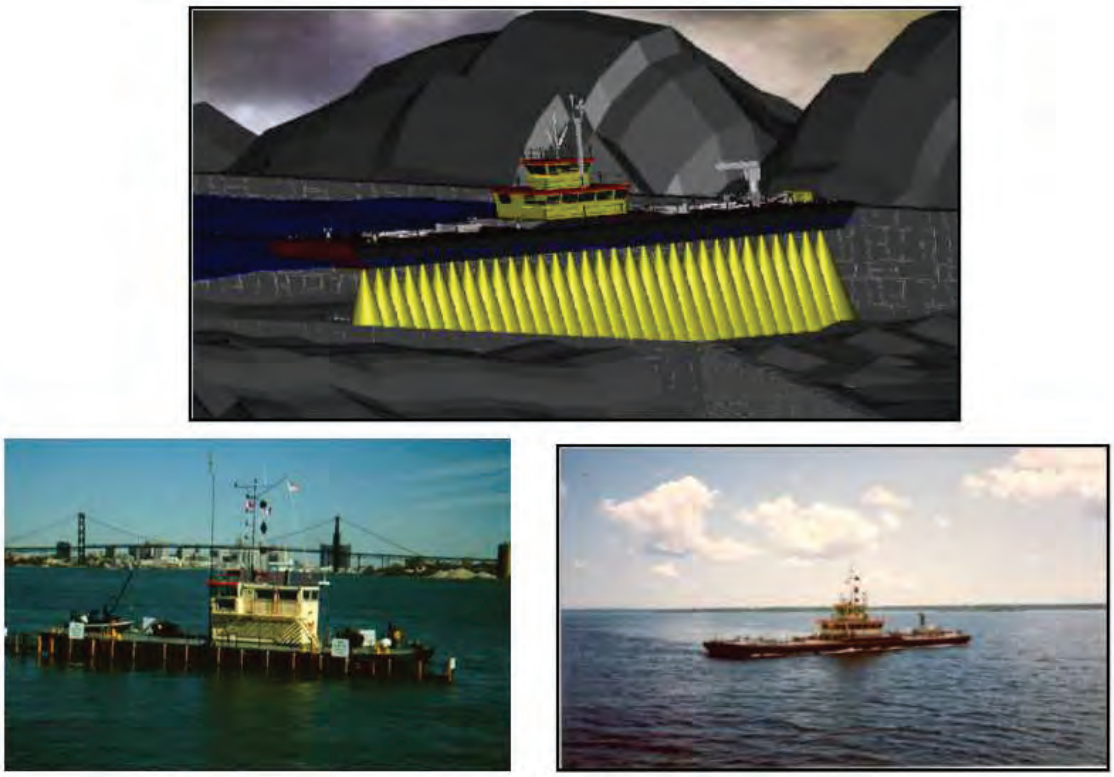


Figure 5-12. Detroit District 32-channel 120-ft sweep systems used on deep-draft navigation projects. On left, SV Bray in Detroit River (Detroit Area Office). On right, SV Bray on St. Marys River (Soo Area Office).

SECTION II

Recommended Quality Control Checklist for Multiple Transducer Sweep Systems

The following Table 5-3 lists quality control and calibration checks recommended for multiple transducer sweep systems. These criteria are similar to those required for single beam systems—see Chapter 4. These criteria are primarily applicable to systems operating in shallow draft waterways. For deeper draft projects, quality control and calibration checks should follow that of single beam systems.

Table 5-3. Recommended Quality Control Checks for Multiple Transducer Sweep Systems.

Sound velocity calibration	Perform twice daily, or more often if required.
Bar/ball check draft calibration	Perform daily on dredging surveys—middle transducers. Periodically on other surveys. Check as many transducers as possible. Annually check all transducers.
Dynamic draft calibration	Check and monitor short- and long-term draft corrections for all transducers, particularly on small boats where loading changes may impact short-term draft.
Vertical Elevation Check (RTK)	Twice daily calibration at tide/staff gage.
Roll motion correction	Required if significant outer boom roll motion exists.
Yaw correction	Flux gate compass correction usually adequate.
Heave correction	IMU/MRU rarely required unless excessive motion.
Pitch correction	Typically negligible in calm waters at slow speeds.
Latency correction	Periodically check and monitor.
Squat correction	Usually minimal at slow speeds … verify at installation.
QA Performance Test	Perform periodically during maintenance periods. Recommended on dredge payment or clearance surveys. When possible, compare with different vessels. Perform lock chamber calibration if available. Note results on transmitted drawings and metadata files.

CHAPTER 6

Acoustic Multibeam Survey Systems

6-1. General Scope and Applications. This chapter provides guidance for the calibration, quality control, and quality assurance of multibeam survey systems used on surveys of Federal navigation projects and water control structures. Only general operating principles are outlined in this chapter. Comprehensive instructions for installing and operating specific multibeam systems, including the data acquisition, processing, and editing of data from these systems, are found in manufacturer's operating manuals and software processing manuals specific to those systems.

6-2. Background. The US Navy developed multibeam swath survey technology in the early 1960s for deep-water bathymetric mapping—i.e., the "Sonar Array Survey System—SASS." In the 1980s, this multibeam technology began to be developed for shallow water applications. In the early 1990s, John E. Chance (now Fugro) of Lafayette, LA, configured a multibeam system ("HI-MAP") for USACE revetment surveys on the Lower Mississippi River. This HI-MAP multibeam system was first deployed in support of USACE during the Mississippi River Flood of 1993, performing high water surveys over levee breaches in the St. Louis District. Subsequently, in the mid 1990s, USACE inland waterway and coastal districts began to acquire these shallow-water multibeam systems. Over 40 multibeam systems are currently deployed in 24 USACE districts (Table 6-1). It is expected that the use of multibeam systems will gradually supplant single beam systems for surveys of most deep-draft navigation projects. Multibeam systems, when coupled with digital side scan imaging systems, have also become primary strike, channel clearance, and shoal detection methods in USACE. When properly deployed and operated, the accuracy, coverage, and strike detection capabilities of multibeam systems now equals or exceeds that of traditional vertical single beam sounding methods. However, there are still many project applications where single beam systems are more effective and efficient than multibeam systems.

Table 6-1. Multibeam Systems Deployed by Corps Districts (2012)

New England - 2 systems	Los Angeles - 1	Galveston - 3
New York - 3	San Francisco - 1	Tulsa - 1
Philadelphia - 3	Portland - 2	St. Louis - 2
Baltimore - 1	Seattle - 1	Nashville - 2
Norfolk - 2	Vicksburg - 1	Louisville - 1
Wilmington - 1	Memphis - 1	New Orleans - 1
Savannah - 1	Huntington - 1	Detroit - 2
Jacksonville - 4	Buffalo - 1	Mobile - 4

6-3. General USACE Applications. Multibeam systems are primarily used to obtain complete coverage of deep-draft navigation projects; in particular, project condition surveys, dredging measurement, channel clearance, and constructed construction payment surveys. Multibeam systems can also be configured for waters-edge to waters-edge coverage (i.e., over 180 deg swath), allowing side-looking, full-coverage underwater topographic mapping of constricted channels, lock chambers, revetments, breakwaters, dams, and other underwater control structures. Most multibeam systems now collect acoustic backscatter information that can produce digital side scan imagery simultaneously with the topographic mapping data; an advantage in locating underwater rock, hazards, shoals, or other objects (strike detection)—see Appendix Q. Multibeam acoustic frequencies and signal processing methods may be configured to match the survey requirements--dredging measurement and payment, strike detection, structure mapping, bottom classification, etc. Some systems can provide near real-time data collection, filtering, editing, quality assessment, and display; along with near real-time (i.e., on board) data processing, plotting, and volume computations. Thus, final plan drawings, 3D terrain models, and dredged payment quantities can be completed in the field the same day the survey is performed. Additional USACE applications are described in Section II of this chapter.

SECTION I

Principles of Multibeam Depth Measurement

6-4. General. Multibeam systems generate a single sonar pulse from which detailed terrain or channel cross-section (swath) data can be developed, as illustrated in Figure 6-1. A single transducer forms a fan array of narrow beams that result in acoustic travel-time and angular measurements over a swath that varies with system-type and bottom depth--typically mapping an area 2 to 14 times the channel depth with each array pulse. Some multibeam systems can obtain 50 or more swath profiles (cross-sections) per second with hundreds of depths recorded on each profile/section, along with additional backscatter or snippet information with each depth. Multibeam systems can obtain 100% bottom ensonification coverage, and can provide high-resolution footprints when narrowly focused beams are formed. A variety of acoustic frequencies are available from manufacturers—100 kHz to 500 kHz being most common on USACE systems. Multibeam system internal depth accuracies are typically better than ± 0.8 ft (95% relative standard deviation) with repeatabilities usually well less than 0.2 ft (at 90-deg restricted array limits). Multibeam accuracies degrade at the outer beams—typically beyond 40- to 50-deg from nadir.

6-5. Depth Measurement Principles. All multibeam systems use the same basic approach to depth measurement. A lateral swath of sea floor is illuminated acoustically and the returning echo signals are processed into vertical depths. All outgoing and incoming sonar is transmitted and received at a single transducer head. Travel time estimates are converted into slant ranges, horizontal off-center distances, and then depth by applying beam angles and sound velocity profile and refraction corrections. Multibeam sonar systems employ various acoustic and electrical signal processing techniques to determine the slant range and angular measurements of seabed points along an array generated from a single acoustic pulse. These include amplitude

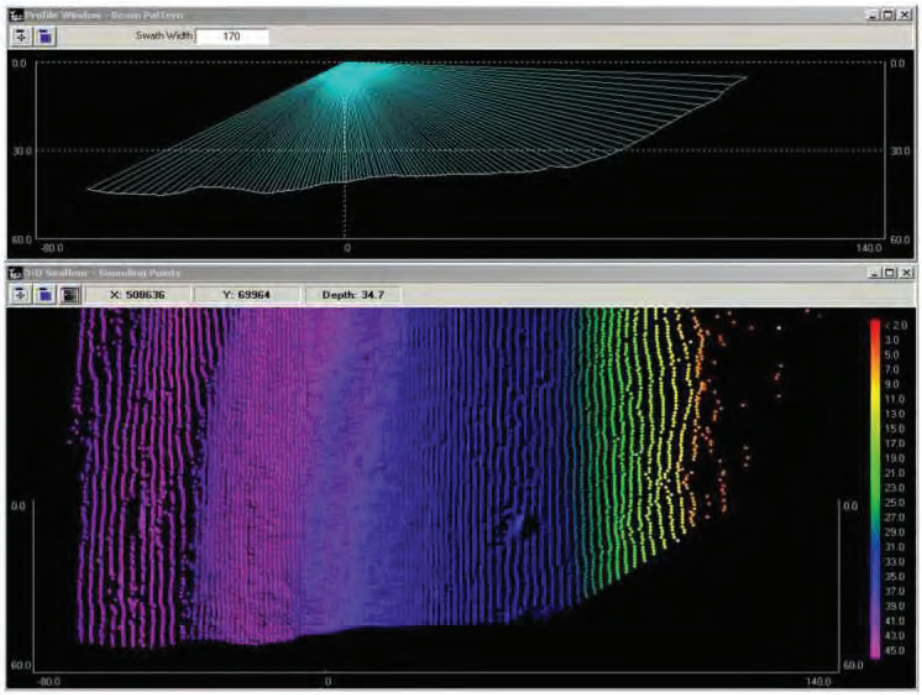


Figure 6-1. The upper image shows a real time display of a multibeam channel cross-section from a single ping. The lower figure shows a real-time plan view image of data collected along a channel and revetment bank on the Mississippi River. The multibeam transducer head was tilted to maximize coverage to starboard (up the revetment bank). Note that coverage spreads out on the outer ends of the port and starboard beams. (St. Louis District)

detection, phased array beamforming, interferometric (phase comparison), and various combinations of all these methods. The signal processing method(s) used on any particular multibeam system is often proprietary. In general, combinations of amplitude detection and transmit or receive beamforming are the most common methods. Phase comparison (interferometric) techniques may also be used directly or included within some proprietary systems. Many of these acoustic measurement techniques were derived from RF and radar signal processing.

a. Amplitude detection relies on finding the time of a beam's interception with the bottom, typically determined using a center-of-energy method, or matched filter method. Phase detection relies on finding the time of the zero phase crossing using two or more subsections of the receive array. Amplitude detection is typically used for the inner beams (e.g., 0 deg to 45-deg off-nadir) and phase detection is typically used for the outer beams (e.g., 45 deg out to 100-deg off-nadir)—see Figure 6-2. The changeover point between amplitude and phase detection is

processed by various methods, such as absolute cutoff, real-time analysis of each beam, and combinations of amplitude and phase. Depth accuracy can change at the bottom detection transition points.

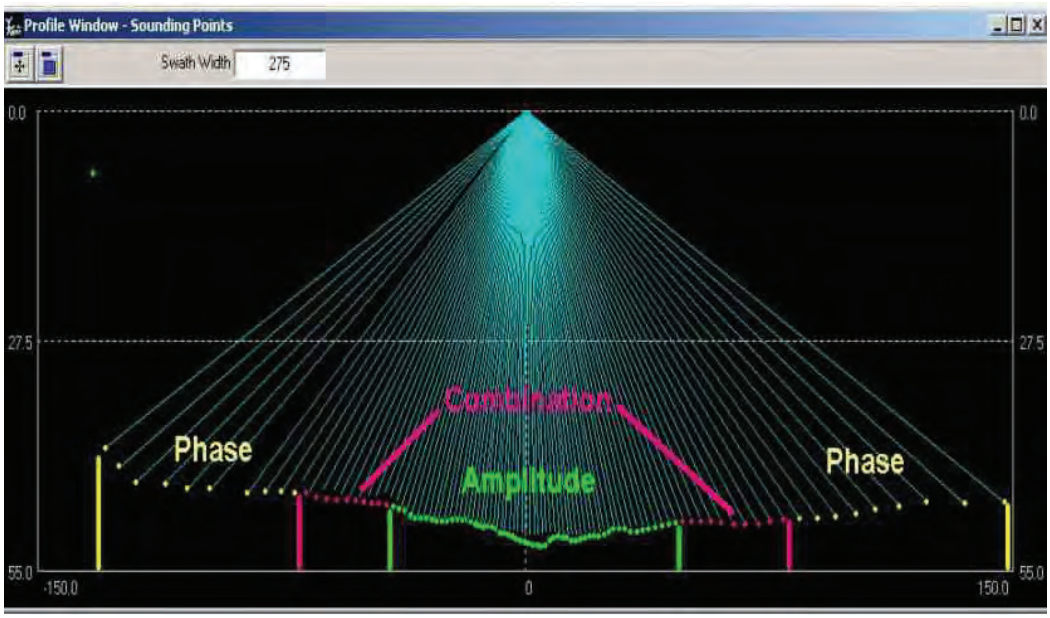


Figure 6-2. Amplitude and phase detection methods used in measuring depths over a typical multibeam array. The "combination" is the changeover area between phase and amplitude detection processing.

(1) Physical beamforming. A physically beamformed system uses a common projector and an array of receive elements physically pointed in the desired direction. Depth is determined based on the amplitude of the return signal (the center-of-energy detection method). Beam parameters are determined by the physical shape of the receive elements.

(2) Electronic beamforming. Electronic beamforming is generally based on electronic filter techniques to differentiate between individual echo contributions from different directions. Basically, each beam is formed by filtering out unwanted components. Depth is resolved based on center-of-energy or phase estimates. Electronic beamforming multibeam systems estimate the slant range to each echo event point based on the strength of the signal relative to a threshold. Electronic beamforming can be applied to either the transmit or receive cycles. To steer a transmit beam downward, multiple staves (elements) are sequenced with a slight delay. Each stave fires in sequence. The sum of the signals from each stave would then produce a wavelet in the desired direction. To steer a beam normal to the face (straight out), all staves would fire at the same time. In the case of a transmit beam formed system, each beam must be formed one at a time. The process of transmit beam steerage is slow since each beam must be formed in sequence. A better solution (and the one used by most electronic beamforming systems) is to apply this "phasing" principle to the receive signals, as shown in Figure 6-3. The angular acoustic wave front strikes each receive element, but at a different time and phase depending on

the angle of the return. By introducing a variable delay to each receive element's information, the phases can be aligned and the beam can be 'steered' in the direction of the return. In order to accurately apply the correct delay, three factors have to be known or measured: (1) the physical distance between each receive element, (2) the time of reception at each receive element, and (3) the instantaneous speed of sound at the receiver face. (R2Sonic 2010).

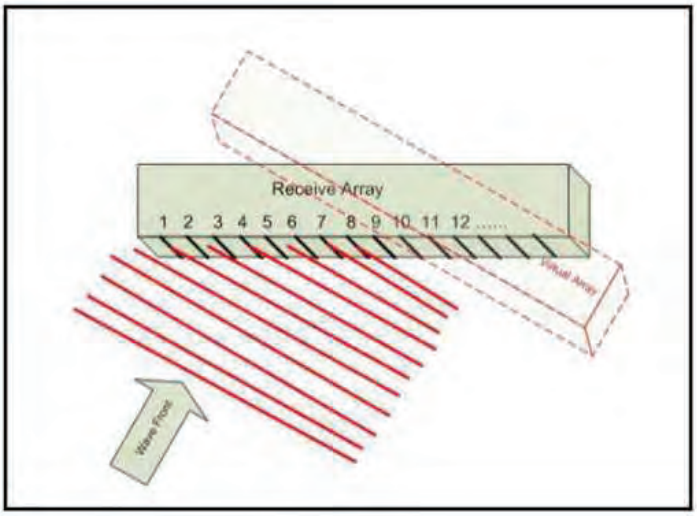


Figure 6-3. Electronic Beamforming. As the returning (reflected) wave progresses across the face, each receive element will see the wave at a slightly different time and thus a slightly different phase (R2Sonic 2010).

b. Interferometric systems (Phase Comparison). In interferometric multibeam systems, beam direction is determined by measuring differences in signal arrival times on an array of receive elements (phase differentiation). Interferometers provide range and bearing estimates to bottom depth points by detecting propagation delays from individual bottom spots to different transducer subsections. This is interpreted by the electronics as a phase difference in the signal. The phase difference is then converted to an angle or receive vector relative to perpendicular. Interferometry differs from the standard beam former in that the beams are created by a signal processor from data stored in the receive buffer. In interferometric systems, discrete beams are not physically formed--phase information from all directions are received and processed simultaneously. Interferometric techniques can provide high resolutions and a large number (hundreds) of beams within each ping array. The disadvantages of a purely interferometric multibeam echo sounder include: (1) phase tracking circuitry can become unstable and cause high data variations, (2) resolution depends on the internal detection rate (i.e., sophistication of the processing system), and (3) resolution and directivity near the nadir is poor.

c. Beam spacing. Beamforming multibeam systems are typically designed with between a 0.5 deg and 3.0 deg beam spacing. To increase resolution along the array, interferometric phase comparison techniques may be employed. The accuracy of a wide-swath multibeam is

determined by the ability of a multibeam system to resolve the actual beam angle in varying situations. A major component of this is correcting refractions due to sound velocity changes in the water column.

d. Beam footprint size. Outer beam quality and accuracy is dependent upon footprint size. As with single beam echo sounders, the smaller the beam angle, the better the system is able to discern true depth and resolve small features. As the size of the footprint increases toward the outer beams due to beam spreading, the stability and accuracy of the data decreases, resulting in a degradation of data quality and accuracy in the outer portions of the beam array. For this reason, angular restrictions are typically placed on the use of outer beam data; which limits the amount of single pass coverage in multibeam surveys.

e. Signal parameters. Each individual bottom spot within the ensonified swath responds with a reflected echo signal in which signal parameters (amplitude, frequency, phase) are all dependent. These parameters are dependent upon the characteristics of the bottom, namely (1) bottom reflectivity and (2) slope angle of incidence of the beam. Other local environmental factors that may need to be adjusted on a typical multibeam system include acoustic absorption, acoustic spreading loss, pulse length, transmit and receive power settings, and related time varied gain (TVG). Estimating these and other settings, and their impact on depth measurement accuracy (uncertainty), is often difficult. The quality of the return signal is also dependent upon the primary projector/receiver characteristics and the geometrical and acoustic reflective properties of the particular bottom material. A multibeam sonar's bottom detection thus provides three pieces of information: (1) the angle of the beam along which the acoustic pulse traveled, relative to the sonar head, (2) the round-trip travel time of the acoustic pulse, and (3) a signal intensity time series of the bottom return. These three pieces of information must be integrated with the other sensor data (e.g., vessel velocity, acceleration, roll, pitch, yaw, and heave motions) to determine the total sounding solution (i.e., X-Y-Z) relative to an earth-fixed coordinate system—e.g., the NSRS or local construction station-offset-depth reference framework.

f. Vessel positioning requirements. Both code-phase US Coast Guard DGPS and carrier-phase (RTK) GPS positioning methods are used to control the horizontal location of the vessel, and ultimately the multibeam transducer. Use of either positioning method depends on a number of project-specific requirements. In distant offshore coastal areas where tidal modeling is uncertain, carrier-phase RTK may be needed to enhance vertical accuracy of measured depths. When the multibeam is deployed horizontally to map underwater structures, RTK techniques may be needed to maintain decimeter-level horizontal accuracy. RTK is also recommended to obtain more reliable and consistent "Patch Test" calibrations.

g. Correcting vessel motion effects (heave, roll, pitch, and yaw). Multibeam accuracy is critically dependent upon the ability of the complete system to compensate for pointing errors caused by vessel heave, roll, pitch, and yaw. Various types of inertial and inertial-aided GPS methods are used to measure these motion parameters in real-time. Across-track location of each bottom point is critical. In wider swath systems, even a small degree of roll error can cause large errors in the outer beams. Vessel heave due to waves must also be accurately measured and

compensated for. These errors are further compounded due to beam spreading. Multibeam systems must be integrated with accurate motion reference units (MRUs) to correct for vessel motions. The inter-relationships between the positioning system, motion sensors, and the multibeam system, are critical. Quality control calibrations are essential to minimize errors due to these motion components.

h. Sound velocity and refraction. Since the array beams travel through varying water column temperatures and suspended materials (e.g., salinity) the refractive characteristics of each array beam must be determined and corrected. Thus, accurate sound velocity through the water column must be measured. Continuous (real-time) sound velocity measurements at the transducer head may be required on some systems.

i. Estimated accuracy. The propagated measurement uncertainties in depth measurements were described in Appendix D. Given the numerous parameters involved in a depth observation at various points along the array, estimating the resultant depth uncertainties is extremely difficult to quantify. Uncertainties tend to degrade away from nadir due to the velocity correction and signal processing methods described above. They can only be estimated from assumed uncertainties in the 40+ individual components that make up the overall uncertainty estimate. Many of these component estimates are, at best, educated guesses. Currently, the only practical method of estimating multibeam data quality is through Performance Tests that compare the multibeam data with more reliable near-nadir data from independent surveys—see details in Section VI in this chapter.

6-6. Overall System Requirements. Configuring an operational multibeam system requires the integration of various processors, sensors, and computers. In addition to the multibeam system itself (transducer and processor), the following primary peripheral devices are typically required on a complete system. All devices are linked through a computer with data acquisition and navigation software.

a. Positioning and navigation system. GPS (DGPS code or carrier phase). A survey Total Station may also be used for positioning in limited applications. Positional data is also fed to the vessel operator for real-time navigation.

b. Heading system. A gyrocompass is linked to the data acquisition computer, providing vessel azimuth orientation. (POS/MV systems may also provide this data.)

c. Motion compensation system. An inertial heave, pitch, and roll system provides real-time vessel motion data. Inertial-aided GPS systems (e.g., POS/MV) will provide this motion data.

d. Sound velocity probes. Sound velocities in the water column must be periodically measured. Some multibeam systems may require a real-time velocity probe at the transducer head.

e. Details on configuring, linking, interfacing, networking, and calibrating all these components are covered in manufacturer's operating manuals and software data acquisition manuals. Figure 6-4 depicts a typical configuration of the peripherals required for a complete multibeam survey system. The specific hardware and software shown is only for illustrative purposes—a variety of different (and equivalent) sources for these devices are available.

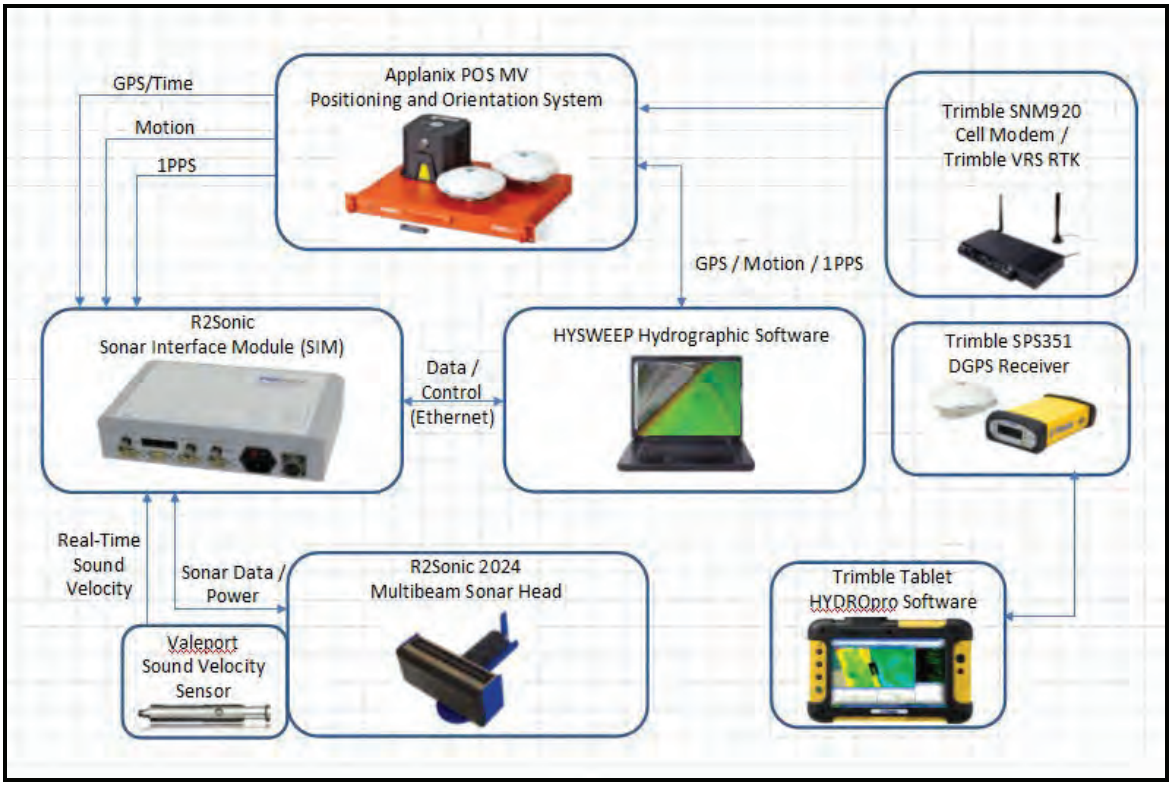


Figure 6-4. Typical configuration of a multibeam survey system. (Measutronics, Inc., Lakeland, FL)

6-7. References. The following references are recommended for more detailed descriptions of the operating principles of multibeam systems. They are also listed in Appendix A. Various manufacturers provide training courses that cover underwater acoustic theory and measurement principles relating to their specific multibeam system.

(1) "R2Sonic Broadband Multibeam Echosounders Operation Manual V3.0," (R2Sonic 2010). Basic general underwater acoustic principles, amplitude and phase detection theory, especially broadband multibeam systems.

(2) "Multibeam Sonar Theory of Operation," (L-3 SeaBeam 2000). Comprehensive multibeam signal processing techniques. Details various beamforming methods used in multibeam systems.

(3) "GeoSwath Product Information Bulletin," (GeoAcoustics 2002). Covers acoustic propagation principles, transmit beamforming, receive beamforming, multiple receive arrays, and phase comparison principles, advantages, and limitations.

(4) "IHO Manual on Hydrography." (IHO 2005). Details amplitude, phase detection, and interferometric techniques, including total propagated uncertainties of collected multibeam data.

SECTION II

Multibeam Applications and Utilization on USACE Civil Works Projects

6-8. General. Multibeam systems are primarily deployed on deep-draft navigation projects where full-bottom coverage is required. A typical example is a coastal navigation entrance project shown at Figure 6-5. Multibeam systems may also be employed on deeper portions of inland projects, and near USACE locks, dams, hydropower plants, reservoirs, river control structures, and revetments. Survey lines are normally run longitudinal with the channel or river alignment. The coverage of each swath is dependent on the depth and beam width. A typical 40- x 400-ft project can be covered with 3 to 5 lines, depending on the selected beam angle limits. (Refer to Section V in this chapter for estimating survey coverage). Vessel speeds are typically run slowly (e.g., 5 to 10 knots) in order to ensure 100% along-track ensonification, ensure multiple hits on potential hazards or shoals, or when collecting side scan imagery. At a nominal update rate of 40 profiles/sec in shallow water, and a 256 beam array, over 10,000 depths/elevations per second are generated; resulting in a large but densely detailed database for the subsequent processing and other engineering applications. Interferometric multibeam systems may obtain upwards of 50,000 depths per second. The tradeoffs to wide-swath, high-density data are increased editing and post processing time and the requirement for more sophisticated computer hardware.

6-9. Project Condition Surveys. Multibeam survey systems are primarily used for project condition surveys of USACE federal navigation channels, revetments, and other underwater structures where complete bottom coverage is desired to delineate the feature or structure. Multibeam sensors can be configured to detail coverage of pipelines, bulkheads, floodwalls, lock walls, revetments, breakwater riprap, and other similar underwater structures. Systems can be configured (or the transducer rotated) to provide up to 190-deg coverage, which would provide "water's-edge to waters-edge" coverage to both port and starboard. In some narrow projects, a single swath pass may provide full coverage.

6-10. Dredging Measurement and Payment Surveys. Multibeam survey systems that provide complete bottom coverage are recommended for use in most dredging measurement and payment surveys, i.e., plans and specifications surveys, pre-dredge surveys, post-dredge surveys, and final acceptance/clearance surveys.

a. Multibeam systems are an effective quality control process on dredging projects requiring 100% bottom coverage to assess and certify project clearance. The full digital terrain model (DTM) generated from a multibeam survey provides a more accurate and equitable (to the

government and contractor) payment quantity than that obtained from traditional single-beam cross-sections. However, the use of multibeam systems on dredging measurement, payment, and clearance work requires rigorous quality control and assurance calibration, and attention to

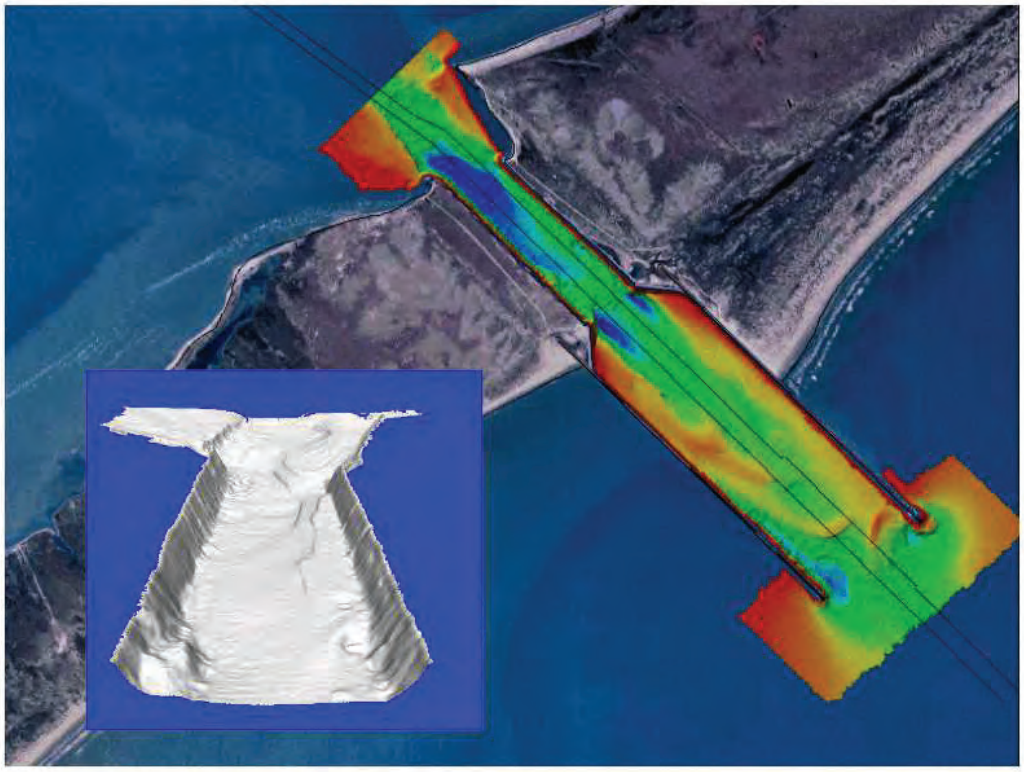


Figure 6-5. Full-coverage multibeam survey of coastal inlet navigation project and shore protection jetties. (Galveston District)

bottom type with respect to frequency. Any resultant biases that are not corrected can significantly affect volume computations. Multibeam systems are normally not used for payment or clearance on shallow-draft projects with sand or silt bottoms; however, less than 100% bottom coverage with multibeam may be acceptable in these shallow-draft projects.

b. Measurement and payment provisions in dredging contract specifications should clearly stipulate the type of multibeam survey system, acoustic frequency, navigation guidance system and software, data acquisition parameters (horizontal and vertical control, density, etc.), data processing and binning techniques, and mathematical volume computational method/software that will be employed by the government. In order to ensure consistency when performing measurement and payment surveys, commercially available software should be employed for data collection, data processing, data quality control, and volume computations.

6-11. Shoal or Strike Detection Applications. Multibeam survey systems represent an effective mechanism for detection of shoals, rocks, wrecks, debris, or other navigation hazards lying

above grade in a navigation channel. The side-looking aspects of both the multibeam signal and the digital backscatter sonar imagery signal may be used for such investigation purposes. In order to enhance the probability of detection, and depending on documented system performance characteristics, 200% bottom coverage may be specified in order to ensure objects are ensonified from two aspects--and to confirm at least three multiple hits are obtained on these objects. Performance demonstration tests on simulated objects should be periodically performed to assure data detection quality and assess the need for overlapping coverage.

a. Emergency operations. Multibeam systems recording both topographic data and digital side scan imagery are recommended for locating underwater objects and marking objects for clearing after natural disasters. New York District successfully deployed multibeam systems along with towed side scan sonar to locate a downed aircraft in the Hudson River.

b. Multiple-transducer, boom-mounted, channel sweep systems are generally preferred for use over multibeam survey systems in shallow-draft (<15 ft), sand/silt-bottomed navigation channels. (However, especially with the ability to tilt the sonar head, multibeam systems are also a valuable tool that can be used in these same projects.) Multi-transducer systems will also provide 100% bottom coverage on shallow draft navigation channels, as will mechanical, or manual, channel sweeping techniques. Mechanical bar sweeps still remain an effective dredging quality control technique when rock is encountered—see Chapter 10.

6-12. Underwater Structure Investigation Surveys. Multibeam systems represent an effective tool for performing detailed investigations of the conditions of Corps locks, dams, and other underwater structures, such as bridge piers, revetments, intake structures, spillways, breakwaters, jetties, and sheet pile bulkheads. Refer to Chapter 9 and Appendix N for details and examples of structure investigation surveys.

6-13. Multibeam Side Scan Imagery. Multibeam systems generate side scan imagery along with the basic depth information. Multibeam side scan imagery is generally not as good as towed side scan imagery (see Appendix Q). The high aspect of a hull mounted transducer results in high grazing angles. These high grazing angles result in small shadows. Off-nadir beam amplitude imagery degrades quickly because of the poor intensity of the returned acoustic energy and is subject to "false target generation" in side lobe interference situations. The larger the beam footprint, the coarser the amplitude imagery. Amplitude imagery is also called “backscatter intensity” and can be exploited for bottom classification (reference Geocoder processing algorithms in HYPACK 2011). Angle independent imagery, or time series imagery, provides an image very similar to towed, low resolution, side scan sonar. The resolution is much higher and the data rates are much higher. Multibeam data acquisition that includes the angle independent imagery results in very large data files.

6-14. Miscellaneous Considerations.

a. USACE personnel training requirements. Multibeam system operators require considerable expertise in both surveying and on CADD workstations. Prior to using multibeam

systems on USACE surveys, system operators should have completed specialized training. Presently, the Corps PROSPECT course on Hydrographic Surveying Techniques is not considered sufficient for multibeam training. Comprehensive training courses are available from: (1) the University of New Brunswick, (2) HYPACK, Inc., (3) University of New Hampshire-NOAA Joint Hydrographic Center, or (4) The Hydrographic Society of America seminars. Multibeam manufacturers also offer specialized training sessions.

b. Plant utilization and justification. Multibeam surveys may be obtained using either USACE hired-labor forces or through A-E service contracts. Commands considering procurement of multibeam systems should internally determine that such a system represents an effective and efficient utilization of floating plant, given the $200 K to $500 K investment for a complete survey-quality multibeam system with auxiliary sensors. Some factors that should be evaluated include: (1) proposed multibeam vessel, (2) system configuration (hardware and software), (3) estimated annual utilization (time and location), (4) FTE allocations, (4) system operator qualifications, (5) field data processing, editing, and plotting, and turnaround capabilities, (6) estimated daily plant and survey crew rental rate, and (7) comparative analyses between hired-labor and contract costs.

c. Calibration and quality control. Field quality control calibration of multibeam acoustic refractions and vessel motion is significantly more critical and complicated than that required for standard single beam systems. Recommended calibration requirements, procedures, and allowable tolerances are described in later sections of this chapter. Quality assurance Performance Tests are essential in order to assess and demonstrate data quality. These quality control calibrations and quality assurance Performance Tests must be processed and adjusted on board the survey vessel prior to and during the survey—after-the-fact checks in the district office are of little value if an uncorrectable field calibration problem is detected. This implies that near real-time field-finish data collection, processing, and editing must be established in the field in order to ensure the most cost-effective utilization of this technology.

SECTION III

Configuring Multibeam Transducers on Corps Floating Plant

6-15. General. Multibeam systems are mounted on a variety of Corps vessels, ranging from 22-ft up to 65-ft vessels. Numerous factors must be considered in selecting the type (and size) of vessel, mounting location, and projected utilization of a multibeam system. Districts procuring multibeam systems should consult other districts with operational systems as part of this decision process—especially districts with similar project conditions. Contacts with multibeam manufacturers and the USACE Marine Design Center in Philadelphia are also recommended. Some of these mounting design considerations are outlined below.

a. Vessel size. Multibeam systems are generally more cost-effectively utilized on small, mobile (trailerable) survey vessels up to 26 to 30 ft in length, with the transducer assembly externally mounted over the bow or either port and starboard sides. This allows the system to be

rapidly deployed on remote projects. Permanent or retractable transducer mountings on large, non-trailerable, 30- to 65-ft survey vessels are generally recommended in situations where such a vessel is primarily based near a major coastal navigation project.

b. Mounting stability. A sturdy transducer mounting is required to eliminate any vibration at the underwater transducer head. In addition, the location should afford a smooth laminar flow at the head.

c. Transducer orientation calibration. A fixed transducer (i.e., hull mounted) minimizes the need for periodically calibrating the orientation parameters (Patch Test). Retractable transducer mounts should be designed such that they rigidly snap into the same underwater location each time they are deployed.

d. Lever arm calibration. Ideally, a multibeam transducer should be located as close as possible to the vessel's center of rotation, and as near as possible to the GPS positioning system antenna and inertial measurement unit. This is rarely possible in practice, especially on smaller vessels. Minimizing these lever arm distances between the transducer, positioning, and inertial units helps reduce errors inherent in these parameters. Measurement of these lever arm distances requires precise survey measurements (± 1 cm). These measurements are often difficult when visual access to any of the units is blocked.

e. Maintenance. Access to the head allows removal of marine growth and ease of repair to the transducer elements if necessary. Retractable or pivoting mounting systems provide such access as opposed to fixed hull mounts.

f. Vessel maneuverability. The ability to retract the transducer from the water allows the vessel to reach project sites at full speed and without danger from hitting underwater obstructions.

g. The following sections provide additional guidance, advantages, disadvantages, and illustrations of various multibeam installations deployed by Corps districts.

6-16. Fixed Hull-Mounted Systems. Fixed hull-mounted systems are installed on large vessels, usually those exceeding 30 ft in length. A main advantage of fixed mountings is stability—orientation parameters remain relatively stable, minimizing the need for periodic calibration Patch Tests. A main disadvantage is maintenance; requiring that the vessel must be lifted into dry dock for access to the transducer housing. Another disadvantage is that the fixed transducer is vulnerable to being hit by any debris in the water. In the 1990s, a number of districts with 65-ft survey vessels elected to install fixed hull transducer mounts. Few such systems are currently deployed on newer large vessels in USACE—retractable transducers on split hull catamarans are now considered more effective. Figure 6-6 depicts a fixed-hull installation of the Reson 8101 system on the Norfolk District 65-ft Survey Vessel Adams II. This system was installed in 1998. This represented an effective fixed-hull installation since this vessel is deployed on nearby deep-water navigation projects in and around Norfolk and Chesapeake Bay.

Figure 6-6. RESON SeaBat 8101 fixed hull-mounted installation on Survey Vessel Adams II. (1998 Norfolk District)

6-17. Through-Hull Transducer Mountings. A number of districts (e.g., Mobile, Portland, Jacksonville) have recently elected to procure 50 to 65 ft split-hull catamaran vessels with a retractable transducer mounting between the hulls. This is sometimes referred to a "moon pool" mounting. The transducer mounting is located near the vessel's center of motion to minimize underway rotation corrections and lever arm distances to the peripheral positioning and inertial motion units. The transducer is hydraulically lowered to its fixed underwater position. The mountings have rigid locks such that the transducer head is always fixed at the same location; thus minimizing the need for periodic Patch Test recalibrations. Since the transducer can be easily retracted, the vessel can reach remote project sites at full speed. As indicated in Figures 6-7 and 6-8, the head can be easily accessed for maintenance.

6-18. Bow-Mounted Transducers. Retractable bow-mounted transducers are typically used on smaller, trailerable vessels, although they may be used on any length vessel. They are either physically (manually) or hydraulically deployed to their underwater position, with a rigid locking mechanism. A disadvantage is that vessel motion at the bow (e.g., pitch) can be large; and that lever arm distances to the positioning system and inertial motion system are lengthy. The following figures (9 through 12) illustrate bow-mounted transducer installations.

Figure 6-7. Portland District S/V Redlinger. The S/V Redlinger is a 60-ft foil supported catamaran. Survey equipment includes an Applanix POS/MV, Simrad EM 3002, and an Odom CV100. The transducer is located just aft of the cabin.

6-19. Side Mounted Transducers. Side-mounted transducers are commonly installed on smaller vessels, such as that shown in Figure 6-13. Installations may be permanent or temporary. As with bow-mounted installations, vessel motion (especially roll) may be significant on side mounts. Vessel pitch may be significant on systems mounted near the stern. Thus, lever arm and vessel motion measurements (corrections) are demanding and critical

a. 45-Ft Survey Launch Vollert, Galveston District. Figure 6-14 depicts the installation of an Odom multibeam system aboard the Survey Launch Vollert. The Vollert is a 45-ft length vessel with twin diesels, a 12-ft beam, and 3-foot draft. This vessel is normally used to conduct hydrographic surveys federal navigation projects in the Houston, Galveston, Texas City, and Freeport areas. The multibeam transducer shown is side-mounted on temporary rigs near the

mid section of the vessel. The guys shown in the figure were used in attempts to reduce vibration down at the head—a more rigid frame near the waterline is required to fully stabilize a side-mounted transducer.

Figure 6-8. Louisville District 30-ft survey boat with through hull mounted transducer (Reson 8125-H multibeam system).

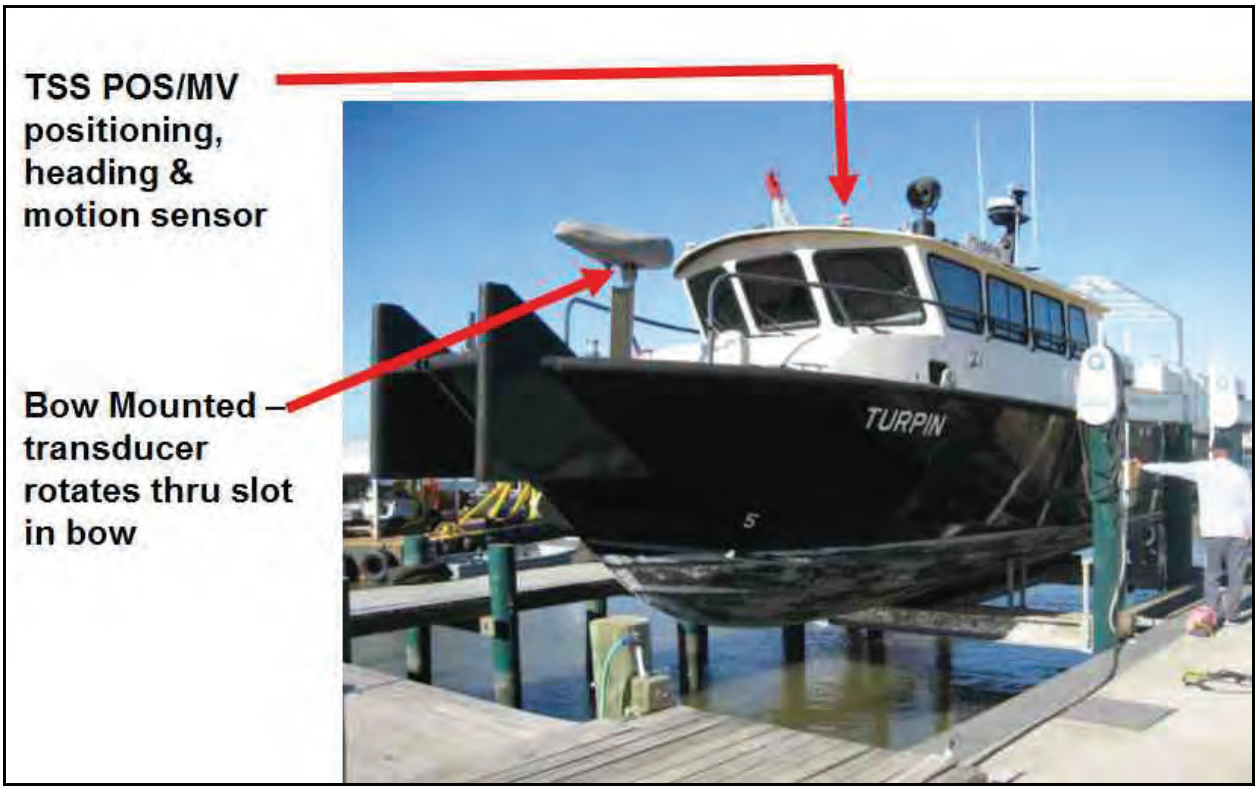


Figure 6-9. S/V Turpin with bow-mounted transducer.

Figure 6-10. Tulsa District retractable bow-mount. It is hydraulically deployed.

Figure 6-11. Bow-mounted transducer on an inflatable raft. This portable vessel is used for USGeological Survey multibeam surveys of the Colorado River in the Grand Canyon. It is manually deployed.

Figure 6-12. Bow-mounted transducer with an optional rigid (locking) tilt capability to providecoverage up to water's edge on revetments or lock & dam structures. This rigid tilt lock minimizes the need for Patch Testing at this optional setting. (St. Louis District S/V Boyer)

Figure 6-13. Typical multibeam transducer systems side-mounted on a rigid pole attached to the survey vessel. (Odom, Inc. and GeoAcoustics, Inc.)

Figure 6-14. Side mounted multibeam transducer on S/V Vollert. (Galveston District)

b. Portable side mount. Figure 6-15 illustrates a compact, lightweight multibeam transducer side-mount on a small vessel. The mount is attached to the hull in two places.

Figure 6-15. Side/aft mount of an Odom ES-3 transducer and inertial motion sensor. Mounting the GPS antenna directly above the transducer and motion sensor minimizes lever arm measurements and corrections.

6-20. Stern-Mounted Multibeam Transducers. Multibeam transducers can be mounted on the side near the stern or on the stern itself, as shown in Figures 6-16 and 6-17. Such mounting

locations are often temporary—i.e., installed on a "vessel of opportunity" on a one-time project. Lever arm corrections and vessel motion measurements may be significant at these locations, and require demanding quality control and quality assurance testing.

Figure 6-16. New England District survey boat with aft/side mounted multibeam system. The GPS positioning antenna is located directly over the multibeam transducer.

Figure 6-17. Temporary stern-mounted multibeam transducer on a small skiff. In this case, engine propeller noise did not appear to affect the data quality. (Portland and St. Louis District)

SECTION IV

Quality Control Procedures for Multibeam Systems

This section provides recommended technical guidance for performing system alignments and quality control calibrations of multibeam sonar systems used on Corps projects.

6-21. Background. Many field calibration requirements for multibeam systems are similar to those required for single beam systems described in Chapter 4. However, some calibration and quality control procedures for multibeam systems are more critical and demanding than those required for single beam echo sounders. Periodic, precise calibration and verification testing is absolutely essential in order to assure multibeam derived elevations meet the prescribed accuracy tolerances for the project--especially near the outer beams of the array where refractive ray bending and vessel alignment and motion variations can significantly degrade the data quality. With improved resolution and increased beam coverage, there is a greater need for accurate sensors to ensure that the recorded depth is reduced to its correct position on the sea floor. This is accomplished by interfacing the multibeam system with position and attitude sensors, such as: (1) a high accuracy, geodetic quality GPS system (including heading and attitude RTK systems), (2) inertial motion reference units to monitor changes in position, velocity, acceleration, heave, pitch, and roll, and/or (3) a gyrocompass. In addition, the time synchronization for all these components is critical. For this reason, the system accuracy is comprised not only of the multibeam sonar accuracy but also the various components that make up the total system.

a. The components that make up a multibeam system must be periodically aligned, calibrated, tested, and monitored in order to ensure overall data quality. Quality control calibration tests are performed to measure alignment and timing biases in the transducer head, inertial measurement unit, gyrocompass, GPS antenna, etc. These calibrations are prescribed to minimize errors due to time latencies, roll, heave, pitch, and heading for the integrated suite of equipment.

b. Quality assurance Performance Tests on multibeam data (covered in Section VI) are periodically performed to determine if the quality control calibrations have been reliably performed, or need to be repeated. A Performance Test will provide a statistical estimate of the data accuracy (or "repeatability"). The test results should be checked against the statistical accuracy criteria prescribed for the particular type of survey.

c. Procedures for performing these calibration tests are outlined in this section and are more fully detailed in the hardware and software manuals provided with the individual sensors making up a multibeam survey system. These include acoustic refraction measurements (i.e., velocity casts and bar checks), system latency calibrations (time variances between positioning, depth, and motion sensors), vessel motion and heading sensor calibration (roll, pitch, yaw, and heave sensors), and various other vessel alignment and coordinate/datum corrections. Many of these calibration requirements are critical--failure to perform adequate calibration may render a

survey invalid. Since many of the alignment and offset parameters are interrelated, failures at one level of test may require recalibration and/or retesting prior levels. Some calibrations are performed during initial equipment installation on the vessel; however, others must be performed on a more frequent basis--especially when dredging measurement and payment surveys are involved. It should be strongly emphasized that the software and procedures for calibrating, processing, editing, and thinning multibeam data are still being refined and will undergo modifications as new systems are acquired and performance is validated.

6-22. Initial Installation Alignment and Static Offset Measurements. Alignment and offset parameters must be measured for the various sensors making up the multibeam system, e.g., MRU and gyroscope alignment/offsets, transducer mounting angles/offsets, GPS antenna offsets, static and dynamic drafts, vessel settlement/squat, and estimated latencies. These measurements are made upon initial installation or upon replacement, removal, and reinstallation of a sensor. Alignment and offset corrections are entered in the software system setup modules.

a. Static offsets of the sensors (Lever Arm measurements). These are the distances between the various sensors and a designated reference point on the vessel (Figure 6-18). This entails physical measurement on the vessel platform--locating the relative X-Y-Z coordinates of the multibeam transducer, GPS antenna(s), gyrocompass, MRU sensor, POS/MV system, etc. These measurements should be performed with the vessel stabilized on a trailer or on blocks where more exact, stable measurements can be made. A total station and/or tape are used to obtain the measurements. The sensors should be measured from a reference point in the vessel. (On cutter suction and excavator dredges, the origin should be established at the trunnion point). This point is typically the center of gravity or the intersection of the pitch and roll axis. The center of gravity will change with varying load conditions of the vessel and thus must be chosen to represent the typical conditions while surveying. On large stable vessels, the center of gravity will slightly change vertically along an axis that contains the center of buoyancy. On smaller vessels, the center of gravity and the center of buoyancy may not be exactly aligned due to eccentric loading. This condition is to be avoided as it also contributes to the instability of the vessel itself. This information can be obtained from the blueprints of the vessel. This reference point (now the coordinate system origin) should be a place which is easily accessible and from where measurements to the sensors will be made. The coordinate system should be aligned with the x-axis along the vessel keel (positive forward), the y-axis abeam the keel (positive to starboard), and the vertical (z-axis) positive down. The offsets of the sensors are measured from the reference point to the center of the sensor. The center of the sensor can be found in the manufacturer's schematic for the sensor, or can be accurately measured with a tape. It is common for the acoustic and physical centers of a multibeam transducer to be in different places. The magnitude and direction of the measurement should be verified and recorded.

b. MRU sensor. If possible, the inertial MRU sensor should be placed on the centerline of the vessel, as close as possible to the center of gravity or the intersection of the roll and pitch axes of the vessel. If the MRU is offset from the keel, it should be accurately aligned parallel to the keel. Mounting MRUs on bow or side mounts is not recommended due to potential heave correction issues. The x-axis of the MRU should ideally match the x-axis of the transducer;

however, this is not always feasible on over-the-side mounts. Azimuthal misalignment of the MRU will result in the depth measurement being in error proportional to the water depth. Misalignment of the MRU sensor in yaw causes a roll error when pitching, and a pitch error while rolling.

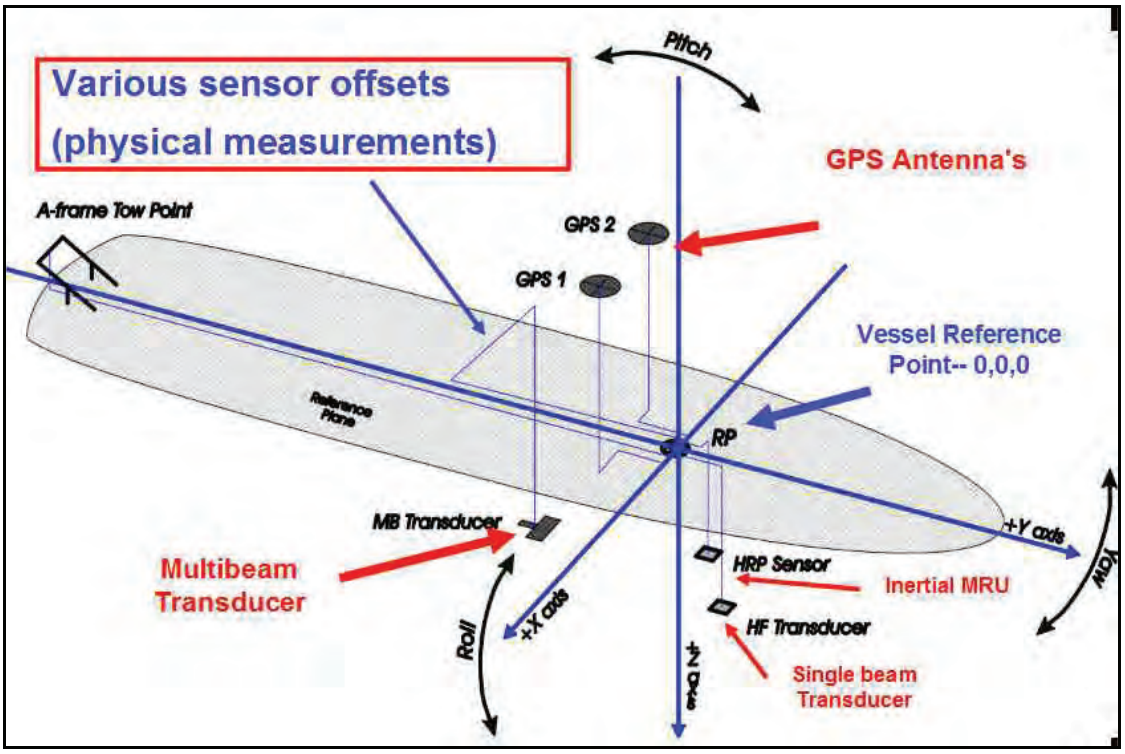


Figure 6-18. Lever arm offsets between various sensors on a survey vessel.

(1) MRU resolution. MRU system accuracy must far exceed the alignment resolutions of the orientation parameters in the vessel system. Thus, if the roll orientation has been calibrated by a Patch test and is believed accurate to ±0.1 deg, then the MRU sensor should have an accuracy to better than, or at least, this same level of accuracy. Most higher-end MRUs can achieve these accuracies.

(2) References. Refer to the "IHO Manual on Hydrography," (IHO 2005) for descriptions of the error magnitudes caused by roll, pitch, and yaw misalignments. If the transducer and MRU are collocated, many alignment corrections become far less critical.

c. Multibeam transducer. The multibeam transducer should ideally be installed as near as possible to the centerline of the vessel and level about the roll axis. However, in practice, the transducer is usually offset from the keel by varying amounts, and may be forward or aft of the center of gravity (e.g., side mounts, bow mounts, twin catamaran hull mounts, etc.). The transducer should also be precisely aligned with the azimuth of the vessel. The depth of the transducer head below the waterline of the vessel must also be determined. As in single beam

systems, bar checks are performed to measure static draft variations, which may include a constant index error that would not be detected if only a physical measurement were made. Likewise, squat/settlement tests are performed to calibrate dynamic vessel variations. Longer-term fuel loading draft variations must also be monitored.

(1) With the over-the-side types of transducer mounts, it is imperative that the azimuthal alignment between the transducer and keel be as close as possible. This can be accomplished with the vessel on a trailer or blocks. Since this side mounted technique allows for raising the transducer at the end of each day of operations and lowering it at the start of the next day's survey, this type of mount should be periodically checked for any alignment changes. The frequency with which it is checked will depend on what type of surveying is performed and under what conditions. Hull mounted or retractable transducers are generally fixed (or rigidly lock) in place and will not need to be checked as frequently.

(2) The fore-and-aft angle of the transducer mount must be evaluated. Since most vessels underway will be lower in the stern, the transducer will generally need to be rotated slightly aft to compensate for this angle. The Patch Test (pitch) will check for this transducer angle. The resulting beam should ideally project nearly normal to the sea floor while conducting surveying operations.

d. Gyroscope heading. The gyroscope should be aligned with the x-axis of the vessel using an electronic total station and geodetic control points. This can be done with the vessel on a trailer or secured tightly against a pier where there is minimal wave action. The gyro should be warmed up and, if necessary, the proper corrections for latitude applied. Locate two points on the centerline of the vessel and position a target on each of them. Observe the two targets with the total station and synchronize the readings with the gyro readings. Several readings will be needed for redundancy. Compute the vessel's azimuth and compare with the gyro readings. Compute the mean and standard deviation of the readings. If the offset is more than 1 deg at the 95% confidence level, realign the gyro with the centerline and repeat the observations. If less than 1 deg, apply the correction to the gyro output. The processing may take longer than with the total station. (Use of a dual antenna CodaOctopus F180/190 or Applanix POS/MV orientation systems eliminates the need for gyro azimuth control.)

e. Positioning time delay (Latency). Time delay in the positioning is the time lag between the time positioning data are received and the time the computed position reaches the logging module. This results in a negative along-track displacement of the depth measurements. While surveying at slow speeds, this displacement will be small. In general, the processing time for the position will vary with the number of observations used in the final GPS solution. If the time imbedded in the GPS message will be used, then you must ensure the correct synchronization between this time and the transducer or signal processing clock. A Patch Test (described below) is performed to determine a constant latency correction.

6-23. Vessel Squat/Settlement, Draft, and Datum Variations.

a. Squat/Settlement measurement. The combined squat and settlement of the vessel should be measured at several speeds and a look-up table produced for correcting the transducer draft. This measurement is essential since a MRU will not measure the long-term change in elevation. A MRU heave sensor will record the sudden change in elevation but the measured heave will drift back to zero. The settlement can be measured with a level on shore and a 2- m level rod or stadia board on the vessel positioned over the MRU sensor. The vessel should make several passes at various speeds in front of the shore station and the rod elevation recorded. The elevation difference at each speed is noted and used as the draft correction while surveying. Ensure that the correct sign is applied when entering the correction in the software. (Refer to Chapter 4 for details on performing these measurements.)

b. Squat/Settlement measurement using RTK. An alternate method for determining squat/settlement makes use of carrier-phase RTK elevation difference measurement. This method is also described in Chapter 4.

c. RTK water surface elevation determination. If precise RTK is being used as an absolute elevation reference correction for the multibeam transducer, then there is no requirement to enter in a squat/settlement correction. Likewise, tide/stage data and dynamic draft corrections may also be eliminated. However, if RTK is used only to determine the tide/stage level, then squat and draft measurements must be input to the processor.

d. Short term dynamic draft measurements. Changes in vessel draft due to fuel or loading changes should be monitored throughout the day, and depth corrections applied if trim variations are significant. These procedures are identical to those described for single beam surveys. Heave corrections output from RTK and/or MRU systems must be monitored to ensure long-term sea swells or vessel turns do not bias the data.

e. Reference datum checks. Vertical datum NSRS/NWLON referencing requirements and calibration methods are described in ER 1110-2-8160, Policies for Referencing Project Elevation Grades to Nationwide Vertical Datums, and EM 1110-2-6056, Standards and Procedures for Referencing Project Elevation Grades to Nationwide Vertical Datums. RTK water surface elevation measurements should be checked at a NSRS or NWLON based staff gage at minimum twice daily. Tolerances should be within the ±0.1-ft range. With current RTK and RTN networks, this represents more of a blunder check that a calibration. Such a check becomes more critical when a local RTK base station is used. Horizontal position checks should also be periodically performed at a known control point, if available. However, when using RTK, a quick comparison with a local code DGPS network is usually adequate for a horizontal blunder check.

6-24. Patch Test (Residual Bias Calibration). Patch Tests are periodically performed to quantify any residual biases in the initial alignment measurements of the sonar head, MRU, and/or gyroscope. The Patch Test is a series of reciprocal lines run at varying speeds, depths, and

bottom terrain in a small test area. It must be performed carefully and repeatedly to ensure that subsequent survey data collected is accurate and reliable. The Patch Test determines the vessel orientation alignment corrections for (1) positioning time delay or latency, (2) pitch, (3) roll, and (4) azimuth/yaw. The determined angular offsets and time delays will be used to correct the initial misalignments; thus, calibrating the sensor orientation system between each component and the vessel.

a. References. Detailed procedures for performing Patch Tests are covered in data collection software manuals, e.g., HYPACK and Caris. Multibeam system vendors also provide guidance on performing Patch Tests (e.g., see R2Sonic Operation Manual—R2Sonic 2010). Position and depth errors due to sensor and Patch Test calibration misalignments are detailed in Chapter 3 of the IHO Manual on Hydrography (IHO 2005). The procedures outlined below are extracted from these references. (Note that there are varying opinions among manufacturers regarding the sequencing of Patch Tests.)

b. Patch Test survey procedures. Reciprocal survey lines are run for each of the four Patch Test components, as shown in Figure 6-19.

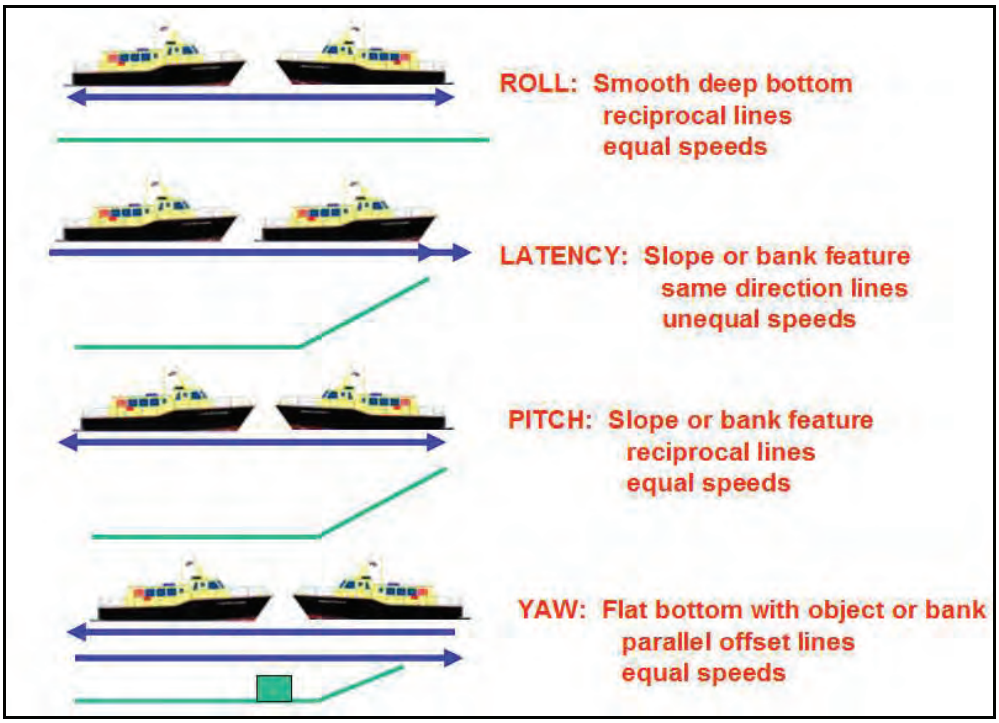


Figure 6-19. General overview of Patch Test runs. Refer to software operating manuals for details.

(1) Test site conditions. The weather and sea states should be calm to ensure good bottom detection and minimal vessel motions. Since most of the test lines to be run will be

reciprocal lines, it is important to have capable vessel steering and handling. Running on slack tides and slow currents is recommended. The lines should be run in deep water since the test results are less reliable in shallow water. The order in which the test lines are run is not important although it is recommended that at least two sets of reciprocal lines for each test be run for redundancy. Vessel speed should be regulated such that 50% forward overlap is obtained.

(2) Positioning. At minimum, survey quality code phase DGPS positioning must be used when conducting the Patch Tests. However, it is strongly recommended that carrier phase (RTK) positioning be used to perform these tests. This is because horizontal positioning accuracy has a significant impact on the repeatability of Patch Test results. For example, a 3-ft difference in DGPS positions during a test can cause a 0.4-sec latency variation and a 4-deg variation in pitch/yaw. Variations of this magnitude will not yield acceptable Patch Test calibration consistencies.

(3) Positioning time delay test and pitch bias test. Two pairs of reciprocal lines are run at different speeds to check for biases in both positioning time delay (latency) and pitch bias. Latency is determined from runs made over the same line in the same direction, but at differing speeds. (Both of these biases may exist simultaneously and must be discerned and separated during the test data processing.) These lines should be run in an area with a smooth, steep slope—10 deg to 20 deg, if possible. The slope should ideally be at least 200 m long in order to obtain good samples. A channel side slope may have to suffice if no other relief is available. At least two pairs of reciprocal lines should be run both up and down slope, at velocities differing by at least 5 knots to best assess the time delay. The greater the difference in velocity, the more accurate the test. Pitch is determined from the runs made over the same lines at the same speed in opposite directions.

(4) Roll bias test. In an area of flat topography, run at least one pair of reciprocal lines approximately 200 m in length to test for roll biases. Roll bias will best show up in deep water. Depending on the type of multibeam system, these lines should be run at a speed to ensure significant forward overlap of the beam's footprint. The beam width can be found in the manufacturer’s specifications.

(5) Azimuth (Yaw) offset test. At least two adjacent parallel pairs of reciprocal lines shall be run normal to a prominent bathymetric feature such as a shoal or channel side slope, in shallow water. Do not use a feature with sharp edges such as wrecks since there is more ambiguity in the interpretation. The adjacent lines should have an overlap of about 15% and the feature should be wide enough to ensure adequate sampling. This width is generally greater than three swath widths. These lines should be run at a speed to ensure significant overlap of the beam forward footprint--use the same equation as that for roll bias.

c. Patch Test data processing and adjustment. Numerous survey software routines have been developed to automatically calculate system latency, roll, pitch, and yaw biases in

multibeam systems, using best-fit image matching techniques. The adjustment procedure outlined below uses the entire data set collected from the Patch Test lines with minimized thinning. Visualization of the data is important. In addition, the position and attitude data should be checked for errors, especially noting the time-tag errors. Cleaning of the bathymetry is usually not necessary since individual soundings will not be adjusted but rather clusters of data points will be analyzed.

(1) Processing sequence. The procedures to process the Patch Test data should be in this order: (1) latency, (2) roll, (3) pitch, and (4) yaw. Latency is processed first and the bias value entered into the software. Processing of the remaining three parameters is an iterative process, in that same order. This is due to the interrelationships between the parameters.

(2) Positioning time delay (latency) bias. This delay is computed by measuring the along-track displacement of soundings from the pair of coincident lines run at different speeds over the steep slope or other prominent topographic feature. Lines run in the same direction should be used to avoid the effect of pitch offset errors. The survey lines are processed, plotted, and compared while assuring that no corrections are made for positioning time delay, pitch error, roll error, and gyro. The time delay is then averaged by getting several measurements of the displacement in the along-track direction. This process is performed iteratively until the profiles and contours match or achieve a minimum difference. The latency bias is applied before the remaining biases are tested. This should actually be an average of biases from repeated latency tests. Note that latency biases are (should be) zero (0) when UTC time-tagged GPS positioning systems are used.

(3) Pitch offset bias. The pitch offset bias is determined from the two pairs of reciprocal lines run over a slope at two different speeds. The important characteristic of pitch offset is that the along-track displacement caused by pitch offset is proportional to water depth. Thus, the deeper the water the larger the offset. Pitch bias errors will impact both the depth and its position. The lines are processed while only applying the positioning time delay correction and the static offsets of the sensors. The pitch offset is then averaged by taking several measurements of the displacement in the along-track direction. This process is performed iteratively until the profiles and contours match or reach a minimum difference.

(4) Roll offset bias. Roll bias is computed using the pairs of reciprocal lines run over a flat, deep area. Generally, this offset is the most critical in deeper water and should be carefully measured. Roll errors directly induce errors in depth measurements, especially in the outer beams. The roll offset is averaged by several measurements of the across track displacement along the test swaths. This process is performed iteratively until the profiles and contours match or achieve a minimum difference.

(5) Azimuthal (Yaw) offset bias. Parallel lines run normal to a bathymetric feature will be used for the measurement of the azimuthal offset. Errors in azimuth alignment cause positional errors in the depth locations. One pair of adjacent lines run in opposite directions is

processed at a time to remove any potential roll offset. The azimuthal offset is averaged by several measurements of the displacement over the feature and knowing the across-track distance at the location of the measurements. This process is performed iteratively until the profiles and contours match or achieve a minimum difference.

d. Patch Test repeatability and resolution. Due to various positioning accuracies, MRU resolutions, poor feature recognition, shallow depths, terrain variations, etc., the numerical result from an image match on a Patch Test parameter can have a high uncertainty. For example, repeated Pitch and Yaw Tests may vary by ±1 deg or more. Roll biases are usually more repeatable, typically at the 0.1-deg to 0.2-deg levels. Likewise, latency repeatability is usually at the 0.1 sec level. Therefore, Patch Tests must be performed over different conditions and times in order to arrive at an average, longer term, correction for each parameter. For example, if the average of 20-yaw bias tests are performed over a year's time is 3.1 deg, and the standard deviation of all these tests is ±0.4 deg, the repeatability of the tests is only about a half degree. However, the "standard error of the mean" of the long-term (20-test) average is ±0.1 deg. Thus, the long-term average yaw bias value of 3.1 deg has a confidence of about ±0.1 deg. Its "resolution" or long-term "estimated accuracy" is to the nearest 0.1 deg A minimum of 10, and preferably more, Patch Tests should be performed to obtain reliable average biases. A log of these repeated tests should be maintained on the vessel. Obviously, and changes or modifications to the sensors requires a restart of this accumulative averaging process.

e. Automated Patch Test. Figure 6-20 depicts screen displays of automated Patch Test residual bias computations in HYPACK. See the “HYPACK Hydrographic Survey Software User Manual,” (HYPACK 2011) for additional details on running these calibration tests. The results are input directly into the real-time processing system. Additional examples of Patch Tests from Philadelphia District are shown in Appendix F.

f. Frequency of Patch Tests. Patch Tests are always required at the initial installation of a multibeam system on a vessel. After initial installation, or after any equipment modifications, more frequent Patch Tests should be performed to verify the consistency of the computed residual biases, and to establish a long-term averaging trend for each bias as discussed above. Depending on the stability of the transducer mount, and the consistency of long-term averages, subsequent tests may only need to be periodically performed. Specifying "periodically" is problematic. Fixed-hull and rigid retractable mounts in moon pools will usually be stable and the Patch Test residual biases are not as likely to vary. Thus, monthly or quarterly checks may be adequate. If repeated Patch Test bias results are not consistent, or Performance Test results are outside tolerances, then more frequent tests are recommended, along with determining the source of the inconsistencies. When a critical dredge measurement and payment survey is begun, a Patch Test is recommended, if only for the record. Patch Test results, as with all other survey calibration tests, should be recorded in a bound survey book maintained aboard the vessel.

6-25. Velocity Measurements. As in single beam systems, the velocity of sound in the water column must be accurately measured. However, in multibeam systems, velocity measurements

are significantly more critical due to the effects of refraction ("ray bending") in the outer beams (Figure 6-21). Changes in sound velocity throughout the water column require corrections to each beam in the array for refraction. In addition, many beamforming systems require continuous velocity measurements directly at the transducer head in order to steer the beams.

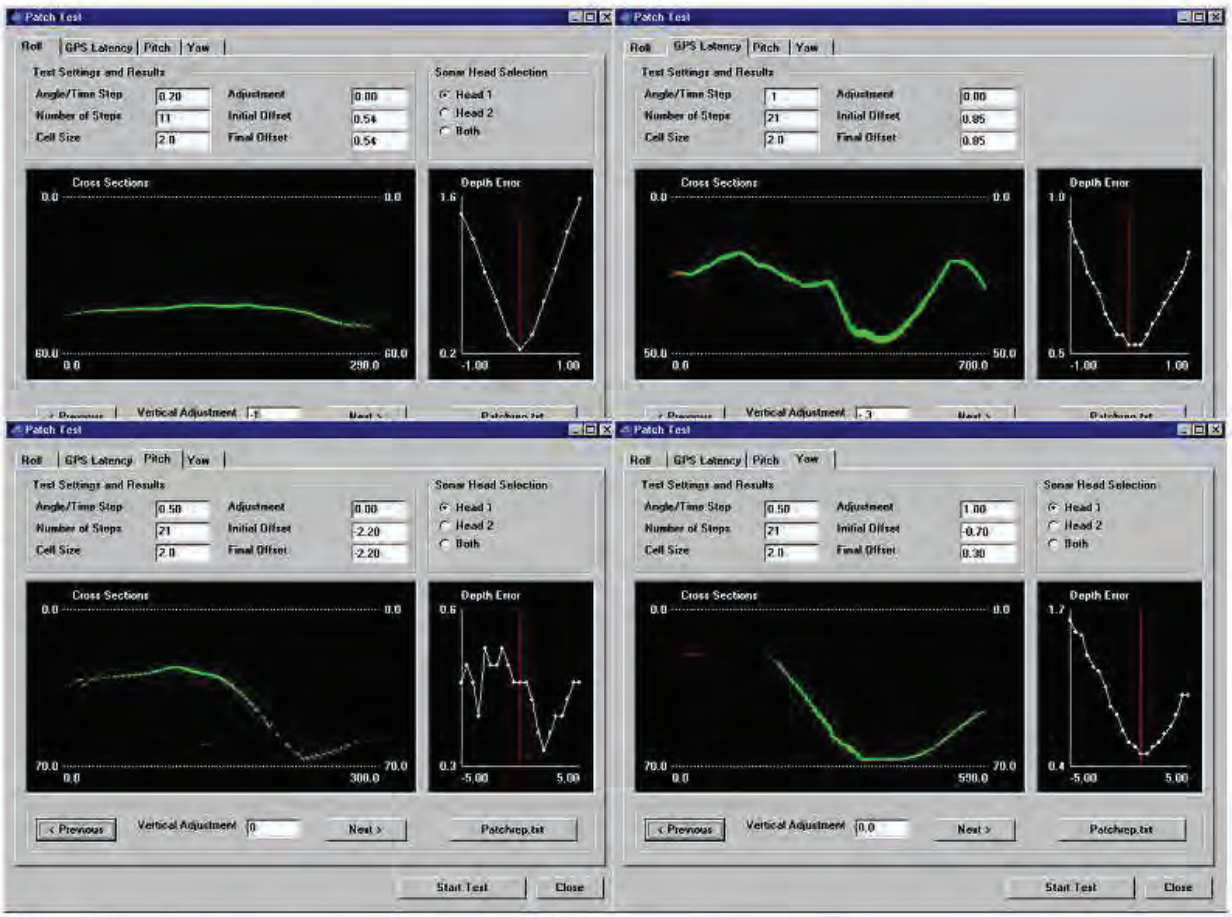


Figure 6-20. Automated Patch Test parameter computations--roll, latency, pitch, and yaw. Note that roll and latency tests on the top row provide the highest image matching resolutions. Pitch and yaw resolutions (bottom row) are typically coarser. (HYPACK, Inc.)

Since sound velocity in the water column can vary spatially and temporally, improper or inadequate determination of sound velocity corrections can often render multibeam data unusable. Velocity calibrations should be performed periodically during the day, no less than twice per day, and at more frequent intervals or locations if physical changes in the water column (e.g., temperature, salinity) are affecting data quality. This frequently occurs at coastal entrances or near power plant outfalls. In some areas, such as in Southwest Pass, LA, extreme salinity and temperature variations may require velocity observations every quarter-mile or closer (Figure 6-22). The quality of velocity data may be subsequently assessed through use of the "Performance Test" which compares overlapping survey data models. Beam angles should be reduced if

velocity data and/or Performance Tests indicate uncertainty (i.e., excessive repeatability or bias) in outer beam depth measurements. Velocity profile data is entered into the survey data acquisition system, typically in real-time during the survey.

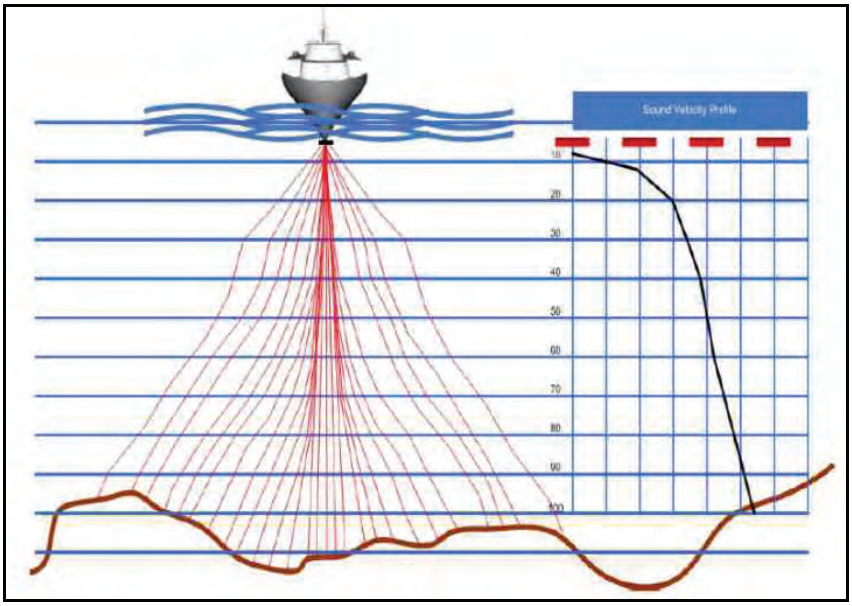


Figure 6-21. Outer beams are refracted due to varying sound velocities in the water column. These refractions on each beam must be corrected to obtain the location and depth at each point on the bottom. (R2Sonic)

6-26. Vessel Draft and Index Measurements (Bar Checks). As in single beam systems, a bar check represents the "reference quality control standard" by which multibeam echo soundings are ultimately calibrated. Upon initial installation, and periodically thereafter, a traditional bar check should be performed to calibrate the multibeam draft and index corrections and verify velocity corrections (from velocity meter casts) are accurate. The frequency of this calibration is a function of the repeated results, the stability of the system, and the nature of the survey. If periodic bar checks verify the draft/index corrections are holding constant, then less frequent checks are needed--perhaps every few months. Multibeam bar checks are performed similarly to single beam bar checks described in Chapter 4. It must be recognized that the acoustic reflectivity properties of a bar will differ from those of the bottom, which could inject a bias into the calibration. Some USACE districts have coated the check bar with foamed material in attempts to more nearly simulate bottom reflectivity conditions.

a. Nadir beam bar checks. Because of possible ray bending due to velocity changes, bar checks are typically performed under the center beams to quantify any draft or index errors in the system. As stated above, these need only be done on an infrequent basis, depending on the long-term stability of the results. This calibration is identical to that performed for single beam transducers. Figure 6-23 depicts a typical bar check over a portion of the multibeam array.

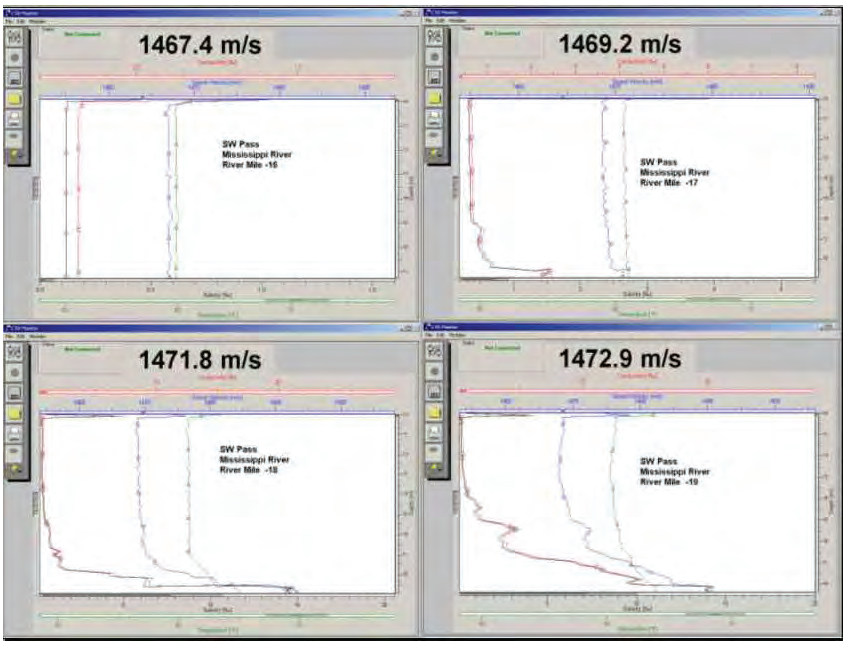


Figure 6-22. Typical conductivity/salinity, temperature, and depth (CTD) profiles at Southwest Pass, Mississippi River. Velocity profiles are shown to vary significantly over a relatively short distance (River Miles 16, 17, 18, and 19). (St. Louis District)

b. Outer beam bar/plate checks. The New York District has developed a quality assurance procedure whereby a small bar or single-line plate can be lowered from either side of the boat to perform a "blunder" or "confidence" check on the recorded multibeam data in the outer beams. Such a check can be quickly performed before or during each survey. Any portion of the multibeam array that is picked up can be used. Although not intended to definitively calibrate draft/index values like a bar check, this check will reveal gross biases. If biases exist between the plate/bar depth and the multibeam depth, then additional tests should be performed to determine the cause of the bias. It is recommended that this type of "blunder" check should be performed before each critical payment survey.

6-27. Beam Width Restrictions on Multibeam Systems. The coverage of multibeam systems is a function of swath width and water depth. Most systems provide coverage of two to approximately seven times the water depth. The number of individual beams (and footprint size) within the swath array varies with the multibeam manufacturer and operating principle. As outlined in previous paragraphs, the outer beams on each side of the swath are subject to more corrections and may not be useful for most dredging and navigation applications. The maximum angular extent of coverage must be verified, and accordingly restricted, by conducting some form of independent Performance Test. Thus, maximum allowable beam limits should be based on a Performance Test to verify the adequacy of the entire array. This beam array limit is typically determined from the HYPACK Performance Test software statistics, and is measured at the angular point where repeatability (bias) between the observed and reference data set exceeds

a prescribed tolerance for the project. Depending on various factors, primarily velocity and bottom reflectivity variations, it may be necessary to restrict beam widths to less than the measured limits in the Performance Test.

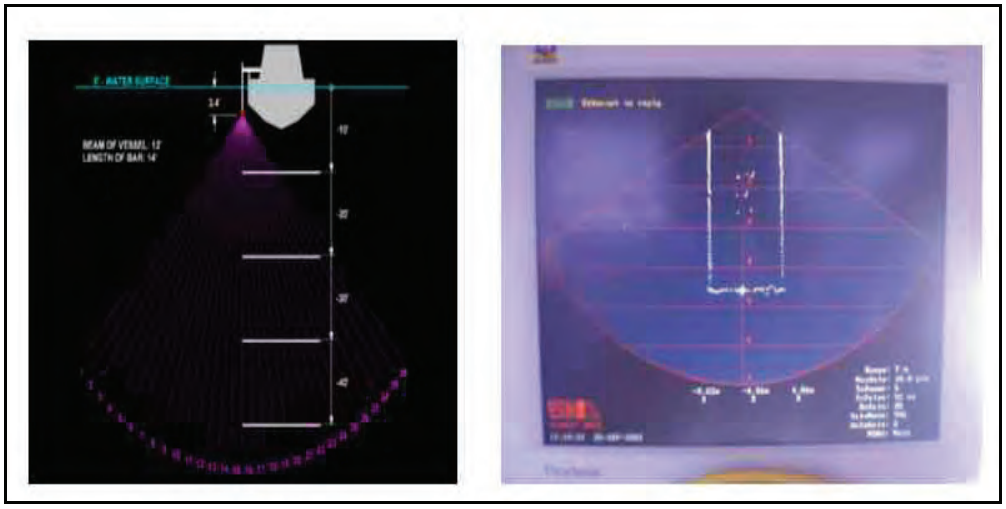


Figure 6-23. Bar check of a multibeam system. (Galveston District)

SECTION V

Multibeam Survey Data Collection, Editing, and Processing

Multibeam data are collected using commercial hydrographic survey software platforms, the most common in USACE being the HYPACK "SURVEY"software platform—see HYPACK 2011. Equipment configuration and line planning procedures are similar to those outlined for single beam surveys in Chapter 4. The main difference is that multibeam surveys may have more peripheral sensors to interface with the controller. This section provides a general overview of the collection and processing actions required for multibeam survey data.

6-28. Determining Coverage and Overlap. Most multibeam surveys are designed to obtain 100% bottom coverage (ensonification). Based simply on the project depth and beam array limit, a rough line spacing can be estimated. For example, with a 90 deg array in a 40-ft project, the line spacing is roughly 80 ft, not allowing for any off track steering. Using a nominal line spacing, survey coverage is performed by visually "painting the screen" or "mowing the grass" on a real-time screen display. The helmsman can then return back to fill in any gaps in the coverage.

a. Overlap. A survey line spacing may be computed to provide for a specified overlap between lines. This may help reduce gaps due to off track steering alignment. Alternatively, a line spacing it may be specified in order to obtain double acoustic coverage over the channel bottom. The multibeam line spacing ("L") and the number of longitudinal run lines ("N") for a typical navigation project can be computed using the methods shown in Figure 6-24. The depth

("d") is the average project depth. The sidelap ("s") should be set to the desired overlap between the parallel multibeam lines. Sidelap is intended to compensate for survey line steering limitations and/or duplicate coverage requirements. A 50% sidelap would provide duplicate (200%) bottom coverage if there were no steering misalignment. For a project condition survey where coverage is only required between the channel toes, a small sidelap allowance (e.g., 5 of 10 ft) may be made for vessel steering misalignment. As depth decreases up the side slopes, line spacing needs to be increased; however, only 100% coverage is normally required on side slopes.

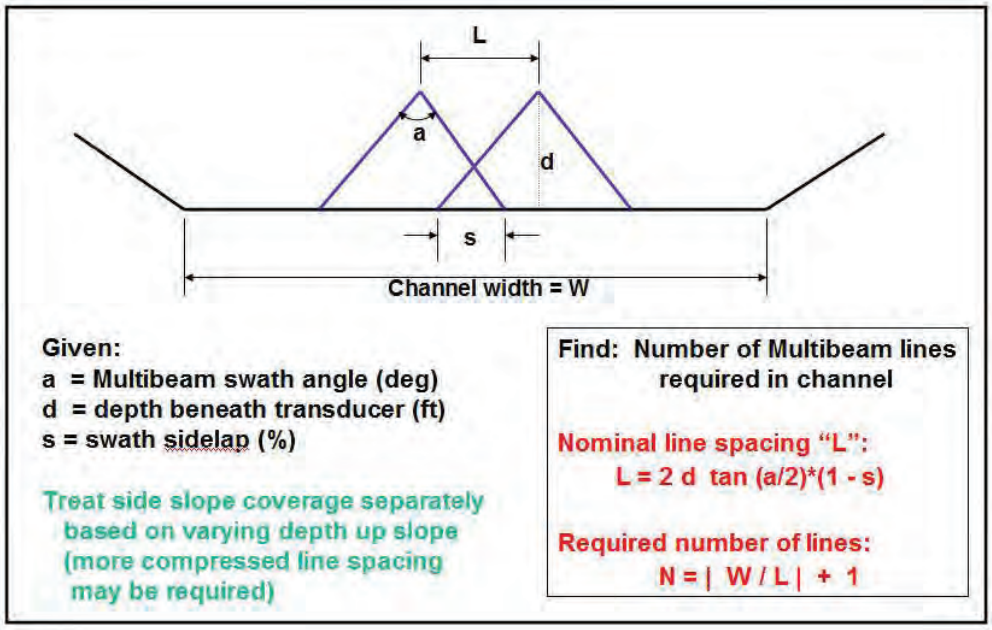


Figure 6-24. Computing multibeam line spacing on a navigation project given array width, project depth, and overlap requirements.

b. Example. The following examples illustrate line spacing computations for multibeam surveys:

Given: Project Condition Survey of 40- x 400-ft channel
(no coverage of side slopes required)
10% overlap between multibeam lines
a = 150-deg multibeam swath angle
d = 40-ft project depth
s = 10%
at 10% overlap, s = [2d tan (a/2)] · 10%) = 30 ft
Line Spacing: L = 2d tan (a/2) · (1-s) = 2 · 40 · tan (75 deg) · (1 - 0.1) = 269 ft … 270 ft
Number of lines: N = | 400 / 270 | + 1 = 2

Since the two lines easily cover the channel area, they would be spaced to provide overlap along the toes and with each other. If a 20-ft steering accuracy were assumed, then the two lines would

be run along channel offsets (+) 85 ft and (-) 85 ft from the centerline. The line spacing in this case would only be 170 ft, resulting in considerable overlapping coverage in the channel center plus a 20-ft tolerance outside the toes. Running offsets + 100 ft would be adequate for this coverage as well. If, in the above example, a more realistic 120 deg multibeam array were used, then the line spacing would be reduced as follows.

Line Spacing: $L = 2d \tan(a/2) \cdot (1-s) = 2 \cdot 40 \cdot \tan(60 \text{ deg}) \cdot (1 - 0.1) = 125$ ft

The number of lines required to cover the channel between the toes is:

Number of lines: $N = | 400 / 125 | + 1 = 3 + 1 = 4$

If the multibeam array were restricted to 90 deg, as might be the case in a pre/post dredging survey, then the following line spacing would result for the same project:

Line Spacing: $L = 2d \tan(a/2) \cdot (1-s) = 2 \cdot 40 \cdot \tan(45 \text{ deg}) \cdot (1 - 0.1) = 72$ ft … use 75 ft

The number of lines required to cover the channel between the toes is:

Number of lines: $N = | 400 / 75 | + 1 = 5 + 1 = 6$

If duplicate coverage were required for this project, the sidelap would be increased to 50%, resulting in the following line spacing:

Line Spacing: $L = 2d \tan(a/2) \cdot (1-s) = 2 \cdot 40 \cdot \tan(45 \text{ deg}) \cdot (1 - 0.5) = 40$ ft

Number of lines: $N = | 400 / 40 | + 1 = 10 + 1 = 11$

The above computation is based on coverage between the channel toes. Additional lines may be required for side slope coverage. From the computed number of lines, an estimate of total lineal multibeam survey miles can be estimated. Given known survey speed, daily plant rental and crew rates, and mob/demob data, the time and cost to conduct the overall survey can be estimated.

6-29. Editing and Processing Multibeam Data. Collected multibeam data is processed and edited on a variety of commercial platforms and software packages. The most common platform used in the Corps is the HYPACK "HYSWEEP EDITOR." This editor operates similarly to the single beam editor described in Chapter 4. Multibeam array depths are time-tagged with the positioning and motion sensors, corrected for water velocity, refraction, draft, lever arm, and dynamic draft variations. This section provides only a brief overview of the "HYSWEEP EDITOR" process—refer to the HYPACK software "User Manual" (HYPACK 2011) for details on editing and processing multibeam data.

a. The data flow through the "HYSWEEP EDITOR" is shown in Figure 6-25. Multibeam processing is done in three phases:

Phase I: Review and edit data collected from various sensors, such as inertial motion, DGPS, RTK, velocity, various constant sensor corrections, and vessel track lines for overlap.

Phase II: Perform detailed review and edit of each sensor and sweep depth data. Sweep data are reviewed section by section. Various filtering options are employed to speed up editing.

Phase III: Grid cell matrices ("bins") are developed and a final review and edit is made. Output to user requested CADD or GIS format.

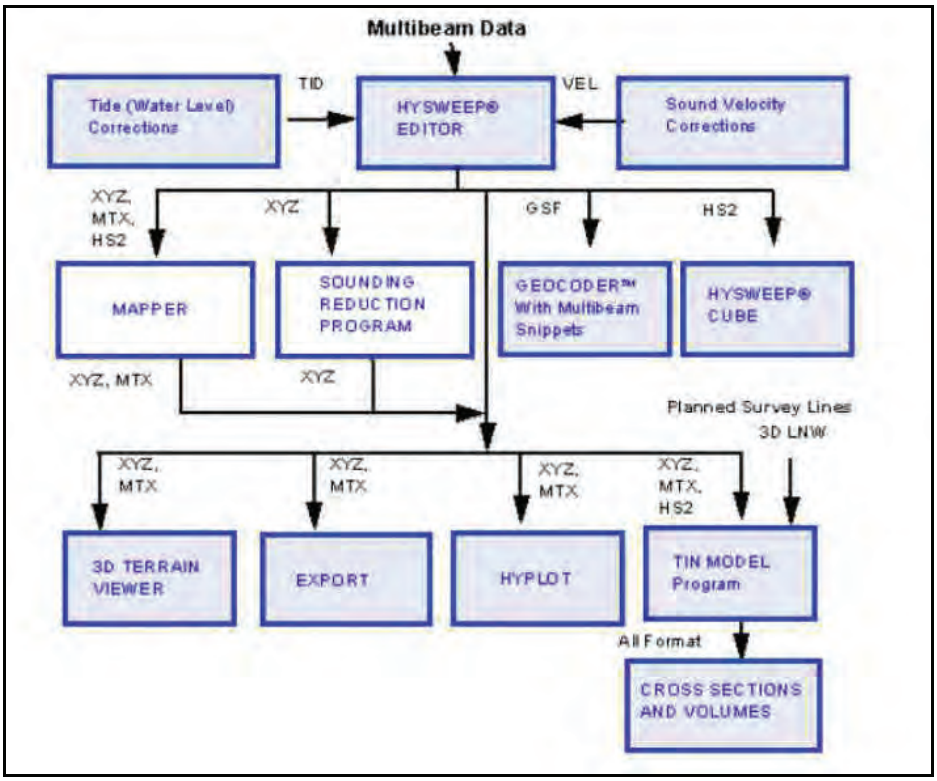


Figure 6-25. Multibeam data processing flow in HYPACK.

b. Generally, Phase I is performed aboard the survey vessel before the data are transmitted to the District Office. Phase II editing may be performed in the field or district office. Phase III is performed in the district office.

6-30. Editing and Filtering Data. Multibeam data typically contains many noise "spikes" that must be edited out of the database. Filtering and editing can be done in real-time, in post-

processing, or in combination. Manual spike editing can be performed by viewing each ping's cross-section and editing out spikes from individual beams—a labor intensive process given 40 cross-sections/sec may have been collected. More commonly, a block dataset is viewed in 3D form and data spikes are edited out manually in the 3D model. This is still a labor-intensive process. Automated spike or data anomaly filtering can also be performed. Such "intelligent" filtering is usually based on setting up maximum data quality or magnitude changes. During this automated filtering process, data can also be thinned if desired. Given the increasing densities of collected multibeam data, coupled with requirements for small bin sizes, smart use of automated filtering and editing has become a practical way to process these large datasets. However, these automated filtering and editing routines must be used with caution in that valid strikes above grade may be erroneously eliminated.

6-31. Thinning and Binning Multibeam Datasets. In theory, there is no need to reduce the size of the collected multibeam dataset. The entire "raw" database could be used for project or dredging condition assessment, volume computations, etc. However, these large datasets are thinned for a number of reasons, such as: (1) plotting in plan view without sounding overlap, (2) dredge volume computations, (3) channel clearance strike plots, (4) controlling channel depth reports, (5) 3D visualization models, or (6) simply to reduce the data down to a manageable storage size. There are a number of methods for reducing (or thinning) the size of large, edited multibeam datasets. For basic terrain visualization requirements (i.e. non-navigation uses), various thinning routines have been developed that can reduce datasets by 95% or more; typically selecting representative depths based on gradient changes over large areas. In current USACE practice, multibeam datasets are thinned into a fixed matrix or grid cell during the "Phase III" editing process. The size of the matrix cell is selected based on terrain irregularity, dredge volume computation requirements, or to prevent overplotting adjacent depths.

6-32. Recommended Bin Sizes and Depth Selection for USACE Navigation Surveys. The following paragraphs contain guidance on bin sizes and depth selection for all types of navigation surveys, to include: dredging measurement and payment surveys, dredge clearance/acceptance surveys, plans and specifications surveys, project condition surveys, and other related navigation surveys. This guidance is based on over 10 years of collective multibeam data processing experience by the districts within the North Atlantic Division. Designated bin sizes for a project should be included in dredging contract specifications. These same criteria are also applicable to multiple transducer sweep systems.

a. Recommended maximum bin size. For new work deepening projects, a maximum 3-ft x 3-ft cell size is recommended. On critical projects (e.g., rock) a 1-ft x 1-ft cell size may be used. For maintenance dredging of soft material, a maximum 5-ft x 5-ft cell size is recommended. Evenly spaced grid matrices should be generated over the full dataset relative to an established (fixed) origin point to ensure that different organizations (or software) processing the same edited dataset will obtain identical results--e.g., dredged quantities.

b. Other civil works surveys. There is no specified maximum bin size or depth selection method for other types of non-navigation surveys. Bin sizes may be varied depending on the

type of bottom or purpose of the project (e.g., beach sand transport studies, hydraulic studies) or final plan plot scale. In smooth, flat areas, bin sizes may be expanded to any level that will adequately depict the terrain. Bin sizes as small as 1-ft sq may be used for applications where maximum detail is required--e.g., underwater structure surveys or Performance Test Reference Surfaces. Instead of binning, more efficient data thinning methods may be used to generate a TIN model for 3D analysis.

6-33. Depth Selection Options from Binned Multibeam Data. Each bin (or cell) will likely contain multiple depths, depending on the density of the multibeam data and the number of overlapping passes made over the area. It is not uncommon for a 3- x 3-ft cell to have 50 or more depths if multiple passes were made over a suspected shoal area. Thus, an established method is needed to represent the depth within this bin. Presently, common selection options include: (1) a shot depth nearest to the bin center, (2) an average depth (placed at bin center), (3) a median depth, or (4) a minimum depth. CUBE depth selection options may also be considered.

a. Dredge measurement and payment surveys. The average or median depth within a bin is recommended for dredge payment surveys. These representative depths are subsequently used in TIN volume computations.

b. General plan drawings. The shot depth nearest the cell center is recommended to be shown as the representative depth on plan drawings, including those used for plans and specifications or project condition reports. Obviously additional thinning will be required to plot 3- x 3-ft bin depth data on a 1 in = 100-ft plan—only every 8 or 10 bin depths could be displayed at this scale.

c. Minimum depths. Minimum depths may be selected for channel condition reports, shoal or strike detection, or some dredge clearance purposes. Special caution must be exercised in using minimum depths in that the dataset will be significantly biased.

d. Figure 6-26 is an example of the representative depth options that can be selected from binned multibeam data on a navigation project. This guidance is also applicable to other bin sizes than those indicated. Additional guidance on depth selection options is covered in Chapter 2.

SECTION VI

Quality Assurance Performance Tests on Multibeam Systems

6-34. General. A Performance Test is used to evaluate the quality and confidence of multibeam data being collected. This test typically compares overlapping data sets from two different multibeam surveys--performed either by the same vessel or by different vessels. This test may also be performed by comparing multibeam data with that collected by another single beam or multiple transducer echo sounder--obtained by either the same vessel or different vessels. Other

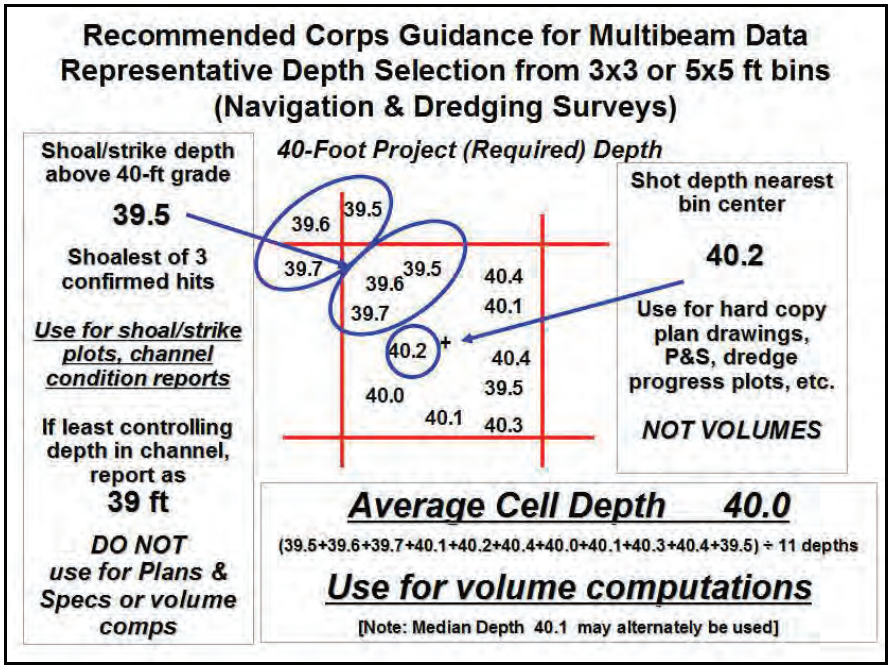


Figure 6-26. Representative depth selection options from binned multibeam data on a navigation project. This guidance is applicable to all cell sizes. The 39 ft reported controlling depth (CCR) was truncated to the nearest whole foot from the observed 39.5-ft shoal depth. In deeper draft projects with higher depth measurement uncertainty (e.g., standard deviations approaching ±1 ft), truncating, rather than rounding, is recommended.

comparison test methods are also used, such as matching multibeam bathymetry of a flooded Corps lock chamber against topographic data measured in the same lock chamber during a dewatered state. Object detection capabilities may also be verified by sweeping over simulated objects of known size; placed either in open water or in controlled lock chambers.

a. Purpose. The purpose of a Performance Test is to obtain an estimate of the accuracy (and, most importantly, repeatability) of a multibeam system dataset. These accuracy estimates can then be compared with defined accuracy standards for a particular type of survey, such as those recommended in Chapter 3. This test also partially checks the parameters and biases that were measured and computed during the previously described quality control calibrations (velocity profile calibrations, Patch Test bias parameters, etc). If performed over different tidal phases, it may also detect poor tidal modeling in the survey area. This is especially critical if RTK surface elevation methods are not being used.

b. Frequency of Performance Tests. Performance Tests should be conducted before a dredging measurement and payment survey project; however, they are not necessarily needed prior to individual surveys in that project. In high cost per cy rock cut channels, daily or twice-

daily Performance Tests are recommended. (See Appendix F for New York District's mandatory QC and QA procedures on critical rock cut navigation projects.) For non-navigation surveys, Performance Tests may be conducted weekly, monthly, quarterly, or less frequently, depending on the long-term stability of the results, known variations in different project areas, etc. Performance Tests should also be conducted upon equipment installation or modification. Performance Test data reduction, processing, and statistical analysis should be performed in near real-time--i.e., on board the survey boat.

c. Undetected biases. Performance Tests conducted by the same vessel, the same multibeam system, and over a short tidal time period, are not truly independent but are only an assessment indicator--a constant bias in the system could go undetected. A more truly independent Performance Test is obtained when comparison surveys are run at different tidal phases, using different multibeam and single beam systems, by different vessels, in different locations, and differing sea state conditions. Such a test provides an estimate of "reproducibility" as opposed to "repeatability." New York and Philadelphia Districts have established fixed Performance Test sites where all their survey vessels have run repeated single beam and multibeam surveys. A composite of all these surveys has developed a "baseline" reference surface to which all subsequent tests are compared. However, this type of ideal test is not always practical if surveys are performed over wide geographical ranges. Typically, a Performance Test is done by a single vessel at the project site, comparing single beam and/or multibeam data from the same vessel. In this case, the test more properly indicates a level of "repeatability" in the data—see Chapter 3. Some of the biases that may not be detected when the same vessel and multibeam/single beam system is used in a Performance Test include:

(1) Squat/settlement bias. A constant error in the squat/settlement correction for the vessel will be undetected since the same vessel speed is run for all tests. Running different speeds might detect this error; however, it is probably small for most vessels. Use of RTK minimizes this potential bias.

(2) Draft errors due to undetected loading variations (dynamic draft). Use of RTK minimizes this potential bias.

(3) Tide/stage modeling errors (non-RTK control). When the comparison test is performed at the same time (tidal phase), errors in the tidal model will not be detected. However, performing the test at the same time will indicate the multibeam system is outputting quality data, independent of any tidal modeling errors. Performing the comparison tests at both the same and different tidal phases is strongly recommended, in that the independent quality of the multibeam system can be checked separately from any biases in the tidal model. As detailed in EM 1110-2-6056, errors in the tidal model can represent the major portion of an error budget for an individual depth measurement, and can easily mask the errors in the multibeam system. If Performance Test biases are small (< 0.05 ft) when run at the same tide phase, and large when tested over different times/phases, then a tidal modeling problem is indicated. No amount of multibeam QC calibration or QA performance testing will rectify this modeling error--the only

practical solutions are to correct the tidal model or utilize RTK direct elevation solutions, which also requires appropriate geoidal and tidal modeling corrections.

(4) Bottom reflectivity. Like single beam systems, multibeam systems can have varying biases due to bottom reflectivity and/or signal processing. These biases can be large, and may vary with beam angle and the signal processing method. They may vary geographically when seabed materials differ from place to place. In soft bottoms (unconsolidated sediments or fluff), multibeam depth measurements may be problematic and possibly unreliable. A constant depth error due to signal processing or bottom reflectivity biases is difficult to detect or calibrate. The most reliable Performance Test is to compare different acoustic systems over the same project area (e.g., different boats, multibeam versus single beam, different frequency systems, etc.).

(5) Given the above, obtaining an absolute (unbiased) Performance Test ("confidence test") on a multibeam system is not a simple task. When the same vessel (and survey system) is used for all USACE measurement and payment surveys on a project, the Performance Test procedures recommended herein will yield a good estimate of the data repeatability and confidence, and indirectly the accuracy of any pay yardage derived from a survey. This presumes any undetected biases are constant (and hopefully small) for both pre and post dredge surveys. To better check for any undetected biases, Performance Tests should be run against different survey vessels and acoustic systems.

6-35. Performance Test Procedures. The following paragraphs outline the Performance Test methods found in HYPACK software. Specific details are found in the HYPACK Operating Manual (HYPACK 2011).

a. Reference Surface and Check Line surface development. The procedure described below compares a "check line" multibeam dataset with a "reference surface" dataset complied from narrowly spaced multibeam data using only near-center beam data. The "reference surface" derived from independent vertical single beam data could also have been used, provided a reasonably dense single beam model is obtained. Failure of the Performance Test survey to meet the recommended tolerances requires corrective action--i.e., re-measurement, recalibration, patch testing, etc.

(1) Reference Surface (Figure 6-27). This is essentially a small survey run over an extremely flat area (less than 1 ft gradient) in water depths of not more than 100 ft. A flat bottom area minimizes the effect of positional errors on the test. It represents the "baseline" area. The bottom soil properties should be similar to the actual project. Performing the tests at slack tides will help minimize tidal biases. Four or five parallel lines are run with at least 150% bottom overlap--i.e., 25% sidelap. The line spacing must be close enough to ensure that the inner beams overlap enough to give redundant data. The beams outside a 45- to 60-deg swath width should be removed prior to editing. After these lines are run, four or five parallel lines are run perpendicular to the previously run lines with the same swath and overlap. The speed over the ground should be the same on both sets of lines. A velocity cast should be made in this area and the corrections applied. All the edited data in the Reference Surface are then binned at 1-ft x

1-ft cell sizes. The data in each cell are then thinned using the average depth of all the depths in a cell.

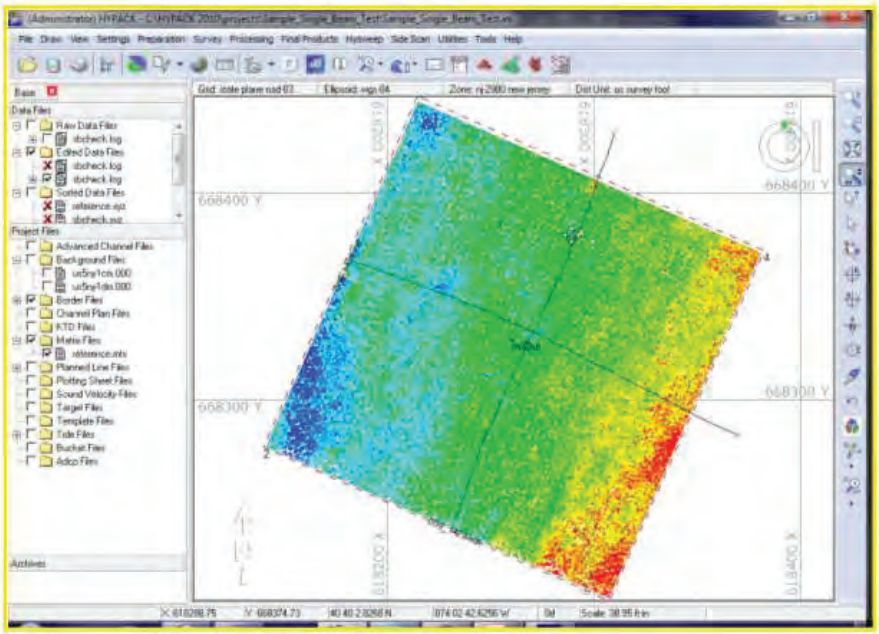


Figure 6-27. Color-coded Reference Surface binned into 1-ft x 1-ft cells. Multibeam line sets were run in each direction and restricted to less than ±45 deg (HYPACK, Inc.)

(2) Check lines. Multibeam "Check Lines" will be run such that the full beam array can be tested against the Reference Surface. At least two perpendicular multibeam swath lines should be run inside the reference surface. The vessel speed is the same as for the reference surface. Ideally, a more independent test is obtained when the Check Lines are additionally surveyed at a different time and tidal phase from that of the Reference Surface survey; however, this is not always feasible in practice. (Another alternative is to run single beam Check Lines-- either from the same vessel or another vessel-- to compare with the multibeam Reference Surface.) The beam width of the Check Lines is not restricted so that the data quality in the outer parts of the array can be assessed. A difference surface between the Reference Surface and the Check Line surface can also be created and statistics computed to assess overall performance.

b. Data processing and analysis. Performance Test data processing and analysis should include assessment of the following statistical parameters.

(1) Outliers. Depth differences between the Check Line surface and Reference Surface are computed at each beam point along the Check Line array (Figure 6-28). Excessive outliers in the dataset should be edited out during processing.

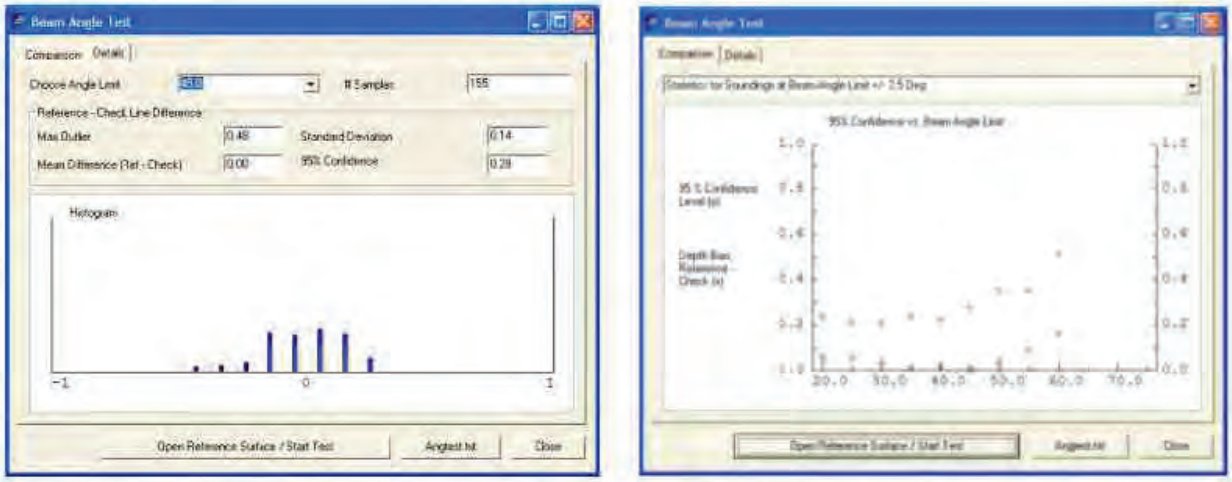


Figure 6-28. Statistical results of a Performance Test. Histogram on left shows dispersions and outliers in the Check Line beam angle set to ±45 deg. No significant bias was present at the 45 deg beam angle. The test on the right indicates that biases between the Reference and Check data surfaces are less 0.05 ft out to 50 deg from nadir. Note that the "standard deviation" and "confidence" statistics are not independent when the same vessel performs the test, and that they have no relationship to the overall survey accuracy. (HYPACK, Inc.)

(2) Mean difference or bias. The difference, or bias, between the Reference and Check surfaces should not exceed the maximum allowable tolerances specified for the type of survey. This is the most critical quality assurance check on the data in that a bias error (i.e., lack of repeatability) will adversely skew depths and related quantity computations. Excessive bias errors require immediate assessment and correction. They could indicate problems with the multibeam data (e.g., MRU alignment) or vertical tide/stage corrections. Given thousands of comparative data points on multibeam surveys, any biases between the Reference Surface and the Check Surface should be small; typically well less than 0.05 ft. The example test in Figure 6-28 shows biases computed at various beam angle widths. This type of plot may be used to determine the maximum beam width that should reliably be used—in this example, array beam width would likely be restricted to ±50 deg from nadir.

(3) Standard deviation and confidence. The standard deviation between the Reference and Check surfaces in Figure 6-28 is output as a one-sigma standard deviation. The standard deviation is simply converted to the "95% confidence" level by multiplying it by 1.96. (This example is not a confidence statistic that is usually based on the standard deviation of the mean statistic.) The existence of excessive outliers and biases will increase the overall standard deviation. Restriction of the beam array angle may reduce this error if most of the excessive outliers are in the outermost portion of the array. Results from this test may be used as an indicator of overall accuracy performance; however, these “95% confidence” statistics should not be confused with the estimated Total Propagated Uncertainty (TPU) of the depths since undetected biases may still be present in the data. Therefore, the nature of these statistics must be considered before setting any maximum limits on Performance Test standard deviations (or

confidences)—keeping in mind the difference between standard deviation and TPU—see Chapter 3.

c. Full-channel Performance Tests. Rather than use a small Reference Area described above, Performance Tests can be conducted over the entire project area, for example, a 3,000-ft acceptance section. Such tests may be multibeam v multibeam or multibeam v single beam. Surveys from different vessels may be tested over the project area. Surface models for each survey are tested against one another for biases and deviations. No survey will be considered the "Reference." Thus, determining which survey contains a bias will be difficult. However, if the statistics prove to be within allowable tolerances (Chapter 3), confidence in either survey (or vessel) will be high.

6-36. Multibeam versus Single Beam Performance Tests. Single beam versus multibeam comparisons are performed similarly to the previously described multibeam versus multibeam tests. The only difference is the Reference Surface is made up of tightly run single beam sections, e.g., 50-ft C/C over the 200-ft x 200-ft test area. Alternatively, the actual navigation project can tested against single beam cross-sections run every 500 ft to 1,000 ft. These Performance Tests are more independent than comparing the same multibeam system against itself, as described above. This is due to each system having different signal processing methods, gain and sensitivity controls, etc. The single beam and multibeam sounders are typically on the same vessel; however, comparisons to another vessel's single beam system will provide an even more independent comparison.

6-37. Real-time Quality Assurance Tests. This simply involves operator assessment of data quality as it is being collected, making visual observations of cross-track swaths (i.e., noting convex, concave, or skewed returns in flat, smooth bottoms), data quality flags/alarms from the GPS, RTK, or MRU systems, or noting comparisons between adjacent overlapping swaths or between independent single beams. Real-time software must have features that allow some form(s) of real-time quality assurance assessment, and performing immediate corrective actions.

6-38. Sample Performance Test—Survey Vessel Shuman (Philadelphia District). The Performance Test results shown below were done over a very flat anchorage area with depth variation of less than ±2 ft over a 200- x 200-ft test area. A reference surface was created by running two sets of four parallel lines, with line sets perpendicular to each other. The line spacing was approximate water depth (45 ft). After editing and application of tide and sound velocity corrections, the reference survey was gridded into 2- x 2-ft cells. The average of each cell (approximately 17 points per cell) was saved to an XYZ file. The results from comparison of the reference surface with two check lines (one in each direction) are shown in Table 6-2. This report was generated by the Beam Angle Test section of HYPACK/HYSWEEP multibeam processing program. (Additional Performance Test examples are shown in Appendix F.) The results of the above sample Performance Test indicate the multibeam system is providing reliable data out to a ± 75-deg beam width. However, the relatively large constant biases of + 0.1 ft between the two surveys might be questioned and further evaluated as to the cause. If this test

had been performed for a payment survey on a rock cut project, then these large biases should have been investigated.

Table 6-2. S/V Shuman Performance Test results.

Beam Angle Limit	Max Outlier	Mean Difference
20	0.37	0.11
25	0.37	0.11
30	0.37	0.11
35	0.40	0.11
40	0.40	0.10
45	0.40	0.10
50	0.40	0.10
55	0.45	0.10
60	0.88	0.10
65	0.88	0.10
70	0.88	0.10
75	0.88	0.11

6-39. Fixed Calibration Barge (Louisville District). Figure 6-29 depicts a sunken barge on the Ohio River used to verify performance on Louisville District multibeam systems. This "reference surface" is in 40 ft of water. Star test patterns are run over the barge.

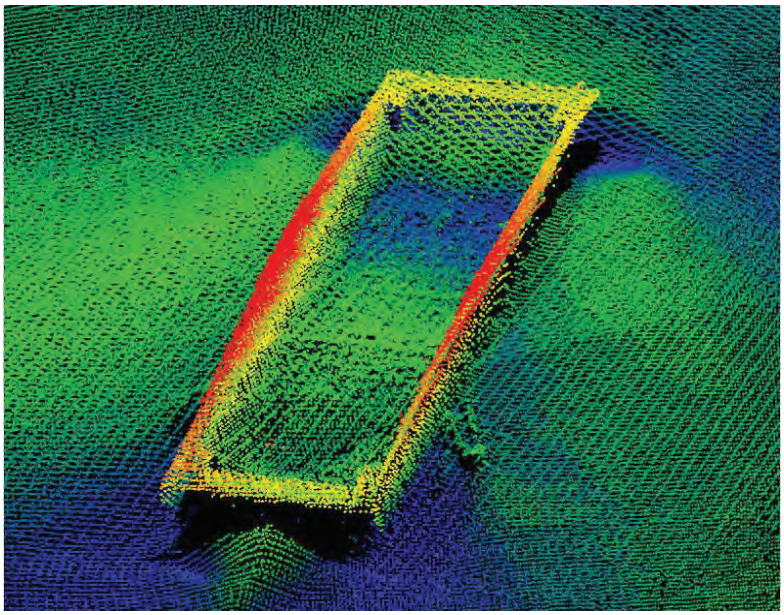


Figure 6-29. Louisville District calibration barge used as reference surface.

SECTION VII

Summary of Multibeam QC and QA Criteria.

Table 6-3. Recommended Quality Control and Quality Assurance Performance Criteria for Multibeam Surveys. (Refer also to Appendix F for additional guidance.)

Requirement	Recommended Frequency or Comment
Bar Check Calibration	Perform periodically (e.g., monthly or quarterly) recommended at start of new dredging project
Sound Velocity Calibration	Twice daily minimum, or more often in varying conditions (continuous velocity recording on some multibeam systems)
Horizontal Position Check	Daily on dredging projects (RTK v Code DGPS adequate)
Vertical Elevation Check (RTK)	Twice daily calibration at tide/staff gage.
System Alignment/Orientation Tests (e.g., Latency/Patch Test)	Perform periodically (e.g., quarterly) or as required. Recommended at start of new dredging project.
Vessel Squat/Settlement Test	Annually
Vertical Datum Verification	Refer to EM 1110-2-6056 for periodic requirements to ensure coastal tidal datums are consistent with NOAA reference datums; including periodic checks of tide/staff gages
Survey Coverage (Density)	100% coverage is recommended for maintenance dredging projects. 200% coverage is recommended for deep-draft projects with critical under keel clearances over rock.
Quality Assurance Performance Test	Periodically or as required based on project requirements. Recommended daily on critical dredging/clearance projects.
Object or Shoal Detection: Minimum object size	3 ft cube (periodically verify by independent detection test)
Minimum number of acoustic hits to confirm a shoal or strike above grade.	3 acoustic hits recommended. (successive passes over object)

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CHAPTER 7

GPS Vessel Positioning, Orientation, and Water Surface Elevation Measurement

7-1. Purpose. This chapter provides guidance on the use of GPS satellite positioning to control hydrographic surveys of USACE navigation and other civil works projects.

7-2. Scope. This chapter covers GPS horizontal positioning and vertical elevation measurement methods. Both code phase Differential GPS (DGPS) and carrier phase Real Time Kinematic (RTK) positioning methods are covered, with an emphasis on RTK techniques to measure water surface elevations. Vessel motion reference units (MRU) and inertial-aided GPS vessel orientation and alignment measurements are also discussed. Given the rapidly evolving technological improvements in GNSS and MRU applications, the guidance in this chapter will be superseded in a relatively short time. Therefore, the focus is on quality control procedures for these systems which will not significantly change over time. Recommended quality control calibration techniques for these systems are provided in Table 7-1.

7-3. Required References. Various USACE and commercial publications cover the theory and principles of GPS surveying, including the operational set up and interfacing of GPS positioning systems with hydrographic survey data collection systems. To avoid duplication, this chapter references these other publications where applicable. The following primary references are required in conjunction with this chapter and are frequently cited.

a. EM 1110-1-1003 (NAVSTAR Global Positioning System Surveying). This manual covers GPS theory of operation, errors and accuracy, autonomous and differential positioning techniques, static and real-time kinematic (RTK) survey methods, and GPS survey adjustment techniques. Although the primary focus is on terrestrial geodetic and topographic surveying, the same principles apply to dynamic hydrographic applications covered in this chapter. Therefore, many of the basic principles of GPS positioning will not be repeated in this chapter.

b. EM 1110-2-6056 (Standards and Procedures for Referencing Project Elevation Grades to Nationwide Vertical Datums). This manual details methods for assuring GPS elevation measurements are properly referenced to project datums. Chapter 4 details procedures for referencing RTK surface elevation measurements to local navigation and construction datums.

c. HYPACK 2011 (HYPACK Hydrographic Survey Software User Manual). This user manual covers the hardware device and driver set up, and field survey operation of various hydrographic survey systems linked to (and time synchronized by) GPS positioning systems. These include various acoustic systems, motion sensors, inertial-aided GPS systems, and RTK water surface elevation measurement procedures.

d. POS/MV 2011 (POS/MV V5 Installation and Operation Guide). This guide covers

installation and operating details on an inertial-aided GPS positioning and orientation system for all high accuracy hydrographic surveying operations.

7-4. GPS Background and Applications in USACE. The GPS has become the standard surveying and navigation mode for most dredging and construction operations in USACE. Since the mid-1990s, GPS has largely replaced the terrestrial hydrographic positioning systems described in attached Appendix G ("Terrestrial (Non-GPS) Positioning Methods"). GPS is a form of a GNSS (Global Navigation Satellite System). A GNSS may refer to GLONASS (Russia), Galileo (European Union), etc. GPS manufacturers are developing receivers capable of tracking satellites in multiple GNSS systems. For the purpose of this manual, the term GPS is used. Autonomous GPS coverage (i.e., non-differential, general vehicle, vessel, or cell phone navigation) is worldwide; however, its 5- to 10+- m accuracy is inadequate for most USACE survey applications. (Future developments in autonomous positioning are expected to provide accuracies below the decimeter level.) Currently, most USACE hydrographic survey and dredging applications use code phase differential GPS (DGPS) positioning. The approximately 2-meter level horizontal accuracy from DGPS systems is generally adequate for dredge and survey vessel location. Numerous public and private DGPS networks now exist, allowing for nationwide and worldwide coverage. On more critical projects, especially in areas where water level tide or stage is uncertain, carrier phase GPS measurements (i.e., RTK) are becoming more common in USACE; and in the future will likely replace code DGPS methods. Like code phase DGPS, many public and private RTK networks (i.e., Real Time Networks—RTN) now exist throughout CONUS and OCONUS, enabling 0.1 ft X-Y-Z measurement resolutions.

a. Real-time code phase DGPS was first implemented in USACE in 1990 by the USACE Engineering Topographic Laboratory (ETL), now the AGC. These early systems consisted of two receivers—one as a base station over a known point and the other a “rover” aboard the survey vessel. In time, public and private DGPS networks evolved, providing DGPS without the need for a user-provided base station.

b. In the mid-1990s, the ETL (AGC) first implemented real-time carrier phase vessel positioning in USACE districts—i.e., RTK. This allowed for accurate (0.1 ft with appropriate filters) measurement of the water surface elevations in areas remote from gages, effectively minimizing the heretofore large uncertainties due to uncertain tidal models. In 1997-8, the first permanent USACE real-time RTK network was established by ETL at the St. Marys River entrance to the U.S. Navy Base at Kings Bay, GA. This single station Real Time Network (RTN) has been in continuous operation since 1998 by the Jacksonville District. See attached Appendix H for additional details on this project.

c. These code DGPS and RTK positioning techniques originally developed and implemented by ETL (AGC) have revolutionized the positioning techniques used aboard USACE survey vessels, dredges, and other mobile platforms. GPS has provided for more accurate payment surveys; and thus reducing disputes and claims, especially those arising from errors in water surface elevation measurements.

7-5. GPS Accuracies. GPS is simply a 3-D trilateration measurement—distances (ranges) are measured from the space-based satellites to the user's receiver. The positional accuracies obtainable from GPS are dependent on the satellite range measurement technique used, e.g., code or carrier. The estimated range accuracies, when coupled with the geometrical relationships of the satellites during the position determination (i.e., dilution of precision-DOP, or geometrical dilution of precision-GDOP), results in a three-dimensional confidence ellipsoid that depicts uncertainties in all three planes. Given the changing satellite geometry and other factors, GPS accuracy is time/location dependent. GPS accuracy is also a function of interferences on the GPS signal, and the processing techniques used to reduce or remove these errors. Given that GPS signals travel from 20,000 km out in space through various atmospheric layers, these effects can impact the signal and the range measurement accuracy, and ambiguity phase resolution in RTK observations. Multipath effects at the base or rover receiver will also impact positioning accuracy. See EM 1110-1-1003 for a complete discussion on GPS errors and their sources. Error propagation techniques are used to define nominal accuracy statistics for the GPS user. These error estimates are often available in real-time from most GPS receivers.

7-6. Reference Datums.

a. Horizontal reference datum. Engineering, construction, and dredging surveys must be referenced to local project datums. The GPS system is based on the World Geodetic System of 1984 (WGS84). This geocentric coordinate system can be easily transformed to any type of local project reference datum (e.g., NAD27, NAD83, local project SPCS grid, and/or dredging construction station-offset reference system). Hydrographic survey software and data collectors can perform these coordinate transformations in real-time. Refer to EM 1110-1-1003 for details on GPS reference datums and transformations to user grids.

b. Vertical reference datums. Observed GPS (RTK) ellipsoid heights must be referenced to the local project vertical datum. Geoid models, tidal datum models (e.g., VDatum), and river stage models are needed to transform observed GPS ellipsoid heights to project elevations (depths). See EM 1110-2-6506 for guidance on developing and modeling vertical reference systems on Corps projects.

SECTION I

Code Phase Differential GPS Positioning

7-7. Real-Time Code Phase DGPS. Code phase tracking differential GPS systems are currently the most commonly used method for positioning hydrographic survey vessels and dredges. These systems typically provide positional accuracies around the 2-m level. They are not suitable for determining water surface elevations. A real-time DGPS positioning system includes a reference station (master or base), communications link, and a user (remote/rover) receiver. In the early 1990s, districts set up and operated reference (base) stations at each project. This is no longer required as there are several federal and commercial DGPS services that provide real-time

pseudo-range corrections. Only in rare circumstances (e.g., OCONUS) would local code phase DGPS system be required.

a. Reference station. The reference station measures timing and ranging information broadcast by the satellites and then computes and formats pseudo-range corrections for broadcast to the user equipment. The reference station consists of a GPS receiver, antenna, and processor. Using differential pseudo-ranging procedures, the position of a survey vessel is found relative to the reference station.

b. Communications link. The communications link is used as a transfer media for the differential corrections. The type of communications system is dependent on the federal or commercial DGPS provider' system. Some commercial DGPS providers utilize satellite communications to transmit correction data.

c. User receiver. The user receiver should be, at minimum, a multichannel single frequency (L1) C/A code GPS receiver. The receiver must be able to accept the differential corrections from the communications link and apply those corrections to the measured pseudo-range. The receiver must also have suitable update rates capable of maintaining positional tolerances for survey speeds up to 10 knots. The receiver must not bias the position during vessel turns due to excessive filtering.

d. Separation distances. The maximum station separation between a reference and remote station should generally not exceed 150 to 200 miles. This range can be extended on some commercial systems that model and adjust the tropospheric and ionospheric corrections. Unmodeled tropospheric and ionospheric errors can average of 0.7 m per every 100 km.

e. Satellite geometry. In code phase DGPS, the Horizontal Dilution of Precision (HDOP) is the critical geometrical component. The HDOP should generally be < 5 for dredging and navigation hydrographic surveys. The current GPS (and expanded GNSS) constellation should maintain a HDOP of approximately 2 to 3 most of the time.

7-8. USCG Code Phase DGPS Radiobeacon Navigation Service. In CONUS, and in some OCONUS locations (e.g., Hawaii, Puerto Rico, Alaska), real-time DGPS correctors may be obtained from the USCG radiobeacon navigation service. This section focuses on the USCG radiobeacon system since it is most widely employed in USACE; however, a number of commercial augmentation systems are capable of providing comparable survey positioning capability. Calibration guidance is applicable to all these augmentation systems.

a. USCG Maritime DGPS Service. Utilizing DGPS and marine radiobeacon technology, the USCG has implemented a real-time code positioning system for CONUS and OCONUS coverage. The USCG has also partnered with USACE and other government agencies to expand this coverage to the inland waterway navigation systems. The system consists of a series of GPS reference stations with known coordinate values based on the NAD83 datum. GPS C/A-code

pseudo-range corrections are computed based on these known coordinate values and transmitted via a marine radiobeacon. A user with a marine radiobeacon receiver and a GPS receiver with the ability to accept and apply pseudo-range corrections can generally obtain a relative accuracy of around 2 m. This accuracy is dependent on many factors, including the design and quality of the user's GPS receiver, distance from the reference station, local weather conditions, and the satellite geometry.

b. Coverage. The system was designed to cover all harbors, harbor approach areas, and other critical waterways for which the USCG provides aids to navigation. Each site has a coverage area between 150 to 300 miles, depending on the transmitter power, terrain, and signal interference. Since the sites utilize an omnidirectional transmitting antenna, some areas have overlapping coverage. Currently the system covers all U.S. coastal harbor areas; the Mississippi, Missouri, and Ohio Rivers; and the Great Lakes Region. Figure 7-1 depicts the system coverage as of 2009.

c. User Requirements and equipment. To receive and apply pseudo-range corrections generated by the USCG reference station, the user needs to have a radiobeacon receiver with antenna, and, at a minimum, a L1 C/A code GPS receiver with antenna. The radiobeacon receiver demodulates the signal from the reference station. Most beacon receivers will automatically select the reference station with the strongest signal strength or allow the user to select a specific reference station. A beacon receiver can be connected to most GPS receivers. The GPS receiver must be capable of accepting RTCM Type 9 messages and applying these corrections to compute a position. Since the reference station generates corrections only for satellites above a 7.5-degree elevation, satellites observed by the user's GPS receiver below a 7.5 deg elevation will not be corrected.

d. EM 1110-1-1003 provides additional information on code phase positioning and recommended receiver specifications.

e. FAA Wide Area Augmentation System (WAAS). The FAA has developed the WAAS to augment GPS, primarily for aviation users. The WAAS provides a signal-in-space to enable WAAS users to navigate the en route through precision approach phases of flight. The signal-in-space provides three services: (1) integrity data on GPS and Geostationary Earth Orbit (GEO) satellites, (2) differential corrections of GPS and GEO satellites broadcast on L1 to improve accuracy, and (3) a ranging capability to improve availability and continuity. Receivers that are capable of processing WAAS corrections may be employed for hydrographic survey purposes where WAAS coverage is available.

7-9. Commercial Differential Navigation and Positioning Systems. Numerous commercial systems provide regional or worldwide coverage. All have USACE application in positioning hydrographic surveys. The following paragraphs describe a few of these systems.

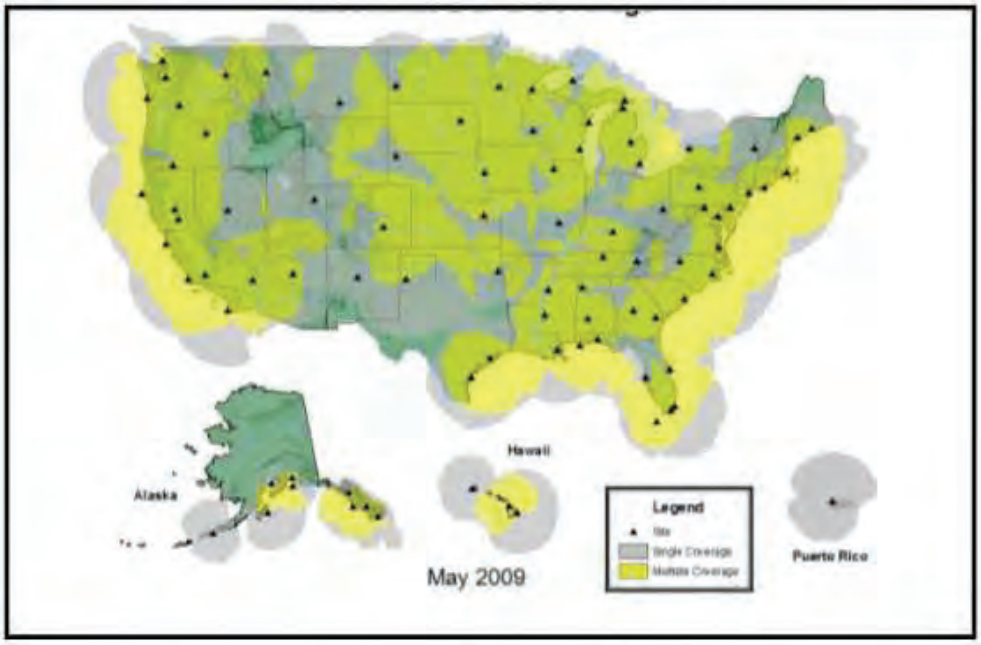

Figure 7-1. USCG Radiobeacon DGPS coverage including USACE coverage in inland navigation system (2009)

a. C-Nav (C&C Technologies). C-Nav is a dynamic differential GPS/GNSS Precise Point Positioning system maintained by C&C Technologies of Lafayette, LA. It provides real-time worldwide coverage (Figure 7-2) with a claimed 1-σ accuracy of <0.1 m horizontally and 0.2 m vertically. C-Nav's solution is based on Real Time GYPSY technology developed by NASA's Jet Propulsion Laboratory to provide centimeter-level accuracy for navigation in space and for a range of complex spacecraft maneuvers. C-Nav does not suffer from the effects of spatial decorrelation found in traditional DGPS systems, nor does it require seeing common GNSS satellites. A C-Nav subscription, combined with C-Nav hardware, which is maintained by C&C Technologies, will provide worldwide positioning capability of 10cm or better. (Excerpt from C&C Technology web site 2011).

b. Fugro satellite positioning. The Fugro DGPS subscription service provides worldwide DGPS coverage in real-time under the brand names Starfix, Seastar and Marinestar. (Figure 7-3.) Within these products there are differing levels of accuracy, ranging from code based sub-meter accuracy to GNSS phase based services with an accuracy of 10 cm (95%) horizontally and 15 cm (95%) vertically.

(1) Within these Fugro services are two, independent, phase-based, Orbit and Clock solutions. The Fugro G2 Orbit and Clock solution uses both GPS and GLONASS satellite observations to produce a decimeter level service, while the second, called XP, produces a GPS Orbit and Clock solution that is generated from a completely separate system of reference sites

and software to produce an independent decimeter level service. A third set of reference sites is used to produce another phase-based GPS solution, called HP, that uses local reference site data to generate a decimeter level service. Another option includes a sub-meter, virtual code solution based on using multiple reference station corrections that are optimized for the user location.

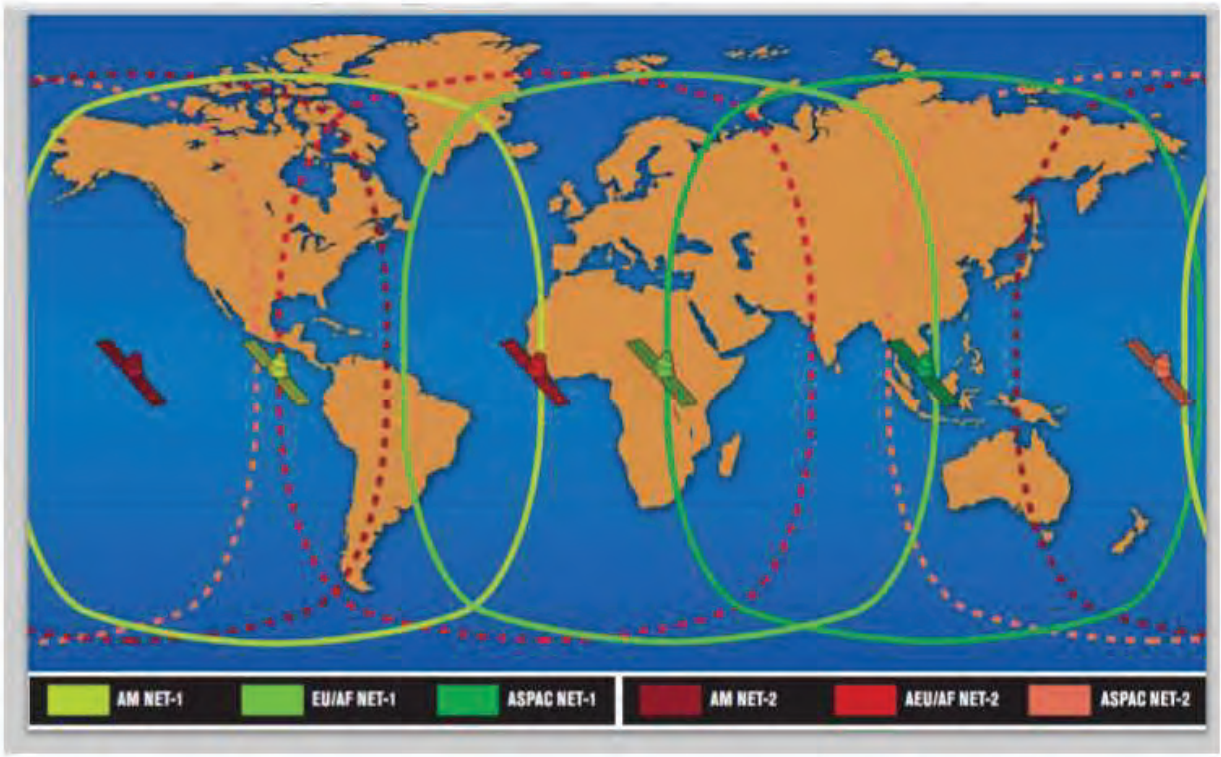

Figure 7-2. C-Nav worldwide coverage map—2011. (C&C Technologies)

(2) Fugro uses a series of eight satellites in order to provide simultaneous coverage from two satellites in all of the marine markets around the world. These satellites are managed from two fully manned Network Control Centers, each of which is capable of up-linking all signals worldwide. Each satellite carries all three of the higher accuracy options. Future capabilities will include higher accuracies and thus higher resolution.

7-10. Position Quality Control Tolerance Checks. Most precise DGPS augmentation systems are capable of providing 1- to 2-meter accuracies at "reasonable" distances from the nearest reference station. However, at increasing distances, spatial decorrelation errors (due to differing ionospheric/tropospheric conditions) can induce systematic positional biases. In general, under nominal atmospheric conditions, a 2-m RMS (95%) positional accuracy may be achieved at distances upwards of 150 miles. During adverse weather fronts, positional errors of 5 meters or more have been observed; thus, positional accuracy checks are important. To confirm a positional accuracy is within a 2-m tolerance, it is recommended that a static check position be obtained at some known survey point near the project. When operating with the USCG maritime

beacon system, static positions should be observed from different radiobeacon reference stations to ascertain if positional systematic biases are present--and select the beacon with minimal biases. In practice, this would normally be the closest beacon. If no fixed survey point is available, then a static comparison of different USCG beacon positions should be observed;

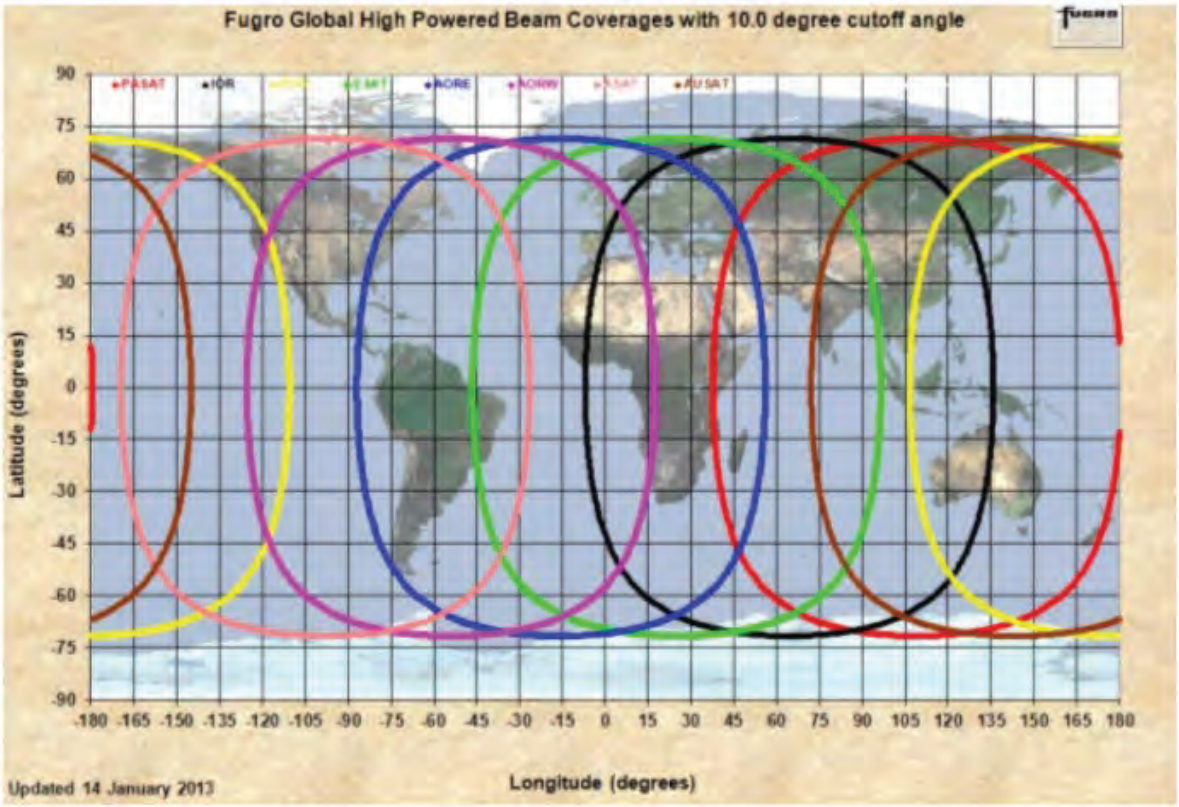

Figure 7-3. Fugro worldwide coverage map—2013. (Fugro)

however, any large biases between beacon positions may be ambiguous. When large or ambiguous positional biases occur in a project area, it may be necessary to establish a local GPS network (code or RTK carrier) if high positional accuracy is critical to the project. Commercial WAAS systems should be checked in a similar manner.

SECTION II

Real-Time Kinematic Carrier Phase GPS Positioning

7-11. Real-Time Kinematic (RTK). RTK carrier phase measurements are increasingly being employed for hydrographic surveys of civil works projects. It is expected that, in the future, RTK positioning will replace code DGPS methods. This is due to the enhanced accuracy and reliability of RTK measurements, and the increased availability of RTN networks. Carrier phase

measurements can provide real-time elevations of survey vessels, dredges, and other moving platforms, and indirectly, the elevation of the water surface, from which acoustic depths are calibrated and referenced to. Some districts now mandate that carrier phase RTK positioning be used for water surface elevation measurements on all navigation projects.

a. Carrier phase RTK positioning is performed similarly to code phase DGPS methods in Section I. The main difference is that the short wavelength carrier phase is used to resolve satellite ranges to centimeter level resolutions. This method of carrier phase positioning and elevation measurement is commonly referred to as “real-time kinematic,” "RTK surveying," and "RTK Tides." Other organizations call it “Ellipsoid Referenced Surveys," or ERS. This is because GPS elevations are referenced to the WGS84 ellipsoid and this ellipsoid height must be transformed to the user's reference datum (e.g., LWRP, MLLW).

b. RTK systems are typically capable of 0.1-ft accuracy in static observations, both horizontally and vertically. However, this accuracy is somewhat degraded on moving survey boats due to vessel motion. Various inertial systems and filtering techniques are used to smooth out these motions, and obtain an average water surface elevation. If adequate motion compensation equipment is used, and project tidal datum modeling has been accomplished, water surface elevations can be referenced to the local project datum; allowing observed soundings to be directly corrected to the reference datum.

7-12. RTK System Requirements. Either a local RTK base station is established at the project site or signals from a permanent “Real-Time Network” (RTN) are used. This section outlines the procedures for performing hydrographic surveys using a local RTK base or RTN. (Post-Processed Kinematic-"PPK"-is covered in a later section.)

a. Reference station. A GPS reference receiver must be located over a known survey monument. The reference station receiver must also be capable of collecting both pseudo-range and carrier phase data from the GNSS satellites. The reference station will usually consist of a dual-frequency, geodetic quality GPS receiver with its associated antenna and cables, processor, and communications link. (See EM 1110-1-1003 for recommended GPS receiver specifications.) The receiver should be capable of at least a 1-sec update rate. The processor used in the reference station will measure the pseudo-range and carrier phase data and format the data for the communications link to the survey vessel.

b. Separation distances. The distance between a RTK base station and the project site is usually kept as short as possible, typically less than 10 miles. At greater distances, integer ambiguity and initialization problems may occur; notwithstanding the communication link’s range. Some RTN applications can extend the effective coverage range.

c. Communications link. The communications link for the carrier phase positioning system differs from the code phase DGPS system given the higher amounts of data that have to

be transmitted. VHF and UHF frequency communications systems are used as communication links. Cellular network and satellite communication systems are also viable communication links for carrier phase positioning systems.

d. User equipment. The user equipment on the survey vessel or dredge consists of a carrier phase, dual-frequency, geodetic survey quality GPS receiver with a built in processor and associated antenna. The built in processor must be capable of resolving the integer ambiguities while the platform (survey vessel or dredge) is moving. Using a “geodetic quality” GPS antenna will reduce the effects of multipath on the GPS signal. A communications link is needed on the dredge or survey vessel to receive data from the reference station. Frequency approval may be necessary for communication link broadcasts using a power source in excess of prescribed levels. The position output for the helmsman is often code phase DGPS using pseudo-ranges (accurate at the meter level) for vessel navigation in real time. Carrier phase data will be time-tagged to allow for recording the true vessel position needed for survey processing. The minimum update rate from the reference station to the vessel(s) is 1 sec. Higher update rates on some RTK systems will provide enhanced vessel heave correction input.

e. Ambiguity resolution. High-precision kinematic positioning is available from the system once the receiver’s processor resolves integer ambiguities. As long as the system remains in the RTK mode, real-time sub-decimeter positioning in three dimensions is available at the remote station or platform. To remain in this RTK “fixed” mode requires both the reference station and the remote station receivers to maintain lock (continuous GPS data) on at least four (and often five) satellites. If that number drops, the RTK fixed solution goes into "float" mode, and the ambiguities will again be resolved after the system reacquires lock on a sufficient number of satellites and reinitializes. Reinitialization may also be triggered if quality factors based upon residuals failing to meet certain predefined limits.

7-13. Real-Time Networks (RTN). Numerous public and private real-time networks have been established throughout CONUS that provide carrier phase correctors for survey users. These networks blanket a region with multiple base stations, and through various modeling techniques, can extend RTK coverage beyond that from a single reference station. Thus, remote channels in large bays may be covered. Where RTNs exist over Corps projects, districts can utilize these networks; thus, eliminating the need to set up RTK base stations at each project site. Many of these RTNs have been established by state DOTs and commercial providers. During the mid 2000s, Philadelphia District established a RTN to cover inland and offshore reaches in the district—see Figure 7-4.

7-14. Inertial-Aided Post-Processed Kinematic (IAPPK) Position and Elevation Computations. Post-processed kinematic (PPK) is simply post-processed RTK observations. It may be used when real-time communications between the base and survey vessel are unavailable, often in distances greater than 10 miles. Applanix “POSPac” software provides an option to post-process inertial-aided POS/MV/RTK observables in a CORS adjusted virtual reference network type solution. POSPac post-processes 5 to 10 CORS stations within 200 km of the vessel, and

performs a network solution. POSPac has application in areas beyond RTK or RTN coverage, or outside of radio or cell coverage. This would include coastal borrow areas 15 or more miles

Figure 7-4. Philadelphia District RTN coverage of navigation projects in Delaware Bay.

offshore, large water bodies, lakes, or bays, and remote reservoirs. POSPac software allows merging of CORS observables with local RTK base stations. If either local RTK or RTN data is lost, then CORS solutions will maintain the required vertical accuracy needed to determine the water surface elevation at the survey site. Since POSPac is a post-processing method, real-time vessel navigation during CORS-only coverage will revert to DGPS—e.g., USCG Maritime System. In remote offshore areas, predicted geoid models must be used. Likewise, tidal range data must be derived from VDatum estimates or other models—see EM 1110-2-6056. Appendix I describes the process for implementing and operating POSPac software to compute accurate water surface elevations ("RTK Tide Corrections") in offshore areas beyond local RTK or RTN coverage.

SECTION III

RTK Water Surface Elevation Measurement

This section covers the use of carrier phase RTK measurements to obtain the elevation of the water surface at the project site. These techniques are usually referred to as "RTK Tides," however, the elevation of any non-tidal river stage, reservoir, or pool may be determined using these "RTK Tide" methods. RTK Tide techniques are especially applicable in coastal areas with significant tide ranges and tidal phase (time) differences between the reference gage and the project site (see example in Chapter 2). Additional information on the use of RTK elevations can be found in EM 1110-2-6056.

7-15. RTK Surface Elevation Requirements in Coastal Navigation Projects. A major correction to depths in navigation project surveys is for tidal phase (latency) variations between the reference tide gage and the location of the dredge or survey vessel at the project site. Local hydrodynamic and meteorological effects (e.g., wind set up) changes the water surface elevation profile in the project. These variations due to tidal phase, along with other hydrodynamic or meteorological effects, increase with the distance from the tide gage. These systematic differences can exceed 1 to 2 ft in moderate range projects, and higher on projects with large tide ranges (over 10 ft); especially during adverse weather conditions. They are most pronounced during periods of full ebb and flood tide. Many dredging measurement and payment survey disputes and claims arise over lack of adequate compensation/correction for tidal phase and meteorological surface set up throughout a project site.

a. Tidal phase latency variations. EM 1110-2-1100, Coastal Engineering Manual, Part II-6, "Hydrodynamics of Tidal Inlets" has numerous examples of the tidal phase and MLLW range variations that typically occur between the ocean and bay at a typical coastal inlet. These tide curves do not include any hydrodynamic or meteorological effects, which could, at times, exceed the basic tidal phase variations. Modeling and correcting these tidal phase variations throughout the project is critical.

b. Water surface elevation measurements using RTK techniques. Tidal phase errors and weather/sea surface set up can be measured using RTK surface elevation measurement techniques, often coupled with inertial measurement and orientation systems. Local water level variations can be measured in real-time using these RTK techniques, either from a local RTK base station set at a project control benchmark or from a regional RTN system. RTK methods effectively measure the local water surface elevation relative to the ellipsoid; thus, providing direct corrections relative to a MLLW datum at a modeled offshore construction or large project site.

(1) RTK methods apply a geoid model to correct observed ellipsoid heights measured relative to the vessel GPS antenna; thus, the orthometric elevation of the antenna is computed. Knowing the distance from the antenna down to the vessel's water surface draft, the corrected

orthometric elevation of the water surface is obtained. Since acoustic depths are calibrated relative to this nominal water surface (e.g., bar checks), they can be directly related to an orthometric datum at each point. If the MLLW datum is modeled relative to the reference gage, then the observed depths can also be corrected for any MLLW variations.

(2) Thus, observed depths have been corrected for (1) geoid model undulations, and (2) tidal range variations based on hydrodynamic models of the tide in the region. The actual offshore water surface level above local MLLW is thereby measured at every observation (typically 1 to 10 Hz) made by a survey vessel, dredge, or commercial vessel employing RTK methods. As long as every user (vessel) employs the same geoid and tidal models for the region, then full repeatability of surface elevation measurements will be achieved. The relative accuracy of the RTK measured surface elevation and tide level will fall around ± 0.05- to 0.1-ft level with appropriate motion sensing and filtering.

(3) Geoid model accuracy is a function of the location and density of NSRS vertical control and gravity data in the area. The predicted geoid undulation from the latest geoid model will be used for offshore entrance channels—areas that obviously have no vertical control but have geoid height estimates using other techniques (airborne gravity). NGS should be contacted to confirm the accuracy of the predicted geoid model does not exceed reasonable tolerances. Likewise, the predicted tidal range in offshore entrance channels 3 to 10 miles seaward may have to be based on established regional models of the ocean tides. In such cases, the estimated accuracy of these regional models may be verified by contacting Engineer Research and Development Center/Coastal Hydraulics Lab or NOAA. Alternatively, these offshore tidal ranges, and indirectly the geoid model, can be confirmed by observing long-term RTK data recorded during the course of a survey in the area.

(4) Geoid and tidal models developed for each project must be published and disseminated to all users. This may be a simple ASCII file in the form of a gridded difference between NAVD88 and MLLW (NAVD88-MLLW), such as a “KTD” file used by commercial navigation dredging software (HYPACK). Since most USACE navigation projects are linear, only a 1D model may be required—e.g., a tidal-geoid correction every 100-ft station down the channel centerline. This is adequate to cover the areal extent of a 100-ft- to 1,000-ft wide-channel. This file may be periodically updated if the MLLW tidal model for the region is significantly modified by NOAA. Thus, the file must clearly identify (metadata) the source of the data. In some navigation/dredging processors, the geoid correction may be performed separately by the GPS receiver from the MLLW tidal model correction. Thus, the KTD file will usually contain only the tidal datum correction (NAVD88-MLLW or "K") or may combine both the tidal datum correction "K" and the geoid correction "N"—i.e., “(N – K).” Users must also be advised that RTK, like any measurement system, must be periodically checked (and site calibrated/localized if necessary) against a physical recording tide gage or staff gage.

7-16. RTK Tide Corrections. The following paragraphs illustrate some of the basic concepts behind the determination of a water surface elevation using RTK technology.

a. Definitions.

(1) "RTK Tide." RTK Tide is the computed measurement between the reference datum (e.g., MLLW, LWRP, IGLD, etc) and the local water surface elevation. RTK Tide could thus be "RTK Stage" or "RTK LWRP." RTK Tide is not the "True Tide" but is really a "RTK Corrector" that is applied to the observed depth. This is because "RTK Tide" only is the same as a "True Tide" reading when a vessel is stationary. When the boat is in motion, the dynamic draft (D) enters into the "RTK Tide" solution rendering a "RTK Corrector" to an observed depth.

(2) "KTD File." The KTD file is used in HYPACK software to correct observed RTK ellipsoid heights to the local datum. Usually this entails determining local geoid height "N" and the modeled difference between the geoid and water level reference datum, or "K" (e.g., MLLW, LWRP, IGLD, MSL). Typically, the geoid height is automatically obtained from the current geoid model and only the "K" relationship is required in the KTD file. In small survey areas where changes in "N" or "K" are minimal, a KTD file is not required in HYPACK and these parameters can be entered as "ortho height corrections."

b. RTK Tide correction schematic. Figure 7-5 depicts the computational process for determining the elevation of the water surface based on RTK ellipsoid observations. Refer also to the HYPACK Software Users Manual (HYPACK 2011). Note that in Figure 7-5, the z-axis is shown as positive upward. This is valid in any topographic survey, where downward slopes would be shown from a higher elevation to a lower elevation. Many engineering projects, i.e., beachfills or revetments, maintain this convention and show elevations underwater as negative numbers. Hydrographic surveying for navigation, however, reverses the direction of this sign to avoid repetitive negative signs on nautical charts and sounding plots. For example, a depth of 40 ft below the chart datum is shown as "40" not "-40". HYPACK software reverses this sign in the software. This can also be illustrated by comparing the tide value in the software in real time to a conventional tide staff. For example, a reading of 3.0 above "0" on the staff will be displayed as -3.0 in the software.

(1) "H (ortho elev)" is the orthometric elevation of the base RTK station. The orthometric elevation is the height above the geoid, which is approximated in CONUS by NAVD88 using the standard relationship "H = h – N," where "H" is the orthometric height (e.g., NAVD88), "h" is the GRS80 ellipsoid height, and "N" is the geoid height (e.g., GEOID09). (The "HI" represents the height of the antenna phase center above the benchmark. The antenna height measurement must be confirmed in the field.)

(2) "N" is the height of the ellipsoid above the geoid (as read from the current geoid model in real time). "N" will vary (geoid undulation - ΔN) with location as illustrated in Figure 7-5. This variance is obtained from the latest geoid model. By incorporating the geoid model into the real-time solution, the observed ellipsoid height measured at the vessel is continuously corrected for geoid undulation at each position update. Over small survey areas near the base station, this geoid undulation may not be significant and may be assumed constant.

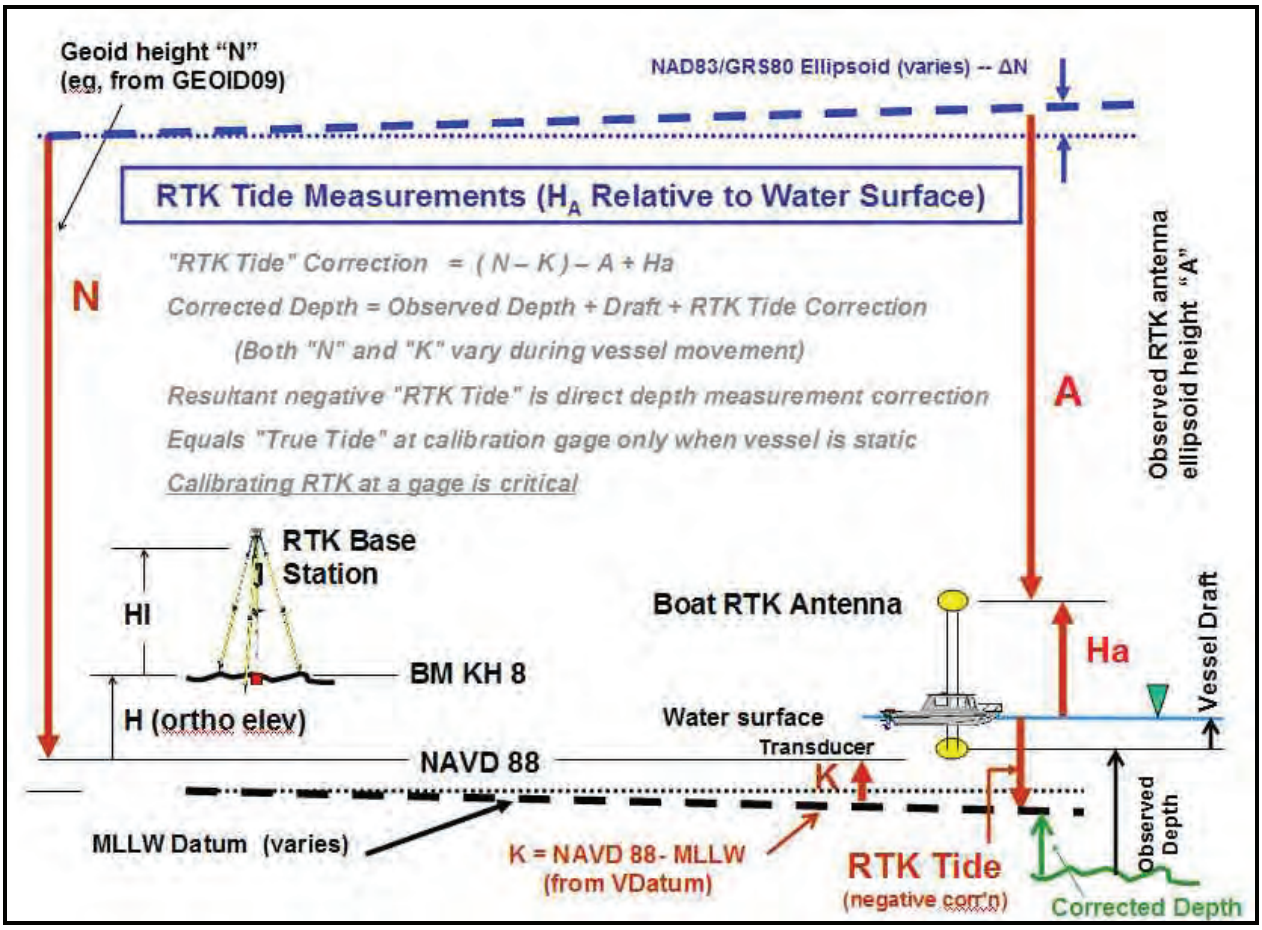

Figure 7-5. RTK Tide Correction Measurements. The RTK Tide Correction is measured relativeto the nominal water surface (vessel vertical reference point = 0), not the transducer. Note that the z-axis is shown positive whereas in HYPACK z measurements are positive downward.

(3) "K" is the orthometric height above the chart datum, e.g., NAVD88 – MLLW. "K" will vary in tidal areas with changes in the tidal range. "K" has been modeled by NOAA in most CONUS regions—"VDatum." Over small areas a constant "K" may be assumed. In the Great Lakes, "K" would represent the difference between IGLD and the low water datum. Likewise, on USACE reservoirs and navigable rivers "K" will vary with the pool or low water reference plane.

(4) "A" is the observed ellipsoid height of the vessel's antenna above or below the reference ellipsoid—in this example the antenna is below the ellipsoid. This is broadcast as a part of a GGA, GGK, or other message from the RTK system. It is corrected for geoid undulation (ΔN) at the survey location.

(5) "H" is the static height of the RTK antenna above the water line. In order to maximize

accuracy, this measurement should be taken at the same time the echo sounder is calibrated (bar checked) relative to the water surface.

(6) "D" (Dynamic Draft) represents the vertical movement of the transducer in the water column. When using RTK, there are no dynamic draft corrections. (The "Static Draft" is determined from periodic bar checks and remains in the depth solution equation).

(7) Not shown in Figure 7-5 would be a calibration correction if needed to ensure the static RTK Tide equals the actual tide at the reference gage. The HYPACK "orthometric correction" may be used for this calibration correction.

7-17. Heave Correction Options from RTK Measurements. RTK observations may be used to measure vessel heave motion. They may be used in conjunction with, or a supplement to, heave from inertial motion sensors. In HYPACK, two options are available on how the software combines RTK water level elevations with heave corrections. (1) Option 1: "Merge Tide Data with Heave" uses the RTK elevations as vertical "anchors." Between the GPS elevation updates, the program "fits" the heave data to predict the change in vessel movement. (2) Option 2: "Average Tide Data to Remove Heave" averages the RTK elevations over a user-defined time period to obtain a "normalized heave plane." In theory, this average vertical level should be the zero plane as defined by the heave-pitch-roll sensor. The program then applies the exact heave corrections to the data to obtain the exact vessel position at the time of the depth measurement. A time period of 30 seconds is typically used. (Option 2 is the recommended method.) If high update RTK rates are available (e.g., > 10 Hz) then direct heave measurements may be computed independent of any MRU input.

7-18. KTD File Generation from VDatum. NOAA's "VDatum" provides a modeled relationship between orthometric datums and tidal datums in coastal waters. Usually the NAVD88-MLLW model is used on Corps navigation projects. (A detailed description of VDatum is covered in EM 1110-2-6056). Although HYPACK contains a built in VDatum database, generating a "KTD" file allows edits to be made to the raw VDatum data. These edits are often necessary since anomalies may (do) exist in some VDatum models. These anomalies may include insufficient coverage or errors in the model itself. The KTD file can be edited (by interpolation or extrapolation) to correct any deficiencies in VDatum. In coastal areas, KTD files are typically only the "K" values—"NAVD88 – MLLW." Various techniques have been developed in districts to create a KTD file from the NOAA VDatum database. An example of a KTD file near a coastal entrance project is shown at Figure 7-6.

SECTION IV

Vessel Motion and Orientation Measurement

This section describes some of the systems used to measure vessel motion, orientation, and alignment; namely, roll, pitch, yaw, and heave.

7-19. Motion Reference Units (MRUs). (Figure 7-7) MRUs are generally designed to provide real-time vessel orientation alignments, typically outputting vessel heave, roll, yaw, and/or pitch. MRUs are variously referred to as "Motion Sensors," "Heave-Roll-Pitch Sensors," "Inertial Measurement Units"—IMU," and "Inertial Navigation Systems"—INS. Inertial systems usually consist of three gyros and three accelerometers, providing dynamic rotational data (yaw, pitch, and roll) and acceleration data (heave, surge, and sway). MRU rotational data is critical in

Figure 7-6. Example of a KTD file generated from VDatum. (Ocean entrance to Mayport Naval Base, St. Johns River, FL). "K" values are "NAVD88 – MLLW." Note incorrect VDatum and KTD interpolation on north side of entrance, between the river and tidal pool. This region required manual edits to the KTD file to correct. Published NOAA gage 8720214 "K" at South Jetty agrees closely with VDatum "K."

correcting observed multibeam array data. Heave data is essential in filtering out short-term and long-term sea swell biases; for both single-beam and multibeam sonar systems. Vessel heading calibration is typically provided to the MRU from a separate sensor (e.g., GPS, gyro, compass, etc.). A variety of MRUs are available, such a ring laser and fiber optic designs. These are essential in providing accurate corrections to vessel motion. a. HYPACK MRU data input. The MRU heave-pitch-roll data is saved in the HYPACK Raw data files as "HCP Records." These records contain the Device Number, Time Tag, Heave, Pitch, Roll, and Status Flag. The HCP records are used when processing data in the SINGLE BEAM EDITOR for single and dual frequency data, or the HYSWEEP EDITOR program for multiple transducer and multibeam data.

Each program takes the exact time of the depth measurement and then interpolates heave-pitch-roll information for the exact time that the depth was measured (HYPACK 2011).

Figure 7-7. Motion Reference Units (MRU).

b. HYPACK Single Beam Editor. In the Single beam Editor, selected options specify how the heave-pitch-roll information from a motion reference unit (MRU) will be applied. These options include: (1) “Apply Heave Correction” - determines a heave correction for every sounding, (2) “Apply Pitch and Roll Corrections” - used to offset the position of the transducer from the navigation antenna, (3) “Remove Heave Drift”- corrects heave values that have drifted off center due to rapid accelerations or changes of direction, or (4) “Steer Sounding Beam” - computes the X-Y coordinate for the point where the center of the transducer cone hits the bottom, based on the pitch and roll data (rather than directly below the transducer) then calculates the corresponding depth.

c. HYPACK HySweep Editor options. If POS/MV Group 111 data have been logged during the survey, the editor programs include a specialized routine that applies that "true heave" data to the multibeam sounding data. The editor recomputes the heave over the specified survey time period, updating the real-time heave with a delay to obtain the “true heave” based on the delay.

7-20. Inertial Aided GPS Motion Measurement. Many districts are now using inertial aided GPS to correct vessel motion in multibeam systems. These systems include the Applanix "Position and Orientation System for Marine Vessels" (POS/MV) and the Coda Octopus "F180 series." (Figure 7-8). These systems determine vessel position, elevation, and orientation, including heading. They combine IMU data with carrier phase GPS observations from two receivers. The two receivers establish a baseline relative to the vessel, thus producing the heading (yaw) value. These systems are recommended for critical dredge measurement and payment surveys. The

following are descriptions of these systems taken from manufacturers specifications. These are current at the time of publication.

Figure 7-8. Inertial-aided GPS systems. Coda Octopus F180series (top) and Applanix POS/MV (bottom). Typical positioning and orientation accuracies are better than 2 to 5 cm (position), 0.025 deg (roll & pitch), heading (0.05º), and heave (greater of 5 cm or 5%).

a. Applanix POS/MV. The Applanix POS/MV provides a six degree-of-freedom position and orientation solution measuring location, velocity, attitude, and heave, plus acceleration and angular rate vectors. The system provides orientation updates at 200HZ, allowing motion corrections and georeferencing of multibeam array depth observations. With inertially-aided RTK, the POS system's Kalman filter also estimates the floated phase ambiguities. Integer ambiguities are fixed using an on-the-fly (OTF) ambiguity resolution algorithm. After a full outage, RTK is typically recovered in 5 to 10 seconds; and after a partial outage, RTK may be recovered in as quickly as 1 second. Refer to POS/MV 2011 in Appendix A for additional information.

b. Coda Octopus F180. The primary function of the F180 is to determine the motion of the vessel it's fitted to – specifically heave, pitch, roll and heading. Motion measurements are derived from a dual antenna GPS system; the GPS receiver inside the attitude sensor derives the heading from a local integer RTK solution between the two antennae. The gyros and accelerometers within the unit allow high accuracy measurements of the changes in these values between GPS updates. These changes are fed into the INS to calculate a position estimate.

c. Figure 7-9 illustrates the flow process between the IMU and the GPS systems in the Applanix POS/MV. Vessel orientation (heading) is obtained from the dual antennas (primary and secondary) rigidly mounted atop the survey vessel. GPS data are input to the processor where ambiguities are resolved ("On-the-Fly") and data are filtered. The "Inertial Navigator" merges the filtered GPS data with the orientation data from the IMU to arrive at a "blended navigation solution" as shown in the figure. Heave data are pulled from the IMU for separate analysis to obtain "true heave" from the instantaneous real-time heave observations—see following section.

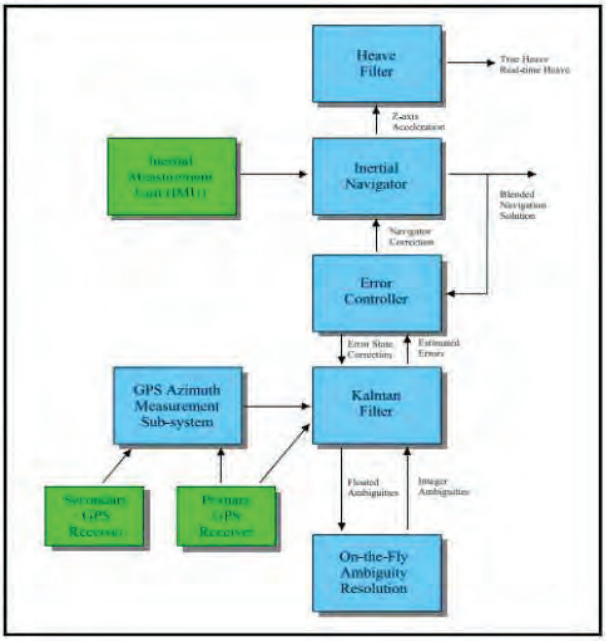

Figure 7-9. Flow diagram of an inertially-aided RTK system. (Applanix)

7-21. Vessel Heave Corrections and Considerations.

a. Heave is the effect caused by the action of sea and swell on the survey vessel, and is measured with inertial sensors or heave compensators. When using inertial sensors, installation should be close to the centre of gravity of the survey vessel with the known lever arms from the centre of gravity to the transducer; with the roll and pitch instantaneous angles, the measured heave can be transferred to the transducer position, through the application of the induced heave—see Figure 7-10. To calculate the induced heave, consider the vessel to be a rigid body that is free to rotate around the three axes (x, y, and z). The rotation about the centre of gravity (roll and pitch), near which heave is usually measured, corresponds to a transducer depth variation, from the vessel reference frame to a local co-ordinate system. This difference is called induced heave. (IHO 2005).

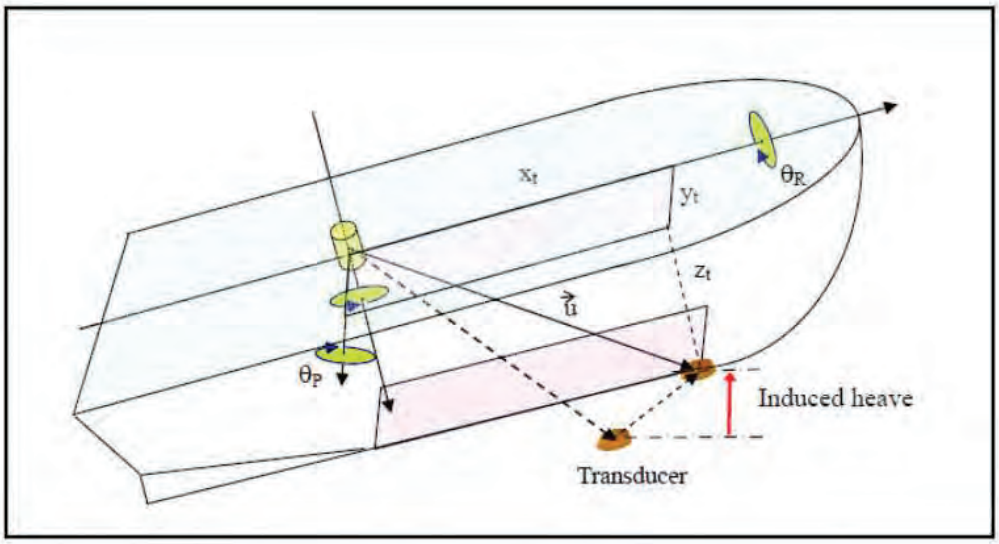

Figure 7-10. Measured heave at the IMU and induced heave at the transducer.

b. True Heave. (Portions of the following are excerpted from OCS 2011.) Heave data are calculated using a double integration of acceleration over a period of time. When recording heave in real-time, the calculation is performed using only past measurements of acceleration. An improved estimate of vessel low-frequency heave can be calculated by performing the integration over a time period centered on the time of interest, resulting in a "True Heave" value (also referred to as "delayed heave"). The difference between observed real-time heave and True Heave is illustrated in Figure 7-11. "True Heave" is an option available with POS/MV. True heave is effective across long-period wave conditions (16- to 30-second period swell), whereas a real-time heave filter tends to exhibit its most notable artifacts in such conditions (>16 seconds). True heave is also effective when performing surveys within areas where the observed swell period is dynamic (i.e., when surveying into the oncoming swell vs. in the same direction as the swell). This is affected (up to 30% of observed swell height) by the settling rate and cannot be fine-tuned in both directions. For this reason, we cannot observe true heave until after the real-time heave has been observed. (Note: True Heave does not replace the need for dynamic draft corrections or water level corrections.) True Heave is logged using the POS/MV Controller software, via the Ethernet connection to the POS/MV PCS. True Heave data logging must be controlled separately from the primary data acquisition software, but it can be continuously recorded throughout the day. The True Heave filter requires a period of up to five (5) minutes after it has been enabled to initialize. The filter uses vertical acceleration data three (3) minutes past real time; hence, logging must continue for at least three (3) minutes past the ending time of survey line data acquisition. The time base used for True Heave data, "Heave Time 1", is user selectable in the POS/MV Controller software. The UTC (default) should be selected, not GPS time. Refer to the POS/MV User manual for more information regarding the theory, operation, and setup of "True Heave."

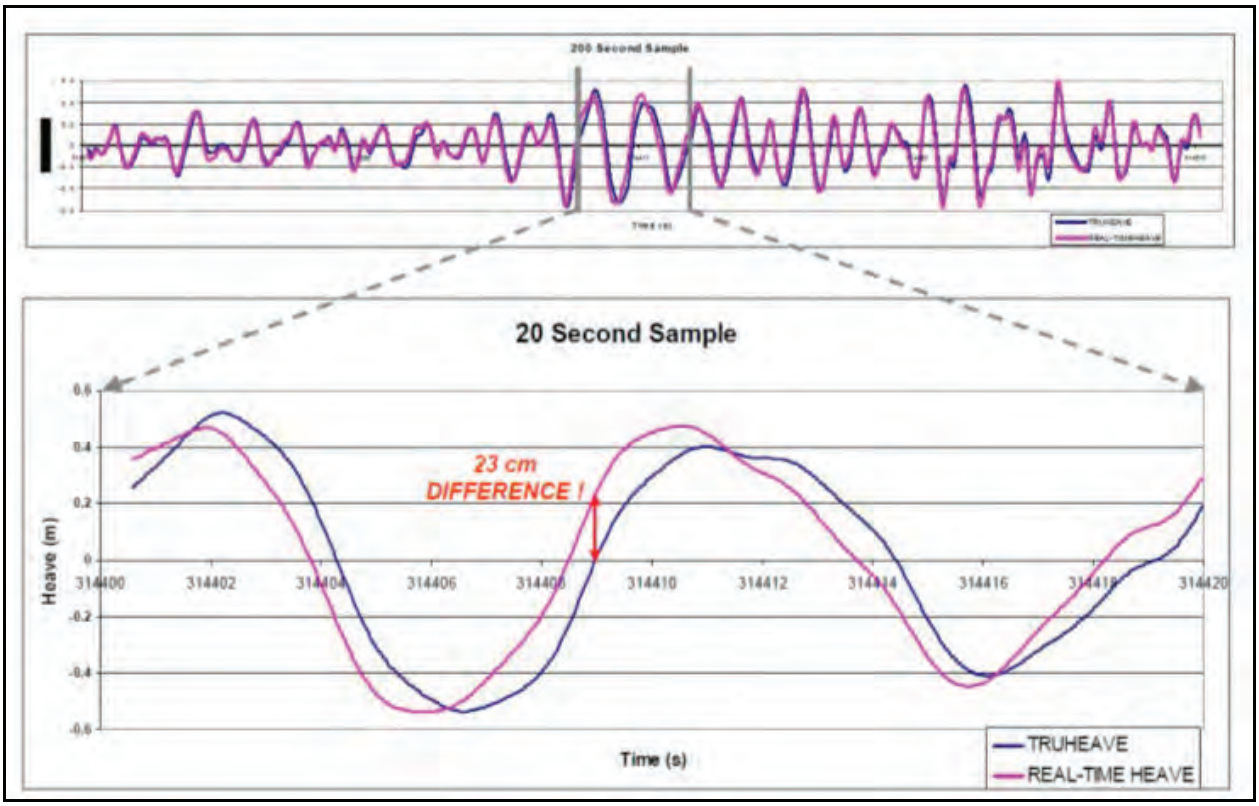

Figure 7-11. Differences between real-time heave and post-processed "True Heave." (Jacksonville District)

c. Quality assurance. Vessel heave corrections must be continuously monitored during survey operations. This is performed by monitoring real-time heave corrections on a screen display, noting any anomalies as the survey line progresses. This is particularly important during and after vessel turns to ensure induced heave on the turn has settled out before the next survey line begins. Office processing should also review heave corrections applied to the data. In cases where heave data has been incorrectly applied the correction will need to be removed.

7-22. Recommended Quality Control Criteria for GPS Positioning Methods. Table 7-1 presents a summary of recommended QC procedures to be followed when using the various positioning and orientation systems described in this chapter. These criteria apply only to dynamic hydrographic survey applications, not to observations made to locate or calibrate a stationary platform or structure.

Table 7-1. Recommended QC Criteria for USACE Hydrographic Survey GPS Positioning

POSITION CHECK RECOMMENDED	1/day at known NSRS or project PPCP or check with alternate positioning system
Acceptable horizontal tolerance	2 m (code DGPS) 0.1 m (carrier RTK)
RTK TIDE VERTICAL CHECK WITH GAGE	2/day (minimum)
Acceptable tolerance	0.1 ft
LEVER ARM MEASUREMENTS transducer, IMU, GPS antenna, gyro	Determine at initial installation or if sensors are relocated (to 0.1 ft or better). Verify correct settings in software (daily).
HEAVE	Monitor continuously in real-time. (post-process for True Heave)

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CHAPTER 8

Coastal Navigation Project Channel Condition Surveys

8-1. Purpose. This chapter covers channel condition surveys that are periodically performed on USACE coastal navigation projects to assess channel clearance conditions and evaluate needs for maintenance dredging. These condition surveys are normally performed annually; however, on high shoaling projects, quarterly, monthly, or even daily condition surveys may be required. Survey data is furnished to the public in various formats: digitally, channel condition reports, and hard-copy drawings or maps. The guidance in this chapter outlines procedures for distributing electronic and hard copy map/chart products to local project sponsors, pilots, NOAA, USCG, commercial and recreational waterway users, and the general public. This guidance supplements applicable portions of ER 1130-2-520, Navigation and Dredging Operations and Maintenance Policies, and EP 1130-2-520.

8-2. Scope. This chapter includes technical guidance on condition survey procedures, accuracy requirements, data content standards, technical compilation criteria, and data distribution procedures. It covers periodic project condition surveys of coastal deep-draft and shallow-draft projects, including the Great Lakes and the Atlantic and Gulf Intracoastal Waterway systems. These projects are typically charted by NOAA using Corps-furnished condition survey data. This chapter does not cover the inland navigation system that is mapped or charted by USACE districts—i.e., the Mississippi, Missouri, and Ohio River systems, including tributaries. These inland surveys are covered in Chapter 9. Channel condition survey data includes, but is not limited to, planimetric, topographic, hydrographic, tabular, and related geospatial data contained in CADD, GIS, or other computer-based systems that are used to collect, process, or store data.

8-3. References. Executive Order (EO) 12906, Coordinating Geographic Data Acquisition and Access: The National Spatial Data Infrastructure (NSDI), and Office of Management and Budget (OMB) Circular A-16, Coordination of Geographic Information and Related Spatial Data Activities, prescribe Federal policy and establishes mechanisms for acquiring, processing, storing, distributing, and improving utilization of geospatial data, including making this data readily and freely available to the public via Internet and other media resources.

a. ER 1110-1-8156, Policies, Guidance, and Requirements for Geospatial Data and Systems, provides implementing guidance for the above references. This implementing guidance is applicable to USACE condition surveys of federal navigation projects.

b. Chapter 2 of both ER 1130-2-520 and EP 1130-2-520 provides current policy and technical guidance on the publication of hard-copy charts and project condition reports on USACE navigation projects.

c. Section 554 of the Water Resources Development Act of 2000 (WRDA 2000) states that not later than 60 days after the Corps completes a channel dredging project, NOAA shall be

provided a digital data format of the results of the survey. The only exception is for pre-dredging or pre-construction surveys.

8-4. Overview. Coastal and Great Lakes navigation projects are surveyed at varying intervals, ranging from daily to annually. Each USACE command prepares and distributes these coastal project/channel condition surveys in hard- and soft-copy formats. Hard copy drawings of project condition surveys are typically furnished in a large-scale engineering drawing format (e.g., 1 in. = 100 ft to 1 in. = 400 ft). These data are provided to local sponsors, pilots, and federal agencies. NOAA is a primary user of this survey data—incorporating it onto NOAA charts that cover the project area. NOAA charts are usually at much smaller scales than the large-scale USACE surveys—typically in the 1 in. = 500 ft to 1 in. = 3,000 ft range. As a result of these scale disparities, detailed USACE project condition survey data is not always directly included on NOAA charts, but is summarized on the charts in tables of channel clearances.

8-5. Condition Survey Standards and Specifications. The following guidance is intended to cover periodic condition surveys of coastal navigation projects. Guidance on survey density and coverage options are provided. Survey methods may include either single beam or multibeam techniques, as covered in Chapter 4 and Chapter 6 respectively.

a. Survey frequency. The required frequency of condition surveys is largely dependent on projected shoaling rates, project use, along with maintenance dredging activity and related funding. Shipper's reports and USCG Notice to Mariners are other indicators of possible shoaling in waterways. Most active authorized federal navigation projects are surveyed annually to assess their condition. Inactive projects may be surveyed once every 5 to 10 years, depending on funding. Critical, high volume projects may get quarterly or monthly condition surveys. For example, New Orleans District surveys Southwest Pass continuously (daily). Reservoir sedimentation surveys may have 5- to 10-year condition survey periods. Every project contains unique parameters that require engineering judgment to predict the correct elapsed time between condition surveys. Unless unique circumstances are present (e.g., hurricanes), condition survey schedules should parallel the recurring maintenance dredging work on a given project.

b. Determining density of survey coverage. Coverage density in this section primarily applies to selecting line spacing on single beam surveys. (Multibeam survey techniques effectively provide 100% coverage density.) The line spacing density required for a condition survey is highly dependent on the type of navigation project. Considerations in selecting line spacing include shoaling rates, potential bottom hazards, survey funding availability, and maintenance dredging frequency. Often, condition survey coverage line spacing is larger than that of dredging measurement and payment surveys. However, if the condition survey is intended to be used for construction plans and specifications, then a maximum density of coverage should be obtained. Surveys can be designed to maximize coverage along critical channel navigation points, such as high shoaling areas, and widen line spacing in non-shoaling or natural grade areas. Navigation projects without defined channel limits, e.g., some Intracoastal Waterway projects, may require broader coverage to define the deepest channel alignment. In some instances, shoal areas encountered during a condition survey should be immediately

resurveyed to a higher density suitable for a plans and specifications. On large deep-draft projects, single beam (and multibeam) lines are often run parallel to the channel alignment, near the toes, quarter points, and centerline. On narrow shallow-draft project with minimal maintenance activity, one single beam or wide-angle multibeam line may be run down the centerline to assess the condition.

c. Survey quality control and quality assurance requirements. Condition survey QC and QA should follow the recommended procedures in the respective chapters in this manual for single beam and multibeam systems. This includes ensuring the condition survey is firmly referenced to NSRS control, in accordance with the policy in ER 1110-2-8160, Policies for Referencing Project Elevation Grades to Nationwide Vertical Datums. Requirements for QA Performance Tests may be relaxed if prior (historical) test results were positive and indicate solid repeatability.

d. Depth accuracy standards. Depth accuracy specifications for project condition surveys should follow the recommended guidance in Chapter 3. If Performance Tests were performed, the results from those tests should be indicated on the drawings. Alternatively, if the data will be furnished to NOAA for inclusion on nautical charts, it may be beneficial to indicate if the estimated accuracy (e.g., TPU) meets one of the IHO standards, e.g., “Special Order” or “Order 1a” (IHO 2008). The estimated TPU (TVU and THU) for the condition survey dataset should also be indicated on the drawing note block/level. TPUs in many shallow draft projects will normally meet IHO “Special Order” standards. These IHO “Special Order” tolerances may be difficult to meet on some coastal deep draft projects where tidal models are uncertain and vessel motion is uncompensated. In this case, the IHO “Special Order” standard would not be met and the IHO “1a Order” standard may be applicable, as reflected by the estimated TPU for the dataset. Refer to Appendix E for details on IHO standards.

e. Field Survey Report. It is recommended that the field survey team prepare a "Field Survey Report" for every condition survey. The report should be brief—one to a few pages. It should cover the general highlights of the survey, e.g., datums, control, positioning, equipment, software, QC, QA, raw/edited file archives, issues or problems, etc. The metadata file for the survey may be attached to this report. An example of a Field Survey Report is in Appendix J.

8-6. Topographic Feature Standards for Condition Surveys. The following paragraphs provide general guidance on topographic features shown on condition survey drawings or maps. Features include shorelines, bulkheads, berthing limits, rights-of-way, fixed NAVAIDS, and other various structures. Aerial imagery or terrestrial laser scans may be substituted if adequate to provide feature detail. (See examples in Appendix N.)

a. General mapping feature requirements. Base channel condition drawings/maps should consist of planimetric line drawings depicting critical navigation features within and adjacent to the navigation channel. Features in CADD/GIS formats should be separated by attribute/layer/level assignments. Care should be taken to ensure a linestring depicting a feature is continuous or linked, rather than a series of disconnected graphic elements. Area features

should also be depicted with closed polygons or shapes. Superimposed digital imagery (e.g., orthophotos) is optional. Except for significant landmark items, features should generally be confined to the waterway. Overbank topography needed to define bankline limits on rivers with significant stage variations should also be included. If these base map products will be used for other planning, engineering or construction purposes, then topographic, DEM/DTM, and/or digital orthophoto images may be included as separate layers/levels with the base planimetry.

b. Base mapping feature accuracy standards for navigation projects. Features shown on channel condition survey products should have an accuracy consistent with maritime charting accuracy in order to ensure mutual consistency with positioned features on NOAA charts. IHO 2008 indicates a 6-ft (2 m) tolerance is adequate to depict features that are "significant to navigation." This feature accuracy tolerance falls within the average accuracy obtainable from GPS receivers using the USCG maritime DGPS radio beacon network along coastal and inland waterways. (Local RTK/RTN networks easily meet this standard.) In some instances, critical navigation features may need to be located to a higher accuracy using conventional survey methods. These features might include fixed navigation aids, lock chambers, lock approach walls, bridge piers/fenders, etc. Short-term (few seconds) static positions with maritime DGPS may provide a sufficient accuracy for these features. Existing as-built drawings may also be used if geographically referenced.

c. Reference datums. All engineering drawings of USACE coastal navigation projects should be horizontally referenced to the current NSRS (National Spatial Reference System). Vertical datums in tidal areas and the Great Lakes should be consistent with NOAA NWLON gage networks. Refer to EM 1110-2-6056 for guidance on NSRS and NWLON datums.

d. Local reference systems. Chainage-Offset coordinates and River Mile systems should be included on all products where applicable.

8-7. Hard Copy Map Scales and Formats. Condition surveys of coastal inlets are typically published at map scales ranging from 1 in. = 100 ft to 1 in = 400 ft. A 1 in = 200 ft scale is most commonly used. Larger scales (e.g., 1 in = 50 ft to 100 ft) may be used in/around critical navigation features--e.g., locks, dams, bridges; however, basic project condition survey map scales should generally not be less (smaller) than 1 in = 400 ft. For Intracoastal Waterway systems, a minimum base map compilation scale of 1 in = 400 ft (1: 4,800) is recommended. A variety of methods may be used to depict the controlling depths and shoals on condition surveys. These include (1) numerical soundings, (2) contours, (3) color coded soundings, or (4) color coded dense pixels. The depth presentation used is also dependent on the preferred requirements of primary users, such as river and harbor pilots. Therefore, varying project-specific formats will be used throughout the Corps. Figures 8-1 to 8-4 are examples of different condition survey plan formats from various districts. They also illustrate the use of contours and color coding to depict areas above an authorized grade.

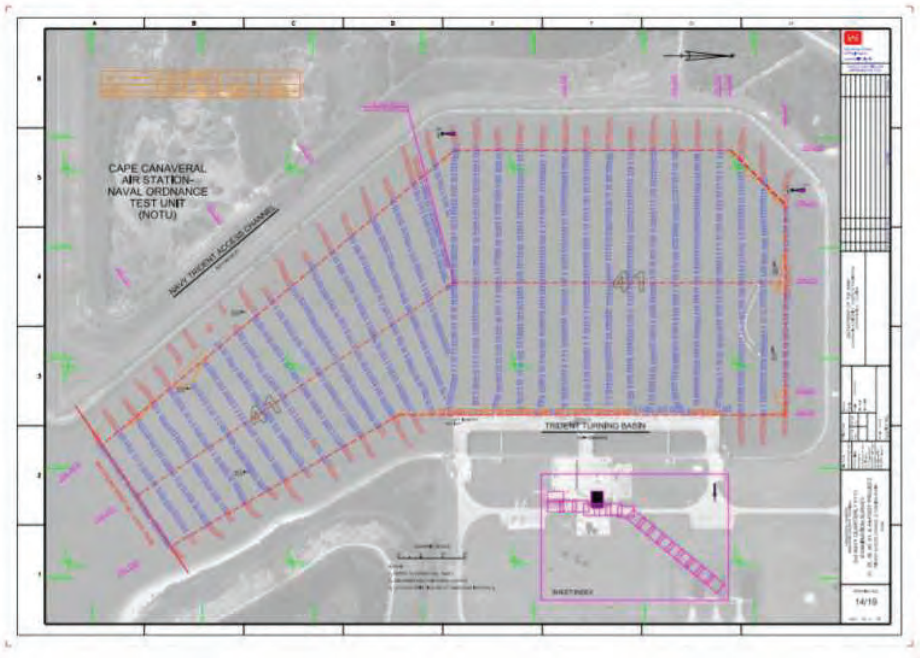

Figure 8-1. 2nd Quarter FY 2011 Jacksonville District condition survey of Cape Canaveral 41-ft project—Trident Turning Basin portion. Single beam cross-sections were run 100 ft c/c throughout project. Published drawing scale is 1 in. = 100 ft.

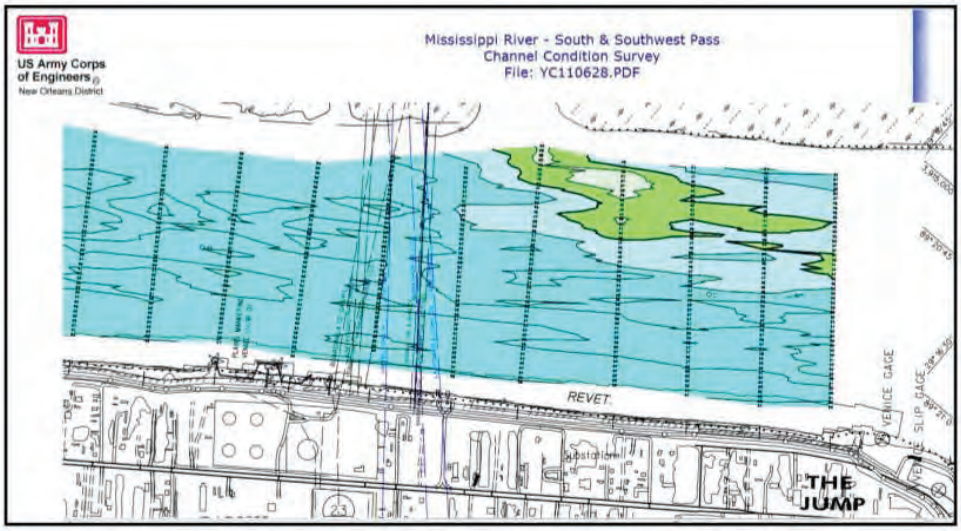

Figure 8-2. Portion of a New Orleans District daily (28 Jun 11) condition survey on the Mississippi River at Venice, LA. Single beam cross-sections spaced approximately 500 ft c/c. Color shaded contours depict regions above and below 50-ft project depth.

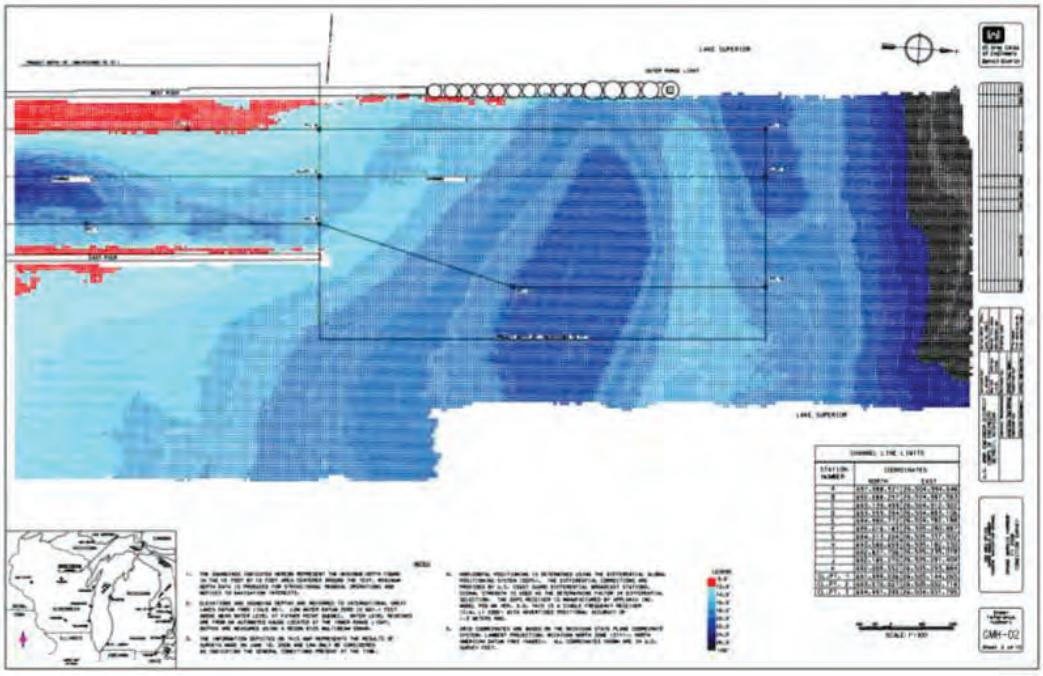

Figure 8-3. Detroit District (Soo Area Office) 2008 multibeam condition survey of Grand Marais Harbor on Lake Superior. Depths are plotted at a fine grid density (approximately 10-ft bins) with color shading to depict areas above the 20-ft project grade. Published drawing scale is 1 in = 100 ft.

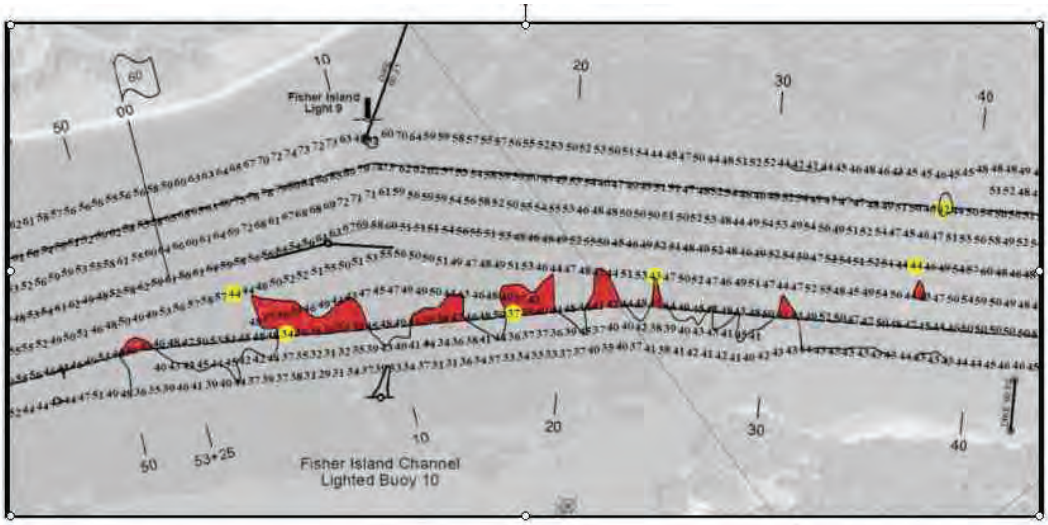

Figure 8-4. Portland District Project Condition Survey of portion of Fisher Island Channel in the Columbia River. Shoaling areas and controlling depths are highlighted. This drawing was produced from an ESRI GIS platform. (Note that soundings are rounded to the nearest even foot)

8-8. Feature Content and Digital Data File Standards. ER 1110-1-8156 directs that non-raster data developed by USACE must comply with (1) Architectural, Engineering, and Construction AEC/CAD Standards, (2) the Spatial Data Standards for Facilities, Infrastructure, and Environment (SDSFIE), and/or (3) the National CAD Standard. The SDSFIE includes a delineation of graphic elements and non-graphic attribute tables and domain lists describing these elements which are indexed into a schema or data dictionary. It also includes graphic symbology and other display and digital characteristics.

a. CADD and GIS standards. Project condition survey data should be collected, processed, and distributed in standardized vectorized formats, with individual feature CADD and/or GIS layers/levels that separate feature categories as much as possible. Text and annotation should also be separated by layers/features. Digital data should use the latest release of the AEC/CADD Standards—to include feature standards, formats, file standards, symbologies, etc.

b. Chart symbolization standards. NOAA has developed a feature symbology library that should be used as the Corps-wide standard for all navigation data products. This library is based directly on the IHO S-52 Standard for hydrographic data presentation—see IHO 2010.

c. S-57 Standard (IHO 2000). IHO Publication S-57 (S-57—IHO Transfer Standard for Digital Hydrographic Data) describes the standard to be used for the exchange of digital hydrographic data between national hydrographic offices and for its distribution to manufacturers, mariners and other data users. This standard is intended to be used for the supply of data for Electronic Chart Display and Information Systems (ECDIS) and/or Electronic Chart Systems (ECS).

d. Electronic data file type and format standards. USACE districts utilize CADD technology for the preparation, distribution, storage, and maintenance of engineering and architectural drawings, including navigation project condition survey data and related maps. Standardized file structures for these CADD platforms should be followed to simplify subsequent file conversion to the S-57 international nautical chart standard. These file structures include defined drawing file origins, units, naming conventions, sheet layout, level/layer assignments, symbology, exchange formats, etc. These standards are defined in the AEC CADD Standards.

e. GIS-based technology. Use of GIS software provides spatial relationships between all geographic features (entities); allowing for more enhanced data query, analysis, retrieval, and display than traditional CADD systems. Such files are more useful to vendors and are more suitable for conversion to the international S-57 charting standard.

8-9. Internet Posting of Project Condition Surveys. Most USACE districts post project condition survey data on the Internet for free public distribution. Periodic condition survey drawings can be uploaded to a district Web server; typically within a few days of receipt of field survey data. This provides near-real-time receipt of channel condition data by project users and federal agencies. USACE procedures for posting vector files and raster images have been

developed in each district in coordination and cooperation with NOAA. The USACE Navigation Data Center (Institute for Water Resources) Web site contains a comprehensive index of links to navigation data in 37 USACE districts.

a. File formats. Raster images can be posted in a format that is Web browser compatible—i.e., without need for plug-ins. These file formats may include PDF, CGM, JPEG, GeoTIFF, CRL, ECW, BSB, IGA, HMR, and IPLOT. Posted vector formats may include DGN, DXF, S-57, ESRI Shapefiles, VPF, or CARIS generated files. Many districts currently provide three or more raster or vector formats for each condition survey on their Web site—most commonly DXF, DGN, PDF, and JPEG. Basic X-Y-Z depth data may also be posted. Position and depth data should be shown to a resolution not exceeding 0.1 ft. It is recommended that districts begin to transition towards providing S-57 compatible data for coastal area navigation projects charted by NOAA. GIS compatible formats are also posted by some districts. HYPACK's "ENC Editor" software provides options for developing digital chart products suitable for Internet posting. CARIS (New Brunswick, Canada) has similar S-57 generating modules. (CARIS software is used to support the USACE IENC program in the inland waterways).

b. Metadata. A metadata file describing the geographic data file(s) content and format should be generated and placed on the Internet along with the appropriate links to the geographic data file(s). Metadata files should be generated following the guidance in EM 1110-1-2909, Geospatial Data and Systems.

c. Hard copy drawings. Districts should attempt to honor specific requests for hard copy paper drawings from agencies, sponsors, pilots, or individuals that cannot access the Internet or cannot print out large-format channel condition survey drawings.

8-10. Channel Framework Data. Coastal navigation projects should have defined channel framework parameters. A channel control framework is simply a digital 2D "plat" of a project's current (authorized) geospatial dimensions and alignments. Consistent channel framework data is essential in transferring surveys to other organizations, in particular, NOAA. It is also useful in maintaining archival geospatial data, as may be needed when comparing surveys from different eras. Channel framework data are normally maintained in CADD and/or GIS database files. Periodic channel condition surveys are surveyed and processed within this consistent channel framework. Mobile District is coordinating with NOAA to develop Corps-wide National Channel Framework standards within a GIS database structure. Additional details on channel framework requirements are attached at Appendix K.

8-11. Channel Condition Survey Drawing Notes. Following are examples of typical notes that should be included on framework files, and included for condition survey drawings that are incorporated into the framework file. Notes should be tailored to each project, sufficient to define the basic horizontal and vertical datums along with related field positioning criteria.

a. Horizontal Reference Datum & Coordinate System. The file should contain a general note that identifies the horizontal reference datum and its origin. Following is an example of a general note.

THE HORIZONTAL REFERENCE DATUM FOR THIS PROJECT IS NAD83, BASED ON THE CURRENT VERSION OF THE NOAA NATIONAL SPATIAL REFERENCE SYSTEM (NSRS). GRID COORDINATES ARE SHOWN IN THE [state] STATE PLANE COORDINATE SYSTEM [zone]. CHANNEL STATIONING AND OFFSETS ARE RELATIVE TO THE CHANNEL BASELINES. CHANNEL ALIGNMENTS ARE GRID BEARINGS REFERENCED TO THE SPCS GRID. UNLESS OTHERWISE INDICATED, CHANNEL WIDTHS AND LIMITS CONFORM TO THE AUTHORIZED PROJECT DIMENSIONS.

b. Primary horizontal control reference. A note should identify the primary reference PBM along with the positioning method employed on the project. On large projects, multiple PBMs may be needed and may be tabulated. An RTN network would be considered a “PBM” presuming it is based on the NSRS CORS network—a local calibration PBM should then be identified.

THE PRIMARY HORIZONTAL REFERENCE FOR THIS PROJECT IS NOAA/NSRS PBM "XXXXXX” (PID XX1234). DATA FOR THIS REFERENCE POINT SHALL BE OBTAINED FROM THE CURRENT NSRS DATABASE. THIS PBM SHALL BE USED FOR [RTK BASE APPLICATIONS] or [GPS/RTK/PPK/RTN POSITION CALIBRATIONS].

c. Vertical Reference Datum. A general note should specify the project datum, tidal epoch, and the primary reference gage.

THE VERTICAL REFERENCE DATUM FOR THIS PROJECT IS MEAN LOWER LOW WATER (MLLW) BASED ON NOAA TIDAL EPOCH 1983-2001. IT IS DEFINED RELATIVE TO PBM "TIDAL 123456 A 310" (NSRS PID XX1234).

In US coastal waters, MLLW datum shall be used exclusively. When a project legacy datum other than MLLW is used (e.g., MLW, NGVD29, MLG, LWRP), condition survey drawings will contain a vertical datum diagram showing the relationship between the particular local datum used and the MLLW (if tidal) and/or NAVD88 (if not tidal) datum—see EM 1110-2-6056. In the Great Lakes all project datums should be referred to IGLD (i.e., IGLD 85).

d. Vertical tidal datum model. Drawings should note the method which variations in the tidal datum are modeled at the project site relative to the primary reference gage. Options include a constant difference, interpolated model, hydrodynamically modeled, tidal zoning, or NOAA VDatum. In some cases a local tidal datum may be identified. Refer to EM 1110-2-6056 for details on tidal modeling and correction options.

e. Survey accuracy estimates. If actual Performance Tests were conducted, then the resultant statistic (standard deviation) from that should be noted. If no test was performed, then an estimated accuracy (standard deviation) based on historical testing results may be noted. Alternatively, the estimated accuracy may reference meeting a standard tolerance in Table 3-1 of this manual. Optionally, condition surveys performed to meet an IHO standard may note that standard on the drawing.

THIS SURVEY WAS PERFORMED TO MEET THE TOLERANCES INDICATED IN TABLE 3-1 OF EM 1110-2-1003. PERFORMANCE TESTS [WERE] [WERE NOT] PERFORMED [add test details and results as appropriate].

THIS SURVEY WAS CONDUCTED TO MEET IHO [SPECIAL ORDER] [ORDER 1a] STANDARDS.

f. Miscellaneous notes. Other pertinent details from the "Survey Report" or other record should be added to the condition survey drawing/file notes. These may include items such as: survey methods, vessel, instrumentation, frequency, dates, personnel, calibration data, etc. It is recommended that the "Survey Report" be attached to the archived metadata file. This is advisable since often drawing file notes are often removed when condition surveys are converted to plans and specification surveys in bid documents.

8-12. Tabular Channel Condition and Controlling Depth Reports. A variety of formats are used to provide project condition surveys and reports to local marine interests and other federal agencies. Plan and profile drawing formats are most commonly used; however, other narrative or tabular methods may alternatively be used, as described in this section.

a. ER 1130-2-520 contains USACE policy that “applicable [commands] shall cooperate in the communication of navigation-related information of specific interest to the recreational and commercial marine industries, users, and other related government entities. Specific guidance is provided in EP 1130-2-520.” Detailed guidance for preparing tabular “Reports of Channel Conditions” is found in Chapter 2 of EP 1130-2-520. This engineer pamphlet specifies that “District commanders shall prepare channel survey/condition reports from the results of each controlled survey, using ENG Forms 4020-R and 4021-R prescribed in Appendixes B and C of EP 1130-2-520 for tabular reports. For coastal areas, a copy of the tabular reports and survey drawings/tracings will be forwarded within 60 days after completion to …” Figures 8-5 to 8-7 are examples of tabular channel condition reports prepared by various districts. These reports may also be posted to district Web sites.

b. Tabular reports of controlling minimum depths in a channel reach are, in effect, large bins encompassing a wide breadth of the channel over its entire length. Reducing hundreds of thousands of recorded multibeam depths in this "bin" down to a single representative "minimum controlling" depth requires some type of standardized process. For example, in a 400-ft x 5,000-ft channel reach, the minimum depth shown for each channel quarter represents a 100-ft x 5,000-ft bin, or a 500,000 square foot area. A "shoal biased" depth selection option is typically selected

to represent the minimum depth over such a large reach. Unless the dataset is evaluated based on a "confirmed hit" type of analysis, a single anomalous and unrepresentative noise spike could end up being the falsely reported controlling depth for the entire channel reach. Reported controlling minimum depths should be truncated to the nearest whole foot, as shown in EP 1130-2-520. Channel Condition Reports are intended to report a minimum (safe) clearance depth based on the latest survey (Post Dredge, Project Condition, etc.). If an additional clearance "safety factor" is desired, then the representative depth could be rounded up to the nearest whole foot using the NOAA 0.7 ft truncation rule.

(1) Standards for "Reports of Channel Conditions." For assessing minimum clearances over an entire project reach "minimum confirmed" depths above grade should be used. Tabular reports of channel conditions should be generated similarly to those used for "strike" or clearance detection covered in Chapter 10 of this manual. Depths are normally binned from the edited dataset, using either 3 x 3 ft (hard material) or 5- x 5-ft (soft material) cell sizes. The "shoalest depth" of all depths in the cell is used as the representative depth for the cell; provided that there are a minimum of three (3) confirmed hits above project grade in the cell, or in an area between adjacent cells when the cells themselves are sparsely populated. The controlling minimum depth within a channel reach is then selected by analyzing all the cells in the given reach and selecting the individual cell with the minimum "confirmed" depth above grade. Automated software (e.g., HYPACK "Channel Condition Reporter") has been developed to perform this analysis over a channel reach.

(2) Plotting or tabulating only selected "minimum confirmed" depths on a Project Condition Survey that accompanies a tabular Report of Channel Conditions is a biased representation of the true project condition. Survey plots depicting only minimum (shoal-biased) depths should never be used for dredging plans and specifications or payment surveys since significant constant biases may be present. Plan drawings (or CADD files) of Project Condition Surveys should clearly note the depth selection option used.

c. Plan drawings and/or tabular reports of channel conditions furnished to other agencies should be prepared in accordance with the provisions of ER 1130-2-520 and EP 1130-2-520. Other significant requirements in this guidance includes (1) coordination and cooperation with the USCG on NAVAID location or relocation during design and construction, (2) USACE-maintained NAVAIDS, (3) requirements to furnish channel condition reports to the National Geospatial Agency (NGA), the US Naval Oceanographic Office (NAVOCEANO), NOAA, and the USCG, (4) required tabular formats for reporting controlling depths, (5) required grid systems, and (5) required plotting and tabulation of NAVAIDS located during the course of a survey.

8-13. HYPACK Channel Condition Reporter (CCR). A HYPACK utility program has been designed to quarter the channel along predefined reaches and tabulate minimum controlling depths along each reach and quarter. A variety of filters are provided, such as eliminating (footnoting) minimum depths near the toes. A DXF or DGN channel framework file is imported and quartering polylines defined for Outside Left, Inside Left, Channel Centerline, Inside Right,

and Outside Right sectors. A Report of Channel Conditions is then automatically generated from the latest condition survey, as shown in Figures 8-8 and 8-9. Full details on running this utility package are outlined in HYPACK 2011.

31-Mar-11

REPORT OF NAVIGATION CHANNELS ER 1130-2-306

COLUMBIA RIVER - OREGON & WASHINGTON
MOUTH THROUGH PILLAR ROCK LOWER RANGE mile 25.2

Authorized Project NAME OF CHART Name of Channel (Mileage)	Date of Survey	Feet Width	Miles Length	Project Depth	Minimum depths in each 1/4 width of channel entering from seaward: Mid-Channel Left Outside Quarter Feet	Left Inside Quarter Feet	Right Inside Quarter Feet	Right Outside Quarter Feet
MOUTH OF COLUMBIA RIVER	**24-Mar-11**							
Entrance Range		640	3.3	48	53	47	46	44
(-2.6 - 0.8)		2000	3.3	55	54	54	54	52
Sand Island Range		640	2.2	48	54	48	48	44
(0.8 - 3.0)		2000	2.2	55	51	54	54	51
LOWER DESDEMONA SHOAL	**01-Dec-10**							
Lower Desdemona Shoal		600	3.4	43	46	47	48	43
(3.0 - 6.4)								
UPPER DESDEMONA SHOAL	**24-Mar-11**							
Upper Desdemona Shoal		600	3.6	43	41	44	45	44
(6.4 - 10.0)								
FLAVEL BAR	**24-Feb-11**							
Tansy Point Turn & Range		600	3.6	43	41	43	43	36
(10.0 -13.6)								
UPPER SANDS	**23-Feb-11**							
Tansy Point Turn & Range		600	1.2	43	41	44	45	44
(13.6 - 14.8)								
Astoria Range		600	2.7	43	43	44	44	43
(14.8 - 17.5)								
TONGUE POINT CROSSING	**22-Feb-11**							
Tongue Point Channel		600	2.2	43	40	43	44	42
(17.5 - 19.7)								
Harrington Point Range		600	1.7	43	41	42	42	37
(19.7 - 21.4)								
MILLER SANDS	**28-Feb-11**							
Harrington Point Range		600	0.9	43	43	44	45	36
(21.4 - 22.3)								
Miller Sands Range		600	2.2	43	42	45	44	41
(22.3 - 24.5)								
Pillar Rock Lower Range		600	0.7	43	42	45	44	43
(24.5 - 25.2)								

ENG Form 4020-R (Nov 1990)
Reference is Navigation Chart No. 18521.
Note: Controlling Depths in Channels Entering from Seaward in feet at Mean Lower Low Water from the Entrance to Harrington Point and Columbia River Datum above that point.

Page 1

Figure 8-5. Tabular ENG FORM 4020-R (> 400 ft) channel condition report for the mouth of the Columbia River. (Portland District) Note that depths are rounded to the nearest even foot as required in EP 1130-2-520.

08-Mar-11

REPORT OF NAVIGATION CHANNELS ER 1130-2-306

COOS BAY - OREGON

Minimum depths channel entering from seaward

Authorized Project NAME OF CHART Name of Channel (Mileage)	Date of Survey	Feet Width	Miles Length	Project Depth	Left Outside Quarter Feet	Mid-Channel for half project width Feet	Right Outside Quarter Feet
COOS BAY ENTRANCE	**2-Feb-11**						
Entrance Range							
(-1.0 - 0.9)			1.9	37	39	41	39
COOS BAY RANGES	**21-Dec-10**						
Entrance Range & Turn		300	0.8	37	38	43	35
(0.9 - 1.7)							
Coos Bay Inside Range		300	0.8	37	35	38	35
(1.7 - 2.5)							
Coos Bay Range		300	0.9	37	36	37	37
(2.5 - 3.4)							
COOS BAY AND EMPIRE RANGES	**7-Dec-10**						
Empire Range		300-800	2.3	37	32	37	29
(3.4 - 5.7)							

ENG Form 4021-R (Nov 1990)
Reference is Navigation Chart No. 18487.
NOTE All Depths refer to Mean Lower Low Water

Page 18

Figure 8-6. Tabular ENG FORM 4021-R (< 400 ft) channel condition report for Coos Bay Entrance Channel. (Portland District)

REPORT OF PREVAILING CHANNEL DIMENSIONS

WILMINGTON HARBOR, NC SHIP CHANNEL
US ARMY ENGINEER DISTRICT, WILMINGTON

NAME OF CHANNEL	MAP FILE NO. WM 105-	DATE SURVEY	PROJECT FEET WIDTH	PROJECT MILES LENGTH	PROJECT FEET DEPTH	MINIMUM DEPTH IN EACH 1/4 WIDTH OF CHANNEL ENTERING FROM SEAWARD: LEFT OUTSIDE QTR-FT	LEFT INSIDE QTR-FT	MID-CHANNEL	RIGHT INSIDE QTR-FT	RIGHT OUTSIDE QTR-FT
BALDHEAD SHOAL	89-20	03-89	500	4.54	40	33.5	35.5	37.0	37.0	32.5
SMITH ISLAND	89-18	03-89	500	0.98	40	24.0	36.5	42.0	41.5	39.5
BALDHEAD CASWELL CHANNEL	89-5	01-89	500	0.38	40	39.5	40.0	40.0	41.5	38.5
SOUTHPORT CHANNEL	89-6	01-89	500	1.02	40	42.5	43.5	41.5	42.0	37.5
BATTERY ISLAND CHANNEL	89-24	04-89	500	0.49	40	43.0	44.0	44.0	39.0	33.5
LOWER SWASH	89-19	03-89	400	1.60	38	33.5	40.0	40.0	40.5	34.0
SNOW MARSH	89-23	04-89	400	3.06	38	36.0	37.5	38.5	38.0	34.5
HORSESHOE SHOAL	89-25	04-89	400	1.22	38	31.5	38.0	38.0	38.0	38.0
REAVES POINT	89-26	04-89	400	1.17	38	35.0	38.0	38.5	38.0	37.0
LOWER MIDNIGHT	89-28	03-89	400	1.64	38	34.5	37.5	37.5	38.0	35.0
UPPER MIDNIGHT	89-22	03-89	400	2.69	38	37.0	38.0	38.0	38.0	35.5
LOWER LILLIPUT	89-29	04-89	400	1.94	38	36.5	37.0	37.0	36.5	36.0
UPPER LILLIPUT	89-31	04-89	400	1.94	38	36.0	36.5	38.0	36.5	37.0
KEG ISLAND	89-32	04-89	400	1.35	38	37.0	38.5	38.5	37.5	33.0
LOWER BIG ISLAND	89-35	04-89	400	0.76	38	36.0	38.5	38.0	37.0	29.0
UPPER BIG ISLAND	89-35	04-89	400	0.50	38	36.0	39.0	40.5	40.0	31.0
LOWER BRUNSWICK	89-34	04-89	400	1.64	38	19.5	39.0	39.5	38.5	35.0
UPPER BRUNSWICK	89-33	04-89	400	1.00	38	21.0	39.5	39.0	39.5	32.5
FOURTH EAST JETTY	89-30	04-89	400	1.24	38	36.0	40.0	39.5	40.0	38.5
BETWEEN CHANNEL	89-16	03-89	550	0.80	38	33.5	40.5	40.5	39.5	38.5
ANCHORAGE BASIN & APP CHANNEL	89-15	03-89	450- 1090	1.30	38	36.0	38.0	38.5	37.0	35.5
BATTLESHIP TO HWY 74-76 BRG 32	88-18	02-88	300	0.62	32	26.5	35.5	36.5	36.0	34.5
HWY 133 TO BTLSHP & TB 32'	89-1	01-88	890	0.00	32	27.0	28.0	31.5	30.5	25.0
HILTON BRG (ACL RR) TO HWY 133	88-20	03-88	300	0.00	32	30.0	31.5	32.5	33.0	29.0
NORTHEAST (CFR) ABV HILTON BRG	89-12	02-89	200	1.23	25	21.0	24.0	18.5	18.0	13.5

NOTE: DEPTHS ARE EXPRESSED TO THE NEAREST HALF-FOOT AND REFER TO LOCAL MEAN-LOW-WATER.
-89

Figure 8-7. Tabular channel condition report for Wilmington Ship Canal (Wilmington District). Same information as reported on ENG FORM 4020-R except a mid-channel controlling depth is added to the report.

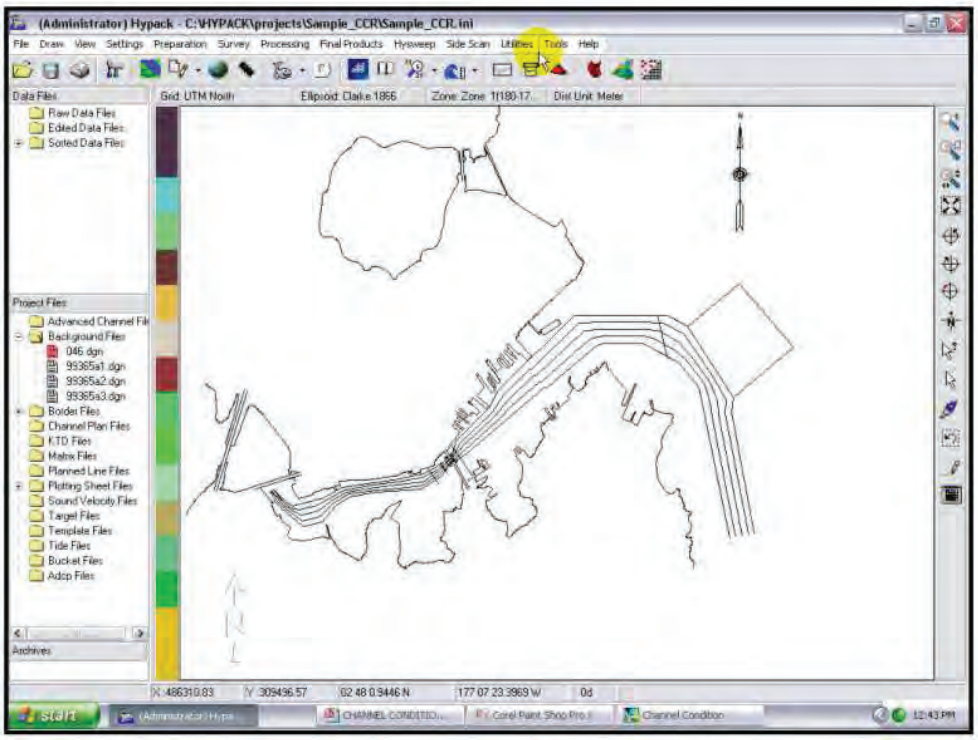

Figure 8-8. Setting up channel quarter polylines and reaches in HYPACK CCR. This utility was originally developed for New England District.

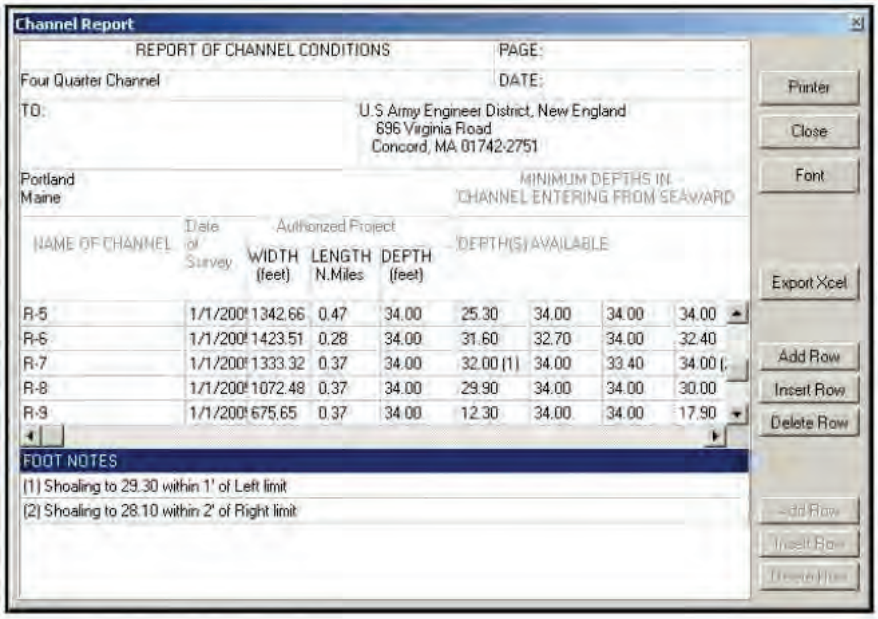

Figure 8-9. Automated HYPACK CCR report generation for a four-quartered channel.

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CHAPTER 9

Surveys of Navigable Inland Rivers, Locks and Dams, River Stabilization Structures, and Reservoir Surveys

This chapter describes hydrographic survey procedures used in support of the Corps inland navigation, water control, and river engineering missions. These activities include survey support for inland charts, hydrologic and hydraulic studies, investigation of river stabilization structures, scour surveys around bridges, locks, and dams, reservoir surveys, and other investigations needed to model physical aspects of river stabilization systems. General guidance on these surveys is detailed in this chapter and in attached appendices. The Atlantic Intracoastal and Gulf Intracoastal waterway systems are covered under coastal projects in Chapter 8.

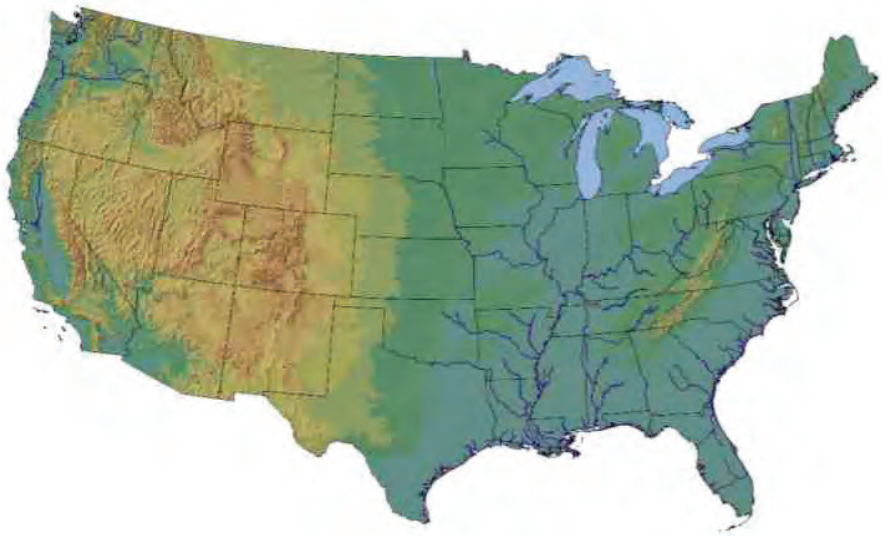

Figure 9-1. Corps inland navigation systems shown in blue. Includes various navigable inland tributaries connecting to the main stems of the Mississippi, Ohio, and Missouri Rivers. In Mobile District, the Tenn-Tom, Black Warrior, and Alabama River. Out west, the Columbia, Snake, and Sacramento River systems.

9-1. General Applications. The Corps performs a variety of hydrographic surveys throughout its inland navigation system (Figure 9-1). Many of these surveys involve underwater mapping and investigation of channel reaches, for the purpose of locating clear passages or shoaled areas requiring maintenance dredging. Hydrographic surveys are also performed in reservoirs and pools around many the Corps 692 dams and hydropower facilities. Surveys supporting hydraulic studies are also performed, measuring channel and overbank profile topography, current velocities, and flow directions; from which flood profiles and flood protection elevations may be estimated. Other survey applications include obtaining source data for inland navigation charts

produced by the various inland districts. These include traditional hard-copy chart books and electronic charting formats (e.g., IENC). Inland river surveys also include developing basic site data for specific localized projects such as river crossings, cutoffs, and bends, sediment movement and deposition, scour in bends, channel stabilization structures, and training structures such as spur dikes, longitudinal dikes, vane dikes, and closure dikes. Detailed hydrographic surveys are also performed around navigation lock approaches, guide walls, guard walls, lock walls, and adjacent dams. Such surveys are used for planning and design of maintenance or improvements to these structures.

9-2. Survey Equipment, Vessels, and Methods. Due to the variety of projects surveyed on inland navigation and water control systems, different hydrographic survey systems are used. In shallow draft projects (<15 ft) single beam systems are most commonly used. In the Middle and Upper Mississippi districts, multiple transducer boom systems are used. In deeper portions of a river (Lower Mississippi, bends, etc) multibeam systems are deployed. Multibeam surveys are also used in condition surveys of revetments, locks, dams, and various river control structures.

a. Survey vessels. Survey vessels on inland projects are usually less than 30 ft in length, 22-ft to 28-ft aluminum workboats being a common length. These trailerable size workboats allow for deployment along the major waterways and inland reservoirs. Various hull types are used: V-hull, cathedral (tri-hull), catamaran, etc. The selected hull type is often based on the mounting requirements for a multibeam transducer. Stability is also a hull selection factor. Power train (inboard, outboard, or inboard/outboard) and fuel types (gasoline or diesel) are dependent on local district preferences. Enclosed cabins are usually specially designed about the intended survey systems that will be installed.

(1) St. Louis District MV Boyer. The Mississippi Valley Division (St. Louis District) MV Boyer is typical of boats used for river engineering surveys and investigations on the Upper, Middle, and Lower Mississippi River, and the Ohio and Missouri Rivers. This 30-ft vessel (Figure 9-2) is equipped with twin 250 HP Yamaha outboards. This trailerable vessel with single beam, multibeam, acoustic doppler current profiling, bottom and fish classification, and side scan capabilities, has the ability to map underwater features of most flood control and river stabilization structures in the Mississippi Valley Division. Its on board data processing equipment provides a "field-finish" capability, enabling same- or next-day delivery of edited data sets to districts in the Mississippi Valley Division.

(2) Louisville District survey boats. Figure 9-3 depicts the various survey boats deployed by Louisville District on their Ohio River navigation projects. These trailerable, cathedral (tri-hull) boats have single/twin 135 HP outboard engines on the 23-ft survey vessels, and twin 225 HP on the 30-ft survey vessel. All three are equipped with single beam echo sounders, USCG Marine Radiobeacon DGPS positioning, RTK positioning, and motion sensors. The 30 ft vessel is a landing craft with a moon pool deployment for a Reson 8125-H multibeam system. The single beam boats are used for channel condition surveys, chart updating, and dredge support surveys. The multibeam survey boat is used to monitor scouring around structures, investigative surveys, and environmental mapping.

Figure 9-2. MV Boyer (St. Louis District)--used for river engineering surveys and investigations on the Middle and Lower Mississippi River.

Figure 9-3. 23-ft and 30-ft survey boats used on the Ohio River. (Louisville District)

b. Positioning and orientation systems. DGPS code phase horizontal positioning is adequate for most inland navigation surveys. Coverage can be obtained from the USCG Radiobeacon System or from commercial providers. Inertial orientation or heave sensing is rarely required for single beam or multiple transducer systems on normally calm inland waterways. Inertial heave-pitch-roll sensors (MRUs/IMUs) are required for multibeam systems. Inertial-aided GPS systems (e.g., POS/MV or F180 series) are used on some vessels. Carrier

phase GPS is recommended to control precise surveys of locks and dams--both horizontally and vertically--where 0.1-ft positioning and elevation resolution is required.

c. Vertical reference datum. Inland surveys are referenced to either the NSRS (i.e., NAVD88) and/or a local low water reference datum (e.g., LWRP, pool, reservoir). In some cases, an undefined (unreferenced) legacy vertical datum may be used. The relationship between any local or legacy datum to the NSRS must be established—see ER 1110-2-8160, Policies for Referencing Project Elevation Grades to Nationwide Vertical Datums. When inland river surveys are interpolated or extrapolated from gages 10 miles or more distant, the uncertainty of the low water reference datum at the project site may be large—often ±1 ft or more. This uncertainty must be factored into the estimated uncertainty of reported depths. Use of carrier phase RTK elevation measurements will help minimize these uncertainties. (Refer to EM 1110-2-6056 for descriptions of hydraulic datums used on USACE inland civil works projects.)

d. Single beam survey coverage methods. For most navigation, hydraulic, or physical modeling applications, single beam cross sections are run at a defined spacing. The spacing will be a function of the engineering detail required, and could range from 100 ft to 500 ft, or more on some general studies. Cross-section spacing will be reduced near lock approaches and other control structures. Cross sections are run perpendicular to the river flow and typically cover bank to bank. Dredging progress surveys are typically run at 100-ft cross-section intervals, channel condition surveys run at 200 ft sections, and IENC condition surveys at 200- to 400-ft spacing.

e. Multibeam and multiple transducer survey coverage methods. Multibeam surveys are usually only performed in deeper river sections—i.e., > 15-ft depths. Multibeam surveys are normally run upstream and downstream, "painting" the bottom with 100% acoustic coverage. Downstream runs in swift currents may result in along-track voids; necessitating only upstream runs against the current. Multibeam transducers may be physically or electronically "tilted" to port or starboard, providing coverage up to the water's edge on banks or revetments.

f. Topographic surveys. Not all river control or stabilization structures are fully submerged, requiring combined hydrographic and topographic survey methods. Fully submerged structures can be mapped using all the acoustic techniques described above, i.e., single beam, multiple transducer, multibeam, and optionally, side scan sonar. A variety of topographic methods may be used to obtain coverage on structures, revetments, or levees above water. Laser scanners (static and dynamic), aerial mapping, and traditional total stations are the most common methods. Topographic data are merged with hydrography to form a continuous model.

g. Recommended accuracies, QC, and QA criteria. Nominal accuracies and related performance standards for inland surveys are summarized in Tables 9-1 and 9-2 at the end of this chapter.

9-3. Inland River Charting Surveys. This section represents a brief overview on inland surveys that are utilized to update navigation charts, hydrographic books, reservoir maps, and related

products published by USACE districts and furnished to waterway users and the general public. Much of the guidance in Chapter 8 for coastal project condition surveys is also applicable to inland surveys.

a. Inland navigation chart products. On the inland waterway systems, USACE-published chart books are produced and distributed to the public in a variety of formats, symbology, scales, and electronic media; in accordance with the recommended guidance currently provided in EP 1130-2-520, Navigation and Dredging Operations and Maintenance Guidance and Procedures, for these products. Currently, hard-copy formats vary between USACE districts and/or waterways (Figure 9-4). Paper chart standards have been developed. The electronic version of all inland navigational charts is produced by the Inland Electronic Navigational Chart program, coordinated by the USACE Army Geospatial Center (AGC), and with production from the USACE Louisville District. These electronic charts are processed using Caris software. An index of these electronic charts can be found at the AGC website.

b. Accuracy standards for measured depths. Recommended accuracy standards for inland federal navigation projects are outlined in Table 9-1. In areas with high shoaling rates, rapid sand wave movement, or distant from river gages, these recommended standards will usually not be met. In such cases, an estimated accuracy (or uncertainty) should be clearly reported (noted) on drawings. Surveys near river control structures with established gages should easily be well within these nominal accuracy standards.

c. Accuracy standards for horizontal chart features. Planimetric navigation features on inland projects should be positioned to an accuracy of ±6 ft at the 95% confidence level. This standard is relative to the NSRS. This feature accuracy tolerance falls within the average accuracy of typical GPS receivers using the USCG/USACE maritime DGPS radio beacon network along the inland waterways. A minimum base map compilation scale of 1 inch = 400 ft is recommended for topographic/planimetric features critical to maritime DGPS referenced navigation. Scales larger than this (e.g., 1 inch = 50 ft to 200 ft) may be used in/around critical navigation features--e.g., locks, dams, bridges. Some critical navigation features may need to be located to a higher accuracy using conventional topographic survey methods. These features might include fixed navigation aids, lock chambers and lock approach walls, bridge piers/fenders, etc. Short-term static positions with maritime DGPS may provide sufficient accuracy for these critical features. Otherwise, RTK positions from a local base station or RTN will suffice. Existing as-built drawings may also be used if geographically referenced to the NSRS. Refer to EM 1110-2-6056 for additional details on locating project features relative to the NSRS.

d. Requirements for depth data on inland navigation chart products. Depth data obtained from periodic channel condition surveys may occasionally be shown on inland navigation charts, often at critical bends or lock approaches. However, some navigation charts published by USACE districts depict only topography and planimetry. This lack of depth data on the chart is due to a variety of reasons; one of which is rapid (daily or even hourly) large bathymetric changes on many river systems. As a result, depth data is quickly obsolete for charts published on a 2- to 10+-year cycle; therefore, these products do not show depths curves. "Hydro Books"

published by some Mississippi Valley Division districts contain subsurface bathymetric data. IENCs show a depth contour representing project depth or deeper from MLLW or Low Pool. The IENCs are in a monthly update cycle so the latest survey depth data can be made accessible to the navigation community. Print-on-Demand (POD) capability is entering mainstream. The USACE 2012 Atchafalaya River Navigation Folio is the first USACE charting publication maintained under print on demand. In POD, new up-to-date versions of the folio can be readily produced. This mechanism can allow for publication and maintenance of safe water depth contours.

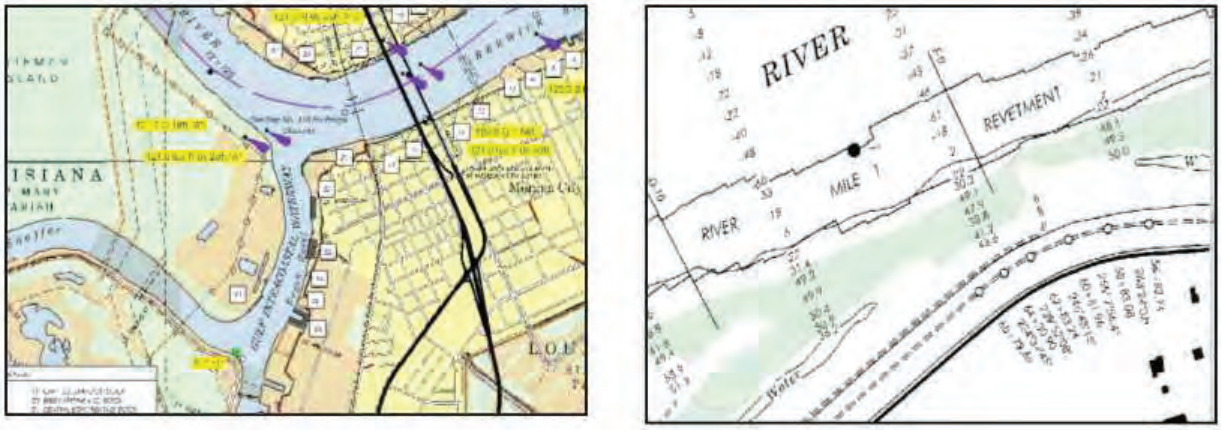

Figure 9-4. (left) Portion of Atchafalaya River navigation chart--Morgan City, LA area. Depth data is not shown on this navigation chart. (right) Portion of Atchafalaya River Hydro Book--Atchafalaya River Mile 1 Revetment. Cross-section bathymetry and overbank data shown.

e. Horizontal chart datum standards. All charts and engineering drawings of USACE inland navigation projects should be horizontally referenced to the NSRS—e.g., NAD83 and the GRS80 reference ellipsoid. Navigation projects still referenced to NAD27 should be transformed to NAD83. SPCS, Chainage-Offset, and River Mile coordinates systems should be included on all products where applicable.

f. Depth selection. Displayed depths on hard-copy charts must be thinned as a function of the engineering drawing or chart scale. Densely acquired hydrographic depth data--e.g., that collected from acoustic multi-transducer or multibeam systems--should be thinned to a bin size (or post spacing) consistent with the largest display scale use of the data. The recommended procedures and software used for such data thinning/binning are covered in Chapter 6 in this manual.

9-4. River Lock and Dam Investigation Surveys. Periodic investigation surveys are performed around river locks and dams (Figure 9-5). These surveys monitor shoaling and scour near the locks, the lock approaches, and adjacent underwater structures. Multibeam surveys provide the best detail in these river structures. In particular, multibeam surveys can identify scour occurring

downstream of gate structures. These surveys can quickly identify potential failure points where further investigation by divers or underwater cameras is required. These surveys require the most demanding QC and QA methods in order to minimize uncertainties in the measurements.

Figure 9-5. Typical inland lock and dam complex (Robert. C. Byrd Locks & Dam at Ohio River Mile 279.2—Gallipolis Ferry, WV—Huntington District). Detailed multibeam surveys are performed at the lock approaches, and upstream/downstream of the gates.

a. Control. Detailed investigation surveys of locks and dams should be controlled using RTK or RTN carrier phase positioning, with attainable X-Y-Z accuracies at <±0.2 ft. Usually a RTK base station is set up over a local benchmark at the lock. The horizontal coordinate system should be referenced to that established on as-built drawings for the lock—either SPCS or a legacy local coordinate system.

b. Reference gage. Most USACE inland lock and dam complexes have two established gages—an upstream gage and a downstream gage. These gages are hydraulically referenced to their respective pools and a local datum established for each pool. RTK surveys should be referenced (calibrated) to these gages and their local pool reference datum.

c. Survey procedures. Multibeam surveys are performed "dead slow" in and around the lock and dams—sometimes drifting over the site against the current. Repeated passes are made over potential scour areas below the gates. Wicket dams are surveyed at high water—they have too much noise in the water at low pool. Surveys of dams are best made during rising water since at high crests the turbulence creates dangerous conditions for the survey boat. Sufficient

redundant data should be collected to ensure the edited data in each 1-ft x 1-ft cell (typical) will be statistically representative of the site. Considerable editing may be required for data collected around structures.

d. Calibration. Multibeam Performance Tests may be made in the lock chamber. "RTK Tide" vertical elevation measurements should be calibrated at the lock pool gages.

e. Application examples. Examples of lock and dam investigation surveys at various USACE projects are shown in Appendix N. Appendix M, "2010 Allegheny River Multibeam/Side Scan Sonar Scour Survey," is a comprehensive report covering surveys of four locks and dams in Pittsburgh District.

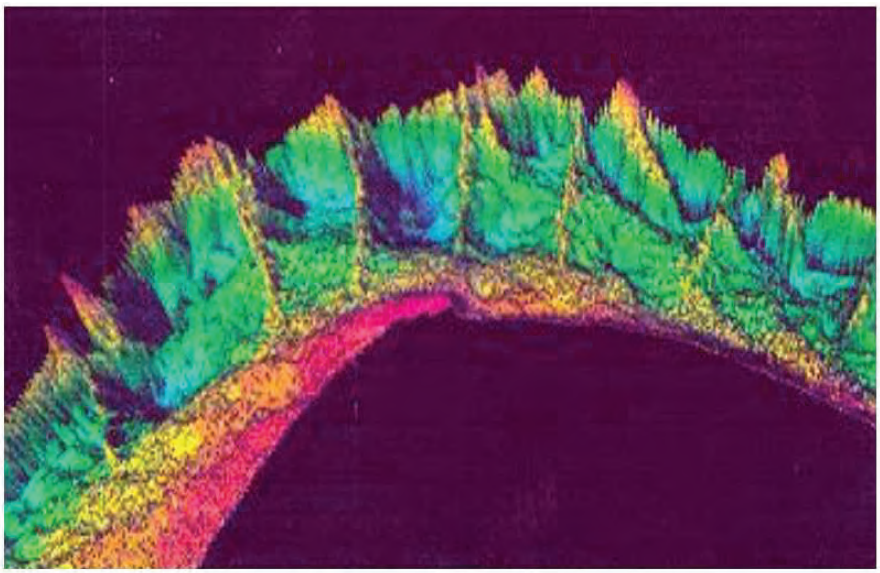

Figure 9-6. Multibeam survey of bendway weirs. This survey was performed in the mid-1990s with the first multibeam systems—newer multibeam systems have significantly better resolution. This coarser resolution in the 1990s was still far better than that obtainable from previous single beam surveys of the weirs. (St. Louis District)

9-5. River Stabilization Structure Surveys. Figure 9-6 is an example of a multibeam system survey over a series of bendway weirs on a bend in the Mississippi River. Periodic surveys can be performed to monitor sediment erosion and deposition in the bends and adjacent to the weirs.

9-6. Underwater Structure and Revetment Surveys. Multibeam transducers can be tilted upward to detail revetments, bridge piers, fenders, pilings, lock guide walls, breakwaters, jetties, and other structures. Depth coverage up to near the water's edge is often possible. In deeper water, coverage under moored barges along a riverbank is feasible. Revetment grading, construction, and maintenance projects require a variety of surveys. During placement of articulated concrete mats, control surveys are needed to accurately align the sinking plant equipment. Subsequent

hydrographic condition multibeam surveys are periodically performed to assess the condition of the concrete mats for needed replacement. The sketch at Figure 9-7 illustrates side viewing multibeam coverage on a riprap embankment. These surveys should be performed to a higher level of accuracy than that recommended for general river navigation surveys. Use of carrier phase RTK is recommended. Selected examples of underwater structure surveys are attached at Appendix N.

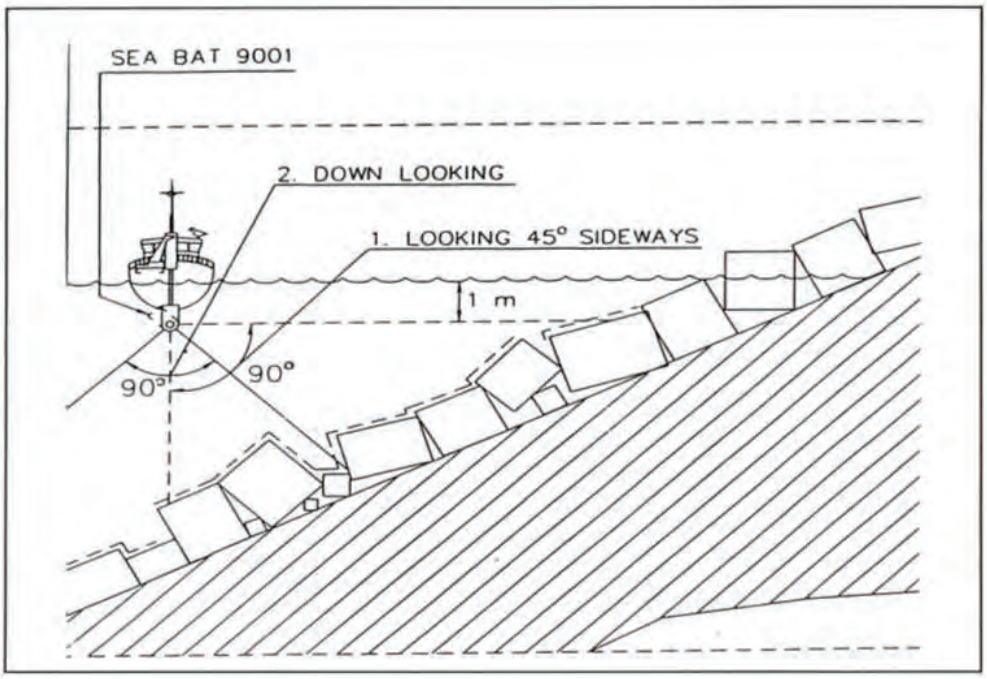

Figure 9-7. Tilting multibeam transducer head for surveying river revetments and other vertical structures. (Reson, Inc.)

9-7. Levee Breech Surveys. Figure 9-8 illustrates the use of multibeam systems during the Mississippi River Flood of 1993. This plot is an example of the first use of multibeam technology in the Corps—JE Chance (now Fugro) obtained the first system and it was deployed during the 1993 emergency flood fight. During high water stages in which levees were overtopped, breeches were located and mapped, allowing repair estimates to be made. Figure 9-8 also depicts a multibeam survey performed over Lock and Dam 25 when much of the structure was covered during high water.

9-8. Mississippi River Sand Wave Mapping. Multibeam systems can be used to track the downstream movement of sand on a river. These large amplitude sand waves found on the Mississippi River have a relatively high downstream velocity, as shown in Figures 9-9 and 9-10. Thus, any mapping survey of depths in these regions is only valid for the time (hour) of the survey, given depths can differ by 10 ft or more a day later.

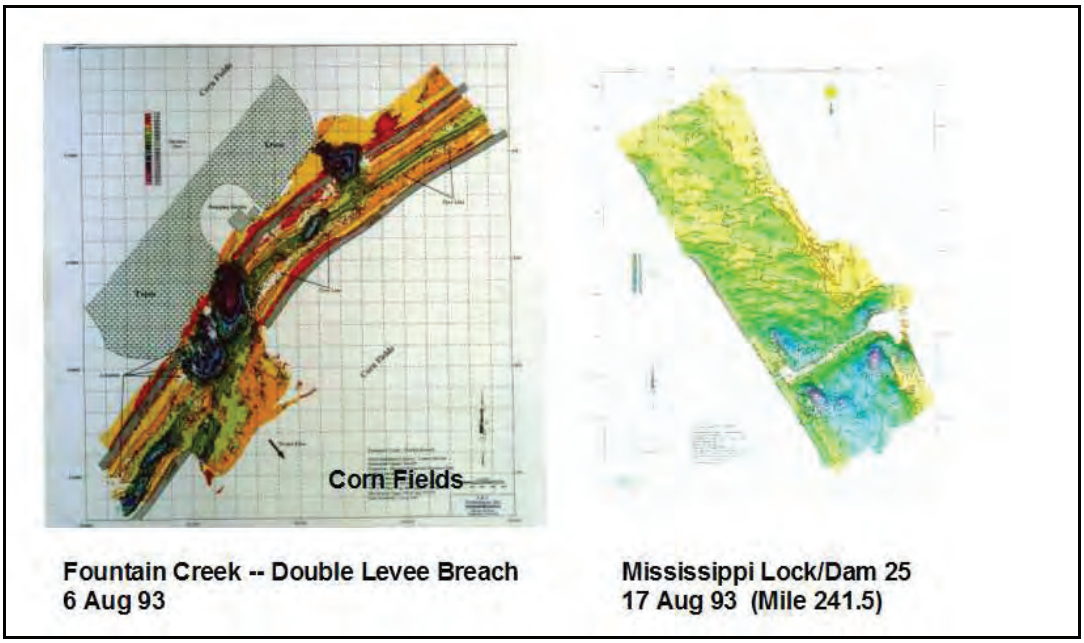

Figure 9-8. Levee breech and lock & dam surveys during high water. Flood of 1993, Mississippi River. (JE Chance & Associates for St. Louis District)

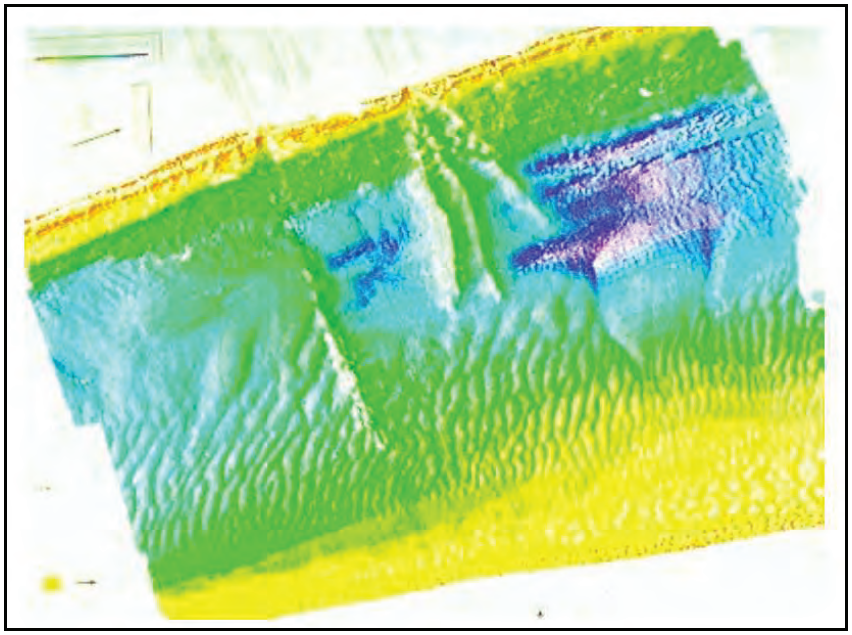

Figure 9-9. Lower Mississippi River sand wave features from multibeam survey.

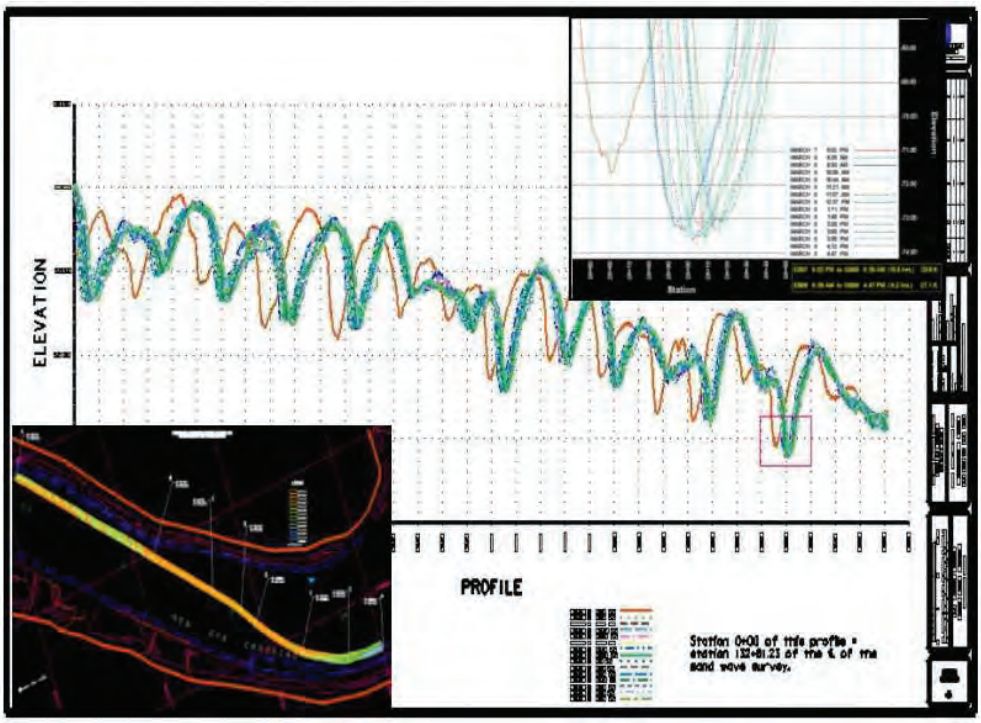

Figure 9-10. Sand wave progression at Red Eye Crossing, Mississippi River. 15-ft sand waves moving downstream at roughly 2 ft per hour.

SECTION I

Hydrographic Surveys for River Hydraulics Studies

9-9. Background. River hydraulic investigations and studies include the evaluations of flow characteristics and physical behavior of rivers--e.g., prediction of stage, discharge, velocity, and sediment transport rates. Basic hydrographic survey data is a critical component of these studies. Other hydraulic studies requiring field survey support may involve topographic details on dams, spillways, levees, and floodwalls. Hydrographic, topographic, and/or photogrammetric surveys may be required to support hydraulic modeling of floodplains, flood control channel design, navigation modeling, water quality assessment, and environmental impact and assessment analysis. Survey data is incorporated into physical and numerical hydraulic models used for analyzing or predicting the physical processes of a river system.

a. Hydraulic engineering studies. A variety of hydrologic engineering studies require hydrographic survey support to define the basic topographic models of river systems. These may include steady flow water surface profiles, unsteady flow simulation, sediment transport modeling, flood inundation modeling, hydraulic flood stage modeling and forecasting, flood inundation modeling and mapping, and flood damage risk assessment. Hydraulic studies typically require three general data categories: (1) discharge, (2) geometry, and (3) sediment. Hydrographic surveyors may be called upon to obtain basic field information for any of these

three categories. Obtaining stream section and adjoining bank and floodplain geometry requires a major amount of field survey effort.

b. Channel Geometry. Channel geometry derived from hydrographic surveys is required for any hydraulic study. Geometric data include channel and overbank topography, stream alignment, bridge and culvert data, channel roughness information, changes in stream cross-section shape or channel alignment. Hydrographic, photogrammetric, and conventional topographic surveys may be required to fully define a streambed, adjacent banks and floodplains. For movable bed studies, repeat surveys may be needed to evaluate a model's performance in reproducing geometric changes. Thalweg profiles or repetitive hydrographic surveys may be needed for analysis of bed forms and the movement of sand waves through rivers.

c. Discharge studies. Flood control projects are usually designed for the discharge corresponding to a specific flood frequency (design event) while navigation studies use a discharge for a specific low flow duration or frequency. Discharge data may include measured flows along with frequency, velocity, duration, and depth information. Surface profile elevations are also measured during flood events as an aid in flood routing studies. Water depth and channel cross-section profile are critical components in computing or predicting discharges. Acoustic Doppler Current Profilers (ADCP) are used to measure currents for determining discharge rates -- Figure 9-11.

9-10. Cross-Sections for Hydraulic Studies. Cross-section data are used to determine the conveyance and storage of a river channel and overbank areas. Stream section requirements are defined by the hydraulic engineer or study manager. Required cross-sections are typically plotted on a small-scale map (e.g., USGS quadrangle) of the study area. Cross-section spacing will vary depending on many hydraulic factors associated with the purpose of the hydraulic study. They must be obtained at sufficient intervals to define the flow carrying capacity of the stream and its adjacent floodplain, and at locations where changes occur in discharge, slope, shape, roughness, at locations where levees begin and end, and at hydraulic structures (bridges, weirs, and culverts)--see example layout at Figure 9-12. The type of hydraulic model (e.g., unsteady flow or steady flow) may also dictate cross-section locations. On the Mississippi River system, cross-section spacing varies from 500 ft to 5,000 ft. The width of the section depends on the extent of the floodplain (if any), existence of levees, and other factors. Some cross-sections may be run bank-to-bank in the river with overbank topographic sections run to the top of a levee and into the floodplain. If extensive flood inundation studies are involved, then the cross-section may be extended far out into the floodplain--to the so-called "bluff" line where maximum flood stages would be limited. These lines could extend significant distances on some river systems--5 to 10 miles or more.

a. Mixed survey methods. Obtaining cross-sections of floodplain basins requires a combination of survey methods. Hydrographic surveys performed in the river must be supplemented by conventional surveys in the overbank and flood plain areas. Surveys of the floodplains are usually more efficiently performed using aerial mapping methods, whereby a gridded digital elevation model (DEM) is created using airborne LIDAR or photogrammetric

methods. Airborne methods are limited by vegetation cover, which is usually dense along river banks. Conventional topographic survey methods (e.g., differential leveling, total station, RTK) will be required to develop obscured areas near riverbanks and to set breaklines in the final terrain model.

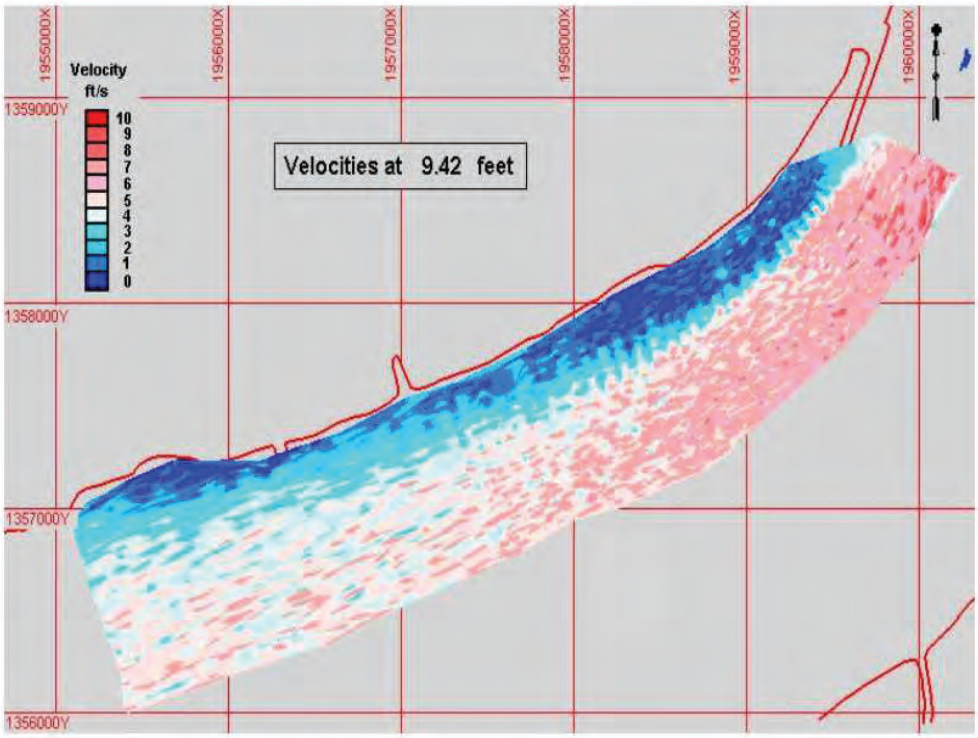

Figure 9-11. ADCP current velocities on the Mississippi River. Velocities shown are processed at 9.4 ft below surface. Surveys were performed using RD Instruments 600 kHz and 1200 kHz ADCP and WinRiver Current Profile Acquisition Software. (St. Louis District)

b. Digital elevation models. Since a variety of survey methods are used to obtain cross-sections, it is important that these independent data sets be accurately consolidated into a database from which cross-sections are generated. The hydrographic cross-sections are typically run over finite lines, as are topographic overbank sections and breaklines. The photogrammetric (LIDAR) DEM, however, is typically obtained at a prescribed grid interval (i.e., "post" spacing). The accuracy of these data sets also varies. The topographic survey elevations may be accurate to ± 0.2 ft, the hydrographic surveys to ± 0.5 ft, and the photogrammetric DEM to only ± 1 ft.

c. Digital terrain model. Typically, the hydrographic, topographic, and photogrammetric DEM data sets of the river, banks, levees, and floodplains are combined into a continuous digital terrain model (DTM) in a CADD or GIS database (e.g., design files, Arc-Info). Using this DTM, hydraulic cross-sections are cut at the prescribed orientations--based on the hydrographic cross-section alignment. If full-bottom hydrographic coverage was obtained using multiple transducer

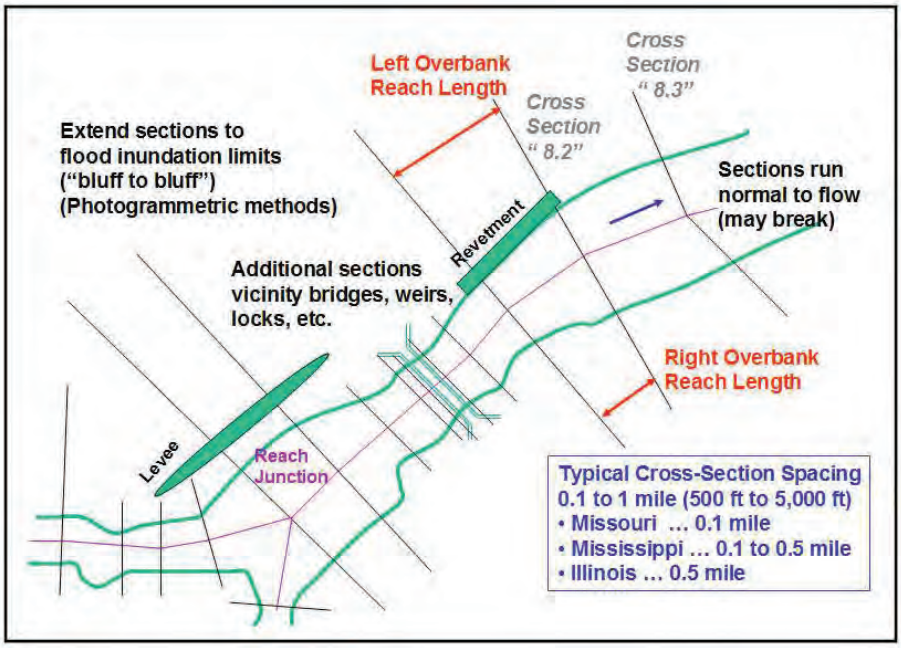

Figure 9-12. Typical cross-section configurations for a HEC-RAS hydraulic model.

or multibeam methods, then more flexibility is available is selecting cross-section alignments and locations for the hydraulic model. If a full, dense, DTM of hydrographic and topographic coverage is available, then an unlimited number of hydraulic cross-sections are available--at any desired alignment or spacing. The following mapping specifications are representative of those used in overbank and flood inundation areas on the Upper Mississippi and Missouri Rivers:

(1) Vertical Accuracy Requirement. 4-ft contour interval. DEM grid elevation accuracy: ±1.33 ft. DTM hard spot elevation accuracy: ± 0.67 ft.

(2) Digital Elevation Model (DEM). 5 m post spacings in flood plain. Add "mass points" on levees … i.e., "Digital Terrain Model (DTM). Cut in all breaklines manually.

d. Deliverables. The cross-sections are converted into the particular hydraulic model format --e.g., HEC-RAS. Usually the surveyor (or A-E firm) is responsible for delivering the cross-section data in a specified model format. Scopes of work will define specifications, lateral coverage, format requirements, and deliverables for items such as: Horizontal Datum -- NAD27 or NAD83; Coordinate grid system -- SPCS or UTM; Vertical Datum -- NGVD29, NAVD88, LWRP, IGLD; DEM & DTM breaklines/mass points; River, River Reach & River Station Identifiers; Cross-Section cut lines; Cross-Section surface line; X-Y coordinates of section end points; X-Y-Z coordinates for each point on section; Transformed coordinates to station-

elevation format; Main Channel Bank Station Points; Left and Right Overbank Lengths; Stream sections (Plan); Stream bank, levee, structure detail & breaklines; In-channel & overbank flow paths. Geometric cross-section data must be entered in hydraulic models in specific formats. These are fully described in operating manuals for these models—for example, the USACE HEC-RAS River Analysis System Hydraulic Reference Manual (Version 4.1 Jan 2010).

e. Survey methods. Hydraulic cross-sections are surveyed using similar equipment and methods as navigation project condition surveys. The main difference is that each cross-section is on a different alignment. The endpoints of each cross-section must be transferred from the map and input into the data acquisition guidance system—e.g., HYPACK. The endpoints coordinates can be digitized from the planning map or scaled by hand. The local SPCS (referenced to NAD83) should be used. The X-Y coordinate values of the cross-section endpoints can be directly input into line planning software, such as LINE EDITOR spreadsheet in HYPACK (Figure 9-13). A single, unique line is created for every cross-section, with no offsets. The line name should correspond to HEC naming convention. Once this spreadsheet is completed, it can be pulled into the survey guidance program to align individual stream sections.

(1) Small, shallow-draft vessels are used in order to obtain depths as close to the bank as possible. Leadline or sounding poles may be needed in shallow bank areas. Depths are logged using standard data acquisition software. A dense sounding density is not necessary for stream sections in that surface areas will be generalized (smoothed) in the hydraulic modeling programs due to data point per section limitations (e.g., 500 points). Thus, there is no point to obtain 20 depths/sec when only one depth per 100 ft may end up being used in the overall model.

(2) Cross-section horizontal positioning accuracy is not critical for hydraulic surveys. USCG DGPS Radiobeacon accuracy is more than adequate; in fact, autonomous GPS accuracy (10-20 m) might be adequate in many cases. Since USCG DGPS is available over much of CONUS, it is recommended for river engineering survey positioning. Code phase USCG DGPS may also be used for horizontal positioning of overbank surveys.

(3) Cross-section elevations are referenced to a consistent vertical datum, such as the legacy NGVD29 or replacement NAVD88. A dense network of benchmarks must be available along rivers or atop levees in order to set river staffs or gages to control hydrographic surveys. The required density of the vertical network will be a function of the river slope and the distance reliable interpretations can be made between gages. In general, the river surface elevation interpolation accuracy should be kept under ± 0.5 ft. Gages should be spaced at intervals to maintain this accuracy. Additional reference gages may be required if abrupt changes in slope occur in bends or around control structures. In general, depth accuracy requirements for hydraulic sections are not as critical as those for dredging and navigation surveys.

(4) Bank and short overbank sections may be run at the ends of lines if equipment and personnel are available. Normally, however, overbank sections are performed relative to baselines on the bank or using RTK or DGPS positioning techniques. Overbank cross-sections must connect with (and be aligned to) the hydrographic sections to ensure the full streambed is profiled.

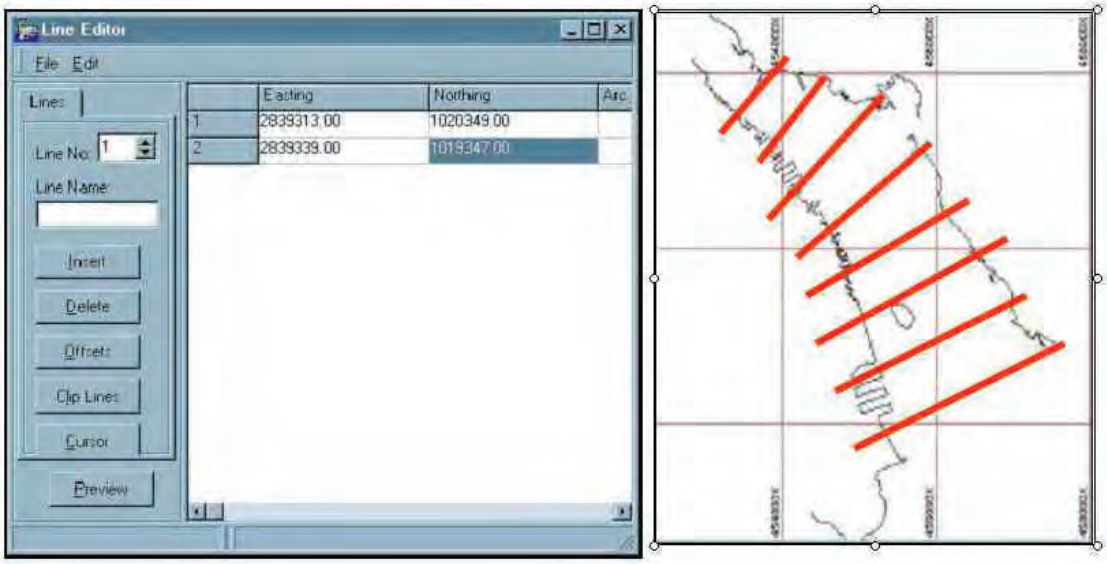

Figure 9-13. Setting up hydraulic stream sections using HYPACK Line Editor spreadsheet--a separate line is created for each cross-section.

9-11. Hydraulic Engineering Guidance on Cross-Section Locations. EM 1110-2-1416, River Hydraulics, contains detailed guidance for determining the location and spacing of stream cross-sections. Surveyors performing these studies should be aware of the hydraulic considerations that dictated the intended placement and alignment of stream sections. This is important in that field conditions may prevent sections being aligned as desired (due to vegetation, barge blockage, structure blockage, etc.). If new stream alignments or structures are discovered in the field, then additional cross-sections might be required. The field surveyor should make contact with the hydraulic engineer to determine alternate locations or need to include additional sections due to changed field conditions. Often, slight adjustments in section alignments can be made in the field without affecting the hydraulic model. Thus, knowledge of the engineering rationale for locating cross-sections is required by field surveyors in order to make reasonable adjustments or recommend modifications to the project engineer. The following guidelines on locating cross-sections for river hydraulic studies are summarized from EM 1110-2-1416.

a. Cross-sections should be located at:

(1) All major breaks in bed profile.

(2) At minimum and maximum cross-sectional area.

(3) At points where roughness changes abruptly.

(4) Closer together in expanding reaches and in bends.

(5) Closer together in reaches where the conveyance changes greatly as a result of changes in width, depth, or roughness.

(6) Between cross sections that are radically different in shape, even if the two areas and conveyances are nearly the same.

(7) Closer together where the lateral distribution of conveyance changes radically with distance.

(8) Closer together in streams of very low gradient which are significantly nonuniform, because the computations are very sensitive to the effects of local disturbances and/or irregularities.

(9) At the head and tail of levees.

(10) At or near control sections, and at shorter intervals immediately upstream from a control (sub-critical flow).

(11) At tributaries that contribute significantly to the main stem flow. Cross sections should be located immediately upstream and downstream from the confluence on the main stream and immediately upstream on the tributary.

(12) At regular intervals along reaches of uniform cross section.

(13) Above, below, and within, bridges.

(14) Cross sections should be representative of the reaches adjacent to them, and located close enough together to ensure accurate computation of the energy losses. If the average conveyance between cross sections is used to estimate the average energy slope, then the variation of conveyance should be linear between any two adjacent cross sections.

(15) Cross sections should be located such that the energy gradient, water-surface slope, and bed slope are all as parallel to each other between cross sections as is pragmatic. If any channel feature causes one of these three profiles to curve, break, or not be parallel to the others, the reach should be further subdivided with more sections.

(16) On large rivers that have average slopes of 2 to 5 ft per mile or less, cross sections within fairly uniform reaches may be taken at intervals of a mile or more.

(17) More closely spaced cross sections are usually needed to define energy losses in urban areas, where steep slopes are encountered, and on small streams. On small streams with steep slopes, it is desirable to take cross sections at intervals of 1/4 mile or less.

(18) Recommended maximum reach lengths (distances between cross sections) are: (1) 1/2 mile for wide floodplains and slopes less than 2 ft per mile, (2) 1,800 ft for slopes less than 3 ft per mile, and (3) 1,200 ft for slopes greater than 3 ft per mile. In addition, no reach between cross sections should be longer than 75 - 100 times the mean depth for the largest discharge, or about twice the width of the reach. The fall of a reach should be equal to or greater than the larger of 0.5 ft or the velocity head, unless the bed slope is so flat that the above criterion holds. The reach length should be equal to, or less than, the downstream depth for the smallest discharge divided by the bed slope.

b. EM 1110-2-1416 also notes the following considerations that are applicable to field surveyors acquiring cross-sectional data.

(1) Cross-sections are run perpendicular to the direction of flow at intervals along the river. The "reach length" is the distance between cross-sections. Flow lines are used to determine the cross-section orientation. The hydraulic engineer will provide these orientations to the surveyor.

(2) The cross-section should be referenced to the stream thalweg and by river mile as measured along the thalweg. From this the reach lengths between sections is computed. Endpoints on the cross-section should be geographically coordinated using the local State Plane Coordinate System.

(3) End station elevations. The maximum elevation of each end of a cross section should be higher than the anticipated maximum water surface elevation.

(4) Local irregularities in bed surface. Local irregularities in the ground surface such as depressions or rises that are not typical of the reach should not be included in the cross-sectional data.

(5) Bent cross sections. A cross section should be laid out on a straight line if possible. However, a cross section should be bent if necessary to keep it perpendicular to the expected flow lines.

(6) Avoid intersection of cross sections. Cross sections must not cross each other. Care must be taken at river bends and tributary junctions to avoid overlap of sections.

(7) Inclusion of channel control structures. Channel control structures such as levees or wing dams should be shown on the cross section, and allowances in cross-sectional areas and wetted perimeters should be made for these structures.

9-12. Hydraulic Cross-Sections Adjacent to Bridges or Culverts. Cross-sections need to be densified near bridges and culverts in order to analyze the flow restrictions caused by these structures. Required sections are shown in Figure 9-14. The downstream section is located such that the flow is not affected by the structure--a distance of about four times the average length of

the side constriction caused by the structure abutments. Two cross-sections are run a few feet upstream and downstream of the structure. The upstream section is located slightly further away from the structure--prior to the flow constriction. The upstream section is typically located at a distance equal to the width of the bridge opening or the length of the abutment. Variations in this general scheme exist.

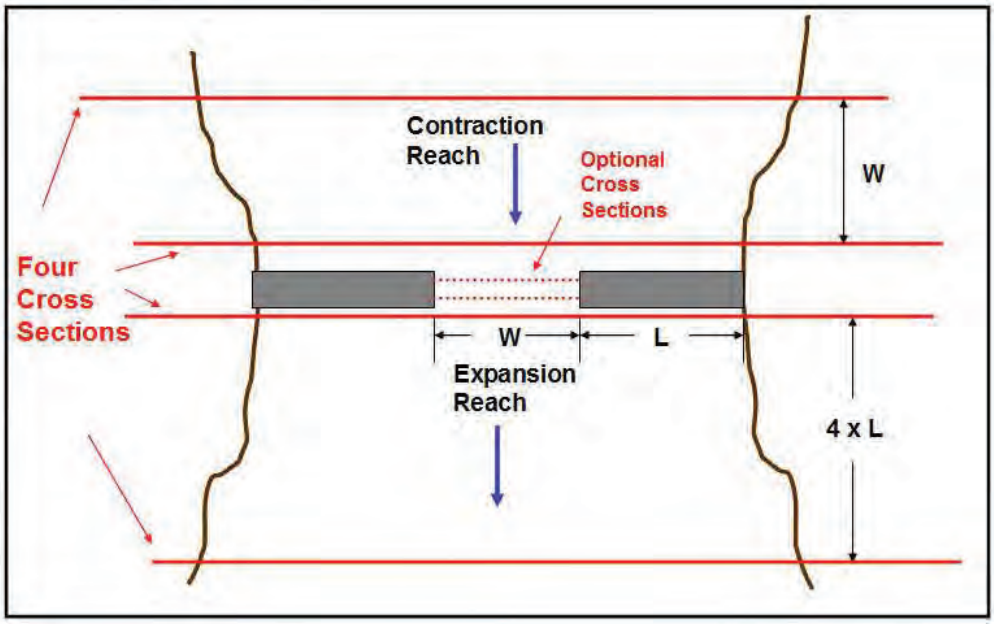

Figure 9-14. Cross-section locations at a bridge or culvert

Other bridge detail is also required, such as dimensions of the bridge deck, abutments, piers, etc. If this information is not available from as-built drawings of the structure, then they will have to be measured as part of the field survey.

a. Navigation locks and dams. Most of the inland navigation projects maintained by the Corps contain navigation locks and dams. The flood profile characteristic in the regulated pools between these structures requires hydraulic modeling. Survey cross-sections may need to be taken more frequently around locks and dams and within the pools due to sediment build up.

b. River control structures. Controls are natural or artificial structures that affect the upstream water surface profile. Control can be dams, rock outcrops, falls, or drop structures. Dikes (i.e., wing dams or jetties) or weirs also impact the flow of water in a channel, depending on the stage. Cross-sections need to be taken on and adjacent to such areas.

c. Levees. Levees prevent floodwaters from entering the floodplain. Levees constrict river flow, resulting in a higher water surface. When levees fail, the protected floodplain becomes available for storage; thus the need for detailed cross-sections over levees and well into the floodplain. Cross-sections are taken at the beginning and end of levees. Floodplain storage

can be computed from the DEM model or from cross-sections generated from the DEM surface. In addition, continuous top of levee profile elevations may be required. These can be accurately and efficiently obtained using topographic RTK survey methods. Levee cross-sections can also be run from the same RTK set up.

9-13. Required Accuracy of Hydraulic Cross-Section Data. The accuracy requirements for cross-sections on a river and floodplain are highly dependent on other factors that make up the overall hydraulic prediction model. Other factors, such as Manning's coefficient, have a far more significant impact on the accuracy of computed water surface profiles. In general, horizontal accuracy is not as critical for hydraulic studies as for other navigation surveys. Vertical accuracy is also not as critical, provided there are no systematic errors or blunders in the data. The Hydrologic Engineering Center (HEC) conducted a study of survey accuracy requirements relative to the resultant accuracy on a predicted water surface model--HEC RD 26, 1986. Following are conclusions derived from this 1986 study.

a. For areas with high Manning n-value reliability, the effect of cross-section elevation inaccuracy is insignificant on the computed water profile accuracy. For example, on a river slope of 1 ft/mile, cross-section elevation points accurate to ± 2.0 ft (1-σ standard deviation) will affect water surface profile accuracy by less than 0.1 ft. A ± 2.0-ft elevation accuracy can be easily achieved by most conventional topographic and hydrographic surveying methods. A ± 2.0 ft (1-σ standard deviation) can also be obtained by manually digitizing the cross-section directly on a photogrammetric stereo model which has been designed to achieve an equivalent 10- to 12-foot contour interval standard--i.e., flown at an altitude that results in a negative scale of 1 inch = 3,333 to 4,000 ft.

b. For cross-sections developed by photogrammetric methods (i.e., an HEC cross-sectional DTM is directly developed by an operator on the stereo plotter), there is no significant impact on water surface profile accuracies between stereo models designed for 2-ft (± 0.3 ft 1-σ) and 5-ft (± 0.8 ft 1-σ) contour accuracies--the accuracy of the computed water surface profile is not significantly improved by using the presumed more accurate 2-ft contour standard. For areas with highly reliable n-values, there is no significant difference on the surface profile's accuracy between 2-ft and 10-ft (± 1.7 ft 1-σ) contour mapping accuracies.

c. Cross-section elevations digitized directly from photogrammetric stereo models are more accurate than cross-section elevations indirectly derived (e.g., scaled--manually or electronically) from topographic contour maps. Thus, cross-sections indirectly derived from an existing contour map, or from a digital terrain model (DTM)--which has been constructed using triangulated irregular networks based on a gridded digital elevation model (DEM) and auxiliary breaklines--will not be as accurate as cross-sections directly digitized on the stereo model. (The 1986 study did not assess the effect of DEM "post" spacing density on indirect elevation accuracy since these techniques were not commonly used at that time. In addition, the old manual process of generating cross-sections by scaling intersecting contours is more rarely used given elevations can be obtained directly from DEM/DTM/TIN models.)

d. Mean water surface profile errors resulting from less reliable estimates of Manning's coefficient are several times those resulting from survey measurement errors alone.

e. Error prediction equations (in the 1986 study) can be used to determine the mapping technique and accuracy needed to achieve a desired computed profile accuracy. Conversely, the error prediction equations can be solved for required digital elevation point accuracy given a specified mean water surface profile accuracy and other hydrologic factors.

f. Assuming a mean water surface profile modeling accuracy requirement of between 0.2 ft and 0.5 ft, a reliably known n-value, and low gradient stream slope, the required digital elevation accuracy along a cross-section is needed to no better than ± 2.2 ft. This accuracy level can be easily achieved by conventional (terrestrial) topographic surveying methods and hydrographic surveying methods. It also could be obtained by digitizing cross-section elevation points from a photogrammetric stereo model designed to meet a 10-ft contour interval accuracy standard--a low accuracy product.

g. If cross-section elevation points are indirectly derived from a newly mapped DTM (DEM) surface, then the point accuracy of the DEM grid (posts) must be better than that needed for directly digitized cross-section points. This increased accuracy will be a function of the "post" spacing (density) and local terrain gradient. Accuracy differences will not be significant in low gradient plains regardless of the post spacing density. Overall, directly observed cross-sections should be obtained in lieu of indirect methods.

h. In low gradient flood plains, cross-sections may be derived using indirect DEM/DTM/TIN model methods. DEM post-spacing should be variable and a function of the (1) required point accuracy, and (2) average terrain gradient. For example, given ± 2 ft required cross-section point elevation accuracy and a 2% gradient, a 50-ft DEM post spacing would be recommended. Breaklines are added at critical points, e.g., tops/bases of levees, roads, etc., resulting in an "irregular network of mass points with breaklines."

i. In high-gradient areas (e.g., levees, road/rail embankments, etc.), photogrammetric cross-sections should be directly digitized from the stereo model. DEM/DTM derived cross-sections would not be recommended due to the dense post spacing that would be required to achieve the equivalent accuracy.

j. Digital elevation data from USGS quadrangle DEMs may be sufficiently accurate for cross-sectional data outside Federal levees--provided these maps are relatively current. Any additional mapping in these potential overbank areas could be performed to 10-ft contour interval standards.

k. Levees, roadways, railroads, and other similar flood control embankments should be profiled to around ± 0.5 ft accuracy. It will often be more cost-effective to perform this profiling using aerial mapping techniques if concurrent mapping/cross-sections are being performed over the same area. On levees with excessive vegetation, ground-based topographic cross-sections will be needed to supplement the photogrammetric sections and/or profiles.

l. Inundation mapping accuracy requirements are independent from water surface profile accuracy requirements. No photogrammetric mapping technique will cost-effectively measure ± 0.1 to ± 0.2-ft first-floor elevation accuracy throughout the study region. RTK methods will not normally reach these accuracy levels either; thus, traditional differential leveling methods may be required.

m. Inundation mapping accuracy requirements will depend on the flood plain gradient, land use, and control features (embankments, etc.).

n. Unnecessary or unanalyzed topographic mapping accuracy specifications will significantly deplete existing mapping resources as mapping costs vary exponentially with the vertical accuracy requirement.

o. A ± 2-ft elevation data point standard deviation may now be easily achievable with airborne inertial-aided GPS control and LIDAR topographic mapping techniques-- i.e., minimal ground photo control points required.

SECTION II

Hydrographic Surveys of Reservoirs and other Impounded Areas

9-14. Reservoir Surveys. The Corps maintains some 704 dams, many of which have upstream reservoirs and downstream pools requiring periodic hydrographic surveys. The reservoirs above the 75 hydropower dams operated by the Corps must also be monitored for sediment build up. A typical hydropower reservoir project shown in Figure 9-15. Most of these reservoirs are primarily used for flood risk management (i.e., flood control) and water storage. Other secondary uses of these reservoirs include recreation and water supply. Reservoirs are impounded by either concrete or earth-fill dams. A variety of outlet works and spillways are used to regulate, control, or release outflows from the reservoirs. Loss of reservoir storage capacity due to sediment accumulation impacts hydroelectric power generation and flood control operation. Useful storage is the volume of water between the minimum pool (e.g., outlet invert elevation) and normal pool (e.g., spillway crest elevation) levels. Storage capacities are affected by sedimentation build up over time--typically below the minimum pool elevation. Reservoir sedimentation surveys are performed to monitor periodic build up of sediment in the reservoir, which allows computation of reductions in reservoir capacities. Other purposes may include base data for recreational navigation maps or charts in support of Natural Resources office activities--e.g., topographic/bathymetric maps depicting fishing or camping areas (Figure 9-16). Reference should be made to EM 1110-2-4000, Sedimentation Investigations for Rivers and Reservoirs, for planning, conducting, and modeling reservoir sedimentation investigations.

a. Survey methodology. Reservoir sedimentation surveys require a combination of hydrographic and topographic methods. Hydrographic surveys are performed to determine the underwater topography. Topographic and photogrammetric methods are performed to map the

areas above the pool in which the hydrographic surveys were performed. The surveys are merged into a digital terrain database from which quantity take-offs are made for reservoir capacities. The recommended accuracies outlined in Table 9-1 will usually suffice for reservoir surveys. However, these standards are only applicable in depths less than 100 ft. IHO standards may be noted in deeper reservoirs—see Chapter 3 and Appendix E. Detailed surveys of the dam, intake structures, or spillways will usually require higher accuracy.

Figure 9-15. Reservoir behind Clarence Cannon Hydropower Dam and Mark Twain Lake, Missouri. (St. Louis District)

b. Survey boats. Hydrographic surveys are usually performed with small, trailerable boats, using automated hydrographic data collection systems. Many reservoirs have boat ramps for recreational purposes, so larger, trailerable boats can be easily launched. If there are no launching facilities, a small, carryable, 12-ft to 16-ft open skiff may have to be used--provided reservoir conditions are calm and protected. Jet ski and small inflatable boats have also been used to survey inaccessible reservoirs.

c. Horizontal positioning. The most efficient positioning method is code phase DGPS--using USCG radiobeacons or private provider networks. Alternately, total stations may be used for small reservoirs or impoundment basins; however, this may require locating or establishing additional horizontal control points around the basin, adding considerable time and cost to the final survey. Total station positioning may be needed near dams, power plants, or outlook structures if satellite signals are obscured or interfered with. Positional accuracy is not critical for reservoir sedimentation surveys--the accuracy levels recommended in Table 9-1 may be followed. Positioning procedures and calibration checks should conform to the guidance in this manual.

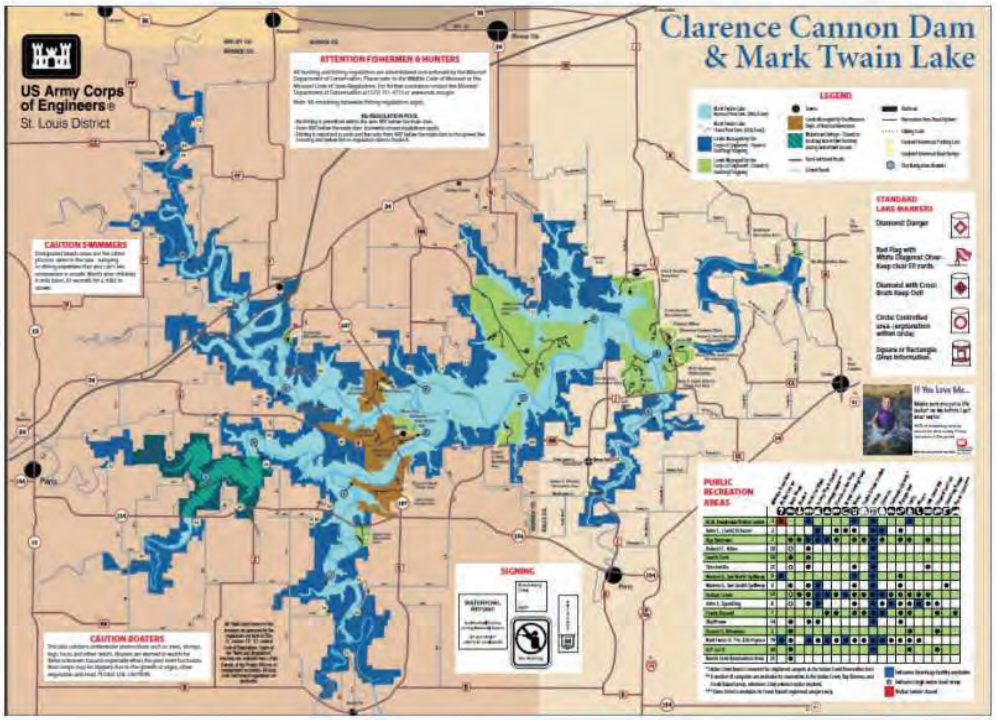

Figure 9-16. Recreational map of Mark Twain Lake, Hannibal, MO. Normal Pool (606.0 ft) and Flood Pool (638.0) contour limits are shown on this map. (St. Louis District)

d. Reference elevations. Depth measurement accuracy is critical in reservoir sedimentation surveys. Depths are measured relative to either NAVD88 or the legacy NGVD29 datum—see EM 1110-2-6056 for additional guidance. The master gage or staff elevation reference used for the project should be used as a reference--usually located near the outlet works or dam. The elevation of the gage/staff should be checked by connection to existing benchmarks. For long reservoirs, a slope gradient may exist; requiring additional gages be set in the upper reaches. Gages must be continuously monitored if there are short-term fluctuations in the pool; otherwise, twice-daily readings may be adequate. Bar checks are critical to ensure no systematic errors are present--especially on small boats. Sound velocity probes are needed to measure and correct for velocity changes in deeper reservoirs, i.e., at depths beyond the bar check reach and where changes in water temperature are most likely. Since most velocity probes are designed for 50- to 75-ft navigation projects, additional cable must be added to reach down to 200- to 300-ft depths.

e. Density of coverage. The topographic relief and size of the reservoir will dictate the coverage requirements. Single beam echo sounders are used; however, a multibeam system might be employed if full coverage detail is required for scour studies near the dam or outlet works. Single beam survey lines are typically run bank-to-bank perpendicular to the axis of the reservoir. Since the objective is to compute the volume of an irregularly shaped impoundment

basin, there is no rigid requirement for a specific cross-section alignment or spacing. Typically, lines are spaced between 200 and 400 ft, with a not-to-exceed spacing specified. If the topography in the reservoir is fairly uniform, then line spacing may be increased. Specifying too tight a line spacing on a large reservoir is uneconomical. The accuracy requirements of the reservoir capacity computation must be fully considered in selecting a line spacing. Since volumes are typically computed by contour intersect methods, the accuracy of the reservoir storage volume is a primary a function of the computed areas for each elevation stage. Thus, the derived digital terrain model (DTM) of the survey must have sufficient density to delineate accurate contours from which areas are computed.

(1) Since successive surveys are measuring storage trends, it is only necessary to obtain data at a density consistent with this requirement--e.g., 1% of capacity. Given a percent error in capacity (acre-ft), area (acres), and average depth at spillway elevation, the average accuracy of the 1-ft DTM contours (in ± acres) can be computed. In general, a contour acreage accuracy of ±1 acre is easily achievable if the survey density is adequate.

(2) Depth accuracy must be free of any systematic biases. A bias of say (+) 0.3 ft over a 1,000 acre reservoir (i.e., 300 acre-ft) would represent a significant error (3%) even if the storage is only 10,000 acre-ft. Thus, accurate gage readings, bar checks, and velocity calibrations are critical to preclude against systematic errors in reservoir surveys. Random errors in the depth measurements are not significant as long as there is no bias--e.g., a depth accuracy of +0.0 ft (bias) ± 1.0 ft (random) is acceptable, whereas an accuracy of (-) 0.3 ft ± 0.3 ft is not. Refer to Chapter 3 for further discussion on depth accuracy requirements.

f. Topographic mapping. In order to compute the full capacity rating for a reservoir, topography must be obtained up to the normal pool or spillway crest elevation; or higher, to a surcharge elevation that may be specified. Existing maps or pre-construction as-built drawings of the project may already be available for this data; otherwise, full topographic and/or photogrammetric mapping surveys of these areas will be required. Approximate computations may be made using USGS quad maps; however, their small-scale and poor vertical accuracy will often not provide adequate results.

g. Area and storage volume capacity computations. A variety of automated techniques are used to compute the storage area-capacities. The combined hydrographic and topographic survey data are used to generate a complete TIN surface model of the entire basin, or perhaps bordered portions of a basin. This TIN model can be derived from all data sources: single beam, multibeam, aerial mapping, LIDAR mapping, USGS quads, etc. From this TIN model, level surface increments (normally 1-ft contours) are generated and the area (in sq-ft or acres) for each contour section computed. The storage volume (typically in acre-ft) for each contour segment can be computed by projecting this area over the selected contour interval. The areas and accumulated storage volumes are tabulated and plotted on a standard area-capacity curve format. Reservoir storage capacity relative to the watershed area runoff may also be computed and tabulated in acre-ft per inch of runoff.

(1) HYPACK reservoir volume calculations. The HYPACK User Manual (HYPACK 2011) provides guidance and examples for computing reservoir storage volumes from TIN (Surface-to-Surface) models. Guidance in developing TIN surface models of the reservoir from hydrographic and topographic survey data is also provided in that manual. The volume calculation module allows storage capacities to be computed at any contour (elevation) interval. In the example at Figure 9-17, each level elevation plane is passed through the reservoir TIN model, providing a surface area of the intersecting plane. This surface area plane is projected down to the TIN model surface for each prismoidial TIN element, from which an accumulated reservoir pool volume for that elevation is computed.

(2) The example in Figure 9-17 illustrates calculated reservoir volumes for increasing 10-ft elevations above MSL—a 1-ft contour increment would normally have been selected. These storage volumes may then be converted to acre-ft (1 acre-ft = 43,560 cu ft or 1,613.3 cy).

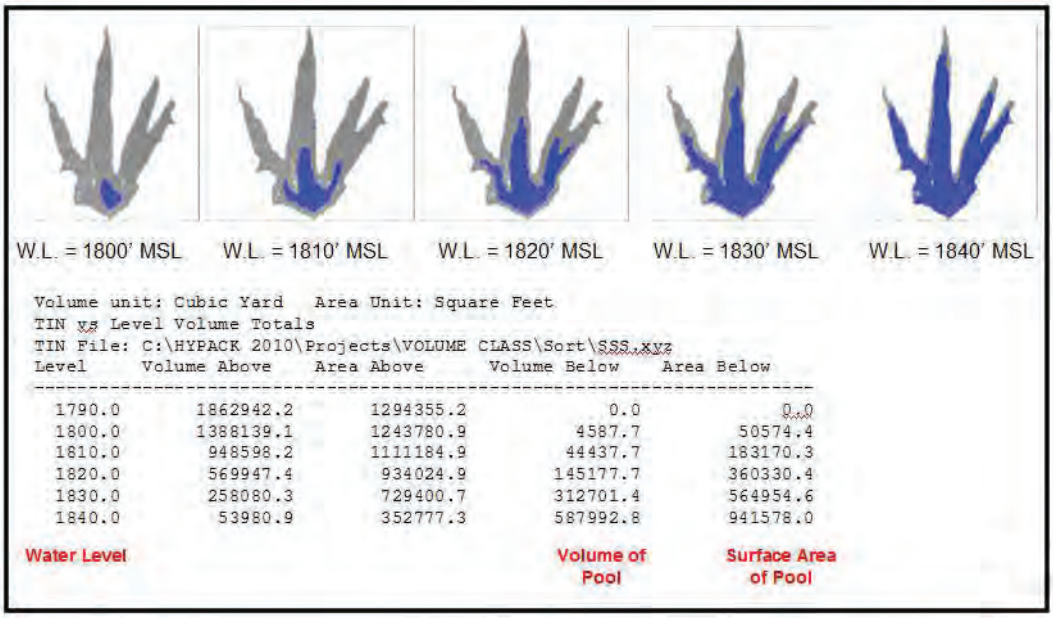

Figure 9-17. HYPACK "TIN to Level" reservoir area and volumes. Water level surface contour intersections with the TIN model for each 10-ft elevation interval shown in blue. Software computes the volume of water and the surface area of the 'pool' as the water level varies between used defined reservoir elevation limits.

(3) Area capacity table. From the above area-volume data, storage capacities can be computed for incremental pool elevations. Figure 9-18 is an example of a typical storage area-capacity tabulation for selected elevations on the Cochiti Reservoir in Albuquerque District.

h. Sediment build-up or scour comparisons. It is often desirable to identify areas within a reservoir where sediment is building up (accreting) and scouring (eroding). This can be done by comparing TIN models from hydrographic surveys taken years apart. Often the original pre-fill

topographic survey is taken as a baseline and successive hydrographic surveys performed over the years are compared with the base survey. The HYPACK "TIN to TIN Difference" software

```
Test File                    : d:\demofiles\areacapacity\cochiti_dtm.sd
Horizontal Coordinate System: FP_NAD27_New_Mexico_Central
Start above bottom           : 0.00
Measurement delta            : 1.00
```

Elevation	Area (Acres)	Volume (Acre Ft.)
5241.89	0.00	-0.00
5242.89	0.20	0.09
5243.89	0.33	0.35
5244.89	0.56	0.78
5245.89	1.06	1.58
5246.89	1.39	2.82
5247.89	1.88	4.42
5248.89	2.46	6.60

Figure 9-18. Portion of Area-Capacity table for Cochiti Reservoir. Dam crest is at 5,482 ft; thus, only the lowermost pool elevation capacities are shown here.

module may be used to identify and quantify material gains and losses between two different reservoir surveys. A color-coded model of gained and lost material is generated as shown in Figure 9-19. Volumes between the two TIN surfaces are calculated at nodes on a gridded dataset. The TIN models can optionally be "bordered" to isolate a particular section of interest.

i. Cochiti Reservoir sedimentation assessment. Figure 9-20 illustrates the use of DTM models in evaluating sediment changes in a reservoir. DTM terrain models were developed from a 1963/1972 Pre-Dam Terrain Model (Base Survey) and a 1999/2004/2005 Post-Dam Terrain Model (Epoch 1 Survey). Surface comparisons were made (Epoch 1 minus Base) to assess sedimentation transport characteristics, calculate available storage for dam control operations, evaluate sediment sampling sites for use in transport modeling, and evaluate impoundment impacts to cultural sites. The cross-section profile in the figure shows sediment erosion and build-up between the Base and Epoch 1 surveys, ranging from (-) 5-ft to + 15-ft changes across this section. In the upper reaches of the reservoir, accretions upwards of 70 ft were measured.

j. Application reservoir survey project. See Appendix L (Almond Lake Reservoir Survey and Area Capacity Curves--Baltimore District) for a survey report describing field to final product compilation.

9-15. Surveys of Howard Hanson Dam (Seattle District). Appendix O attached to this manual contains a survey report describing a multi-sensor survey of a large earth and rockfill dam in Seattle District. This effort involved precision upland control and terrestrial laser scanning survey, in conjunction with a multibeam bathymetric survey conducted on Howard A. Hanson Dam and Reservoir near Enumclaw, Washington in December 2009. The survey was conducted by David Evans and Associates for the Seattle District. A variety of survey sensors and software

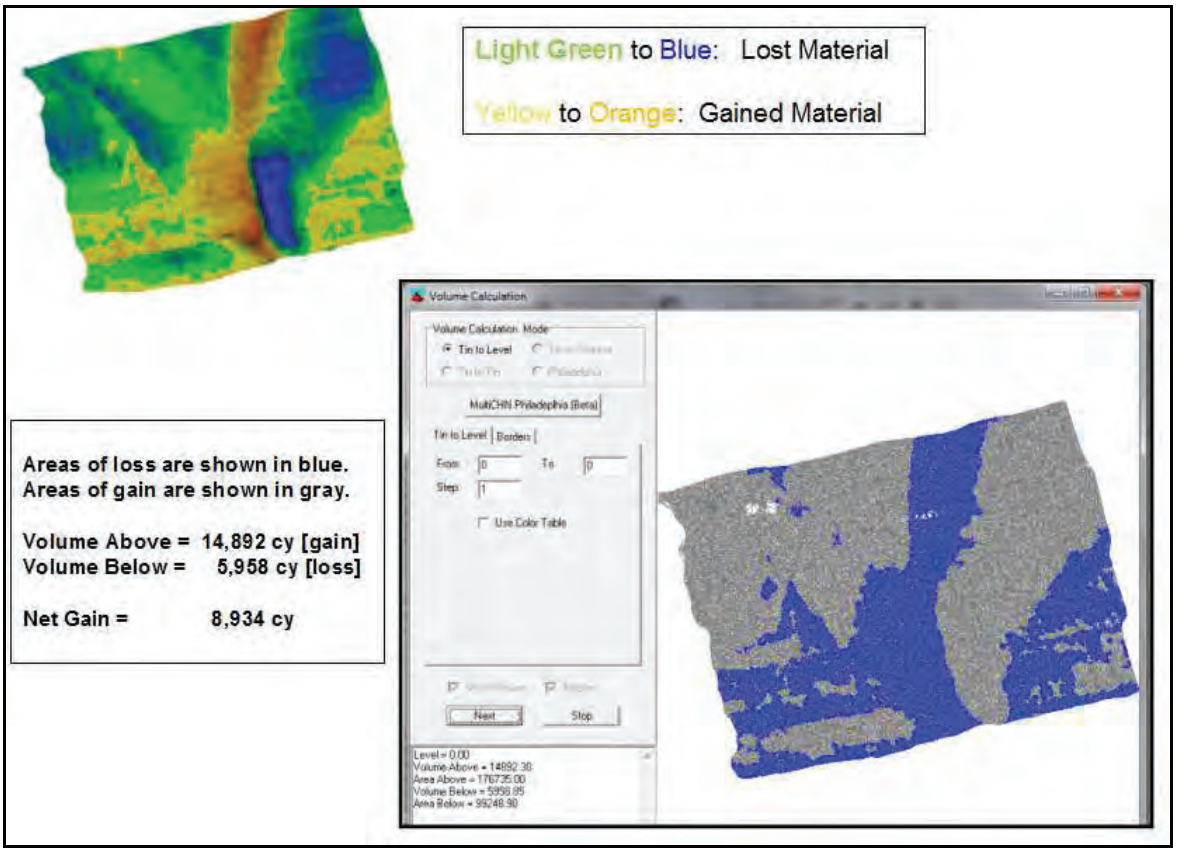

Figure 9-19. Accretion and erosion areas in a reservoir from TIN models comparing two hydrographic surveys. Net gain or loss of material is calculated over the defined project. (HYPACK "TIN to TIN" Volumes)

was utilized to map the dam site. These included terrestrial laser scanning, marine based laser scanning, multibeam swath bathymetry, RTK, conventional total station equipment, cyclone XYZ point cloud editing, CARIS hydrographic processing, and CARIS gridding and difference calculations.

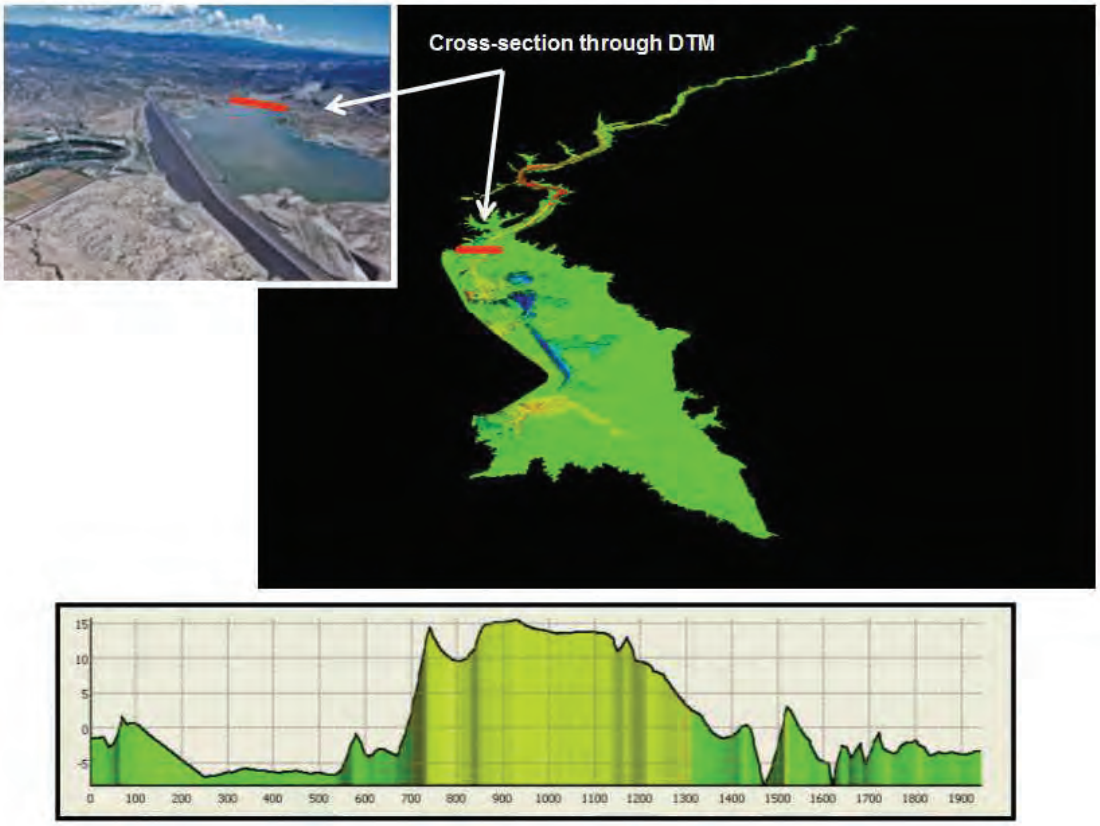

Figure 9-20. Upper portion of figure is a DTM model of the elevation differences between the Base Survey and the Epoch 1 Survey. The lower portion shows a cross-section profile at the approximate location indicated. (Cochiti Reservoir, Albuquerque District.)

SECTION III

Summary of Recommended Elevation Accuracy and Performance Standards for Inland Surveys

Table 9-1. Summary of Recommended Elevation Accuracies for Inland Surveys.

Project	Repeatability	95% RMS Accuracy
Inland Navigation Surveys		
Controlled Pools	0.3 ft	±0.5 ft
Free flowing rivers (non-RTK)	0.5 ft	±0.8 ft to > ±1 ft

Lock and Dam Surveys	0.2 ft	±0.2 ft
Revetment and River Stabilization Structure Surveys	0.2 ft	±0.2 ft to ±0.5 ft
H&H Surveys		
Hydrography	n/a	±1.0 ft
Topography (DEM)	n/a	±1.33 ft (4-ft contour)
Breaklines	n/a	±0.5 ft
Reservoir Surveys		
Hydrography	0.3 ft	±0.8 ft
Topography	n/a	±1.33 ft (4-ft contour)
Dam embankment	0.1 ft	±0.2 ft

NOTE: These are recommended standards based on typical USACE project conditions and current survey instrumentation. They are based on the experience and recommendations from USACE personnel who developed and reviewed this manual. Each inland civil works project will have unique requirements that may require different standards. Refer also to discussions in Chapter 3.

Table 9-2. Recommended QC and QA Procedural Standards for Inland Surveys.

Procedure	Recommended Application
Bar Check Calibration	Perform periodically, or at minimum, quarterly. Frequency of bar checks can be reduced if average velocity repeatedly correlates with velocity cast data. Perform at beginning of critical site or structure investigation project.

Velocity Cast Calibration	Perform, at minimum, twice daily. More often in highly variable waters.
Squat/Settlement Calibration	Perform annually over different vessel speeds and loading conditions.
Latency Calibration (Single beam)	Perform periodically to obtain average correction over time. Perform at beginning of any critical structure survey.
Patch Test (Multibeam)	Perform periodically (at minimum semi-annually) to obtain average roll, pitch, yaw, and latency corrections over time.
Motion Compensation (Heave, Pitch, Roll, Yaw)	Required for multibeam surveys. Apply on single beam surveys if sea conditions warrant correction.
Inertial-aided RTK/PPK	Recommended in obstructed areas (bridges, dams, etc). Optional: Total Station control.
Position Calibration (Horizontal)	Perform at beginning of new project at PPCP or periodically check RTN/RTK v code DGPS.
Stage/Pool Calibration	Twice daily at reference gage. On free-flowing rivers minimize uncertain gage extrapolations or interpolations with RTK elevation transfer.
Vertical Check (RTK)	Perform twice daily at project reference gage.
Vertical Datum Verification	Refer to EM 1110-2-6056 for periodic requirements to ensure river, pool, and reservoir datums are consistent with NOAA reference datums.
Survey Coverage (Density)	Cross section spacing as required in project scope. 100% or 200+% coverage recommended on critical underwater structure surveys.
Quality Assurance Performance Tests	Perform periodically against other vessels at constant test site or in lock chamber if available. Perform internal repeatability check daily on critical structure surveys.

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CHAPTER 10

Construction Dredging Measurement, Payment, and Clearance Surveys

10-1. General Scope. This chapter provides an overview on hydrographic surveys performed in support of the USACE dredging program. Dredging support surveys, channel templates, project clearance assessment, and payment quantity computation methods are covered. This chapter primarily focuses on in-place measurement and payment surveys in coastal navigation projects, as distinguished from dredging projects where payment is based on daily rental rates. It also provides general background information on dredging contract clauses that deal with measurement and payment surveys. The Civil Works Cost Engineering Mandatory Center of Expertise at the Walla Walla District can provide more comprehensive information on dredging estimates with several online tools .

a. "Best Practices." The guidance presented in this chapter is compiled from best hydrographic survey practices recommended and utilized by various USACE districts with extensive dredging programs. It may not be applicable to all dredging projects that may have unique environmental conditions or survey assessment requirements. Thus, all recommended "standards," QC calibrations, QA performance testing, bin sizes, etc. in this chapter shall be considered as general guidance only; they are not absolute or mandatory requirements.

b. Survey methods. Survey procedures, including quality control calibrations and quality assurance performance testing, are covered in Chapter 4 (Single beam), Chapter 5 (Multi-transducer), and Chapter 6 (Multibeam).

c. Survey accuracy standards. Recommended accuracy standards for dredging surveys are covered in Chapter 3. As detailed in Chapter 3, these generic "standards" may not be applicable to all dredging projects.

d. For detailed guidance on USACE dredging policies and practices, refer to the appropriate regulations and supplemental guidance manuals applicable to dredging--e.g., ER 1130-2-520, Navigation and Dredging Operations and Maintenance Policies. Hydrographic survey data is also used to provide input for applicable topographic parameters (e.g., average bank height) in the USACE Cost Engineering Dredge Estimating Program (CEDEP) for Pipeline Dredges.

10-2. Background. The USACE performs hundreds of surveys annually that are used to monitor dredging in over 12,000 miles of navigable inland and intracoastal waterways, and some 926 authorized coastal and Great Lakes deep- and shallow-draft harbors. During Fiscal Year 2009, the USACE dredged 263 million cubic yards of material. Approximately 82% of this work was done by contract dredging, involving over 183 contracts. The USACE-owned dredge fleet performed the remainder of the work. Hydrographic surveys are conducted in support of these

dredging operations--both for USACE-owned dredging plant and private contracted dredging operations.

a. Dredging measurement and payment surveys for contracted construction are usually performed by USACE survey crews; however, they may be conducted by independent Architect-Engineer (A-E) survey firms or the dredging contractor's survey crews. Most dredging contractors generally maintain an independent survey capability to monitor dredge performance and progress, and often as a quality check on USACE measurement and payment surveys.

b. Dredging support surveys typically require high degrees of accuracy since they are used to estimate annual dredging budget and quantity requirements, determine dredging contractor payment, and to certify final acceptance and clearance of a project to its authorized or constructed navigation depth. In many instances, the adequacy and accuracy of these hydrographic surveys are reviewed and challenged by contractors, with resultant disputes involving: the amount of material removed for payment; unexcavated shoal material remaining above the required dredging grade; or the adequacy of acoustic and density measurements of unconsolidated materials in the channel bottom. In order to minimize these disputes and construction contract claims, the quality control procedures and performance testing guidance covered in previous chapters of this manual should be rigorously followed. All dredging surveys thus require the utmost in accuracy, quality control, and timeliness, as explained below.

10-3. Types of Dredging Support Surveys. The following paragraphs describe some of the surveys used to monitor dredging operations in river and harbor navigation projects.

a. Dredging Plans and Specifications (P&S) surveys. Surveys and investigative studies performed to gather terrain, bathymetric, geophysical data, and related site plan information in advance of a design effort are referred to as "P&S" surveys, or often "bid surveys." These P&S surveys will be used to produce a set of engineering plans and specifications (and related cost estimates) for construction or dredging. P&S hydrographic surveys are required on river and harbor dredging construction and also for many other forms of marine construction in which detailed site plans are essential to the bid documents. This includes construction of offshore structures (jetties, groins, etc.), disposal areas, control structures (locks, dams, spillways, dikes, control structures, reservoirs, etc.), and beach/bank erosion protection. P&S surveys should be conducted as close to the solicitation advertisement date as possible--typically within 120 days or less, depending on estimated shoaling rates.

b. Project Condition Surveys. Hydrographic surveys of USACE deep-draft navigation projects are typically performed on at least an annual basis. These Project Condition Surveys are used to assess needs for maintenance dredging, and are often used as the basis for the estimated quantities in dredging contract documents from which bids are made. In effect, they often become P&S surveys.

c. Pre-dredge surveys. Once a dredging contract is awarded and dredging plant and equipment are on site, pre-dredge surveys are performed by the government over the contract area as close to the start of dredging as possible--generally within 14 days prior to commencement of work in a defined reach (i.e., Acceptance Section) to be dredged. These Pre-Dredge surveys are often referred to as "Before-Dredging" surveys, or "BDs." Plots of Pre-Dredge surveys and related quantities requiring excavation are usually required within two (2) days of completion of the surveys. The quantities from the Pre-Dredge surveys are compared with the quantities that were estimated in the contract solicitation documents--i.e., the Plans & Specifications surveys. Construction contracts typically contain a "Variation in Estimated Quantities" (VEQ) clause that is invoked when significant disparities between these surveys occurs. This clause provides for a modification of the unit price originally bid due to a significant change (usually ± 15%) between the estimated and actual quantities. Thus, both the contract P&S (Bid) survey and the Pre Dredge survey must be timely and accurate, especially in areas subject to rapid shoaling.

d. Progress payment surveys. Progress payment surveys are performed during the course of a dredging project for the purpose of estimating interim payments (normally monthly). These surveys are usually performed by the construction contractor and may be compiled from his daily surveys monitoring dredging progress.

e. After dredge, final clearance, and acceptance surveys. After-Dredging (AD) surveys are performed by the government as soon as possible after dredging in a reach or acceptance section is completed -- generally within five (5) days or less. Final survey plots and quantity computations are typically required within two (2) days of the survey in order to release the dredge to other work. Normally the After-Dredging survey suffices for assessing contract performance, and the project, or an individual acceptance section therein, is contractually "accepted" based on this survey.

(1) In many cases, the After Dredge survey reveals not all material has been removed and subsequent dredging, along with re-surveys, must be performed before final clearance/acceptance is verified. Often, repeated full-coverage channel sweep surveys must be performed to locate and remove material or man-made objects above grade. Channel sweep surveys may be made with multi-transducer boom sweeps, multibeam (swath) transducers, or bar-sweeps (sweep rafts).

(2) Typically, contract disputes over remaining material above the required depth involve the positional and depth measurement accuracy capabilities of the survey. These disputes often involve shoal material or objects that may be within the achievable tolerances of acoustic sounding equipment. Other issues may involve remaining shoal material 5 to 10 ft inside the channel toes--also near the tolerances of some survey positioning systems. In many cases, repeated surveys of these shoal areas yield different results, or may not agree with those performed by the dredging contractor's survey crew.

f. Offshore disposal or borrow area surveys. Disposal sites may be periodically surveyed to monitor misplaced material, minimum clearances, or required capping elevations. These surveys are performed by either single beam or multibeam systems. Quantity estimates of material placed are usually only rough estimates, particularly in deep sites (> 100 ft) where material may have been dispersed outside the area. Offshore borrow areas are surveyed on beach renourishment projects during the preparation of plans and specifications, and subsequently during construction to monitor area and grade restrictions.

g. As-Built drawings. The various after dredge and clearance surveys are combined to form the as-built survey drawing for the completed project, which is furnished to local sponsors and navigation interests.

h. Contractor access to government records. In accordance with USACE practice, dredge contractors are provided full and open access to all survey data obtained and processed by the USACE, for all surveys listed above. In addition, dredge contractor representatives are normally on board the survey vessel to observe any survey performed for payment or acceptance.

10-4. Dredge Contracting and Production Measurement Methods. There are two general methods for contracting dredging work: (1) Unit Price contracts, and (2) Firm Fixed Price (FFP) contracts. Unit price contracts are preferred by the USACE and are far more predominant than fixed price contracts. A short description of these contracts follows since hydrographic survey support and accuracy requirements will vary somewhat with the type of contract payment method.

a. Unit price--in-place volume measure. A majority of coastal dredging contracts in the USACE are awarded with payment based on in-place volume measure. These contracts determine payment based on the amount of material removed from a navigation channel (or placed, as in beach renourishment projects). This measurement is performed by comparing before and after dredging hydrographic surveys, and deducting any material that has been unexcavated; or over-excavated as indicated by the overdredged "non-pay" area in Figure 10-1. Payment is made based on the unit price bid by the contractor--typically per cubic yard (cy) or cubic meter. Use of in-place volume measurement requires that the USACE has the capability to "perform payment surveys in a timely and accurate manner" and can "assure that the surveys specified in the contract are sufficient to verify that the contract requirements are met." For beach renourishment projects, payment is based on before and after beach fill profiles, not from quantity excavated at the borrow area

b. Unit price--time measure. This type of dredging contract is used when the quantities of material cannot be accurately estimated by in-place volume survey methods, such as in active or erratic shoaling areas on river navigation projects, where rapidly fluctuating river stages exist, or where "accurate and timely surveys are difficult to accomplish" (ER 1130-2-520.) Dredging plant and equipment is leased at an hourly or daily rate bid by the contractor. On these types of

contracts, hydrographic survey accuracy requirements are not as demanding as in-place payment methods--usually due to high shoaling and material transport rates encountered. However, survey support is required to monitor channel dimensions and overall contract compliance. These rental contracts are most common on the inland navigation system, especially in the high shoaling areas of the Lower Mississippi River.

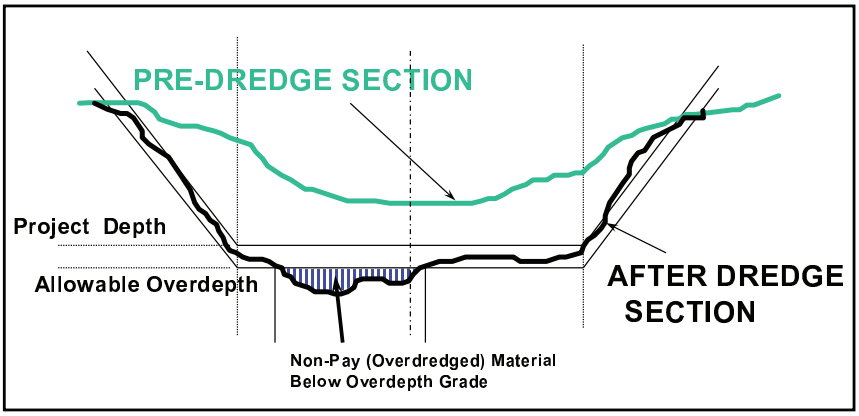

Figure 10-1. Typical Pre/Post Dredge Section. Payment limits and restrictions vary Corps-wide (e.g., Contour and Non-Contour Dredging methods--see paragraph 10-20).

c. Unit price--area measure. Area measure contracts are used in channels where depths of cut are relatively small and constant, and the area of dredge cut is the determining price factor, not depth of the "face" cut. The bid unit area (in square yards) is a channel section between fixed stations--thus the term "Station Dredging" for this method (see Figure 10-2.) Final hydrographic surveys are performed to ensure clearance to grade and acceptance of work--quantities may be computed; however, payment is made for the fixed section of work completed and accepted. These contracts are typically used in smaller navigation canals.

d. Unit price--scow or bin measure. Payment based on scow or bin measure, and/or related production/density flow meters, requires final after-dredging hydrographic surveys to certify clearance and contract acceptance. In addition, hydrographic surveys are needed to determine the amount of any excess dredging, for a payment reduction. Surveys may also be required to verify placement of stone or other material on shoreline protection projects, such as breakwaters or jetties.

e. Firm Fixed price--lump sum contracts. This method is used on projects where the rate of shoaling is small or predictable over the length of the contract. In this method, the dredge contractor bids a lump sum price for the job based on the contract plan and specification surveys. No pre-dredge survey need be performed; however, after-dredge clearance and acceptance

surveys are required to ensure the contractor has removed all material from the required prism. Dredging lump sum contracts are relatively rare.

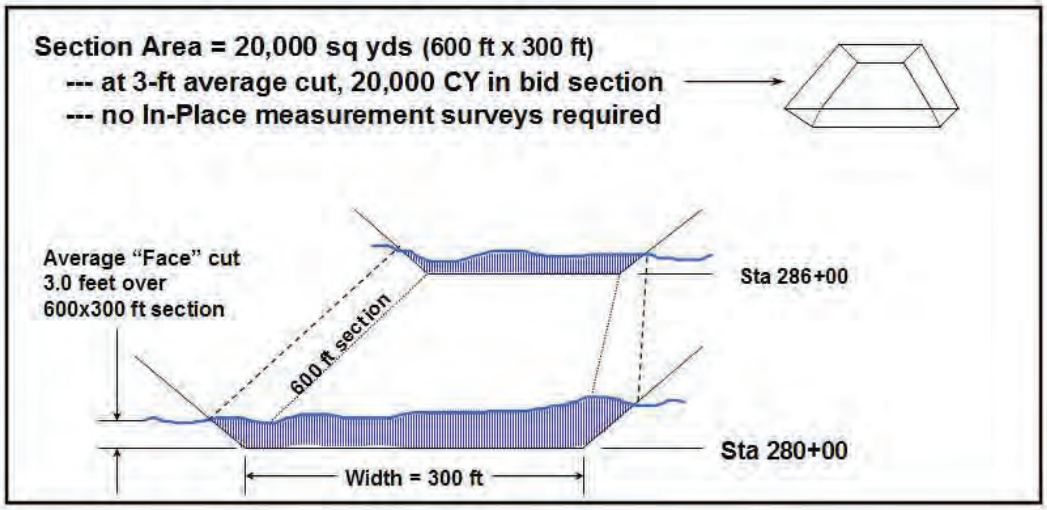

Figure 10-2. Station Dredging.

10-5. Definitions of Dredging Grades. Hydrographic surveys supporting dredging operations, and related dredge volume and payment computations, are performed with respect to a variety of payment prisms. Survey data must be collected at sufficient accuracy, coverage, and density so it can be evaluated relative to these prisms. Failure to collect survey data with sufficient coverage makes accurate pay quantity computation difficult, and can result in payment disputes. The following terms, excerpted in part from ERDC Technical Note EEDP-04-37 2007 (see Appendix A), are used to define the various payment reference surfaces found on navigation projects.

a. Authorized project dimensions. A channel's "required depth" or "project depth" and width are specified in the Congressional authorizing legislation for each project. This legislation may also detail the dimensions of channel entrances, bends (wideners), sidings, anchorages, and turning basins. The required project depth (authorized project depth) is based on the draft of the loaded "design vessel" plus, squat, sinkage in fresh water, effect of wind and wave action, under-keel safety and efficiency clearance, etc.--see ER 1110-2-1404, Hydraulic Design of Deep-Draft Navigation Projects. Project width of a channel is a function of traffic, winds, currents, curvature, vessel maneuverability, bank conditions, etc. (see Figure 10-3). In some instances, over-width dredging may be performed for advance maintenance purposes (EM 1110-2-1202, Environmental Engineering for Deep-Draft Navigation Projects).

b. Required Project Grade. This is the depth specified by the USACE for each dredging contract. Often it is the federally authorized depth, but in some cases can be less or more (for example, when advance maintenance has been authorized).

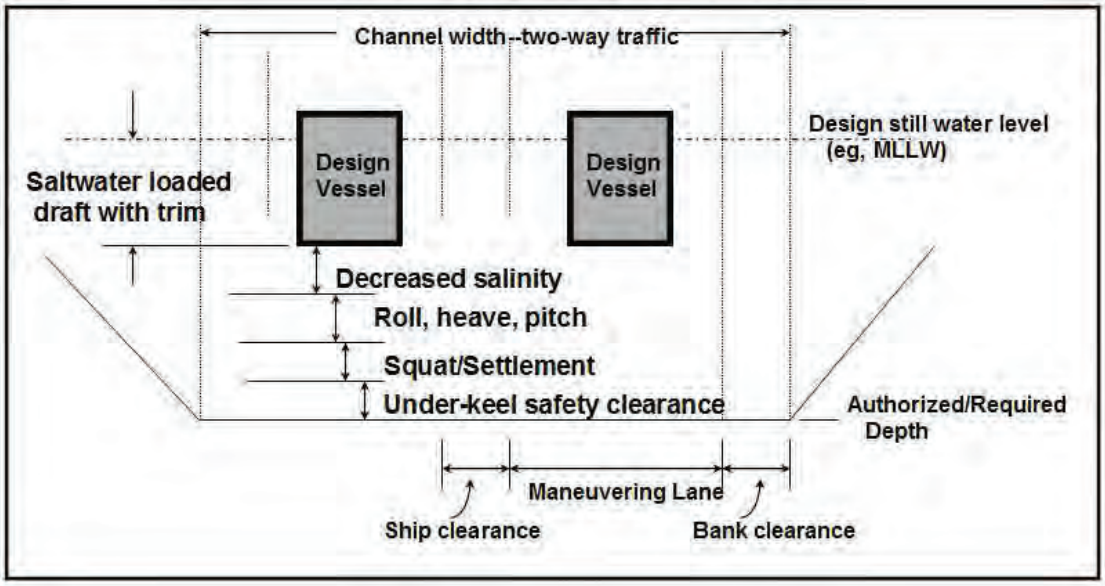

Figure 10-3. Typical Deep-Draft Navigation Channel Dimension and Clearance Parameters. (EM 1110-2-1613, Hydraulic Design of Deep-Draft Navigation Projects)

c. Paid Allowable Overdepth. Paid allowable overdepth dredging (depth and/or width) is a construction method for dredging that occurs outside the required authorized dimensions and advance maintenance (as applicable) prism to compensate for physical conditions and inaccuracies in the dredging process and allow for efficient dredging practices. The term "allowable" must be understood in the contracting context of what dredging quantities are eligible for payment, rather than in the regulatory context of what dredging quantities are reflected in environmental compliance documents and permits. Environmental documentation must reflect the total quantities likely to be dredged, including authorized dimensions, advance maintenance, allowable overdepth, and non-pay dredging. The paid allowable overdepth should reflect a process that seeks to balance consideration of cost, minimizing environmental impact and dredging capability considering physical conditions, equipment, and material to be excavated. ER 1130-2-520 provides that District Commanders may authorize dredging of a maximum of two feet of allowable overdepth in coastal regions and in inland navigation channels. Paid allowable overdepth in excess of those allowances or the use of zero paid allowable overdepth requires the prior approval of the MSC Commander. The USACE recognizes that there may be circumstances where there is a need for increased excavation accuracy in the dredging process, for example in environmental dredging of contaminated material, which dictate trading potential increased costs for a reduction in paid allowable overdepth, i.e., reducing the quantity of material required for special handling/placement or treatment.

d. Advance Maintenance. Advance maintenance is dredging to a specified depth and/or width beyond the authorized channel dimensions in critical and fast shoaling areas to avoid frequent re-dredging and ensure the reliability and least overall cost of operating and maintaining the project authorized dimensions. For maintenance dredging of existing projects, Major Subordinate Commands (MSCs) (Division Commanders) are authorized to approve advance maintenance based on written justification. For new navigation projects, advance maintenance is approved as part of the feasibility report review and approval process based on justification provided in the feasibility report.

e. Non-pay Dredging. Non-pay dredging, also known as "non-pay yardage," , is dredging outside the paid allowable overdepth (or outside contour or non-contour dredging boundaries) that may and does occur due to such factors as unanticipated variation in substrate, incidental removal of submerged obstructions, or wind or wave conditions that reduce the operators' ability to control the excavation head. In environmental documentation, non-pay dredging is normally recognized as a contingency allowance on dredging quantities, and may and does occur in varying magnitude and locations during construction and maintenance of a project.

f. Characterization Depth. Regulatory compliance necessitates that material to be dredged be characterized and evaluated with regard to its suitability for the proposed placement of the material. Characterization and evaluation of dredged material must consider the entire dredging prism, including paid allowable overdepth and non-pay dredging.

g. Channel side slopes and box cut allowances. Side slope grades are designed based on the geophysical properties of the material on the channel banks. Side slope grades typically vary between from 1 H on 1 V (45 deg) up to 5 H on 1 V (11 deg). Advance maintenance and overdepth payment prisms are extended up the side slopes parallel to the authorized project depth prism, and payment may be allowed for material removed within these sections. In some instances, allowance may be made for material excavated below the payment prism based on the potential for undisturbed material to slough downward to the channel toe. This is commonly referred to as a "box cut allowance."

10-6. Factors Impacting Survey Coverage and Accuracy Requirements. This paragraph outlines some of the factors that will determine the requirements for a particular hydrographic survey supporting a dredging operation.

a. Type of excavated material. The type of excavated material (including its disposal) will impact required survey procedures. Areas with hard material, such as rock, may require blasting which could result in numerous rock fragments remaining above project grade by small amounts (e.g., 0.1 ft to 0.5 ft). Accurate acoustic or mechanical sweep surveys will be performed to locate these fragments and excavate or drag them clear. Maintenance dredging of soft material allows for less stringent survey methods.

b. Unit price. The bid unit price may impact accuracy requirements in a number of ways. High unit price material may often cause higher scrutiny of payment surveys and/or volume computations. The unit price will also determine whether it is cost-effective for the contractor to dredge close to the required depth or to dredge significant amounts of overdepth material. When economics dictate that overdepth dredging is not economical, dredging close to the required depth can result in many remaining areas left above grade, and resultant clearance disputes.

c. Dredge equipment. The type of bottom material and resultant dredging equipment used may impact the accuracy requirements for a hydrographic survey. In the USACE, removal of loose, softer materials is normally accomplished by suction dredging (dustpan dredges, hopper dredges, hydraulic pipeline suction dredges, or sidecasters). Since these types of dredging operations are not as precisely controlled (in depth and location), survey accuracy and density of coverage may be reduced. For removal of hard, compacted material (e.g., rock), mechanical dredging is performed, using clamshell, dipper, or ladder dredges. This is typical of new work. A cutterhead dredge (combined suction and mechanical) is employed for either soft or hard material. Survey accuracy requirements are generally higher for mechanical or cutterhead dredge equipment since these operations can more precisely control the location and depth of cut. See also EM 1110-2-5025, Dredging and Dredged Material Disposal.

d. Unconsolidated sediments. One of the most difficult issues in evaluating hydrographic survey data occurs when low-density suspended sediments obscure the echo sounding return. This phenomena, commonly know as fluff or fluid mud, occurs in the natural low-flow environments, and may also occur during dredging operations due to the agitation of the bottom material. It is most pronounced in southeastern CONUS navigation projects. Multiple layers of fluff can occur, with these layers ranging from 1 to 15 ft above the bottom. Assessment of dredging progress, clearance above required depth, and the equitable payment grade can be extremely difficult--even when dual frequency sounders are used, or when correlation is made with non-acoustic devices (lead lines, sounding poles, density probes, etc.). As a result, contract payment techniques based on in-place volume measure can often be difficult and may require negotiated settlement. In some instances, after dredge surveys have shown more material in a channel than before dredging surveys. Certification of the clear navigable depth may also be tenuous where the firm channel bottom cannot be clearly determined. Procedures for performing and evaluating surveys in unconsolidated sediments are described in Appendix P attached to this manual.

10-7. Measurement, Payment, and Acceptance Survey Contract Specifications. The following excerpts are taken from clauses contained in most dredging contracts involving payment based on hydrographic surveys. These contract requirements have significance to the survey measurement process, both procedurally and technically, and the interpretation of the adequacy of USACE survey data. Although the government, as the contracting agent, developed these clauses to protect the government's interests, they also provide mechanisms for the contractor to challenge the government's interpretations and assessments, and obtain relief if necessary.

Contract clauses are continually changing; therefore, the abbreviated excerpts below may not be current. The currently approved contract clause should be obtained from the applicable procurement regulations.

(1) "Surveys for Acceptance: ... the [P&S hydrographic survey] drawings are believed to accurately represent conditions existing at the time indicated but the depth shown thereon will be updated as required by [Pre Dredge] soundings taken prior to commencement of dredging. [Final survey] determination of quantities removed to be paid for in the areas specified, after having once been made, will not be reopened, except on evidence of collusion, fraud, or obvious error ... The time for redredging to remove shoals and for [second] [third] and subsequent [hydrographic] surveys shall be the responsibility of the contractor."

(2) "… Final Examination and Acceptance: As soon as practicable after completion of the entire work or any section thereof ... such work will be thoroughly examined at the cost and expense of the Government by sounding or sweeping, or both, as determined by the Contracting Officer. Should any shoals, lumps, or other lack of contract depth be disclosed by this examination, the Contractor will be required to remove same by dragging the bottom or by dredging at the contract rate for dredging, but if the bottom is soft and the shoal areas are small and form no material obstruction to navigation, the removal of such shoal may be waived by the discretion of the Contracting Officer. The Contractor will be notified when soundings and/or sweepings are to be made, and will be permitted to accompany the survey party. When the area is found to be in a satisfactory condition, it will be accepted finally. Should more than two sounding or sweeping operations by the Government over an area be necessary by reason of work for removal of shoals disclosed by a prior sounding or sweeping, the cost of such third and any subsequent sounding or sweeping operations will be charged against the Contractor. The rate for each day in which the Government [survey] plant is engaged in such sounding or sweeping operations and/or is en route to or from the site, or is held, for the Contractor's convenience at or near the site for these operations, shall be [$_____]*, except on Saturday, Sunday and holidays when the rate shall be [$_____]…"

(3) " … Inspection of Construction: ... the Government shall accept, as promptly as practicable after completion and inspection, all work required by the contract ... Acceptance shall be final and conclusive except for latent defects, fraud, gross mistakes amounting to fraud, or the Government's rights under warranty or guarantee …"

a. Survey errors. The above contract acceptance clauses typically provide for a contractor to challenge the accuracy of any payment survey based on an "obvious error" in that survey. "Obvious error" provides extremely wide latitude for alleged survey deficiencies in that no specific magnitude of the error is defined. However, by implication, any allegations of "obvious error" must relate to recognized survey practices--i.e., conformance or non-conformance with the

“best practices” and other criteria in this engineer manual and references therein. Government-performed surveys, and assessments or evaluations thereof, must always be "above board" and performed in a manner that both represents the government's interests and is equitable to the contractor for the actual work performed under the contract.

b. Remaining shoals. The above excerpt from a typical acceptance clause provides latitude to the government in assessing the significance of remaining shoals. This assessment will evaluate the magnitude of the shoal relative to the achievable survey tolerances, achievable dredging tolerances, and/or navigation impacts. Obviously, the positional and depth measurement accuracy tolerances of a survey must be thoroughly considered before a contractor is directed to undertake additional work at his time and expense. The Contracting Officer has authority to unilaterally direct a contractor to continue dredging any disputed shoal material under the “Disputes” clause.

c. The above part of the "Final Examination and Acceptance" clause requires the USACE to perform final (After-Dredging) acceptance surveys as expeditiously as practicable, and to release the contractor's dredge from the work. This clause also is applicable in cases where fraudulent work may have been performed. In the past, numerous cases exist where dredging was performed only on the even 100-ft stations/sections surveyed by the USACE (usually by manual tagline/leadline techniques), and no material was excavated between the sections. Often this fraudulent work was not discovered until long after the work was accepted. Such incidents are rare today given full-bottom sweep capabilities of modern survey equipment.

10-8. Measurement and Payment Surveys Performed by Other than USACE Hired-Labor. On most projects, quantity survey measurements are performed by USACE hired-labor (in-house) survey forces. However, FAR and USACE policy provides for contractor-performed measurement and payment surveys. Often there are insufficient USACE survey personnel to cover surveying requirements for many ongoing construction and dredging contracts. Many contracts (e.g., beach renourishment and revetment construction) require full-time survey capability throughout the construction season; thus, it is more efficient to contract this effort.

a. When necessary, either independent A-E contractors or dredge contractor survey forces may be used in lieu of USACE surveyors. USACE policy regarding contracting measurement and payment surveys is prescribed in EP 1130-2-520, Navigation and Dredging Operations and Maintenance Guidance and Procedures. Basically, surveys may be performed using (1) USACE hired-labor forces, (2) Architect-Engineer (A-E) service contractor forces selected using Brook's A-E Act (PL 92-582) qualification-based selection procedures, or (3) Dredge contractor forces, provided a qualified government representative is on board the contractor's vessel during the surveying operation.

b. EP 1130-2-520 outlines a preference for performing surveys with USACE forces. This policy is justified in that payment and project clearance/acceptance is based on these surveys, and

any disputes (between the USACE and construction contractor) over survey adequacy or accuracy become difficult to resolve unless the contract agent is fully responsible for the survey data.

c. The use of construction/dredging contractors performing their own payment surveys represents a special case, given the need for quality assurance oversight that must be performed by the USACE when such surveys are performed. This oversight includes government inspection aboard the contractor's survey vessel and review of all data processing phases, including pay quantity computations. EP 1130-2-520 outlines steps that must be taken when a district elects to use dredge contractor forces for hydrographic payment/acceptance surveys. Basically, districts must provide a rationale and justification for proposing to use dredge contractor's surveys forces and document their unsuccessful efforts to obtain contracts with qualified independent A-E hydrographic survey firms. Guidance in EP 1130-2-520 notes that districts may require that a contractor's surveyor be a licensed land surveyor or hold hydrographer certification from the American Congress on Surveying and Mapping (now the National Society of Professional Surveyors). Certain minimum equipment specifications may also be required in the dredging contract.

d. Most dredge contractors normally have survey forces on the project to perform progress payment surveys, and these same forces can be used for payment and acceptance surveys as well. In some instances, dredge contractors will subcontract their hydrographic survey work.

SECTION I

Channel Clearance Surveys

Government channel clearance surveys should be expeditiously performed and processed, such that a preliminary evaluation of acceptable or unacceptable clearance can be made at least within 24 hours after completion of the survey, and preferably, concurrent with the survey aboard the vessel. In new work or deepening projects in hard material, authoritative government and contractor representatives may be present during actual clearance surveys so that potential strikes or shoals above grade can be immediately assessed and/or resurveyed, for either confirmation or acceptable clearance. In such cases, near-real-time data processing needs to be performed aboard the survey vessel at the project site so that additional verification surveys can be immediately performed over questionable areas. These expedited survey procedures are essential for contracted construction acceptance, clearing dredges to relocate to other project sites. Both mechanical and acoustic methods are used to verify channel clearance, as described below.

10-9. Definitions.

a. Strike detection or minimum channel clearance. For strike detection or dredge clearance/acceptance purposes, multiple "hits" on strikes or shoals above a specified grade are

required. Typically, the specified grade is the “Required Grade” although an overdepth grade or supergrade could also be used. An additional tolerance grade for rock cuts may also be specified. Multiple confirmation sweep passes are always recommended for channel clearance surveys in that strikes above grade detected from different sweep aspects helps to minimize the possibility of noise spikes creating false strikes on a single pass. The representative "shoalest depths" are used to generate "strike plots" depicting project areas remaining above grade, and the possible need for additional excavation.

b. Confirmed hits. The multiple "hits" may be obtained on a single sweep pass or (best) from multiple sweep passes over a suspected shoal/strike area. A USACE recognized rule of three (3) hits is recommended to represent a “confirmed” hit. This "3-hit rule" should not be arbitrarily applied, as it does not have a valid statistical sampling basis relative to the magnitude of the strike and the depth measurement uncertainty. The “multiple hits” above grade are determined by assessing “minimum” edited depths recorded in a cell matrix, or from a series of adjacent cells. Three confirmed hits within various cell sizes are used; however, adjacent cells may need to be assessed if only sporadic hits occur in a single cell.

c. Strike plots--plotting minimum hits above grade in plan. If many shoals/strikes exist in bins over a small area, then the processing software will have to select the most representative (e.g., highest/shoalest) confirmed strike to plot for this area--to avoid overplotting depths at the plot scale. If contour or color-coded depth plots are generated, then all the minimum confirmed hits can be easily represented in plan or 3D format.

10-10. Channel Clearance Bar Sweeps. (Figure 10-4). A bar sweep is a non-acoustic technique for clearing channels or determining the elevations of underwater obstructions. In rock cut channels, a heavy bar or pipe may be dragged along the bottom by a tug to knock down spikes or smooth out the grade. In this case, no elevation of the bar is maintained and acoustic surveys are still required to verify clearance. Elevation controlled channel sweeps are performed using sweep rafts or sweep barges. A bar is lowered to a controlling grade elevation and the channel is “swept” clear by the bar to ensure safe navigation. A bar sweep has particular application in blasted or cut rock dredging construction where hull clearance verification is especially critical. In many cases, a bar sweep represents a more reliable clearance verification than that obtained by acoustic methods. Bar sweeps were once more prevalent in USACE but currently are rarely employed, except in special cases where channel clearance is critical. The following paragraphs describe the bar sweep process that was once used in the Detroit District. These same techniques (or modifications thereto) could still be employed should a need arise on a current project.

a. Background. The Sault Ste. Marie (Soo) Area Office (Detroit District) began deploying sweep rafts in the St. Mary's River (MI) around 1930. The purpose was to certify clear grades in the approach channels around the Soo Locks. Channel depths swept vary from 27 to 30 ft. The original channel was designed based on a design draft of 25.5 ft. Channels in hard rock areas are cut to 28.0 ft with very little overdredging below that level due to the hard material.

The channels that produce the most dangerous grounding hazards to commercial vessels are those constructed in native bedrock. The next most dangerous channels are those cut through glacial deposits containing boulders. Commercial vessel groundings in other channels constructed in soft material have not proven significant. Vessel loadings are driving the need to clear the channels free of navigation hazards. Commercial ore carriers will typically load close to the 28.0 ft level, typically to 0.3-ft clearances above the swept clear grade reported by the Corps. Groundings on commercial vessels have occurred on the west approach to the Soo Locks due to loading too close to the cleared grade.

b. Detroit District sweep raft design. The Detroit District operated four sweep rafts on the Detroit River, St. Claire River, and St. Mary's River. They were wooden rafts or barges 120- to 130-ft-long, with a 15-ft beam and 4-foot draft. The sweep system dragged six, in-line, 21-ft-long by 2.5-inch diameter solid steel bars, each bar weighing approximately 600 lb. This resulted in a clearing swath of some 120-ft. The bars were suspended by a 3/8-inch diameter cable wound on manually operated reels designed to raise and lower the bars by 0.1-ft increments. The bars are suspended along the center of the sweep raft with a 1-ft overlap between adjacent bars.

(1) Three observers were required to monitor the sweep bars--each person responsible for two bars. Concurrent river stage observations are required to continually adjust the depth of the bar. Sweeping is done at a slow speed (slightly greater than drift velocity) in order to keep the bar(s) suspended vertically at the proper depth. Strikes are detected by manual feel of vibration in the cables suspending the bar. When the bar "strikes" a hazard, the position is fixed and the height above grade determined. Individuals monitoring the suspended cables are able to determine the relative hardness and softness of a struck object by feel and sound in the wires. The raft is towed, pushed, and maneuvered by a 45-ft harbor tug. The tug requires a two-person crew. The tug was traditionally powered by a 170 HP engine using low power to avoid dragging the head anchor. Control of the sweeping is done using a headwire anchor about 600 feet upstream, as shown in Figure 10-5. The tug drops the anchor, connects to the towline, and the sweep pulled downstream to the sweep area while letting out cable. Sweeping is performed with the tug attached to the fixed-length tow line, the sweep and tug held by the anchor to prevent them from going downstream, and pulling the sweep back and forth on the cable. The length of the cable payed out represents the radius of the sweep. Sweeping begins at one side of the channel. The bars are wheeled down, set at depth, and corrected for river stage. After each swept arc, an additional 100 ft of cable is payed out downstream and the next arc swept. This provides a 20-ft overlap between successive sweep arcs. Upon completion of sweeping, the cable is picked up onto the drum of the hoist and the anchor brought back aboard.

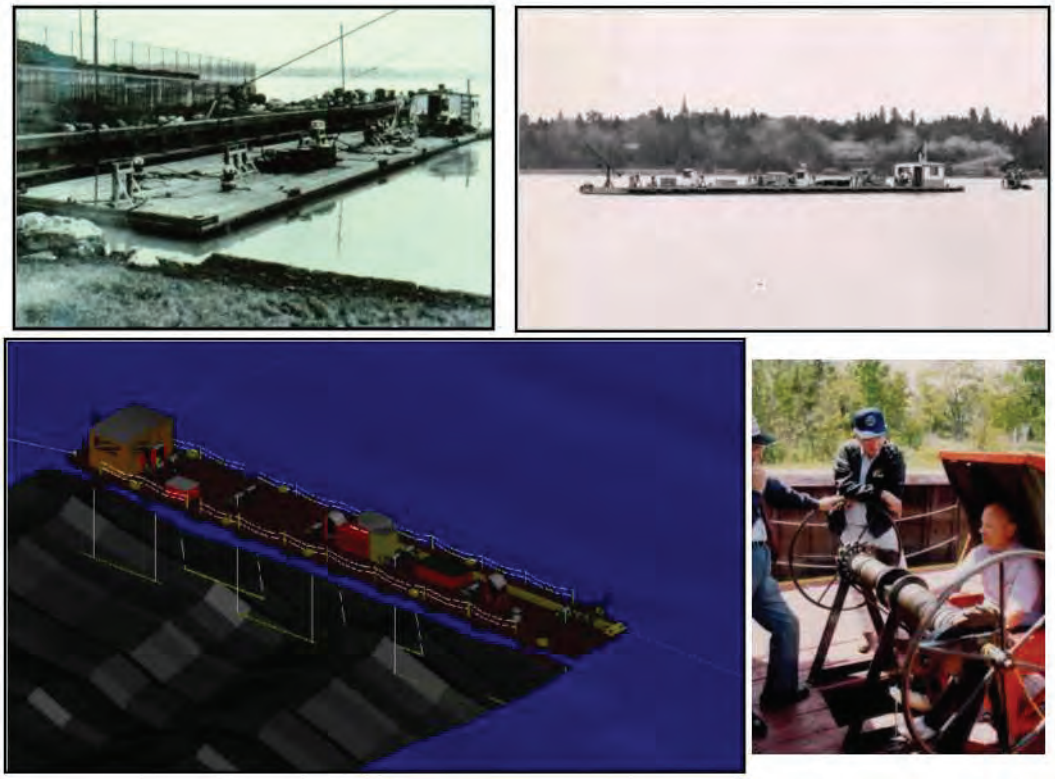

Figure 10-4. 130-Ft Sweep Raft on Detroit River (upper left) and St. Marys River (upper right). The concept sketch on lower left shows the six 21-ft sweep bars. "Chairpersons" (lower right) manually feel rock "strikes" from vibrations on the cables. (Detroit District)

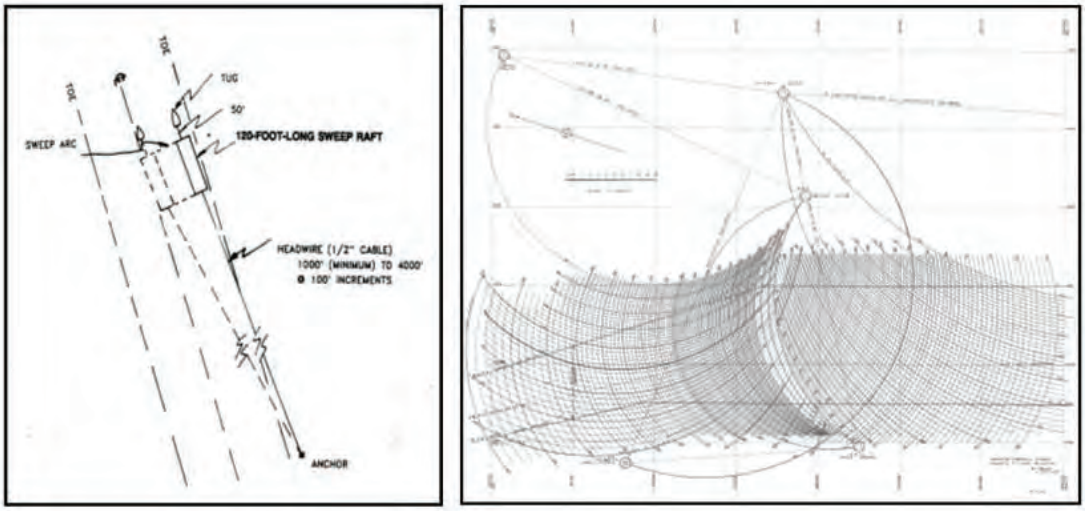

Figure 10-5. Sweep raft control from upstream head anchor (left side). Constant sextant angle curves were once used to position the sweep raft and locate strikes (right side).

(2) Horizontal positioning was accomplished using sextant resection from fixed targets along the river bank, and later microwave electronic positioning. For sextant positioning, an "arc chart" of the channel was prepared consisting of two families of constant sextant angle circles (Figure 10-5). Positions of the beginning and end of the swept arc are determined by sextant resection. When a strike was detected, the resected position from two observed sextant angles could be quickly plotted aboard the sweep raft.

(3) Locations of any snagged obstructions (i.e., strikes above grade) are positioned, and the pinnacle or obstruction elevation is measured by sweeping at successively higher elevations until it is cleared. It is estimated that the accuracy of mechanical sweep raft measured elevations was 0.2 ft. A "strike plot" is prepared showing all contacts encountered. Sweep rafts often work in conjunction with a derrick barge or crane barge to remove strikes. A derrick barge clears the strike either by dragging a bar over the area or by blind pattern digging with a clam shell bucket.

(4) The total crew required for a sweep operation was nine persons. These includes a Party Chief, Sweep Foreman, two tug boat operators, three bar sweep tenders ("Chairpersons"), an on shore gage reader, and one relief person.

c. Replacement sweep clearance systems. In the mid to late 1980s, the Detroit District began using 32-transducer (130-ft) multiple transducer systems to sweep the Detroit River and St. Marys River, replacing the above mechanical detection system. Subsequently, around 2002, this 32-transducer multiple transducer system was replaced by a multibeam system permanently hull-mounted aboard a trailerable boat. Although labor-intensive and slow relative to current acoustic methods, these bar sweep systems provided reliable, certifiable channel clearance verification in rock cut areas. Many contend these older bar sweep methods provide a more definitive (and confident) clearance assessment than acoustic techniques. In fact, the Detroit District Soo Area office still deploys a small, single-bar sweep on the Derrick Barge Nicolet working the St. Marys River (Figure 10-6). The derrick barge is also equipped with a multibeam system. It is supported by a multibeam boat that locates potential strikes and provides “strike plots” to the derrick barge (Figure 10-7).

d. Wire sweeps. Wire sweeping methods were once commonly performed by the U.S. Coast & Geodetic Survey and the USACE Lake Survey District for sweeping wide areas, usually in deeper (non-maintained) approaches to navigation projects. Wire sweeps were not considered as reliable as the bar sweep methods described above. The USACE Lake Survey District last performed wire sweeps at Cleveland Harbor, Lake Erie, in the early 1970s.

10-11. Acoustic Evaluation of Clearances on Dredging Projects. Multibeam systems are now the primary method used to verify channel clearance, especially in deep-draft, rock cut projects. (Single beam surveys may be used on maintenance dredging projects with soft material.) Multiple sweep passes are performed over the channel and the data binned into small grid cells for evaluation. Typical cell sizes on clearance evaluation surveys range from 1 x 1 ft to 5 x 5 ft.

Figure 10-6. Detroit District Derrick Barge Nicolet. The barge deploys both a single bar sweep and a multibeam system to aid in object detection and removal.

a. Strike verification (new work or rock). When multiple adjacent/contiguous cells on a single acoustic multibeam survey sweep over an area contain multiple depths above the required grade, then a confirmed strike above the required grade may be inferred, and additional dredging clearance may be indicated. When an isolated cell indicates a single depth above the required grade, further confirmation should be made to verify the strike by making at least two (2) or more additional "dead slow" survey passes [sweeps] over the suspected strike area, i.e., slow enough to accumulate a statistically significant number of depths from which to evaluate the confidence of the average representative depth.

b. Shoal verification (maintenance dredging/soft bottom material). When adjacent/contiguous depths on a single acoustic survey (single-beam or multibeam) over an area contain multiple depths above grade, then a confirmed shoal above grade may be inferred and additional dredging clearance may be indicated. When an isolated depth above grade is recorded, further confirmation should be made to verify the shoal by making at least two (2) additional slow speed passes over the suspected shoal area in order to accumulate a statistically significant number of depths from which to evaluate the confidence of a representative clearance depth.

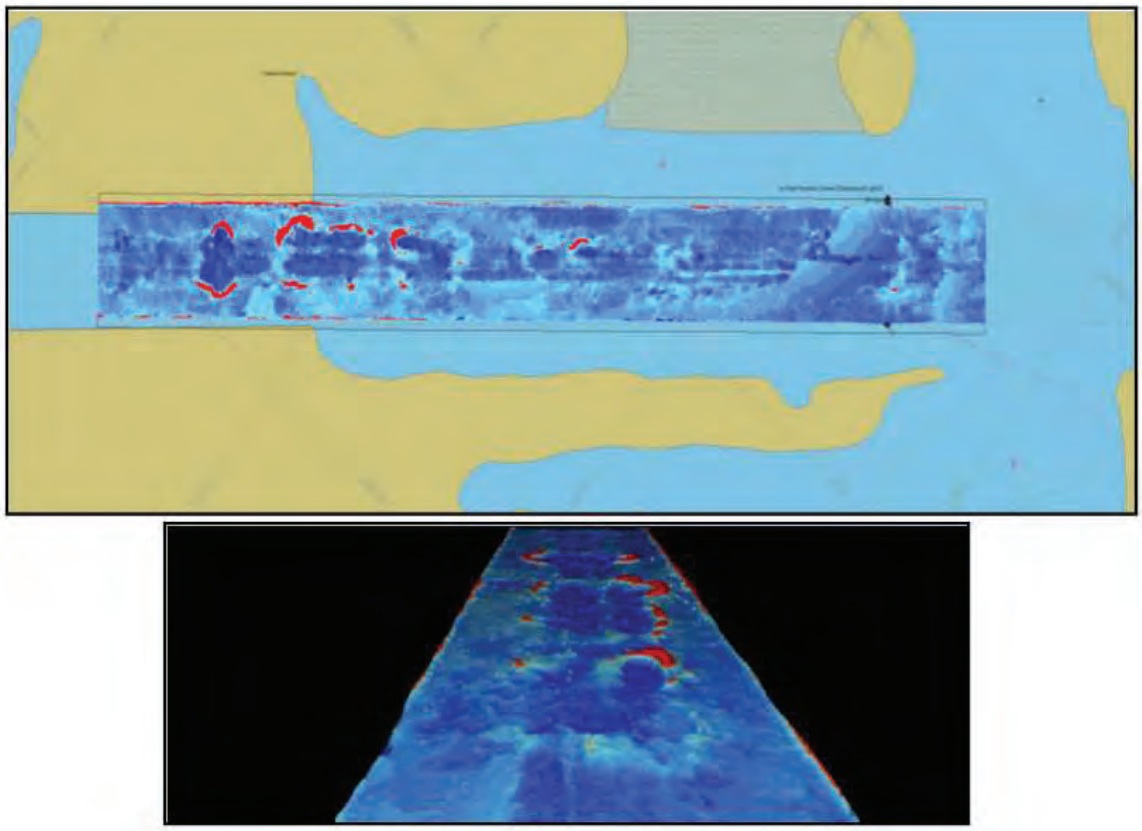

Figure 10-7. Strike plot of rock above grade in the St. Marys River channel. Reson 8125 multibeam survey by S/V Bancroft W. Bufe, Detroit District, Soo Area Office (2004)

c. Minimum number of recorded depths for assessing clearance. A minimum of 3 depths above grade is usually considered as indicating the presence of a shoal or strike—i.e., the so-called "3-hit rule." Depending on the magnitude of the strike above grade, this “3 hit rule” may not be statistically significant relative to the uncertainty of the individual depth measurements. For example, 3 depths 1 ft above grade may be significant whereas 3 depths 0.2 ft above grade may not be. Clearance depths should be assessed considering the confidence of all the measurements in a cluster or cell.

(1) Most object detection criteria typically specify that a minimum number of acoustic "hits" be obtained on a potential shoal or strike. These hits should ideally be obtained on repeated passes over an object, and be recorded on each pass. A single pass is adequate if numerous hits above grade are obtained, the strike elevations are consistently above the required grade, and the magnitude of the strike is within the accuracy of the depth measurement system.

(2) Evaluating channel clearance on dredging projects involves a review of the soundings obtained on the final after dredge survey and/or final channel clearance sweep survey. Numerous

shoals or strikes above the required grade may be present on these surveys. The project manager or contracting officer's representative (COR) must ultimately determine whether these shoals/strikes above grade warrant additional work effort to assure project clearance, or they are isolated, stray soundings within the "noise" (i.e., uncertainty) level of the depth measurement system. Therefore, this assessment of above-grade soundings must consider (1) the error budget (uncertainty) of individual depth measurements, (2) their relative magnitude, (3) survey accuracy standards specified for the project, and (4) the detection repeatability of the acoustic system.

(3) A single recorded “hit” 0.1 ft to 0.2 ft above grade presents clearance assessment problems. This hit could be the edge of a shoal or rock of larger size with even a shoaler elevation. If the estimated RMS uncertainty of the depth measurement system is ±1.0 ft, then this small strike could be an observation lying within that 95% accuracy tolerance--e.g., taken when a vessel without heave compensation was surging down in the trough of a wave. Thus, additional observations are needed to confirm the existence (or non-existence) of material lying above the project grade. Additional passes over the area are thus required. If acoustic hits above grade are repeatedly obtained on these additional passes, then a high probability exists that a shoal or rock strike is present in the channel. The confidence levels of shoal detection can be roughly estimated given (1) height of hits above grade, (2) standard deviations of depth measurements, and (3) number of hits. Using approximate t-density functions, it can be mathematically shown that all three of the above factors (variables) will determine the overall confidence of detection. For example, given 3 hits averaging 1-ft above grade and a ±1.0 ft standard deviation, the detection confidence is roughly 75%. If only 2 hits were recorded, the confidence of a shoal drops to 60%. If 10 hits are recorded, the confidence of detection increases to 98%. Thus, obtaining a 95% detection confidence may require more than "3 hits," depending on the magnitude of the three variables described above.

(4) Obtaining multiple hits with a single beam (narrow beam) echo sounder is difficult. Stealth-like objects may not always be detected with vertical beams. Close line spacing must be run over a suspected strike--e.g., 10 ft to 20 ft intervals. A multibeam system is far more efficient in detecting strikes and confirming them with multiple passes. Multibeam sweeps should be conducted such that the beam aspect is varied from near vertical to an outside beam. The outside beams have a better chance of detecting vertical, stealth-like objects above grade. Multibeam side scan imagery on the outer beams will also be of value in detecting strikes above grade. A towed side scan can also be used to indicate potential objects; however, it will not provide clearance depth information—see Appendix Q.

(5) For a detailed analysis on object detection with multibeam systems see "Provisional Swath Sonar Survey Specifications" (LINZ 1999). This specification analyzed detection criteria used by various international hydrographic surveying agencies and proposed that "at least 'three strikes' on the minimum target dimension be provided in both the along and across track dimension." This specification also qualifies other critical factors in strike detection, such as vessel speed, frequency, beam spacing, and footprint size. No statistical basis was given for this

"3 strike (hit)" specification; its proposed adoption was based largely on field survey experience. This analysis is, to some extent, consistent with the USACE recommended use of a "3-hit rule" detection method.

(6) Figure 10-8 illustrates the difficulty in evaluating small recorded heights above grade, given the noise of the depth measurements and their ±0.8 sample (61 depths) standard deviation. (This ±0.8 deviation is not necessarily the TPU (TVU) of the depth measurements since other biases could be present.) This apparent uncertainty in the observed depths must be considered in evaluating whether isolated depths above grade are realistic. In this example, given the preponderance of depths below the 42.0 required grade, the two isolated depths above grade are likely noise and would be rejected. If the required grade was 42.2 ft, then only 6 of the 61 depths are above grade, and the existence of a shoal is still statistically problematic. However, if the required grade was 42.4 ft, then a significant number of depths (12 of 61) above that grade would indicate a likelihood of a lack of clearance.

d. The relative height of an object or shoal above grade will determine the need for clearance. This may depend on the location of the shoal within the channel, type of bottom material, size of shoal, potential navigation hazard, etc.

e. Object and shoal/strike detection criteria. A detection performance criteria should be specified based on the size of the minimum object being searched for in a particular project, using either mechanical bar sweeps or acoustic sweeping/scanning methods. Demonstration testing of an acoustic detection system's capability should be specified on critical projects. This would entail deployment of an artificial object with the required dimensions. A minimum of three acoustic returns from a shoal or object should be specified to confirm its existence. These acoustic hits may be obtained on a single pass or, more conclusively, over successive passes. Reconfirmation of a strike above project grade by successive passes on different courses is strongly recommended for dredging clearance surveys.

f. Evaluating clearance depth uncertainties in multibeam cells. The uncertainty of the resultant average of a series of depth measurements over a fixed area is usually represented by the estimated standard deviation of the resultant mean—i.e., the "standard deviation of the mean" or “confidence level.” This statistical estimate of dispersion may be applicable when multiple depths are grouped in a defined bin, cell, or DTM node, as is done on multibeam dredge clearance assessment surveys. The multiple depth measurements in a defined cell area may have been obtained from a single pass by a multibeam system or accumulated from different multibeam passes on different days—see example cell data at Figure 10-9. In this example, the standard deviation of the 59 depths in the cell sample is ±0.8 ft (95% or 2-sigma). The 95% confidence of the representative 42.2 ft average depth may be estimated based on the standard deviation of the mean.

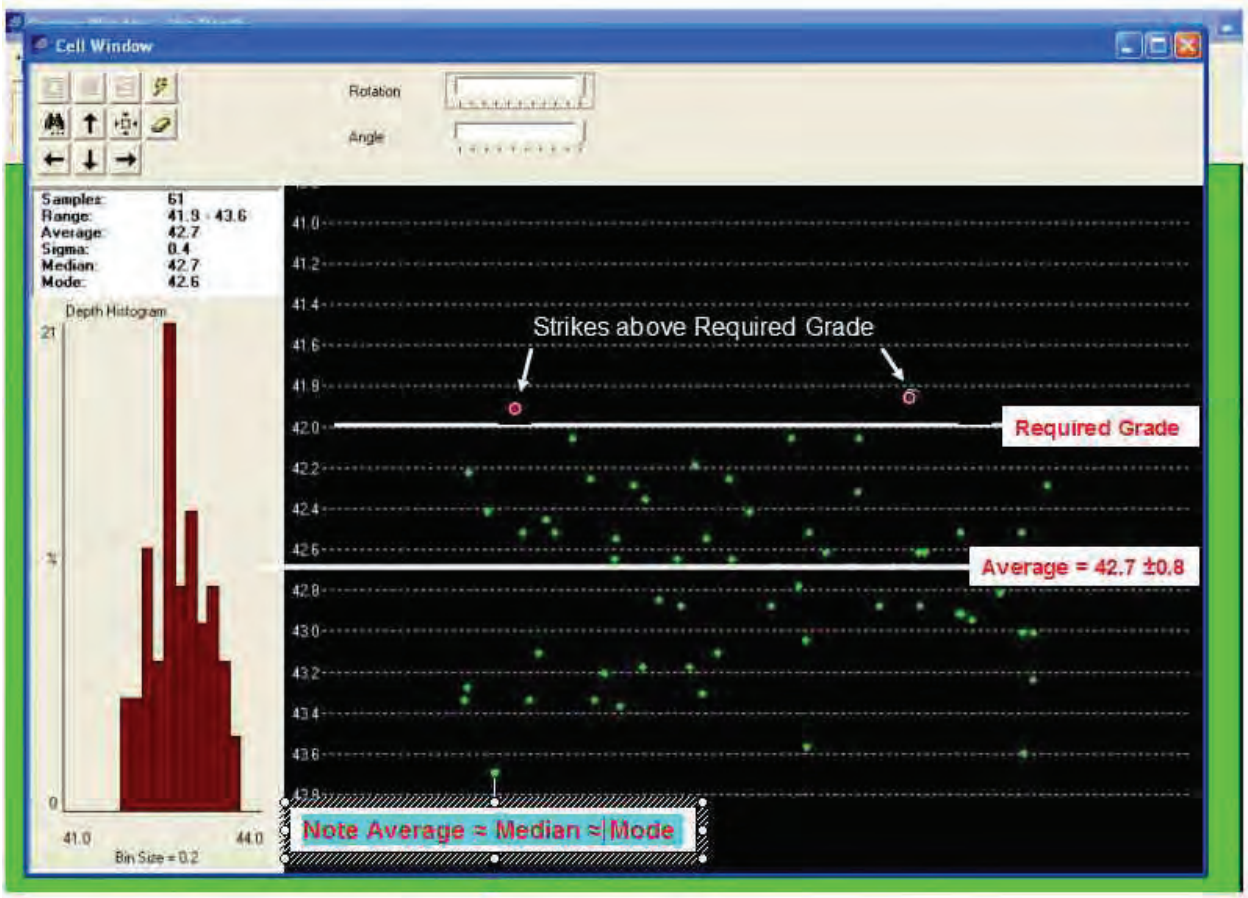

Figure 10-8. After dredge clearance survey. Typical dispersion of 61 multiple depths recordedin a 3 ft x 3 ft cell. Two depths recorded above 42.0 required grade. Sample standard deviation of 61 depths is ±0.8 ft (95%).

(1) The scattered dispersion of depths in Figure 10-9 clearly illustrates why a statistical evaluation is necessary to evaluate dredged clearance, and that none of the individual depths can be conclusively selected to represent the cell.

(2) Depending on the number of depths in a cell, the confidence of the mean will be less than the estimated standard deviation of the individual depths. This is why repeated surveys (performed over different days, tide phases, or even with different vessels) over a suspected shoal or strike will generally “repeat” or "reproduce" each other to the 0.2 to 0.5 foot level when the average representative depth is evaluated, even though the dispersion (standard deviation) of the individual depths in the cell may be ±2.0 ft. As the number of depths in a cell increases, the more confidence in the mean is obtained. Although in theory the confidence level of the average

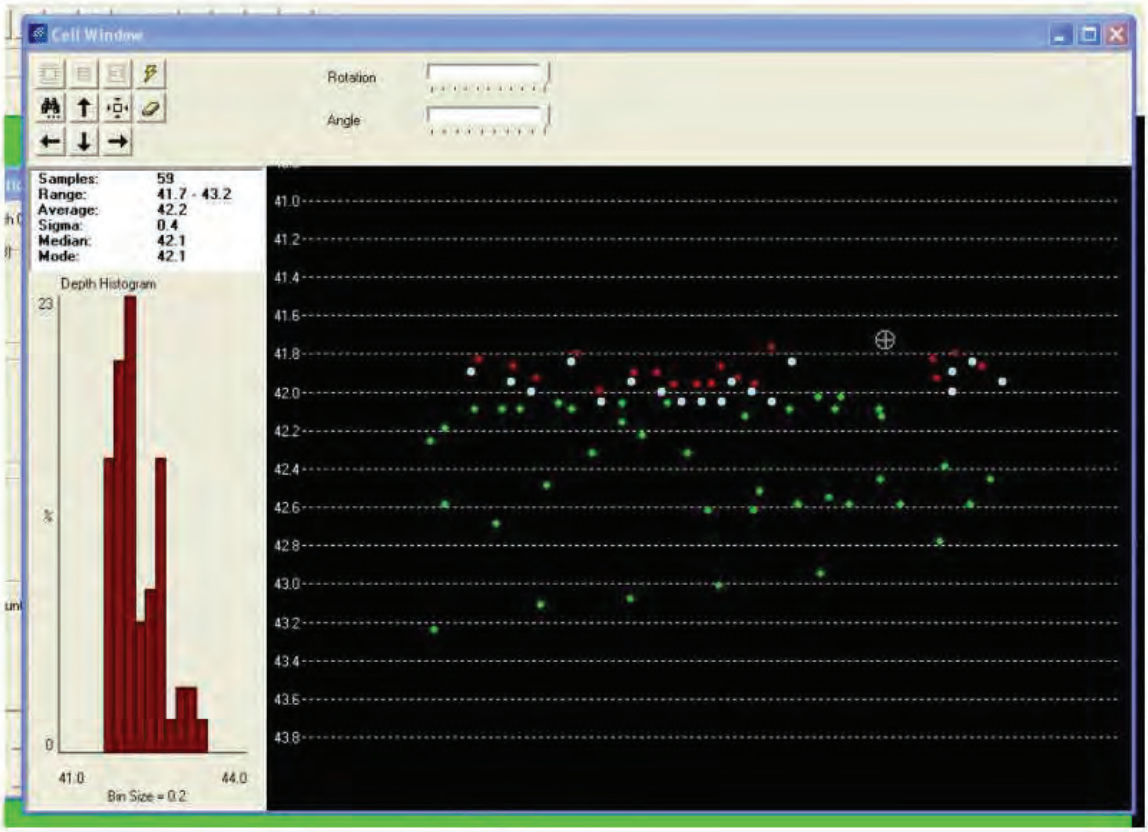

Figure 10-9. Typical dispersion of 59 individual multibeam depths observed in a 3-ft x3-ft cell—multiple passes over a suspected strike in a rock-cut turning basin. Red, white, and green depths were obtained on different passes—their apparent biases likely due to being recorded on different angles of the multibeam array. Depths above the required 42-ft grade are statistically significant in this example. Miami Harbor—Jacksonville District (2006)

depth in each cell could be evaluated (computed), such a procedure is currently not a practical engineering option—an estimated confidence based on an average measurement repeatability needs to be established for a given survey and project site.

(3) Cell size. There is no statistical significance for the USACE recommended cell sizes of 1x1, 3x3, or 5x5 ft. These cell sizes represent practical engineering practice so that consistent clearance and pay computation practices can be performed Corps-wide. In the future, more statistically relevant procedures may be developed.

(4) Number of sample depths in a cell sample. The more depths that can be collected in a defined cell, the more reliable is the precision/confidence statistic computed based on the average cell depth over a flat bottom. In critical channels (rock or hard clay), the vessel speed

should be minimized over suspected strikes above grade, and multiple passes made over the strike using different aspects of the multibeam array. In this manner, 20 to over 100 depths may be collected within a 3- x3-ft cell—over 30 typically being considered statistically significant, although lesser numbers will still have validity for strike assessment. In large samples, the average representative depth in the cell will have maximum validity for clearance assessment, or hypothesis testing if multiple depth levels appear—i.e., a CUBE type analysis outlined below. For practical engineering use, a fixed criteria for the minimum number of depths in a cell is usually specified.

(5) Average or median representative depth. When large samples are available in a defined cell, the difference between the statistical mean (average) depth and the median depth will be insignificant, and is not likely to bias over an entire project area. Thus, either value may be selected as the representative (and reported) clearance depth for the cell. When an even number of depths result in the cell, the representative median depths must be computed as the average of the two depths closer to the median, or the first occurring depth may be selected. Given the typical echo-sounder footprint size, coupled with the horizontal positioning uncertainties, in small cell sizes the horizontal location of the actual median depth may be ignored—use the cell center (centroid) at the location for the represented depth. Better results are usually obtained when a matrix cell spans a toe line and the median depth can be saved in its exact location, whereas the average depth is moved to the center of the cell. Many USACE districts recommend use of median depths rather than averaged depths.

10-12. Evaluating Clearance Grades in Unconsolidated Material. See Appendix P for guidance on evaluating clearance grades in suspended sediments, fluid mud, and other unconsolidated materials.

10-13. Side Scan Sonar. Side scan sonar is a high resolution tool that provides a general depictive map on both sides of a survey vessel's path. Side scan sonar will not provide absolute elevations of objects above a defined grade. It will provide relative heights of objects off the surrounding sea floor, from which an approximate top elevation may be roughly estimated. Side scan sonar can provide acoustical pictures of the sea floor, usually in digital format. Actual applications on dredge clearance surveys are limited, especially in rock cut channels. This is because numerous rocks will be detected, many of which will be below grade—side scan sonar records cannot distinguish between rocks above and below grade. Towed side scan sonar systems, or multibeam data coupled with backscatter data, have application in visualizing potential strikes above grade. Details on side scan sonar theory and applications are contained in various publications and manufacturer references. For information on side scan survey specifications, refer to Appendix Q, and "NOS Hydrographic Surveys Specifications and Deliverables" (NOS 2011) and the NOAA "Field Procedures Manual," (OCS 2011).

10-14. Combined Uncertainty and Bathymetry Estimator (CUBE). Statistical hypothesis testing algorithms, such as CUBE, may be of use in evaluating the potential existence of strikes or

shoals above grade. See "Automatic Processing of High-Rate, High-Density Multibeam Echosounder Data" (Calder and Mayer 2003). CUBE is especially useful in locating multiple depth clusters in a defined region (node or cell) that may indicate isolated strikes above grade but are masked by an average or median depth. CUBE also develops a most probable representative depth (or multiple hypothetical strike depths) at each nodal location, along with an estimate of its statistical uncertainty—Figure 10-10. The estimated depths selected by CUBE generally represent a median subset of the input data. Those depths should NOT be used to determine the presence of shoals in the survey area. The user should examine nodes with multiple depth estimates to determine if a possible shoal exists that might require further examination. CUBE is recommended as a detection tool on critical projects involving rock near the project grade. See also "The Navigation Surface and Hydrographic System Uncertainty at NOAA's Office of Coast Survey," (NOAA 2005). CUBE analysis of datasets, and searches for potential strikes above grade, can be run from edited multibeam survey data processed through the HYPACK "HYSWEEP CUBE" utility software option. Details on running HYSWEEP CUBE and analyzing results are available in the HYPACK User Manual (HYPACK 2011).

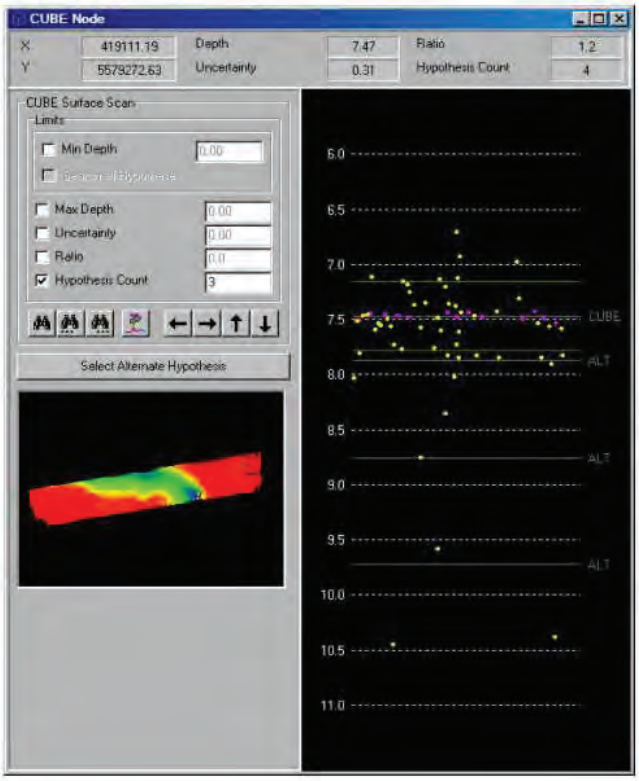

Figure 10-10. CUBE selected depth at 7.47 m with uncertainty boundary (±0.31 m). Three alternate depth hypotheses are also generated by CUBE, with higher uncertainties.

SECTION II

Dredge Payment Volume Calculations

The following paragraphs describe the general concepts and methods used in computing volumes from single beam and multibeam surveys. This section is only intended to give an overview of the computational quantity take-off procedures used in the Corps of Engineers. Detailed descriptions of construction volume computational methods are covered in various surveying and engineering textbooks. Procedural methods are described in CADD software manuals and USACE PROSPECT courses.

10-15. Dredge Quantity Computation Techniques—Background. A primary use of hydrographic surveys supporting river and harbor construction is to determine the quantity of material that is excavated or placed. These material quantity estimates are used for design/bidding purposes and contracted construction payment. The following sections deal with the computation of dredged quantities (either excavated or placed) as determined from in-place hydrographic surveys. Other methods of estimating dredged quantities (scow/bin load measurements, production flow rates, station/face cut dredging, etc.) are not covered.

a. In general, all commonly used volume computation methods for estimating excavated or placed material reduces down to that of determining the area bounded by a finite group of data points and projecting this area over some length to obtain a prismoidal volume. These projections may be done either horizontally or vertically, as shown in Figure 10-11. The methods used in the USACE for dredged material are:

(1) Average End Area (AEA).

(2) Surface Differencing or Triangulated Irregular Network (TIN).

(3) Grid or Bin.

b. Figure 10-11 illustrates the general differences between these three computational methods. An overview of each method is outlined in subsequent paragraphs. Later sections in this chapter cover the first two methods in more detail.

(1) In Figure 10-11, the AEA volume is a function of the horizontally projected areas of each cross-section—A1 and A2 -- projected along the distance (L) between the two sections. An approximate volume results from this AEA computation. When TIN prismoidal elements are generated for data points between the two cross-sections, the volume of each prismoidal element can be computed given the X-Y-Z coordinates of the three vertices--i.e., observed depths converted to elevation differences above (below) the reference channel surface/prism. The resultant volume computation is more accurate than the AEA method. This is particularly true if

the bottom is above design depth at one end of the prism and below design depth at the opposite end of the prism. One source of error in AEA is that depths are moved perpendicular to the planned line, whereas TIN models use the exact position of each depth.

(2) If full-coverage binned data are available, then the vertically-projected volume of each grid cell can be computed given the cell area on the reference surface (A) and the elevation (h) of the cell depth above (or below) that reference surface. The cell surface area is either the grid size or that based on TIN vertices, as shown in Figure 10-11. TIN vertices can be determined between dense bins – Figure 10-11 shows only TINs generated between cross-sections. Given the higher-density coverage, this is the most accurate volume.

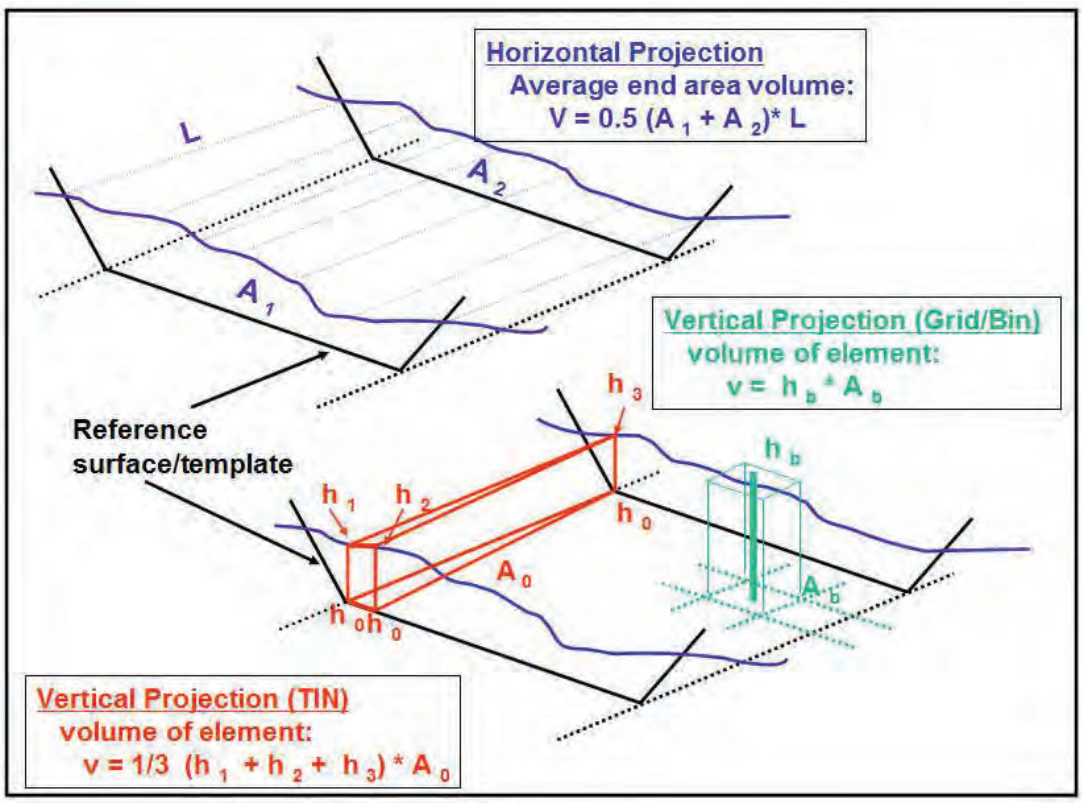

Figure 10-11. Generalized depiction of Average End Area, TIN, and binned volume computation methods. Note that TIN models may be generated between either cross-sections (as shown) or densely gridded bins (not shown).

10-16. Average End Area Method. Dredge quantity computation procedures in the USACE for dredging work originated from methods used in railroad and roadway construction—i.e., the "Average End Area" (AEA) method. Topographic, tag line, or single beam cross-sections of a channel are taken at prescribed intervals, the area of material in each cross-section is computed, and the volume of material computed by projecting the cross-sectional area along the alignment.

a. The AEA method is used by most USACE offices to compute payment volumes for contract dredging work, in particular for single beam surveys. Although this method is well known to be only an approximation, and contains biases, its use is widely accepted within the USACE and the dredging industry. Large biases in computed material can be generated by the AEA method when material is located primarily on the inside or outside of a turn in the channel.

b. The major AEA assumption is that the cross-sectional area is relatively constant between two successive cross-sections. If not, then this method becomes an approximation (or estimate) of the true volume. Decreasing cross-sectional spacing to improve the AEA computation accuracy had economic limits due to increased field survey costs. Thus, cross-sectional spacing for most dredging work ranged from 100- to 500-ft throughout the USACE. This cross-section spacing was (and still is) usually adequate in maintenance dredging projects involving soft material. Better estimates of volumes can be achieved on non-parallel lines by using separate distance-between-lines for the side slopes and center channels.

10-17. Surface Differencing Methods—"TIN Models." Since the 1970s, multiple-transducer sweep systems, and later multibeam systems, have provided a dense, full bottom coverage of a channel, allowing for more accurate quantity take-offs than those using only sparse, single beam 100- to 500-ft cross-sections. Multibeam binned matrix files can be converted into TIN models, which can be compared against a 3D model file of the channel framework template to obtain quantities—i.e., "surface differencing" volumes. TIN models can also be derived from cross-section surveys. Quantities from TIN models can be still computed using the AEA method if cross-sections are mathematically generated from the TIN model; however, this is not recommended—see Section IV for alternate options.

10-18. Grid or Bin Vertical Projection Methods. Vertically projected bins from a fixed grid network are occasionally used to compute volumes of borrow areas and reservoirs. It is not commonly used to compute dredged quantities. As shown in Figure 10-11 this is not materially different from the TIN method and quantity estimates should be fairly similar since TIN methods typically originate from the same binned data (assuming the same average or median elevation of the bin are the same for both methods).

10-19. Average End Area Computation. For most USACE construction and dredging work, the horizontally projected average end area (AEA) method illustrated in Figure 10-11 has been the recognized volume computation method when cross-section data has been surveyed.

a. Accuracy. AEA volumes are generally accurate in straight trapezoidal channels with minimum topographic irregularity. However, in projects with varying dimensions and high topographic irregularity, it is recognized that surface differencing TIN methods yield far more accurate quantity estimates than AEA methods. This is mainly due to the inherent approximations in AEA methods.

b. Computation variations in USACE. Currently there are numerous dredged quantity computation methods, options, and reporting variations unique to USACE Districts, and even separate regional Area Offices. These variations involve nuances (and often unnecessary complexities) in overdepth allowances, dredging limits, side slope allowances, box cuts, and reporting formats. These individualized payment methods have necessitated duplicative procurement of dedicated software (and training) by the USACE and dredging industry personnel.

c. Volume reporting tabulations. For contract bid estimates, volumes within dredging acceptance sections are usually tabulated relative to cross-section intervals within each section. When AEA methods are used, accumulated required and overdepth quantities are easily determined. Surface differencing TIN volumes can be broken down to section-by-section volumes to obtain equivalent AEA volumes between sections. Software procedures have been developed to perform this breakdown—i.e., the HYPACK "Philadelphia District" method described in Section IV.

d. Contract specifications. Dredging contract specifications should clearly spell out the volume computation method used for payment, including the version of the software, and any special settings for the treatment of side slope, overdepth, infill, and over-dredged material. Failure to specify these parameters can result in unnecessary disputes over pay quantities.

10-20. Reference Surfaces and Payment Templates used in USACE. There is variation among USACE districts in dredge payment methods or templates. Even Area Offices within districts are known to have unique templates and payment methods. There at least a dozen distinct dredge payment methods used by USACE districts--e.g., Jacksonville Method, Grand Haven Area Office Method, Philadelphia Method, Savannah Method, etc. This variation adds complexity to attempts to standardize quantity computation software. Figures 10-12a and 10-12b depict the two most common in place payment methods found in the USACE.

a. The difference between the two payment methods is how material between the project grade and overdepth payment grade is handled. Neither method pays for material excavated below the overdepth grade—i.e., “Non-Pay” or "Over-Dredged" material. Both methods do pay for material excavated below the design grade (down to the overdepth grade) provided the Predredge (or P&S) survey indicated material existed above the design grade. If the Predredge survey indicated the area was clear to the design grade, then the Contour Dredging Method would not allow payment for material excavated below the project grade in that area. The Non-Contour (or Bordered) Method will provide payment allowance for material removed in this area. Thus, for the Contour Method, dredging payment limits are defined by the project grade depth contour for the Predredge survey; the dredging pay limit for the Non-Contour Method is defined by the overdepth grade contour for the Afterdredge survey. Some districts using the Non-Contour Method will place physical dredging limits within the channel for areas below project

grade—i.e., "Border Files." This is, in effect, another form of Contour Dredging except the rigid dredging limits are used instead of the Predredge contours.

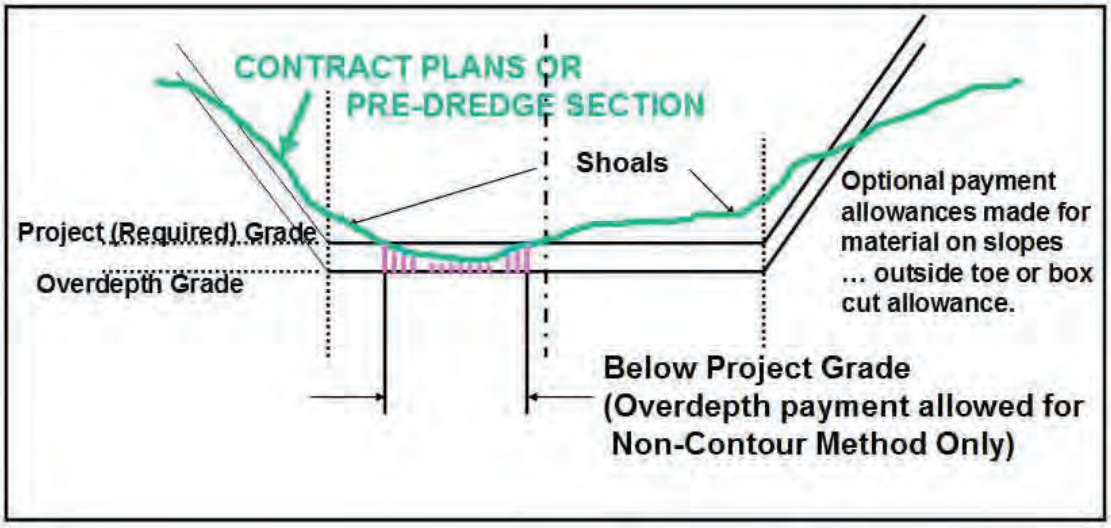

Figure 10-12a. Section view of Contour and Non-Contour dredging payment template. Contour dredging does not pay for overdepth in the shaded area where the grade is clear. Non-Contour dredging will allow payment for this material.

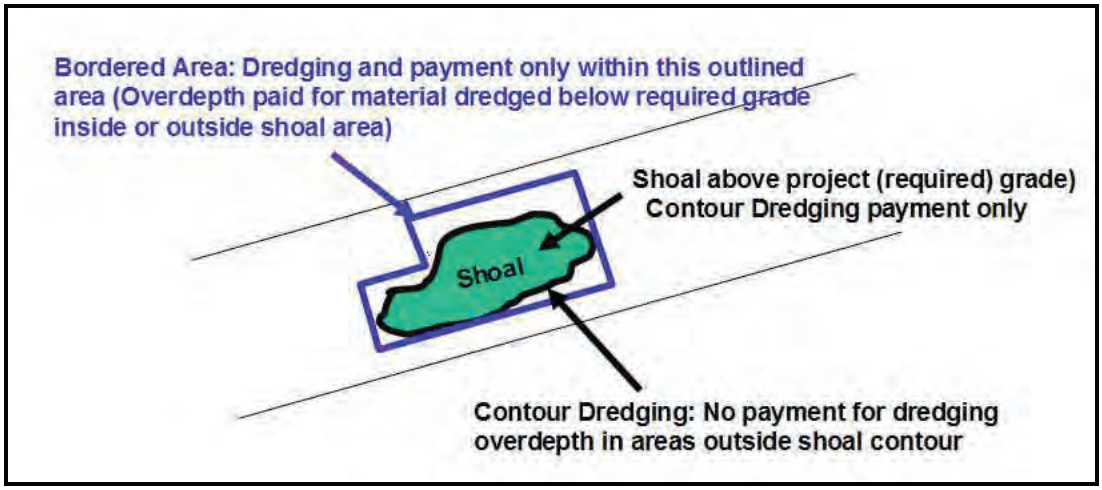

Figure 10-12b. Non-Contour (Bordered) Method: Payment allowed for material excavated above Overdepth Grade. Contour Method: Payment allowed for all material excavated above Overdepth Grade if shoal material exists above Project Grade.

b. Side slope payment. Districts vary widely on payment for excavation in side slopes. Some districts treat side slopes the same as the main channel, and pay relative to the Bordered Method or Contour Method. Others do not allow payment for any material removed from the side slopes (presumably such removal is factored into the unit price in the main channel). Some districts provide side slope excavation payment only on new work, not on maintenance dredging projects. Other districts provide for a box cut payment allowance described in Section III.

SECTION III

Average End Area Computation Methods

This section provides additional details on the Average End Area method used for estimating dredged quantities. As stated in the previous section, there are a variety of computational methods used throughout the USACE. Likewise, numerous software platforms are used, such as MicroStation, AutoCAD, and HYPACK. This section primarily illustrates the software techniques in the HYPACK "CROSS SECTIONS AND VOLUMES" (CSV) module since it is tailored specifically to dredging work, and is more commonly used by USACE districts and dredge contractors for volume computations.

10-21. Background. Traditionally, earthwork or dredging quantities for purposes of design estimates and construction payment have been obtained from cross-sectional topographic or lead line surveys of the project area. Survey data were recorded in field books. These surveys were normally run perpendicular to the general project (channel) alignment at a predetermined constant spacing. The elevation data were then manually plotted in section view along with the design/required depth and/or allowable overdepth templates. One or more reference or payment templates were plotted on these section views, e.g., required and overdepth templates. Given large scale sectional plots (e.g., 1 inch = 5 ft) of both preconstruction and postconstruction grades (or, in some cases, intermediate partial construction grades), the amount of excavated (cut) or placed (fill) area could be determined at each cross section, usually from coordinate computations or polar planimeters that measured the area between grades and templates. The areas at two successive cross-sections were computed, and the average of these end areas projected along the project alignment (linear or curved) by a distance equal to the sectional spacing, resulting in an approximate estimate of the volume of material cut or filled during construction. This approximate estimating technique is known as the trapezoidal or average-end-area method and is universally used (and accepted) in highway, railroad, and marine construction for design estimating and payment purposes.

a. Average End Area computation formulas. Given two successive cross sections of end areas A1 and A2, and a spacing distance L apart, the equation for an average end area volume between two cross sections is:

$$V = (L/2) \cdot (A_1 + A_2) \qquad \text{(Eq 10-1)}$$

Cross-sectional areas are measured in square feet, and the resultant volume is converted to cubic yards by dividing the measure area by 27 cubic feet/cubic yard (cf/cy).

$$V = (L/54) \cdot (A 1 + A 2) \qquad \text{(Eq 10-2)}$$

where A1 and A2 are expressed in square feet.

In cases in which even 100-ft cross sections are run, the above formula simplifies to

$$V = (1.852) \cdot (A 1 + A 2) \qquad \text{(Eq 10-3)}$$

The results of Equations 10-1 through 10-3 are exact only when the end areas are exactly equal (i.e., A1 = A2). As one end area approaches zero, the trapezoidal element becomes a pyramid, and the error in using the average-end-area volume formula approaches 50% This commonly occurs in dredging projects where large area variations are found between successive cross-sections, especially along the toes and slopes.

b. Prismoidal corrections to AEA. Various types of prismoidal correction formulas have been developed over the centuries to compensate for the inherent inaccuracy in the AEA formulas above. Most prismoidial corrections are based on the so-called "Simsons Rule" for approximate numerical integration.

$$V = (L/6) \cdot (A 1 + 4 \cdot Am + A 2) \qquad \text{(Eq 10-4)}$$

where Am is the area of a mid point cross section run between sections A 1 and A 2.

These prismoidal corrections were once widely used in earthwork and dredging quantity computations, perhaps to imply a sense of mathematical precision to widely varying survey data (i.e., varying end areas). They are no longer applied in practice for dredging estimates. A higher accuracy was often achieved by decreasing the cross-sectional spacing in attempts to define the terrain more precisely (e.g., cross-sectional end areas become more nearly equal). This increased field survey densification increased costs, which may not be proportionate to the increase in accuracy of the computed volumes. (This highlights the obvious advantage of full-coverage multibeam systems over single beam cross sections in computing pay estimates. Multibeam systems effectively provide equivalent cross section spacing at dense intervals; roughly equal to their footprint or reduced cell size.)

10-22. Box Cut Allowance. Many districts provide an allowance for material left above the pay prism grade on side slopes when sufficient non-pay excavation has been performed at the base of the slope to allow for sloughing. Such box cut quantities must be computed separately due to limitations in payment, which shall not exceed the excessive excavated yardage at the base of the slope. This allowance is illustrated in Figure 10-13. Box cut payment allowances are not

uniformly applied throughout the USACE--e.g., payment for over-excavation inside or outside the channel toe. Automated computation of box cut allowances adds complexity to the quantity take-off process. Since traditional box cut computation methods were derived from manual cross-section planimeter techniques, automated terrain model analysis cannot be effectively performed; thus, AEA sections may need to be generated even though full terrain model data is available. Often box cut quantities are negligible relative to the overall volume. More significantly, AEA box cut quantity computations have been shown to have significant biases (up to 50%) due to zero allowances on many successive cross-sections. For these, and other reasons, use of a box cut allowance should be justified on a project-by-project basis.

a. The following contract clause is typical of those used for box cut allowances:

"Side Slopes. Side slopes may be formed by box cutting or dredging along the side slope. Material actually removed, within the limits approved by the Contracting Officer, to provide for final side slopes not flatter than shown on the contract drawings, but not in excess of the amount originally lying above this limiting side slope, will be estimated and paid for in accordance with the provisions contained in paragraphs, "Measurement" and "Payment" above. Such amount will be estimated and paid for whether dredged in original position or by box cut dredging whereby a space is dredged below the allowable side slope plane on the bottom of the slope for upslope material capable of falling into the cut. [Specify any tolerance limits relative to channel toes]"

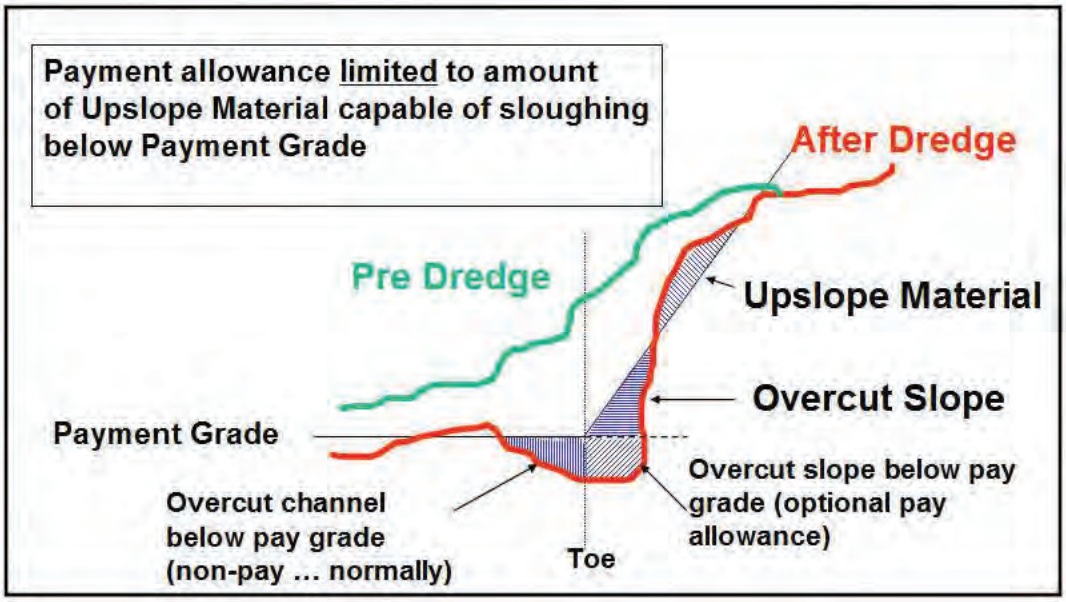

Figure 10-13. Box cut payment allowance is limited to amount of upslope material capable of sloughing below payment grade (see EP 1130-2-520). Pay extensions restrictions) are usually specified inside or outside the toe—typically 25 ft.

b. There are two methods in the HYPACK CSV software that handle Box Cut allowances. Both of them only consider the void underneath the allowable overdepth template. In the "AEA3 Method," only material in the allowable overdepth side slope can fall into a void beneath the allowable overdepth template, inward from the toe a user specified distance. In the Jacksonville District "PostDredge Method," material on the side slope that is above the design template and in the allowable overdepth template can be considered available for credit. The void can be computed outward from the toe, and inward from the toe.

10-23. Cross-Section End Area and Volume Computations. Over the years, USACE districts have used a number of methods to compute the area of a cross-section that is used in the AEA volume computation. Some of the more prevalent methods of computing cross-sectional areas for dredging are listed below. Details on most of these methods can be obtained in any engineering or surveying handbook.

a. Direct formula methods. Prior to automated data collection and computers, various formulas were used for computing end areas directly from cross-section notes in field books. These computations were performed on simple calculators using the grade and template coordinates. Generally, data along each section was sparse (i.e., tag line surveys) so these coordinate computations were not too difficult to manually perform. The most commonly used calculation was the "double meridian distance" (DMD) method. The cut (or fill) section is treated as a closed traverse, and the area is computed using the offsets (departures) and the depths (latitudes). Offset and depth at the slope-grade intersect (slope stake point) must be interpolated or scaled on the cross-section plot since these values are not directly measured in the field. Likewise, a depth must be scaled at each channel toe. A simple cross-multiplication system was used for computing the (double) area of the section.

(1) A simplified example of this manual DMD computation is shown in Figure 10-14. In this example, pre- and post-dredge end areas are computed separately and relative to the (-) 40.0-ft payment prism. These end areas are combined for use in the AEA volume computation with adjacent cross-sectional areas. Alternatively, the payment end area (4,225 sq ft) could have been directly computed. It was usually desirable to compute available pay quantities as soon as the pre-dredge survey was completed (to compare with the bid quantity estimates); thus, the (usually) small amount of material remaining on the after-dredge survey is easily computed and deducted from the pre-dredge quantity.

(2) As computers evolved in the 1960s, cross-sections coordinates were input and coordinate end area computations (and quantities) performed on a mainframe computer. The coordinate data was typically input from punch cards, also a labor-intensive process.

(3) As the density of points along a given cross section increases, this manual computation process can become time-consuming. It would be prohibitive given current data collection where hundreds of points are obtained along a cross-section. However, dense

automated cross-section data could be pasted into a spreadsheet and the quantity computation performed using the DMD method. Such a process might be used to check that end areas computed in automated software are performing "exact" results.

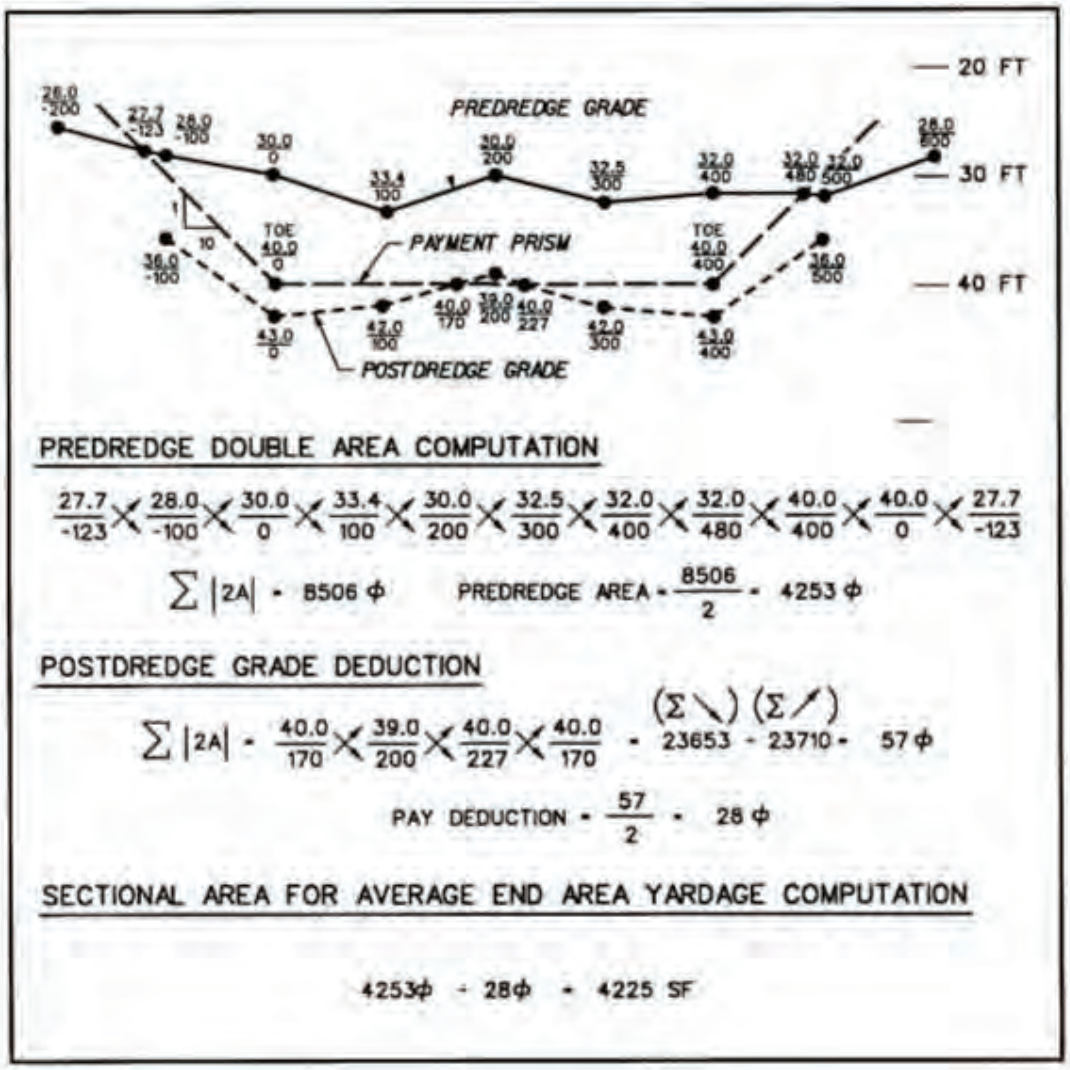

Figure 10-14. Typical predredge and postdredge quantity take-off by coordinate method.

b. Planimeter end areas. A polar planimeter (Figure 10-15) is a mechanical device that can directly measure areas on a drawing. It was once commonly used by many districts to measure end areas directly from the plotted section drawings. Although not as precise as a direct coordinate computation, it is typically accurate to about 1 or 2%of the computed end area. Normally, the end area was measured two or three times and the average taken as the final end

area. The disadvantage is that large-scale sectional plots of the survey data and payment templates are required for each cross-section. Section drawings were retained with bid, pre-dredge, and post-dredge cross-sections plotted, and the resultant pay area in the cross-section in Figure 10-14 would be measured. Non-pay areas were eliminated during this process. Box cut sloughing areas were separately measured with the planimeter.

c. Digitizing tablets. In the 1970s, mainframe and mini-computers with digitizing tablets were used to automate plotted sections and raw survey data, in effect, establishing coordinates for the data for subsequent automated end area computations. Older analog echo sounder paper records were digitized on these tablets—see Figure 10-15. This eliminated the need to plot large scale section drawings for each cross-section. The digitized data, along with the channel template, could then be used to compute end areas using coordinate or numerical integration methods, and subsequently volumes.

Figure 10-15. Quantity take-offs from polar planimeters (on left) and a digitizing tablet. The echo sounder analog record is directly digitized. (ca 1976 Jacksonville District)

d. Automated methods (numerical integration). As computer automation evolved in the 1970s, end areas (and quantities) could be directly computed from digitized and/or field-automated hydrographic survey data. This process is essentially unchanged to this date. The end area on a cross-section may be computed by a number of methods, such as coordinate/DMD areas, summing trapezoidal elements, or numerical integration. The first two methods require interpolation routines to determine toes and slope stake points, but the third method (numerical integration) does not. Numerical integration simply breaks up the cross-section at a fixed interval (e.g., 0.1 or 1 foot) and interpolates depths within this interval; summing up the small area increments across the channel to obtain the total sectional area. Most CADD software systems use some form of this method to compute end areas. In addition, upslope box cut payment allowances can be simply and directly computed using numerical integration methods.

10-24. HYPACK Average End Area Dredge Volume Computations. The basic option in the HYPACK "Cross Sections and Volumes--CSV" routine computes volumes using the "traditional" average end formula shown above. The CSV routine first subdivides the channel template into segments: LL = Left side slope, LC = Center channel (or LCL = Left of Center Channel and LCR = Right of Center Channel), and LR = Right side slope. The area of each of these segments on a cross section is computed by an exact polygonal end area formula. Average end area volumes are then computed for each channel segment by multiplying the average end area of each segment by the projected distance between each segment.

a. Standard HYPACK. The "Standard HYPACK" optional average end area calculation in CSV is slightly different from the above basic AEA method in that each segment is subdivided into 100 slices. Standard HYPACK then interpolates a depth for each corner of the slice, computes the volume of each slice, and sums all the slices to determine the volume for the segment (Figure 10-16). This computational method more closely resembles the TIN prismoidial method of volume calculation. Computing prismoidial volume elements with the Standard HYPACK method is more accurate than the traditional (basic) AEA methods, especially when there are significant differences in end areas between successive sections, or when the material is located on the inside or outside regions between non-parallel cross-sections.

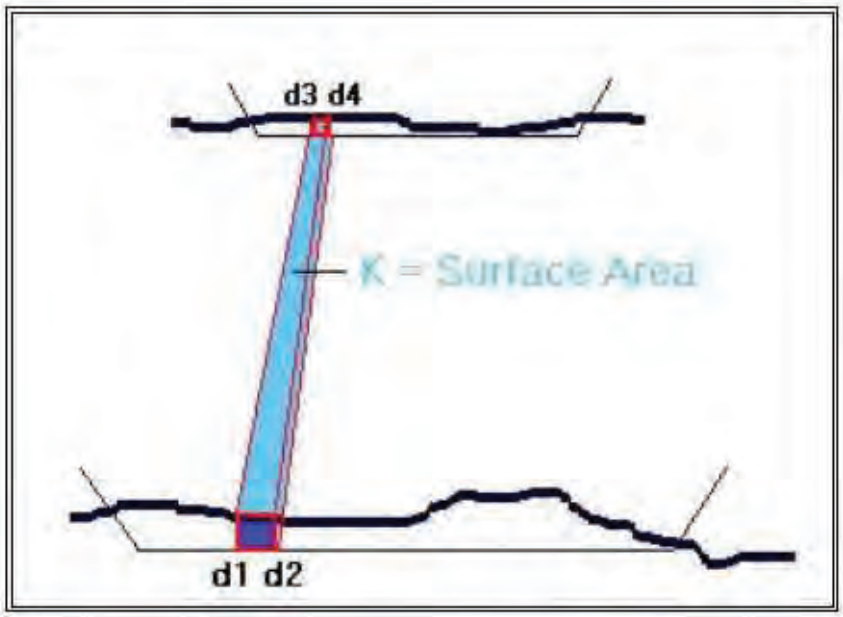

Figure 10-16. Standard HYPACK prismoidial end area and volume computation method.

b. Templates. For all end area computations, channel prism templates must be defined for each cross-section. For most navigation channels these templates are regular, defined by the channel depth, the two toes, and side slopes—i.e., 3 segments. Template variations occur in channel wideners, turning basins, depth grade changes, or channel width changes. Grade changes may occur across the channel template, necessitating additional segments (HYPACK can accommodate up to 20 segment changes in a cross section). As channel prisms and grade change segments get more complex, TIN Model surface differencing volume computation routines are preferable to average end area methods.

(1) HYPACK's CSV module has options tailored to these varied payment templates; providing methods to determine both Non-Contour and Contour Dredging payment computations, side slope payment options, box cut allowances, complex channel segments, and both average end area and surface-to-surface methods. This is illustrated in the cross-section shown in Figure 10-17. This example contains both the project grade (design grade) and overdepth grade (subgrade) areas/volumes. It also adds a third template--termed a "supergrade"--that could be an advance maintenance grade limit or used for estimating quantities at different grades. Figure 10-17 also shows some of the segmented subdivisions used to cover the various payment methods used in the USACE. These subdivided areas in the cross-section allow for separating Non-Contour and Contour methods, side slope payment variations, box cut allowances, non-pay material, shoaling, etc. These options have application to project managers and design engineers studying and evaluating shoaling rates and locations, or non-pay dredging. The cross section end area subdivision codes used in Figure 10-17 are listed in Figure 10-18.

(2) As an example of how the end area zones are used to accommodate the differing payment methods, the V2 sector represents all material in the overdepth zone (between the toes); all of which would be paid under the Non-Contour Method but only a portion of which is paid under the Contour Method. That portion is defined by the sectors V2P (Pay) and V2NP (Non-pay). The Contour Method would provide payment for the V2P sector, but the V2NP sector would not be paid since there was no material lying above the required depth. Contour Dredging Method volume computations require comparisons between the pre- and post-dredge surveys since payment is restricted to areas where material lies above the required grade on the pre-dredge survey. If material in the sector V2NP is excavated during dredging, it is not paid. The Contour Method presumes a degree of dredging accuracy that may not be achievable--especially in hopper dredging. Its intent is to avoid paying for substantial quantities of material lying below the required grade but above the overdepth grade. This material is paid in the Non-Contour Method unless physical dredging limits ("Borders") are placed in areas where material lies below the required grade but above the overdepth grade.

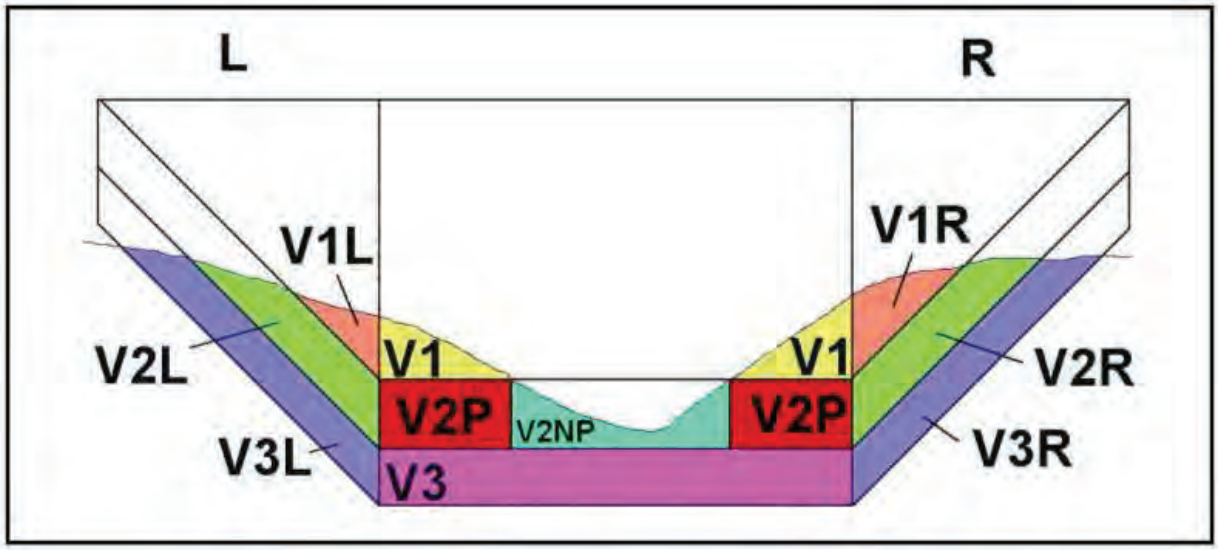

Figure 10-17. Segmented channel cross-section depicting pay and non-pay areas. (HYPACK, Inc.)

V1:	The volume of material above the design surface in the center of the channel.
V1L:	The volume of material above the design surface of the left bank.
V1R:	The volume of material above the design surface of the right bank.
V2:	The volume of material between the design and the overdepth grade surfaces in the channel center.
V2P:	The volume of material between the design and the overdepth grade surfaces in the channel center where the depth is less than the design surface.
V2NP:	The volume of material between the design and the overdepth grade surfaces in the channel center where the depth is greater than the design surface.
V2L:	The volume of material between the design and the overdepth grade surfaces of the left bank.
V2R:	The volume of material between the design and the overdepth grade surfaces of the right bank.
V3:	The volume of material between the overdepth grade and the supergrade surfaces in the channel center where the depth is less than the design surface.
V3L:	The volume of material between the overdepth grade and the supergrade surfaces of the left bank.
V3R:	The volume of material between the overdepth grade and the supergrade surfaces of the right bank.
X2:	The amount of material removed beneath the design surface by a box cut inside the channel toes. Enter the distance used to consider box cuts. (Not shown in Figure 10-17)
X1:	The amount of material on the left or right banks that is above the design surface. X1 can be credited to fall into an X2 hole. (Not shown in Figure 10-17)
Y1:	The amount of material which has been deposited during the dredging process. (Infill) (Not shown)
DELTA	Predredge –Postdredge of each V value [Computed]
TOYPAY	Delta + Y1: The quantity of material removed, ignoring areas where the Postdredge profile is above the Predredge profile. [Computed]

Figure 10-18. Sectional end area subdivisions used by HYPACK.

c. USACE Average End Area calculation methods. Figure 10-19 is a list of some of the volume computations options in HYPACK that are tailored to individual USACE districts.

Method	Single Survey	Average End Area Method	Target Number of Template Points	# of Templates
AEA 1	Yes	Yes	4	3
AEA 2	Yes	Yes	4	3
AEA 3	Pre vs. Post	Yes	4	3
Standard HYPACK	Yes	No	Up to 20	2
Savannah	Yes	Yes	4	2
Philadelphia PreDredge	Yes	Yes	5	2
Philadelphia PostDredge	Pre vs. Post	Yes	5	2
Jacksonville PreDredge	Yes	Yes	4	3
Jacksonville PostDredge	Pre vs. Post	Yes	4	3
Norfolk	Yes	Yes	4	4
GLDD 1	Yes	Yes	4	3
GLDD 3	Pre vs. Post	Yes	4	3
Kingfisher	Yes	Yes	4	3
AEA No Segments	Yes	Yes	N/A	2
Beach Pre-Dredge 'New'	Yes	Yes	Up to 20	3
Beach Post-Dredge 'New'	Pre vs. Post	Yes	Up to 20	3
Zone Listing PreDredge	Yes	Yes	N/A	2
Zone Listing PostDredge	Pre vs. Post	Yes	N/A	2
End Area No Template	Pre vs. Post	Yes	No Template is Used	N/A

Figure 10-19. HYPACK Average End Area computation methods and options.

d. Example Average End Area computation. The following sample computation in Figure 10-20 is performed over a 1,188 ft dredging acceptance section. The channel limits are irregular as shown by varying offsets for each cross-section—this dredging section encompasses a channel widener. The final yardage values represent the material available on the pre-dredge survey. A similar take off would be made on the after-dredge survey and any remaining material from that survey would be subtracted from the pre-dredge results. The HYPACK Software Manual (HYPACK 2011) contains sample outputs of other USACE dredge quantity computations

Tampa Harbor, Cut-D (HB), Acceptance Section - 3
Office Engineering Section, Survey Branch, Jacksonville District
Pre-Dredge Survey (No. 98-C041) Cont. No. DACW17-98-C-0004
Date of Survey: 24 February 1998

Station to Station		Project Depth	Over Depth	Left Slope	Right Slope
61+00	72+88	34.0	36.0	3.0/1	3.0/1

Dredging Quantities Summary
==========

Total Material to Project Depth ..... 11309.4 CY
Total Allowable Overdepth ..... 11853.4 CY
Total Pay Place ..... 23162.8 CY

Dredging Quantities Computation
==========

	-------- Reference Depth = 34.0 ft -------					---------- Overdepth = 2 ft ----------				
Station	Left Slope	Left Channel	Right Channel	Right Slope	Volume (CY)	Left Slope	Left Channel	Right Channel	Right Slope	Volume (CY)
61+00	0.0	0.3	0.0	0.0	0	2.0	4.0	0.0	0.0	0
Offset:	-302	-200	+200	+302						
62+00	11.6	99.2	50.3	5.9	309.8	20.0	134.0	98.0	12.0	500.1
Offset:	-302	-200	+200	+302						
63+00	24.5	172.3	33.5	5.6	746.2	26.0	144.0	98.0	14.0	1011.2
Offset:	-302	-200	+200	+302						
64+00	24.4	204.4	26.6	4.6	918.7	26.0	158.0	72.0	12.0	1018.6
Offset:	-302	-200	+200	+302						
65+00	33.5	191.5	0.5	0.1	900.2	28.0	166.0	8.0	2.0	876.2
Offset:	-302	-200	+210	+317						
66+00	29.3	188.5	7.9	1.5	837.9	26.0	170.0	34.0	6.0	812.9
Offset:	-302	-200	+239	+346						
67+00	27.5	194.2	24.7	12.0	931.3	30.0	174.0	50.0	22.0	969.3
Offset:	-303	-200	+262	+367						
68+00	37.8	261.4	10.3	2.1	1093.6	34.0	202.0	32.0	8.0	1045.7
Offset:	-303	-201	+290	+394						
69+00	38.2	277.7	0.0	0.0	1210.2	34.0	200.0	0.0	0.0	978.6
Offset:	-305	-201	+314	+418						
70+00	33.9	239.1	5.4	1.1	1143.2	32.0	200.0	24.0	6.0	946.2
Offset:	-306	-203	+341	+444						
71+00	29.2	214.7	53.5	5.7	1095.9	30.0	190.0	132.0	12.0	1150.8
Offset:	-309	-204	+369	+469						
72+00	22.8	201.6	84.4	13.5	1145.0	24.0	202.0	142.0	20.0	1349.4
Offset:	-312	-206	+395	+497						
72+88	10.0	176.8	96.9	14.3	977.4	16.0	218.0	124.0	18.0	1194.5
Offset:	-315	-208	+419	+521						

Figure 10-20. Typical average end area computation output for a predredge survey.

10-25. Average End Area Computations on Irregular Channels or Non-Parallel Sections. Average End Area computation methods from single-beam surveys become complex when channel sections have varying limits, at channel intersections with widener sections present, in irregularly shaped turning basins, when survey cross-sections are not run perpendicular to the channel alignment, and when cross-sections are not parallel. An example is shown in Figure 10-21. When cross sections are not run normal, or perpendicular, to the project centerline, the section's projected intercept with the side slope must be adjusted in section plots or automated software when computing end areas. This commonly occurs in turning basins and widener sections. The plotted side slope is corrected as a function of the angle of intercept. Average-end-area projections are made relative to the actual survey spacing interval, not to the project alignment stationing. In areas where different sectional alignments merge, irregularly shaped triangular or trapezoidal surface areas result, often resulting in overlapping (duplicate) volumes or voids where material was actually removed. Various methods are employed to proportionately distribute end areas over these irregular areas, both during field surveys (HYPACK "Smart Corners") or in volume computation software.

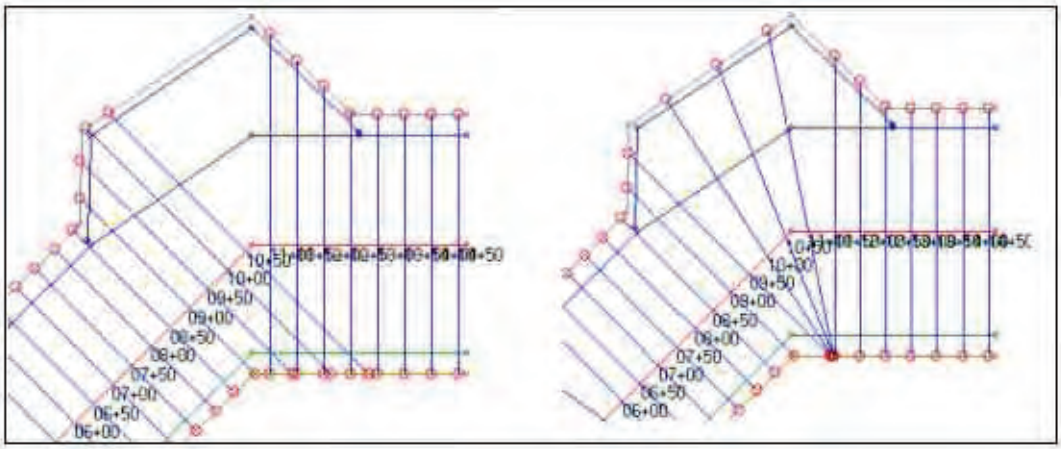

Figure 10-21. Problems with average end area volumes in irregular channels and non-normal cross-section alignments. The large void on the left is improved by adding additional cross-sections ("Smart Corners") as shown on the right.

a. On the left side of Figure 10-21, volumes for each of the overlapping and void areas must be estimated. These cross sections hit the slopes at differing angles, requiring adjustments to the projected areas. Projecting the end areas on the void at the outside of the channel turn is a guess, at best. Deducting end areas at the intersecting section is likewise a rough estimate.

b. The solution is to employ the 'Smart Corners' option in HYPACK's CHANNEL DESIGN program when creating the field survey line files--running additional sections as shown on the right side of Figure 10-21. Volume computation programs will generate more accurate

volume quantities when this survey coverage option is selected, as long as accurate projection distances between the sections are applied. To better eliminate the small voids at the two turning basin corners, “bisector” sections should have been run through the points.

c. The above example clearly illustrates the difficulty in using average end area techniques (and single beam surveys) for irregular shapes or non-normal sections. Quantity estimates in such areas are truly "estimates," and are often educated guesses. For this reason, surfacing differencing TIN volume computation techniques should be employed even if only cross section data is available. The irregular channel template surface (nodes and slopes—i.e., "channel framework") can be input as a 3D terrain model, as shown in Figure 10-22. The channel template surface model is then not dependent on the survey coverage or alignment method. The volume is simply computed between the two surfaces.

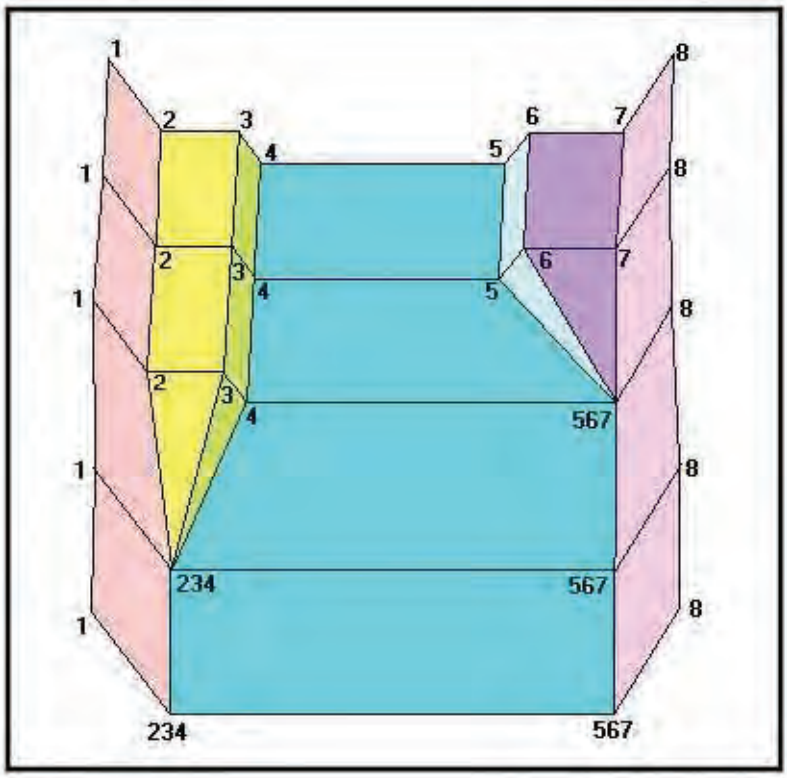

Figure 10-22. Channel template models (HYPACK Advanced Channel Design)

d. Curved channel sections. Some USACE navigation projects are defined relative to a circular alignment and cross-sections are taken normal to that alignment. These sections may be

in the navigation or flood control project or up the overbank levees. In the case of curved alignments with cross sections run perpendicular to the alignment, average end areas are projected about the radius of the centroid for each section in order to compute the volume. Various mechanical and numerical methods exist for computing the centroids of irregular areas (see Figure 10-23).

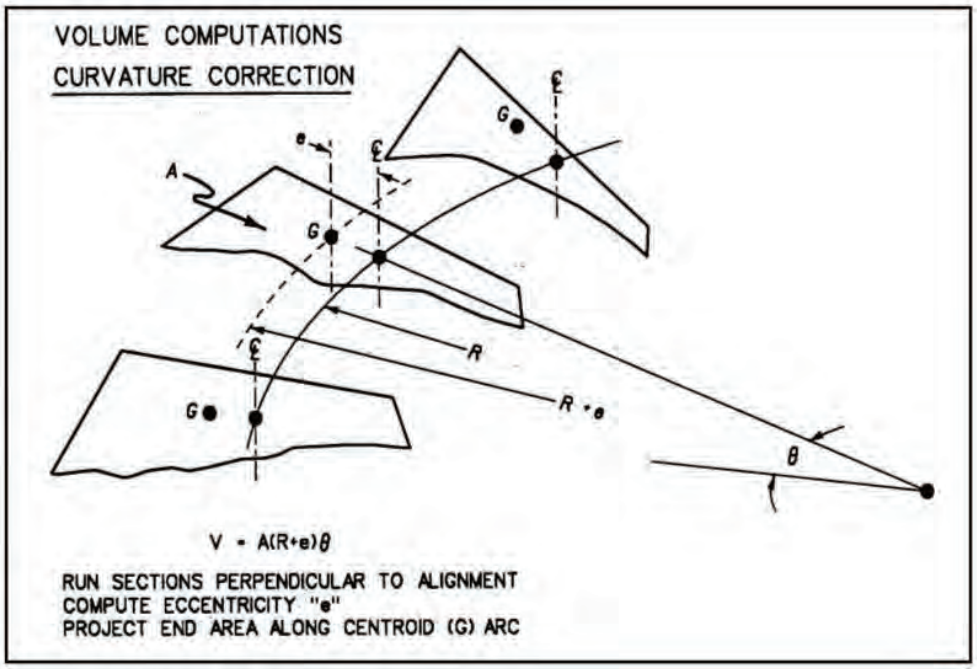

Figure 10-23. Curved channel volume computations.

e. Obtaining complete coverage for quantity computations. A major survey deficiency exists when complete coverage is not obtained over the entire payment area. This often occurs when survey vessels are unable to perform pre-dredge surveys into shallow waters where excavation is subsequently performed. In other cases, the slope-grade intersect point may be above the surface, requiring land topographic survey coverage at the junction area. In either case, volume computations are incomplete without full coverage through the slope-grade intersect points. This is the case regardless of the computation method (AEA or TIN). The distance ("t") that coverage is required outside the toe of a channel may be estimated by the following:

$$t = \text{Slope} \cdot (\text{Required depth} - \text{Upslope depth}) \qquad \text{(Eq 10-5)}$$

where:

t	=	slope-grade intersect distance from toe
Slope	=	design slope ratio (H/V)
Required depth	=	project design or overdepth

Upslope depth = average minimum depth atop slope/bank

For example, given a 40-ft project with typical 20 ft natural grades up a 3 on 1 side slope, the required coverage outside the channel toes would be 60 ft ($t = 3 \cdot (40\text{-}20)$). A distance of 100 ft would likely be specified to allow for topographic irregularities and vessel maneuvering. It is essential that coverages be verified prior to computing quantities using automated software. Most programs have no alarm to indicate inadequate coverage. Verifying coverage is done by viewing 3-D models or section views of the project to ensure coverage.

SECTION IV

Surface Differing Volume Computations (Triangulated Irregular Networks)

This section describes surface differencing (TIN) methods used for estimating dredged quantities. As with AEA techniques, there are a variety of computational methods used throughout the USACE. Likewise, numerous software platforms are used, such as MicroStation, AutoCAD, and HYPACK. This section primarily illustrates the techniques in the HYPACK "TIN Model Program" since it is designed directly for dredging projects.

10-26. Background. The Triangulated Irregular Network (TIN) volume computation technique is based on a comparison of two terrain models. In the case of dredged material volumes, one model represents the actual bottom terrain as surveyed (Figure 10-24), and the other model usually represents a design surface (e.g., required depth and overdepth), although two surveyed surfaces can also be compared. TIN routines offer great flexibility in the collection of survey data, since the terrain coordinates need not be in any particular pattern or alignment. TIN programs also enable visual terrain models of the surveyed topography and of design, or hypothetical, terrain surfaces. As stated earlier, a TIN model volume is also more accurate than an AEA volume computed from the same database. TIN routines for volume determination and terrain visualization are commonly available in commercial site design and some survey software packages. For dredged material volume applications, TIN routines are particularly well suited to cases in which the channel is not a simple straight layout, such as in turning basins, settling basins, widener sections, curved channels, etc.

a. General concept of TINs. A TIN is actually a set of triangles that represent the terrain surface. Consider a set of survey coordinates marked on a map. These coordinates are "triangulated": a set of triangles is specified such that their vertices are these spatial points, no triangle contains coordinates other than its vertices, and the triangles cover the area of interest exactly and without overlapping each other. Any such set of triangles defines a TIN. The maximum area a TIN can cover is the "convex hull" of all coordinates. That convex hull is the polygon which contains all coordinates, whose vertices are the coordinates, and which is convex; that is, any straight line segment connecting two points in the interior of the polygon is entirely contained by the polygon. The convex hull of all coordinates is also the convex polygon of

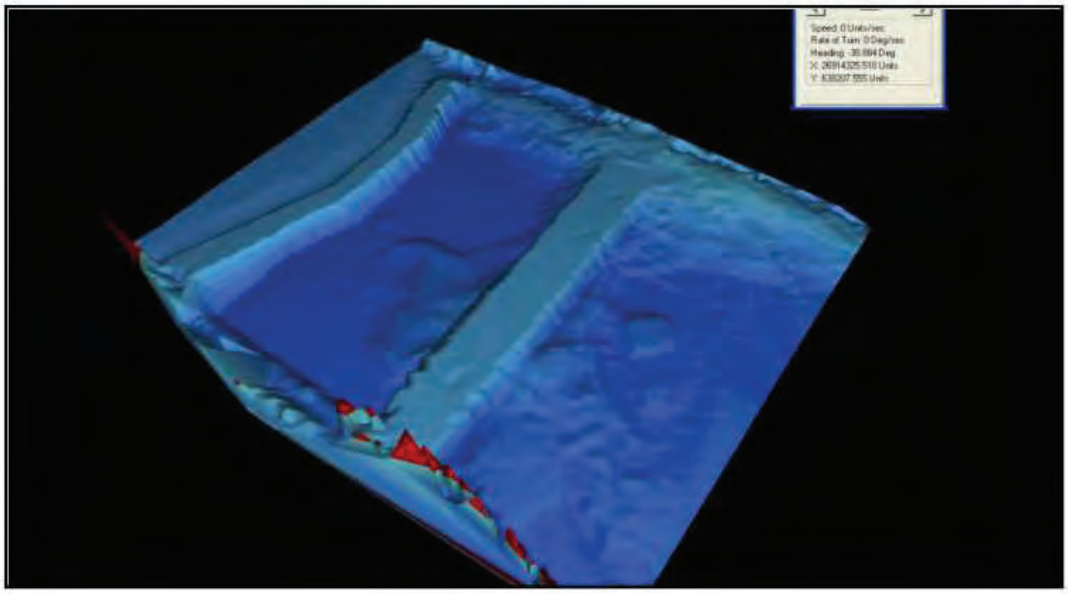

Figure 10-24. Color-coded three-dimensional TIN surface model of Poe Lock Debris Pit, St. Marys River, Detroit District.

the smallest area containing all coordinates. A TIN may fail to cover its maximum area while still covering all available coordinates; some triangles along the boundary may be missing.

b. Terrain and design surfaces. The salient feature of the TIN volume methods is that they construct two surfaces, a TIN "terrain surface" developed from depth (elevation) measurements and a "design surface" which represents the design specifications. Terrain information consists typically of a list of X-Y-Z coordinates, with the horizontal coordinates specified by X-Y and the spatial coordinate z recording the measured elevation. When a TIN is generated for the given measurement sites and the corresponding triangles and vertices are joined in space, a terrain surface results. The design surface consists of polygonal surfaces. A desired design surface (navigation channel), for instance, is sometimes specified as a long rectangle with adjacent polygons for side slopes. X-Y points on the channel are termed "nodes." Polygonal surfaces are represented by their constituent planar polygons or "facets" in space. For input purposes, they are mainly defined in terms of "design breaklines," the line segments at which facets are joined. Those breaklines terminate at "design breakpoints." Typically, three breaklines meet in a breakpoint.

c. Polygonal surfaces. TIN surfaces are also instances of polygonal surfaces. They represent the special case in which all polygonal facets are triangles. Polygonal surfaces are often represented, somewhat artificially, as a TIN surface if the polygonal facets are partitioned into triangles. In that case, breaklines are generic to all such surfaces. The design surfaces

encountered in road construction, as well as in hydrographic applications, tend to be of a special form: their cross sections perpendicular to a centerline are similar to each other. Some commercial packages, therefore, offer an alternate surface specification method suited to surfaces of this particular kind. The idea is to "push a template," that is, to interpolate a design surface through a sequence of cross-sectional design delineations or "templates." This design specification method is ideal for long stretches of channels. However, if a channel changes direction, side slopes vary, or more complex designs such as turning basins are used, the template method characterizes the true design surface only approximately.

d. Cut volume. The space bounded by the terrain and design surfaces defines the volume to be determined. This space is subdivided into vertical triangular prisms, that is, polytopes with three vertical edges capped by two, not necessarily parallel, triangles, as shown back in Figure 10-11. The volume of such a prism is rendered exactly by the formula:

$$V = [(h 1 + h 2 + h 3) / 3] \cdot (A) \qquad \text{(Eq 10-6)}$$

where

h = height of vertices above design (pay) prism
A = triangular area of prismoidal element projected on design surface

Thus, the "h1," "h2," and "h3" heights represent the lengths of the three vertical edges of the prism, and "A" denotes the area of the triangle that arises as a vertical projection or footprint of the prisms onto a horizontal plane. Indeed, "A" is the area of the underlying TIN triangle. The volumes of all the prisms that constitute the cut body are then added to arrive at its total volume. The cut volume is therefore calculated on a triangle-by-triangle basis. This requires, however, that the dredged area (that is, the projection of the cut body onto the reference plane) be fully triangulated.

(1) Note that some TIN triangles of the dredging area may be clipped by the boundary of the dredge area so that their remainders within the dredge area are non-triangular polygons, typically quadrangles. A straightforward way of dealing with this situation is to subdivide these polygons into triangles. In this fashion, the volume of the cut body, as defined by the TIN terrain surface, is rendered exactly. There are, in general, several different ways to subdivide a non-triangular polygon into triangles. Since each of the polygons to be subdivided is part of a TIN triangle corresponding to a planar region on the terrain.

(2) As with the average-end-area computation, the user should be cautious of areas in which the design surface extends, in the X-Y plane, beyond the terrain surface. In such areas, there exists no terrain surface with which to compare for volume information. Similarly, no volumes can be obtained for areas in which the terrain model has no corresponding design surface. TIN routines usually assume vertical bounds at the edges of the terrain and design

surfaces. Therefore, volumes are only determined for those X-Y areas in which terrain and design information exists. Note that if vertical bounds are not created by the TIN routine, the program may produce erroneous results in those areas of discrepancy. The user should check the TIN routine for proper handling of terrain/design surface gaps.

10-27. Computing Dredge Volumes from TIN Models. The "TIN Model Program" in HYPACK calculates the volumes between two different surfaces. Applicable USACE options include the following.

a. Survey Surface vs. Level. This option compares a TIN surface against a level plane. This would be applicable to disposal or borrow area surveys. It is also used to determine the volume and surface area of a 'pool' when performing reservoir calculations.

b. Survey Surface TIN vs. Channel. This is the most common dredging application--comparing a TIN surface against a defined channel framework prism. This option is a common application for USACE navigation projects, such as computing Bid, Predredge, and/or Postdredge quantities relative to the fixed channel template(s). This option is especially applicable in projects irregular boundaries, grades, and side slopes, as illustrated in Figure 10-25. There are multiple options in the TIN vs. Channel calculations, as outlined below.

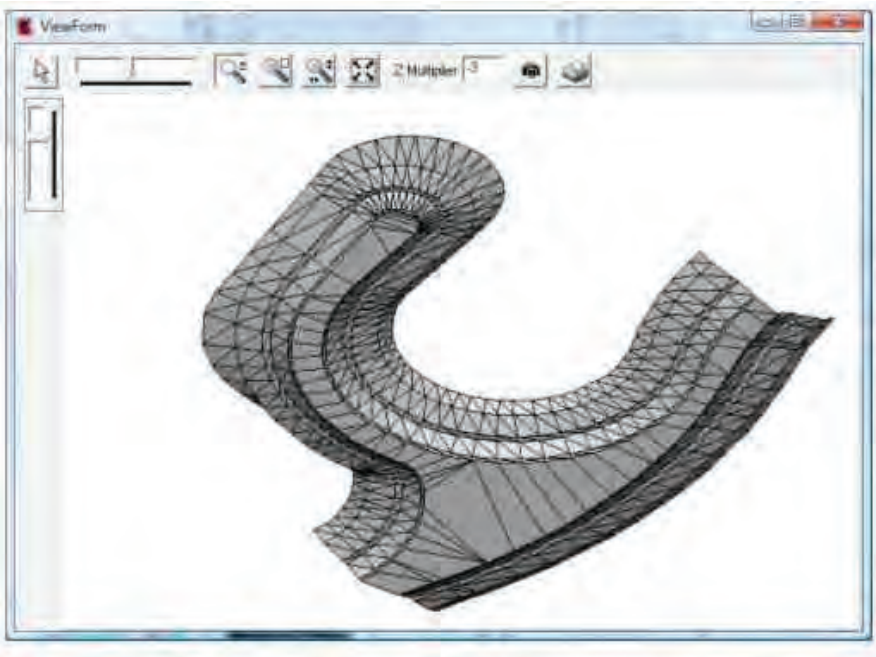

Figure 10-25. Design surface template. TIN volume computations are especially applicable when the framework template consists of curved channel alignments and varying pay grades and side slopes. (Curved channels are actually modeled by a series of straight segments.)

(1) Standard TIN-to-Channel. This option computes four values (Volume Above, Volume Below, Area Above, Area Below) for each face of the channel file specified, as well as their totals for the entire channel.

(2) TIN-to-Channel Zones. If defined reporting zones were created in ADVANCED CHANNEL DESIGN, the program can compute volumes for each reporting zone, subdivided between pairs of planned lines, instead of each face. Areas are not calculated.

(3) Border-limited TIN-to-Channel. Volume calculations can be limited to user-defined border areas in the channel.

(4) Survey Surface vs. Second Survey Surface (TIN to TIN). This option compares two TINs irrespective of any payment prism—e.g., pre- versus post-dredge survey volumes.

(5) Survey Surfaces vs. Design Surface. This option represents the volume between the Design Surface and the survey surfaces.

Dredging Quantities Summary
==========

Materials	Gross Material	Infill	Net Material
Total Pay Removed to Project Depth	7510.9	803.8	6707.1
Total Pay Removed in Overdepth	2749.7	112.4	2637.3
Total Pay Removed	10260.6	916.2	9344.4
Total Removed	12504.3	2533.6	9970.7
Total Remaining Above Project Depth	2519.8		2519.8
Total Overdredged Material	2243.7	1617.4	626.2
Total Infill Material		2533.6	

Total Pay Removed to Project Depth: Material removed above the channel design template.
Total Pay Removed in Overdepth: Material removed between the channel design and overdepth templates.
Total Pay Removed: The sum of the above two items.
Total Removed: The Total Pay Removed plus the Total Overdredged Material.
Total Remaining Above Design: Based on the After Dredge survey, the material that remains above the channel design template.
Total Overdredged Material: The amount of material that was removed beneath the allowable overdepth template.
Total Infill Material: Material where the After Dredge survey is shoaler than the Before Dredge survey.

Figure 10-26. Sample Philadelphia Method Summary Report—Predredge versus Postdredge Survey.

c. Philadelphia (District) Method. The Philadelphia District Method calculates pre-dredge and post-dredge volumes using surface-to-surface (TIN) methods and outputs the results in a format similar to station-by-station average end area reports. The advantage of this method is that accurate TIN volumes are computed but they are additionally output in an AEA format desired by project managers and engineers. In other words, the output resembles that generated from traditional AEA quantity computations. The "Philadelphia Predredge Method" computes

volumes relative to the design/pay grade template surface model. The "Philadelphia Postdredge Method" computes volumes between two surfaces—e.g., the Predredge and Postdredge surveys—and the payment templates. Both Non-Contour and Contour payment methods are supported. A summary report (Figure 10-26) of the material volumes is also generated by the Philadelphia District Method.

d. A sample Philadelphia District Method volume computation is shown on the plates below. Additional details and examples on each of the above Philadelphia District methods, and options therein, are covered in the HYPACK User Manual (HYPACK 2011).

Plate 9-1. Philadelphia District TIN Volume Computation Method. The following examples depict volume computations from full-coverage multibeam surveys using the Philadelphia District Method. The first section computes quantities between a pre-dredge multibeam survey and the channel required depth and overdepth templates. The second section computes final pay, non-pay, and infill (remaining) quantities between the pre-dredge and post-dredge surveys relative to the channel templates.

Project: Philadelphia to the Sea--Acceptance Sections 1 and 19 (2,945 ft channel length)
Pre-Dredge Survey: 1 Nov 12
Post-Dredge Survey: 27 Nov 12

Philadelphia to the Sea encompasses the navigation channel from the city of Philadelphia to the Lower Delaware Bay where it empties into the Atlantic between Cape Henlopen, De and Cape May, NJ. This particular project is deepening the channel from 40 ft to 45 ft in the river between Philadelphia, PA and Camden, NJ.

PRE-DREDGE VOLUMES [PRE-DREDGE SURVEY v CHANNEL FRAMEWORK TEMPLATE]
PHILADELPHIA TIN V TIN SURFACE DIFFERENCING METHOD

File Version 12.0.0.23
TIN File: C:\HYPACK 2012\Projects\Philadelphia to the Sea\Sort\1Nov12_AS1,2,19,20_BD_MLLW_3x3avg.xyz
Section File: C:\HYPACK 2012\Projects\Philadelphia to the Sea\AS#1&19_Reach A.lnw
Mode: Depth
Aligned to LNW: No
Remove Narrow Triangle: No
Max Leg: 15.00
X Maximum: 315362.19 X Minimum: 312770.68 Y Maximum: 391083.42 Y Minimum: 385650.22 Z Maximum: 56.72 Z Minimum: 14.69
Number of Points: 520866 Number of Triangles: 1041730 Volume unit: Cubic Yard
Philadelphia Pre-Dredge Report Volume Totals
TIN File: C:\HYPACK 2012\Projects\Philadelphia to the Sea\Sort\1Nov12_AS1,2,19,20_BD_MLLW_3x3avg.xyz
Section File: C:\HYPACK 2012\Projects\Philadelphia to the Sea\AS#1&19_Reach A.lnw

Dredge File: C:\HYPACK 2012\Projects\Philadelphia to the Sea\Sort\1Nov12_AS1,2,19,20_BD_MLLW_3x3avg.xyz
Line File: C:\HYPACK 2012\Projects\Philadelphia to the Sea\AS#1&19_Reach A.lnw
Method: Side Slope
Dredge Option: Non Contour

Plate 9-1 (continued).

Section to Section	Project Depth	Over Depth	Left Slope	Right Slope
32+755 to 35+700	45.00	46.00	3.0/1.0	3.0/1.0

PRE-DREDGE VOLUME ESTIMATES AT 100-FT STATIONS

Pre Dredge report Section Name	Volume above Design				Volume in Overdepth			
	Left Slope	Left Channel	Right Channel	Right Slope	Left Slope	Left Channel	Right Channel	Right Slope
32+755 to 32+800	0.0	0.0	899.2	28.7	0.0	0.0	273.6	14.6
32+800 to 32+900	0.0	0.0	2011.3	57.6	0.0	0.0	743.6	42.0
32+900 to 33+000	0.0	0.0	1383.5	60.5	0.0	0.0	746.1	42.9
33+000 to 33+100	0.0	0.0	919.5	87.5	0.0	0.0	672.2	50.9
33+100 to 33+200	0.0	0.0	816.6	107.3	0.0	0.0	590.2	56.2
33+200 to 33+300	0.0	0.0	943.5	151.9	0.0	0.0	451.1	67.0
33+300 to 33+400	0.0	0.0	1554.3	166.0	0.0	0.0	545.4	67.4
33+400 to 33+500	0.0	0.0	1962.2	176.4	0.0	0.0	763.7	70.8
33+500 to 33+600	0.0	0.0	2275.7	194.8	0.0	0.0	767.5	75.7
33+600 to 33+700	0.0	0.0	2272.1	201.3	0.0	0.0	771.0	77.8
33+700 to 33+800	0.0	0.0	2181.3	218.5	0.0	0.0	774.4	80.6
33+800 to 33+900	0.0	0.0	1969.9	213.6	0.0	0.0	777.8	78.7
33+900 to 34+000	0.0	0.0	1780.0	172.2	0.0	0.0	781.2	70.3
34+000 to 34+100	0.0	0.0	1134.0	170.3	0.0	0.0	775.4	70.7
34+100 to 34+200	0.0	0.0	1573.9	171.8	0.0	0.0	774.8	70.5
34+200 to 34+300	0.0	0.0	1782.4	130.7	0.0	0.0	766.2	62.0
34+300 to 34+400	0.0	0.0	1774.4	145.8	0.0	0.0	776.2	63.3
34+400 to 34+500	0.0	0.0	1517.1	115.1	0.0	0.0	782.1	58.6
34+500 to 34+600	0.0	0.0	1175.3	86.4	0.0	0.0	702.3	50.3
34+600 to 34+700	0.0	0.0	857.4	26.3	0.0	0.0	636.5	28.5
34+700 to 34+800	0.0	0.0	662.0	24.3	0.0	0.0	550.1	29.5
34+800 to 34+900	0.0	0.0	553.1	30.2	0.0	0.0	523.6	33.4
34+900 to 35+000	0.0	0.0	363.4	40.4	0.0	0.0	512.3	36.5
35+000 to 35+100	0.0	0.0	292.7	40.3	0.0	0.0	563.6	36.8

Plate 9-1 (continued).

35+100 to 35+200	0.0	0.0	227.3	27.9	0.0	0.0	693.6	32.2
35+200 to 35+300	0.0	0.0	416.5	8.2	0.0	0.0	769.1	19.7
35+300 to 35+400	0.0	0.0	310.4	3.7	0.0	0.0	727.9	15.8
35+400 to 35+500	0.0	0.0	423.9	2.0	0.0	0.0	745.2	12.5
35+500 to 35+600	0.0	0.0	832.2	17.1	0.0	0.0	715.8	25.8
35+600 to 35+700	0.0	0.0	1257.8	39.0	0.0	0.0	692.6	34.1
Total:	0.0	0.0	36122.9	2915.7	0.0	0.0	20365.0	1475.2

Dredging Quantities Summary

Total Material To Project Depth	39038.6
Total Allowable Overdepth	21840.2
Total Pay Place	60878.7

PRE-DREDGE V POST DREDGE VOLUME COMPUTATIONS
PHILADELPHIA TIN V TIN SURFACE DIFFERENCING METHOD

File Version 12.0.0.23
TIN File: X:__DATA_ARCHIVES___HYDRO_DATA_2012\PHILADELPHIA_TO_THE_SEA\Contract_Dredging\Reach A Deepening (12-C-0034)\Befores\AS#1 1 Nov 12 (32+755 to 35+700)\XYZ\1 Nov 12_AS #1_BD_MLLW_3X3_AVG.xyz
Additional File: E:\AS 1_2_3_19_20_21_37_27 NOV 2012\Edit (mllw)\27Nov12_AS1&19_AD_MLLW_3x3avg.xyz
Section File: C:\HYPACK 2012\Projects\Philadelphia to the Sea\AS#1&19_Reach A.lnw
Mode: Depth Aligned to LNW: No Remove Narrow Triangle: No Max Leg: 15.00
X Maximum: 315061.95 X Minimum: 313573.27 Y Maximum: 391089.95 Y Minimum: 388113.93 Z Maximum: 51.71 Z Minimum: 30.84
Number of Points: 294045 Number of Triangles: 588084

Volume unit: Cubic Yard
Philadelphia Post-Dredge (Tin to Tin) Volume Totals
TIN File: X:__DATA_ARCHIVES___HYDRO_DATA_2012\PHILADELPHIA_TO_THE_SEA\Contract_Dredging\Reach A Deepening (12-C-0034)\Befores\AS#1 1 Nov 12 (32+755 to 35+700)\XYZ\1 Nov 12_AS #1_BD_MLLW_3X3_AVG.xyz
Section File: C:\HYPACK 2012\Projects\Philadelphia to the Sea\AS#1&19_Reach A.lnw

Dredge File: X:__DATA_ARCHIVES___HYDRO_DATA_2012\PHILADELPHIA_TO_THE_SEA\Contract_Dredging\Reach A Deepening (12-C-0034)\Befores\AS#1 1 Nov 12 (32+755 to 35+700)\XYZ\1 Nov 12_AS #1_BD_MLLW_3X3_AVG.xyz

Plate 9-1 (continued).

Post-Dredge File: E:\AS 1_2_3_19_20_21_37_27 NOV 2012\Edit (mllw)\27Nov12_AS1&19_AD_MLLW_3x3avg.xyz
Line File: C:\HYPACK 2012\Projects\Philadelphia to the Sea\AS#1&19_Reach A.lnw
Method: Side Slope
Dredge Option: Non Contour

Section to Section	Project Depth	Over Depth	Left Slope	Right Slope
32+755 to 35+700	45.00	46.00	3.0/1.0	3.0/1.0

DREDGING QUANTITIES SUMMARY

Materials	Gross Material	Infill	Net Material
Total Pay Removed to Project Depth	37605.2	14.8	37590.4
Total Pay Removed in Overdepth	20456.0	90.4	20365.6
Total Pay Removed	58061.2	105.2	57955.9
Total Removed	88415.1	6137.7	82277.5
Total Remaining Above Project Depth	41.5		41.5
Total Overdredged Material	30354.0	6032.4	24321.6
Total Infill Material		6137.7	

PRE-DREDGE V POST-DREDGE VOLUMES AT 100-FT SECTIONS

Section	Volume Removed Above Channel Design				Volume Removed in Overdepth Region				Volume Removed Beneath Overdepth Template			
	Left Channel	Left Channel	Right Box	Right Box	Left Channel	Left Channel	Right Box	Right Box	Left Channel	Left Channel	Right Box	Right Box
32+755 to 32+800	0.0	0.0	885.4	27.8	0.0	0.0	271.7	14.3	0.0	0.0	148.3	57.2
32+800 to 32+900	0.0	0.0	1949.6	55.9	0.0	0.0	737.9	41.5	0.0	0.0	342.8	165.2
32+900 to 33+000	0.0	0.0	1335.5	58.4	0.0	0.0	745.8	42.2	0.0	0.0	835.5	168.6
33+000 to 33+100	0.0	0.0	887.2	85.9	0.0	0.0	640.8	50.3	0.0	0.0	959.3	217.2
33+100 to 33+200	0.0	0.0	794.6	104.8	0.0	0.0	563.8	55.5	0.0	0.0	872.2	217.0
33+200 to 33+300	0.0	0.0	920.5	148.4	0.0	0.0	442.2	66.3	0.0	0.0	697.8	218.2
33+300 to 33+400	0.0	0.0	1519.3	163.7	0.0	0.0	528.7	66.9	0.0	0.0	1400.9	236.5

Plate 9-1 (continued).

33+400 to 33+500	0.0	0.0	1907.0	173.7	0.0	0.0	762.2	70.0	0.0	0.0	1305.4	231.9
33+500 to 33+600	0.0	0.0	2225.1	191.6	0.0	0.0	767.5	75.2	0.0	0.0	1083.8	223.7
33+600 to 33+700	0.0	0.0	2220.2	197.2	0.0	0.0	771.0	77.5	0.0	0.0	1101.5	306.0
33+700 to 33+800	0.0	0.0	2129.9	215.0	0.0	0.0	768.7	78.3	0.0	0.0	1180.9	144.8
33+800 to 33+900	0.0	0.0	1916.3	209.8	0.0	0.0	760.9	75.6	0.0	0.0	1095.8	101.9
33+900 to 34+000	0.0	0.0	1724.1	169.4	0.0	0.0	777.0	68.4	0.0	0.0	1234.7	166.2
34+000 to 34+100	0.0	0.0	1082.0	166.8	0.0	0.0	753.2	66.1	0.0	0.0	1219.5	156.4
34+100 to 34+200	0.0	0.0	1528.2	167.0	0.0	0.0	737.9	61.2	0.0	0.0	1025.2	129.0
34+200 to 34+300	0.0	0.0	1738.9	125.8	0.0	0.0	693.4	41.7	0.0	0.0	470.3	31.5
34+300 to 34+400	0.0	0.0	1710.3	138.3	0.0	0.0	566.9	36.3	0.0	0.0	330.0	20.5
34+400 to 34+500	0.0	0.0	1441.2	110.2	0.0	0.0	619.7	43.3	0.0	0.0	425.1	31.2
34+500 to 34+600	0.0	0.0	1128.7	83.8	0.0	0.0	669.3	48.0	0.0	0.0	775.7	144.1
34+600 to 34+700	0.0	0.0	808.0	25.2	0.0	0.0	619.8	27.9	0.0	0.0	1025.4	206.6
34+700 to 34+800	0.0	0.0	624.9	23.2	0.0	0.0	536.3	28.8	0.0	0.0	826.7	279.0
34+800 to 34+900	0.0	0.0	520.7	28.6	0.0	0.0	494.6	32.6	0.0	0.0	577.5	231.6
34+900 to 35+000	0.0	0.0	336.8	37.8	0.0	0.0	475.8	35.3	0.0	0.0	399.0	196.3
35+000 to 35+100	0.0	0.0	276.1	37.7	0.0	0.0	440.3	35.8	0.0	0.0	374.0	228.4
35+100 to 35+200	0.0	0.0	207.6	26.0	0.0	0.0	588.7	31.1	0.0	0.0	557.9	203.5
35+200 to 35+300	0.0	0.0	355.2	7.3	0.0	0.0	707.4	18.7	0.0	0.0	1102.6	164.7
35+300 to 35+400	0.0	0.0	259.9	3.0	0.0	0.0	650.1	14.8	0.0	0.0	1116.3	164.2
35+400 to 35+500	0.0	0.0	367.1	1.6	0.0	0.0	691.2	11.7	0.0	0.0	1009.8	165.2
35+500 to 35+600	0.0	0.0	772.4	16.1	0.0	0.0	628.4	25.2	0.0	0.0	750.2	245.7
35+600 to 35+700	0.0	0.0	1195.4	36.9	0.0	0.0	670.8	33.5	0.0	0.0	873.0	184.5
Total:	0.0	0.0	34768.2	2837.0	0.0	0.0	19081.9	1374.1	0.0	0.0	25117.2	5236.8

Plate 9-1 (continued). INFILL QUANTITIES (ACCRETED OR MISPLACED MATERIAL)

Section	Infill Above Channel Design				Infill in Overdepth Region				Infill Beneath Overdepth Template			
	Left Box	Left Channel	Right Channel	Right Box	Left Box	Left Channel	Right Channel	Right Box	Left Box	Left Channel	Right Channel	Right Box
32+755 to 32+800	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	23.1
32+800 to 32+900	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	73.5
32+900 to 33+000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	85.6
33+000 to 33+100	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	117.9
33+100 to 33+200	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	133.6
33+200 to 33+300	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	62.5	148.5
33+300 to 33+400	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	181.5
33+400 to 33+500	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	203.1
33+500 to 33+600	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	155.7
33+600 to 33+700	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	92.6
33+700 to 33+800	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	129.1
33+800 to 33+900	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	189.3
33+900 to 34+000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	212.9
34+000 to 34+100	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.9	0.0	0.0	0.0	220.6
34+100 to 34+200	0.0	0.0	0.1	0.4	0.0	0.0	1.6	2.8	0.0	0.0	0.0	276.4
34+200 to 34+300	0.0	0.0	0.0	1.7	0.0	0.0	0.1	4.4	0.0	0.0	0.0	284.4
34+300 to 34+400	0.0	0.0	0.7	2.5	0.0	0.0	1.0	5.6	0.0	0.0	0.0	335.3
34+400 to 34+500	0.0	0.0	5.1	0.7	0.0	0.0	3.5	2.9	0.0	0.0	0.0	288.7
34+500 to 34+600	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.3	0.0	0.0	0.4	232.5
34+600 to 34+700	0.0	0.0	0.0	0.0	0.0	0.0	1.2	0.0	0.0	0.0	0.9	379.4
34+700 to 34+800	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.8	241.0
34+800 to 34+900	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	22.1	216.9
34+900 to 35+000	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	26.9	254.2
35+000 to 35+100	0.0	0.0	0.0	0.0	0.0	0.0	4.6	0.0	0.0	0.0	11.2	202.2
35+100 to 35+200	0.0	0.0	0.0	0.0	0.0	0.0	13.1	0.0	0.0	0.0	1.0	244.7
35+200 to 35+300	0.0	0.0	0.0	0.0	0.0	0.0	7.0	0.0	0.0	0.0	0.0	305.8
35+300 to 35+400	0.0	0.0	0.0	0.0	0.0	0.0	16.5	0.0	0.0	0.0	0.0	208.3
35+400 to 35+500	0.0	0.0	0.6	0.0	0.0	0.0	11.7	0.0	0.0	0.0	4.4	110.8
35+500 to 35+600	0.0	0.0	2.9	0.0	0.0	0.0	9.2	0.0	0.0	0.0	6.2	120.5
35+600 to 35+700	0.0	0.0	0.0	0.0	0.0	0.0	1.5	0.0	0.0	0.0	13.3	200.6
Total:	0.0	0.0	9.5	5.3	0.0	0.0	71.9	18.5	0.0	0.0	163.8	5868.6

Plate 9-1 (concluded). MATERIAL REMAINING ABOVE REQUIRED GRADE AND IN OVERDEPTH REGION

Section	Remaining Above Channel Design				Remaining in Overdepth Region			
	Left Slope	Left Channel	Right Channel	Right Slope	Left Slope	Left Channel	Right Channel	Right Slope
32+755 to 32+800	0.0	0.0	0.0	0.0	0.0	0.0	1.6	0.0
32+800 to 32+900	0.0	0.0	0.0	0.0	0.0	0.0	5.7	0.0
32+900 to 33+000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
33+000 to 33+100	0.0	0.0	0.1	0.0	0.0	0.0	15.9	0.0
33+100 to 33+200	0.0	0.0	0.0	0.0	0.0	0.0	1.5	0.0
33+200 to 33+300	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0
33+300 to 33+400	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
33+400 to 33+500	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6
33+500 to 33+600	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
33+600 to 33+700	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
33+700 to 33+800	0.0	0.0	0.0	0.0	0.0	0.0	5.7	2.4
33+800 to 33+900	0.0	0.0	0.0	0.0	0.0	0.0	16.9	2.7
33+900 to 34+000	0.0	0.0	0.0	0.0	0.0	0.0	4.2	1.3
34+000 to 34+100	0.0	0.0	0.0	0.0	0.0	0.0	14.9	5.5
34+100 to 34+200	0.0	0.0	0.1	1.6	0.0	0.0	32.7	11.7
34+200 to 34+300	0.0	0.0	0.0	4.1	0.0	0.0	68.7	24.1
34+300 to 34+400	0.0	0.0	6.9	7.4	0.0	0.0	205.8	32.1
34+400 to 34+500	0.0	0.0	15.1	2.0	0.0	0.0	160.6	17.4
34+500 to 34+600	0.0	0.0	0.0	0.0	0.0	0.0	25.9	1.7
34+600 to 34+700	0.0	0.0	0.0	0.0	0.0	0.0	7.0	0.0
34+700 to 34+800	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0
34+800 to 34+900	0.0	0.0	0.0	0.0	0.0	0.0	8.8	0.0
34+900 to 35+000	0.0	0.0	0.0	0.0	0.0	0.0	9.6	0.0
35+000 to 35+100	0.0	0.0	0.0	0.0	0.0	0.0	86.8	0.1
35+100 to 35+200	0.0	0.0	0.0	0.0	0.0	0.0	78.1	0.0
35+200 to 35+300	0.0	0.0	0.0	0.0	0.0	0.0	57.9	0.0
35+300 to 35+400	0.0	0.0	0.0	0.0	0.0	0.0	72.9	0.0
35+400 to 35+500	0.0	0.0	0.6	0.0	0.0	0.0	55.3	0.0
35+500 to 35+600	0.0	0.0	3.5	0.0	0.0	0.0	89.5	0.0
35+600 to 35+700	0.0	0.0	0.0	0.0	0.0	0.0	18.8	0.0
Total:	0.0	0.0	26.3	15.2	0.0	0.0	1046.4	99.5

10-28. Overdepth Dredging Statistics (HYPACK "DREDGESTATS"). This program option calculates the statistics to show how many final depths in a data set are above and below a user-specified depth within a given area. The program accepts one or two data sets and compares them against the user-defined project depth. Data is only compared in the main channel; the depths on the side slopes and outside the main channel are ignored. A use of the program is to statistically evaluate the amount of dredging below the required grade, in the overdepth prism, and non-pay material below the overdepth pay grade. (Figure 10-27.) This program was developed in support of ERDC/CHL. For further details on overdepth dredging issues refer to ERDC/TN EEDP-04-37, Overdepth Dredging and Characterization Depth Recommendations, listed in Appendix A.

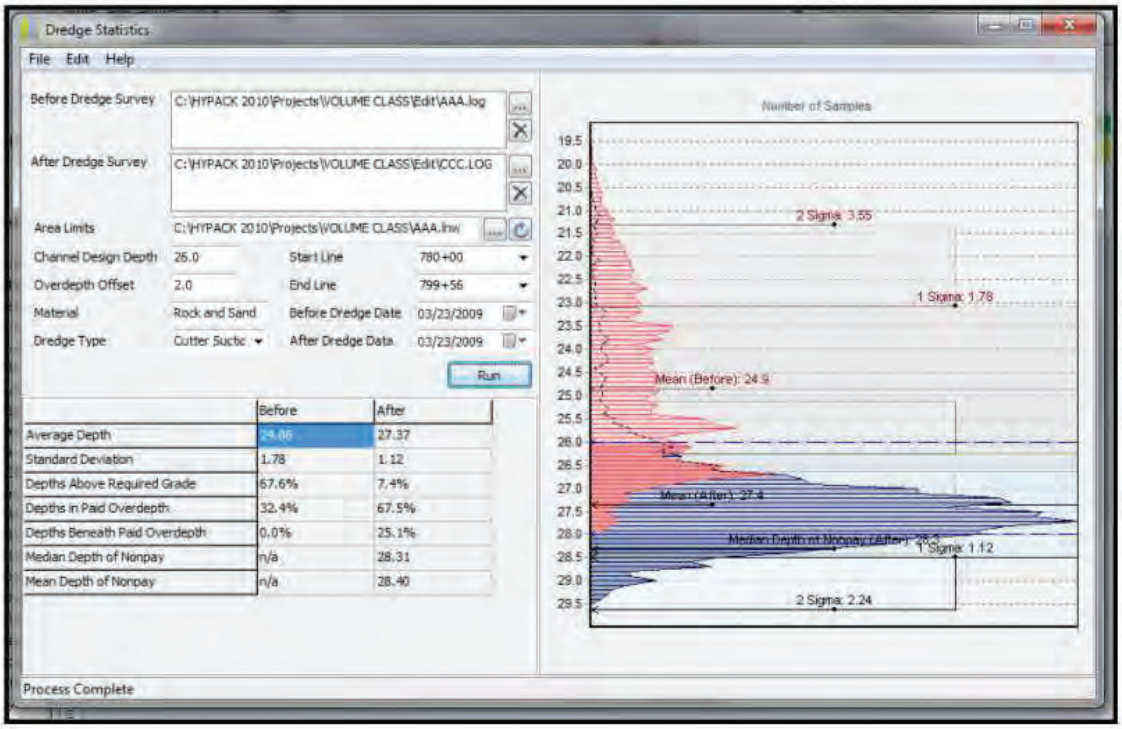

Figure 10-27. DREDGESTATS Dredge Statistic screen display. Statistics are given for depths within overdepth pay region (26 to 28 ft) and depths greater than 28 ft (non-pay over-dredging).

10-29. Evaluation of Dredge Quantity Estimates Based on Depth Accuracy and Density. Three primary factors affect the accuracy of dredge volume computations, in this order:

(1) Terrain irregularity and data density

(2) Bias errors in depth measurements

(3) Deviation of depth observations

Data density typically has the most important effect on the overall accuracy of a quantity computation. Required data density is a function of the irregularities in the terrain, as is clearly illustrated in Figure 10-28. Systematic biases in the depth database will obviously cause constant dredge volume errors. The deviation or estimated accuracy of the depths can cause volume errors if the standard deviation is large and an insufficient number of points are observed. A volume derived from a densely gridded/binned multibeam survey will usually yield a more accurate quantity than that obtained from 100-ft spaced cross-sections, even if the depth accuracy (i.e., standard deviation) of the multibeam survey is not a good as the cross-section depths. These concepts are discussed below.

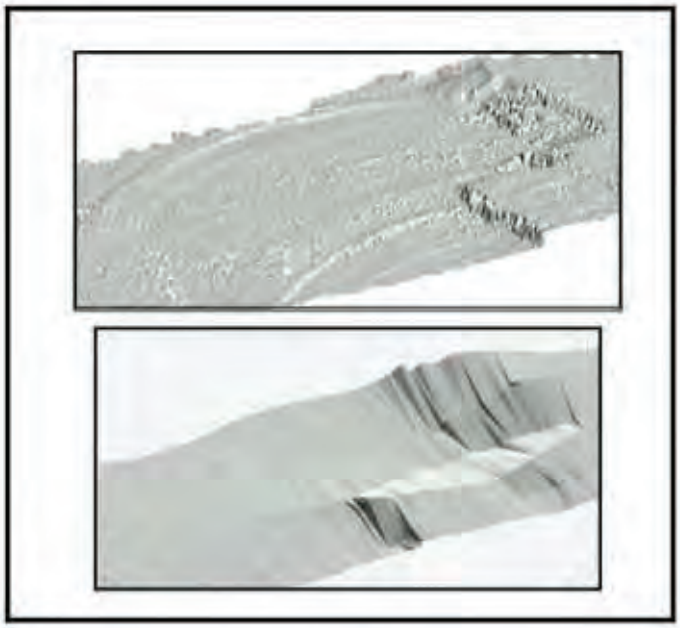

Figure 10-28. Single beam versus multibeam coverage -Port of Los Angeles. Drawings compare low density single beam coverage (bottom view) with detailed multibeam coverage (top view). Dredged sections are generalized in the single beam coverage. (HYPACK, Inc. and Los Angeles District)

a. Terrain irregularity impacts on volume accuracy. The effects of terrain irregularities on dredge volume computations depend on the density of data coverage. When end areas are computed for single beam cross-sections, large variations in the end areas would indicate terrain irregularity exists between the sections. Even if the cross-section data points were absolutely error free (no bias or standard deviation) volume errors due to terrain irregularity would still exist due to lack of measurements between the 100-ft sections. These effects can be illustrated by the following single-beam survey example.

Given: Typical 400-ft wide box-cut channel (no side slope quantities computed).
Predredge shoaling fairly uniform at around 10 ft above pay grade.
100-ft cross-sections run over 3,000 ft Acceptance Section.
Average-end-area volume computation.

Station	Cross-sectional End Area
60+00	3850 sq ft
61+00	4125
62+00	3975
63+00	4225
64+00	4150
.	.
.	.
.	.
89+00	4125
90+00	3950

(1) In looking at the variations in end areas for the cross-sections, it is determined that their average deviation is approximately ±100 sq ft. If depth measurement biases and deviations are assumed to be zero, then this end-area variance between cross-sections in a uniform shoal area is likely due to irregularities in the terrain and random survey errors. Had cross-sections been observed at 1-ft intervals (e.g., multibeam) then the end-area variations would be expected to be significantly less. The volume error over due to this ±100 sq ft end area deviation can be computed by comparing the quantities over the section for a 4,000 sq ft and 4,100 sq ft end area. The percentage quantity error is simply:

% error in volume = (100 sq ft / 4,000 sq ft) = 2.5 %

This 2.5 % error equates to 370 cy per 100-ft section or about 11,000 cy over the entire acceptance section (which has a total yardage of nearly 450,000 cy).

(2) Had the bottom terrain been more uniform, then the computed end-area variations would be smaller. A variation of ±20 sq ft would have represented only a 0.5 % error on this project. If the end-areas were linearly increasing or decreasing (sloping shoal), then this slope would be considered in looking at variations in end areas. On the other hand, had there only been an average of 4 feet of shoaling above grade, then the relative volume error would be larger--i.e., (100 sq ft/1,600 sq ft) · 100% = 6.25%.

(3) Minimizing end-area volume errors due to terrain irregularities between single beam cross-sections is often impractical. Since the only way to minimize the error is to decrease line spacing, practical limitations prevent this. Decreasing line spacing to, say 20 ft, adds field survey time and cost. In addition, a 20-ft line spacing is near the tolerance of the ability to control the

survey vessel on line. Since most average-end-area computations assume cross-sections are equally spaced--i.e., no off line steering deviations--projecting these lines over 20-ft distances is no longer valid. However, given the sparse cross-sections data sets, a TIN model may be generated for all the observed data points and volumes computed using the vertical TIN prismoidal elements rather than average-end-area projections. This would represent a more accurate volume computation than average-end-area methods.

b. Impact of depth measurement bias errors on volume computations. A constant depth bias in the data set is estimated from single-beam cross-line checks or multibeam Performance Test data. The effect of a constant depth bias on a dredged quantity computation is obvious--the error projects over the entire dredging section (e.g., an Acceptance Section). Thus, minimizing any depth biases is critical. Using the 3,000 ft acceptance section in the above example, the quantity error due to a 0.1 ft depth bias can be approximately computed by projecting the bias over the entire section:

$$\text{volume error} = 0.1\ \text{ft} \cdot 400\ \text{ft} \cdot 3{,}000\ \text{ft} / (27\ \text{cy/ft}) = 4{,}450\ \text{cy}$$

$$\text{percent error} = 4{,}450\ \text{cy} / 450{,}000\ \text{cy} = 1\ \%$$

In the above example, it is seen that the bias error (1%) is smaller than the error due to terrain variations (2.5%). This corresponds to theory and is roughly what occurs in practice. Bias error can become more significant in offshore tidal areas where modeling becomes difficult.

c. Impact of deviations in depth observations on volume computations. As an example, the standard deviation of depth measurements from Performance Tests on a navigation project is estimated to be ±0.9 ft, or ±1.8 ft at the 95% level. If there are no biases in the data, volumes computed over a given area from an infinite number of observed data points would have no error due to inaccuracies in individual depths. However, an infinite number of points are never observed. When single-beam cross-sections are taken, "full-coverage" is observed along the section if depths are recorded at intervals of 10-15 per sec. Normally, however, for both single-beam and multibeam surveys, data sets are generalized or "thinned"--i.e., binned or gridded. For example, single-beam cross-section data collected at 1-ft intervals may be generalized to points every 5- or 25-ft along the line, or dense multibeam data may be generalized into one data point in a 5- x 5-ft (25 sq ft) cell. This generalization is usually performed to reduce the size of the database. Either an average of all the points in a range or area is used or a single point nearest the cell center is used. The following over-simplified example illustrates how the data point accuracy and number of points can affect the dredge quantity computation.

Given: 100-ft single beam cross-section run over 26.0-ft lock chamber

OFFSET	DEPTH	Depth Used
0	26.1	26.1
5	26	
10	26	
15	26	
20	26.2	
25	26	26
30	25.9	
35	25.9	
40	26	
45	26.2	
50	25.9	25.9
55	26	
60	26	
65	25.8	
70	25.9	
75	26.3	26.3
80	26	
85	25.7	
90	26.1	
95	26	
100	26.2	26.2

(1) The mean of the 21 depths observed at 5-ft intervals is 26.0 ft and their 1-σ standard deviation is ±0.14 ft. This indicates no bias in the data was observed in this dataset. The 95% confidence of the mean is ±0.06 ft. Thus, if all the points were used to compute an end-area of this cross-section, the accuracy of the end area would be good.

(2) If depths were thinned to the even 25-ft intervals as shown in the above table, and only these depths used to compute the end-area of the cross-section, the end area accuracy would degrade significantly due to the few data points used. In this example, the mean of the five points is 26.1 ft, which, in effect adds a false 0.1 ft bias to the data. This 0.1 ft bias would be projected over the project area. The 95% confidence of this mean is also only (roughly) ±0.14 ft., indicating little confidence in the measurements and ultimately the volume.

(3) The above illustrates that higher data density improves volume accuracy, either for average-end-area cross-sections or in binned matrix models. Larger numbers of data points minimizes the effects of random errors in the individual data points. Improperly thinning datasets will cause errors in the volumes. For example, to maintain a confidence level of ±0.05 ft

on a 30-ft project (estimated 95% depth accuracy is ±1.0 ft), at least 400 points should be accurately collected. For a shallow-draft project, then only 100 data points would be needed to ensure ±0.05 ft confidence.

d. Conclusions.

(1) Terrain irregularity has the major impact on the accuracy of volume computations. These effects are minimized by increasing data density and using spatial (TIN) volume computation methods. Average-end-area volume computation methods should only be used on projects with relatively uniform bottom terrain and where linearized end-area variations between successive sections are less than 0.5%. If end-area variations are large due to irregular bottom topography, then closer spaced cross-sections should be run or full-coverage multibeam surveys obtained.

(2) When sparse data sets (i.e., single beam cross-sections) are observed, TIN or dense grid volume computation methods using prismoidal projection elements are more accurate than average-end-area methods. If full multibeam datasets are observed, volumes should not be computed by passing sparse cross-sections through the dataset and using average-end-area methods.

(3) Collected survey data used for volume computations should not be thinned in order to minimize volume errors due to data density and data point variance. If thinning is needed due to data processing limitations, it should be kept to a minimum. The degree of bottom irregularity will determine the amount of allowable thinning--i.e., maximum cell size. All observed depths on single beam surveys should be used in computing end-areas. For multibeam surveys, cell sizes should generally not exceed 5- x 5-ft bins. The smallest bin size that can be efficiently computed should always be used.

(4) Other factors that may impact dredge volumes. These may include errors due to fluff, vegetation, short-term draft or velocity variations, or sensitivity drift. These errors are difficult or impossible to quantify.

SECTION V

Recommended Guidance for Dredging Surveys and Quantity Computations

The following guidance is derived from best practices by USACE districts heavily involved in deep-draft dredging projects. These criteria were developed at numerous Multibeam User Group meetings held in the North Atlantic Division. Most USACE coastal districts were represented at these meetings or had input to this guidance. It is important to note that this guidance is recommended, not directive. Thus, there is no USACE policy requirement to follow these best practices.

10-30. Recommended Dredge Quantity Computation Procedures.

a. USACE payment templates. Both the Contour and Non-Contour payment templates may be used, depending on the dredging platform and purpose. The Non-Contour (Bordered) payment template is recommended for hopper dredging.

b. Side slope payment. In general, payment should be made for material lying above either the overdepth or required grade on the side slopes. Side slope payment may be optional on maintenance dredging in soft material. No payment might be made where there is minimal build up of shoal material along the toes, say less than 2 ft above required grade. If there is a major build up of material along the toe and extending into the side slope, then side slope payment would be warranted.

c. Box cut allowance. A box cut payment may optionally be measured and paid. Pay allowance should be made in non-pay areas lying any distance outside the channel toe and up to 25 feet inside the toe. Payment is not restricted to any depth below project grade. Payment cannot exceed the amount of above-grade material capable of sloughing into the cut areas. Continued use of the box cut allowance is discouraged due to excessive computational biases, computational complexities, disparities in software packages, disputes over payment techniques, and usually insignificant yardage allowances for box cuts on actual projects. If box cut allowances are computed from full-coverage sweep data contained in a TIN model, AEA cross-sections should be generated through the TIN model at a high density--say every 5 or 10 ft.

d. Volume computation method. Average end area (AEA) methods (Basic HYPACK) should be used for closely spaced cross-sectional data, and preferably only on straight, continuous, trapezoidal channels. The "Standard HYPACK AEA Method" is recommended for non-parallel cross-sections. Otherwise, surface differencing or TIN differencing methods are recommended. TIN methods should be used where cross-sections exceed 100 ft and/or where AEA cross-sections indicate large area variances between successive sections. TIN methods should also be used for mixed cross-section and cross-line data in order to utilize the full data set. Where full-bottom coverage is available from multibeam surveys, TIN volume techniques are recommended. TIN terrain model differencing is recommended for irregular basins or channels. The "Philadelphia District Method" is recommended for most TIN volume computations. Construction contract specifications should always detail the specific computation requirements.

e. Thinning and binning data sets. Thinning data sets is not recommended for dredge volume computations using single beam data. Data thinning is necessary when using data from multibeam surveys, since the full surface model contains millions of data points that may overload computer memory. If data thinning is necessary to reduce the size of the data set of a multibeam survey, users should utilize a binning program where the bin size is kept to a minimum and the average or median depths are used. If median depths are used, they should be

saved in their actual X-Y location and not moved to the center of the bin. Typical bin sizes used range from 1x1 ft to 5x5 ft.

f. Volume computation software verification. Automated volume computation software shall be initially tested to ensure accurate, repeatable values are being computed. This may be done by comparison with a manual computation. An average end area computation may be checked by using data points from a single cross-section and computing the section end-area by the exact coordinate method described previously. At least 100 data points on the cross-section should be used. The manual and automated sectional end areas should agree to well within 0.1 sq ft. Box cut computational accuracy should similarly be tested and verified, using data from simulated pre and post dredging surveys. The survey data should have multiple intersect points with the template. TIN volume computations may be tested by comparing volumes computed from densely spaced AEA sections passed through the TIN model--e.g., 1-ft cross-sections cut through a 100-ft section of the model. Volumes should agree within one cubic yard. Automated software should be re-verified at each upgrade.

10-31. Contract Guide Specifications for Multibeam Measurement and Payment. The following contract clauses are recommended when multibeam systems are used on dredge payment or acceptance surveys. This version was developed by the North Atlantic Division Multibeam User's Group in 2004.

a. "HYDROGRAPHIC SURVEY EQUIPMENT. Hydrographic surveys will be conducted to meet USACE accuracy standards defined in EM 1110-2-1003, Hydrographic Surveying; specifically *[specify any standard deviation or repeatability tolerances]*. Surveys will be performed by single vertical beam transducer, or multiple vertical beam transducer sweep, or multibeam sweep methods. When vertical single beam or multiple sweep beam transducers are employed, an acoustic frequency of *[200 kHz (± 20%)] [or insert alternate frequency]* will be used. When utilizing multibeam technology, the operating acoustic frequency will range from [180 kHz to 250 kHz] *[or insert alternate frequency]*. All depth measurement devices, positioning, and motion compensation systems will be calibrated following the quality control procedures outlined in EM 1110-2-1003. Quality assurance Performance Tests to estimate data accuracy, repeatability, and maximum multibeam array limits [will] *[will not]* be performed."

b. "MEASUREMENT AND PAYMENT. The total amount of material removed and to be paid for under the contract, will be measured by the cubic yard in place. Measurement of the number of cubic yards in place will be made by computing the volume between the bottom surface shown by soundings of the last survey made before dredging and the bottom surface shown by the soundings of surveys made as soon as practicable after the work specified in each acceptance section has been completed. The volume for measurement will include the material within the limits described in the Paragraph entitled: "OVERDEPTH AND SIDE SLOPES', less any deductions that may be required for misplaced material described in the Paragraph entitled:

"DISPOSAL OF EXCAVATED MATERIAL" of this section. The volume of material removed will be generated by using either the Average End Area Method or by the TIN (Triangulated Irregular Network) computation, as outlined in the Hydrographic Surveying Manual EM 1110-2-1003, and subsequent changes/revisions issued by HQUSACE. All depths obtained from single beam surveys will be utilized for volume computation purposes. If multiple vertical transducer sweep systems or multibeam survey technology is used, a *[5-foot by 5-foot] matrix using the *[average] [median] depth of all depths recorded in a cell will be generated from the edited multibeam data to perform the TIN volume computations, following the procedures outlined in EM 1110-2-1003. Any corresponding plotted plan view sounding sheets depicting representative depths over a dredging project will be generated using a cell size that is plot-scale dependent, utilizing a randomly selected sounding that is closest to cell center (shot depth) shifted to the center of the cell from the edited multi-beam data, as described in EM 1110-2-1003. If the material to be dredged in the contract is categorized to be hard bottom or rock, the matrix used for the volume computations will be reduced to a *[3 foot by 3-foot]* matrix and an *[average] [median]* of the soundings in the cell will be used. Shoal or strike plots depicting material above the required dredging grade will be generated using confirmed minimum depths in accordance with the data processing procedures outlined in EM 1110-2-1003. All raw survey data and edited/processed binned data used for volume computations shall be available to the Contractor upon request."

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CHAPTER 11

Coastal Engineering Surveys for Beach Renourishment Projects and Shoreline Protection Structures

11-1. Introduction. This chapter provides guidance in performing coastal engineering surveys on USACE projects. Coastal engineering surveys are performed in support of sand transport studies, berm movement studies, beach renourishment placement measurement and payment, offshore borrow area dredging, jetty and breakwater construction, underwater investigation, and construction of shore and hurricane protection structures. An important component in this process is selecting the appropriate survey tools to collect data that meet project requirements and the needs of end users. Guidance in this chapter is intended to assist project planners and designers in reaching a common knowledge base for specifying effective survey data collection programs. This chapter also presents summary information on traditional, as well as newer, technologies for coastal surveying. Recommended accuracy standards and procedural methods are outlined for various coastal engineering projects.

Figure 11-1. Coastal surveys involve both topographic and hydrographic survey techniques. (Arc Surveying and Mapping, Inc.)

11-2. Required Supplemental Reference. Chapter 5, Procedures for Referencing Datums on Coastal Hurricane and Shore Protection Projects, of EM 1110-2-6056, Standards and Procedures

for Referencing Project Elevation Grades to Nationwide Vertical Datums, is incorporated by reference into this chapter. This reference describes the requirements for establishing primary control for all types of coastal engineering projects, to include Primary Project Control Points (PPCP) and Local Project Control Points (LPCP). It also describes how to establish firm geodetic connections and relationships between tidal, ellipsoidal, and geodetic (orthometric) datums. EM 1110-2-6056 supplements ER 1110-2-8160, Policies for Referencing Project Elevation Grades to Nationwide Vertical Datums, that requires project elevation grades shall be referenced to nationwide vertical datums established and maintained by the U.S. Department of Commerce.

11-3. General Procedures. A variety of topographic and hydrographic methods, equipment, and floating plant are used in performing coastal surveys. These technologies range from basic differential leveling methods to complex airborne platforms. Some methods directly measure topographic elevations through direct contact with the surface being surveyed, while others remotely measure water depth and must be corrected for water surface conditions such as waves and tides. Each method has its own inherent performance specifications, operational limitations, costs of operation, and special considerations. The type of technology selected to survey a project will largely depend upon a combination of requirements related to data end use accuracies, spatial data density, and survey budget. The selection of a particular system also depends on the project location, size, and environment. Coastal engineering studies typically do not need the high data density required for beach renourishment construction, jetty construction, or offshore breakwater construction. The following sections describe some of the techniques used for different types of coastal projects.

a. Beach surveys. Beach surveys combine land topographic cross-sections with offshore hydrographic sections—Figure 11-1. Beach profile lines (i.e., cross sections) are run perpendicular to the shoreline relative to the project baseline. Permanent benchmarks (PBM) are typically maintained along the entire project length. These benchmarks are set and published in the horizontal and vertical project datums. Temporary benchmarks (TBM) are used during beachfill operations or when total stations or levels are used for portions of the surveys. The fixed baseline is normally established well beyond (inland from) the dune line to ensure permanency for subsequent construction or periodic monitoring surveys. Permanent reference azimuths for each profile line are established relative to the fixed baseline. Profile elevations are obtained using boats, sleds, aircraft, hand-held rods, and other topographic measurement methods described in the remainder of this chapter.

(1) Profile spacing is highly project-dependent. For general coastal erosion or sand transport studies, profile lines may be spaced from 500 to 5,000 ft, depending on the regularity of the coast. Often funding availability drives the density of coverage for studies. Beach renourishment construction surveys for payment require denser spacing--typically at 100-ft intervals.

(2) Both topographic and hydrographic survey methods are employed to obtain continuous coverage of a beach profile line. As shown in Figure 11-2, topographic surveys are

run as far into the water as possible, usually at low tide. Single beam echo soundings are obtained at high tide to cover the surf zone and the offshore portions of the line. Topographic methods may only be needed for beach fill placement if material is placed out to wading depths. Coastal studies usually require depths out to a specified depth of closure; necessitating a hydrographic survey vessel to reach this point. The depth of closure is a depth where the ocean floor is generally stable and does not change with seasonal variation or storms.

(3) Although beach studies have traditionally been performed by running spaced profile lines, some districts (Los Angeles) have recently adopted full coverage surveys of the land and offshore areas. This can be accomplished by employing airborne LIDAR bathymetric and topographic techniques, along with multibeam full coverage surveys. This results in a complete topographic surface model of the study site rather than sparse cross-sections.

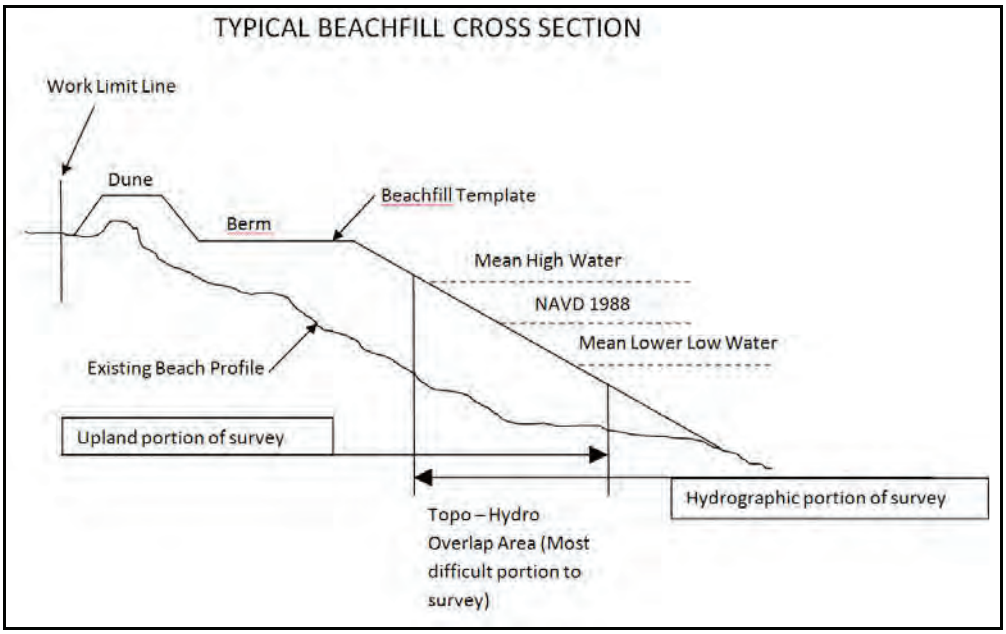

Figure 11-2. Topographic and hydrographic profile overlaps of typical beach renourishment sections.

b. Jetty, groin, and breakwater surveys. Construction and condition assessment surveys of shore protection structures requires far more detail than beach surveys described above. Although these structures can be surveyed using traditional topographic and hydrographic cross-sectioning methods, recent advances in acoustic multibeam and terrestrial LIDAR systems allow for detailed above- and below-water georeferenced cloud images of these structures.

c. Primary and local project control. Reference Chapter 5 of EM 1110-2-6056. EM 1110-2-6056 provides detailed guidance on establishing and maintaining primary control for coastal engineering projects. Figure 11-3 (taken from EM 1110-2-6056) depicts a typical reference baseline established for a beach renourishment project. Prior to the start of a project,

all local project control points (LPCP) should be connected to the primary project control point (PPCP), either by differential leveling or RTK. In accordance with the guidance in EM 1110-2-6056, every project should have at least one PPCP that has established orthometric and tidal elevation relationships. Supplemental LPCPs may be PBMs or TBMs. Beach renourishment projects often have established (permanent) baselines with PBMs at 500 ft or more intervals. During construction, temporary hubs may be set between these PBMs at 100-ft intervals. Jetties, seawalls, breakwaters, etc. will also have a PPCP from which local construction control (LPCPs) can be established during maintenance work. Appendix G in EM 1110-2-6056 contains an actual example of control established for a Wilmington District project—"Fort Fisher Shore Protection and Beach Stabilization Project."

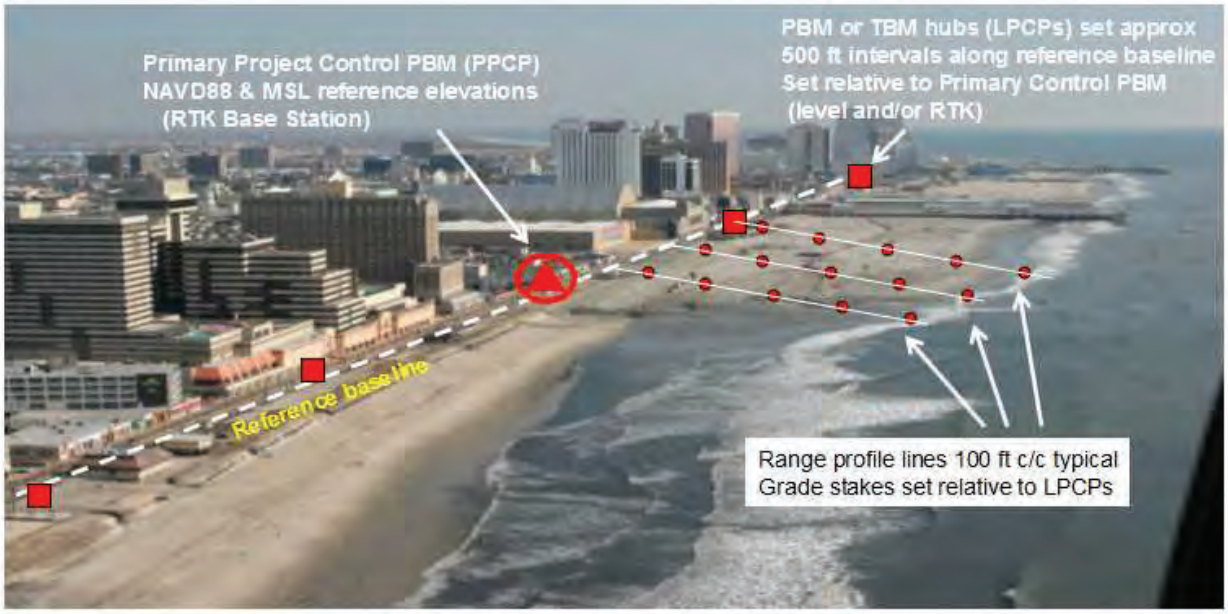

Figure 11-3. Primary and secondary construction control on reference baseline. Beach renourishment project at Atlantic City, NJ. (Philadelphia District)

d. Elevation and grading accuracy. Depending on the survey technique, the accuracy (or propagated uncertainty) of elevation data along the profile will be highly variable. Topographic sections can generally be measured to 0.1 ft relative to the baseline PBM or TBM control. In the surf zone, topographic elevation accuracy begins to degrade in deeper water, notwithstanding the temporal variations of the seabed due to the turbulent surf. Thus, any "accuracy standard" for measurements in the land sections or surf zone cannot be specified given the short-term changes of the topography, which may occur in minutes after the observation. The deviations shown in Table 11-1 for these areas are representative of the typical survey accuracies over changing, irregular terrain, not repeated survey comparisons. Therefore, any stated "accuracy" is temporal and valid only for the point in time the observation was made. Offshore hydrographic depth measurement accuracy will vary with the depth of water. In the near-shore surf zone, extreme vessel motions must be corrected with either inertial and/or inertial-aide GPS methods. Table

11-1 also lists recommended datum connections and relative accuracies generally required on beach and shoreline protection projects. Since the accuracies are shown relative to a local fixed reference monument (LPCP), they will approach the achievable repeatability levels for beach fill measurement & payment surveys. This table is intended as general guidance. Site-dependent factors may require variations from this guidance.

Table 11-1. Recommended Survey Elevation Accuracies Common to Various Shore Protection Projects.

Bench Mark/Activity	Std Dev (95%)	Relative to
Primary Project Control Point (PPCP)	± 0.25 ft	Regional NOAA/NGS NSRS and NOAA tidal NWLON network
Local Project Control Points (LPCP)	± 0.02 to 0.05 ft	PPCP
Construction TBMs (hubs, nails, etc)	± 0.02 to 0.05 ft	LPCP
Beach fill construction grade stakes	± 0.1 ft	LPCP or TBMs
Beach fill grading tolerance	± 0.5 ft	LPCP or TBMs
Beach profile surveys		
Topographic—land section	± 0.25 ft	LPCP or TBMs
Topographic--surf area [1]	± 0.4 ft	LPCP or TBMs
Hydrographic--surf area [1]	± 0.5 to 1 ft	LPCP or TBMs
Hydrographic—offshore [1]	± 0.25 to 0.5 ft	LPCP or TBMs
Feasibility or Sand Transport Studies	± 0.2 ft	LPCP or TBMs
Offshore borrow area excavation	± 0.5 to 1 ft	PPCP
Shore protection breakwater caps	± 0.2 ft	LPCP or TBMs
Offshore stone placement (jetties, breakwaters, etc)	± 0.5 to 1 ft	PPCP, LPCP, or TBMs

[1.] Assumes carrier phase RTK and/or inertial-aided GPS measurement systems are employed. Direct Measurement Techniques (i.e. CRAB or sea sled) accuracies in deeper water may be better than those shown. Temporal accuracies in varying beach and surf areas are a function of the survey technique and equipment, not those based on any repeated testing.

e. Horizontal accuracy. Relative horizontal accuracies obtainable using carrier phase RTK topographic or hydrographic survey methods should be in the order of ± 0.2 to 0.5 ft; again relative to the local PPCP or LPCP bench mark. These horizontal tolerances are acceptable for breakwater or jetty surveys. On beach profile surveys, acceptable horizontal tolerances are much larger, especially in the surf zone where visual topographic alignment is used by a wader with a level rod. In such cases, variations from the intended profile line can exceed 5 ft or more (i.e. cross track error). These variations are usually not significant to the end user or volume computation.

f. Florida standards for beach erosion control studies. The Florida Department of Environmental Protection (FL DEP) has published survey data collection and processing standards for erosion control projects—"Monitoring Standards for Beach Erosion Control Projects," (DEP 2004). The intent of these standards "is to provide for systematic physical data collection monitoring of erosion control projects along Florida beaches for beach management and regulatory purposes." These standards cover topographic and bathymetric profile surveys, bathymetric surveys for open water areas, aerial photography, and aerial photography for environmental assessments. An excerpt of some the requirements for beach and offshore profiling surveys in this document are listed in Table 11-2 below.

Table 11-2. Florida DEP Standards for Beach Profiling Study Surveys.

	Upland Profiles	Offshore
Hydrography		
Horizontal Datum (1990)	HARN NAD83 (1990)	HARN NAD83
Vertical Datum	NAVD88	NAVD88
Reference PBM Accuracy	≥ 2nd Order	≥ 2nd Order
Control Surveys of Reference PBMs	[meet NGS guidelines for 5-cm GPS-derived heights]	
Profile Spacing	[approximately 1,000 ft typical or as specified in SOW]	
Accuracy-Horizontal (RMSE)	±3 ft	±2 ft
Accuracy-Vertical (RMSE)	±0.16 ft	±0.2 to ±0.5 ft
Coverage	150 ft landward of vegetation	3,000 ft or (-) 30 NAVD88
Density along profile	25 ft and breaklines	25 ft and breaklines

Off-line Horizontal Deviation	NTE ±3 ft		NTE ±30 ft
Topo-Hydro Time Difference	[	NTE 14 days	]
Maximum Allowable Sea State	n/a		3 ft

SECTION I

Coastal Engineering Survey Techniques

This section describes the various techniques used by Corps districts to perform surveys in near shore areas. Advantages, disadvantages, and recommended quality control procedures for the various survey methods are outlined.

11-4. Differential Leveling Methods. A standard differential level and level rod is a simple method for obtaining beach profiles out to wading depths in the surf zone, as shown in Figure 11-4. A differential level can be set up at any location on the beach suitable for backsighting on a PPCP or LPCP, and foresighting elevations on a 25 ft expandable level rod along the profile line. Stakes (range poles) need to be preset along the range profile line so the rodman can maintain alignment visually. Distance along line can be measured using a lightweight tape or string tag line fixed at the baseline LPCP monument. Alternatively, a hand-held EDM can be used to measure the distance from the LPCP to the level rod. (Older stadia distance methods are rarely used today). The rodman progresses out along the profile range and shots are taken at preset distances (e.g., every 10 or 25 ft) or breaks in grade. If a tag line is used, even increments along line can be taken. The level instrumentman records the tagline/EDM distance and rod elevation in a field book. The rodman wades out into the surf as far as possible while holding line. Final grade elevations to the required reference datum are reduced manually in the field book. These profile offset and elevations are then input to a spreadsheet for subsequent conversion to georeferenced coordinates or volume computations. If an EDM (reflector type or reflectorless) is used, then increments are paced by the rodman and actual distances shot by the EDM. Some specifications require the use of electronic data collection in order to ensure cross track error tolerances are maintained and to reduce the chances of error in manually recording elevations.

a. Limitations on this method include large grade differentials between the LPCP (often atop a dune) and the project grade. The instrument "HI" needs to be set near the LPCP elevation in order to maximize shots on the 25-ft rod at the furthest offshore reaches. In some cases, a TBM will need to be established on the intermediate beach area. Maintaining horizontal alignment relative to the required profile line becomes difficult for the rodman out in the surf zone. Deviations of 5-ft or greater are common. Alongshore currents affect the ability of the rodman to maintain adequate tension on the tape or tagline, thus affecting the accuracy of the offshore distance measurement.

b. The rodman has a most difficult position on this crew. He must maintain tag line intervals, hold alignment visually on the range, and stabilize a 25-ft rod vertically.

c. A three-man crew is generally required on these surveys—an instrumentman, rodman, and helper to set ranges and maintain the fixed end of the tag line or operate the EDM.

d. An EDM is the recommended method for measuring distances along line, as opposed to a tag line. Tag line measurements over 500 ft degrade rapidly; thus, an intermediate turn point may need to be set along line. Similarly, since some hand held EDMs have limited ranges, an intermediate point may need to be set along the profile line.

e. The major advantage of leveled profiles is its use in daily beach fill monitoring surveys. Sometimes the rodman can reach the offshore limit of fill by wading. A small kayak or inflatable raft may also be used to obtain the deep water shots—Figure 11-5. This eliminates the need to launch a full-size survey boat each day to monitor construction progress and verify fill grades.

Figure 11-4. Beach profiles using a level and tagline for control. On left photo, fixed end of tag line is held at TBM next to grade stake. Range poles or grade stakes are used for visual alignment. Rodman on right photo is shown with 25-ft level rod.

f. Elevation accuracy of shot points is usually at around ±0.2 ft since a differential level is being used. The level should be frequently "peg tested" since backsight and foresight distances are highly unequal. Levels should also be "closed" between two LPCPs on the baseline—before and after profile line elevations are observed. Horizontal accuracy relative to the profile line is typically ±5 ft.

Figure 11-5. Kayak for obtaining deep water points just beyond wading range in Gulf of Mexico. Note that updated (2012) Corps policy requires surveyors to wear approved PFDs when working on a platform such as this.

11-5. Total Station Methods. The Total Station (Figure 11-6) is used for controlling topographic survey position and elevation measurements on coastal engineering surveys. The Total Station is set up over a known PPCP or LPCP and backsighted on another PPCP or LPCP. The instrument is sighted on a reflector attached to a fixed height pole held by the rodman. The instrument records the horizontal and vertical angles to the reflector and automatically adjusts and records the absolute elevation of the point on the project datum. The Total Station does not directly provide alignment for the rodman. Normally range poles are previously set along the desired profile line using the Total Station software, and the rodman visually aligns himself out to wading depth. If the Total Station is set up over the range profile LPCP bench mark, then the rodman can be aligned using hand signals. Alternately, stake-out software in the data collector can be used to align the rodman along the profile line. Points are taken along the profile line at paced distances and/or at breaks in grade. Profile line distance and elevations are automatically recorded and georeferenced in the controller.

a. Limitations of this method are the distance from the LPCP on the baseline to the offshore end of the profile line. Often these distances (over 1,500 ft) may be beyond the range of the Total Station EDM and the trigonometric elevation accuracy. Having to establish supplemental Total Station traverse TBMs out on the beach may be involved or not feasible—especially during beach fill construction. In some instances, a Total Station may be used to control an offshore survey vessel out to limited distances. Tracking a moving reflector aboard the survey vessel is usually difficult, so this positioning method is rarely employed.

b. QC checks should include tests over an adjacent LPCP at a distance comparable to those observed on profile lines. Elevations should check to ±0.2 ft.

c. A minimum crew of two persons is required for performing a Total Station beach survey. A robotic Total Station may be used for the topographic or wading portion. The advantage of a robotic is that the prism is constantly tracked by the total station, eliminating the

need to manually sight in the prism. The range of a robotic system will generally exceed a conventional total station. A robotic Total Station would entail use of a 2-m fixed height pole and remote controller.

Figure 11-6. Total station control of topographic beach profiles.

11-6. Real Time Kinematic GPS Methods. RTK survey methods are largely replacing the above leveling or total station techniques. RTK methods are readily adaptable for performing both the land topographic and offshore hydrographic surveys. In addition, both portions are on the same horizontal and vertical reference systems. Most coastal projects can be easily covered by a local GPS base station set over a PPCP. If a regional Real Time Network (RTN) coverage is available, then a local RTK base is not needed. A rodman obtains topographic range profiles with a GPS antenna/receiver atop a fixed-height 2-m pole. Both dune and offshore wading portions of the profile are simultaneously obtained. A survey controller (e.g., Trimble Survey Controller) records and transforms data using wired or Bluetooth connections to the GPS antenna. LPCP and range profile data are pre-entered into the controller and guidance/alignment is obtained using stake-out software. Profile data are recorded continuously along the range by time or incremental distances, along with grade breaks. Offshore hydrographic profile data is recorded using single beam and RTK systems as described in Chapters 4 and 7. Recorded data from the topographic and hydrographic portions is transferred from the data collection

controllers (or HYPACK) to a computer/CADD system for subsequent processing or volume computations.

a. Wading depths in the surf zone are limited by the antenna height and ability to water-proof recording instruments. A 3- or 4-m fixed height pole allows for deeper depths to be obtained if deploying off a floating platform (e.g., an inflatable raft).

b. If a permanent RTK base station has been established, or a RTN network is available, only one person is required to perform the topographic portion of the beach profile. A two-person crew is recommended in remote areas outside the established beach fill construction zone. When working in an active construction zone, where there are bulldozers, front-end loaders, etc. working, a second person is highly recommended to maintain a lookout for moving construction equipment. It is common practice for the dredging company to require crews to check in with the beachfill foreman prior to working in the active area. Dredging companies may also require all personnel working on a project to complete required safety training.

c. RTK QC check shots should be periodically taken on baseline LPCPs—e.g., every few profile lines. A tolerance of ±0.2 ft is typically allowed.

11-7. Coastal Amphibious Research Buggy (CRAB). The CRAB is a topographic survey platform developed by the ERDC Coastal and Hydraulics Laboratory (CHL) at its field research facility in Duck, NC. It has been in operation since the 1980s. As shown in Figures 11-7 and 11-8 it is a self-powered rigid platform capable of surveying profile lines out to approximately 20 feet of water. The top of the platform is positioned using either Total Station or RTK methods described above. The elevation of the grade is projected down from the top, with applicable tilt corrections applied. Data are recorded and processed by a GPS controller device. The CRAB is limited to hydrographic surveys of smooth sand beaches due to its size, instability, lack of mobility, and slow speed. The CRAB is especially useful during winter conditions, where sharks are present, or in contaminated water. Its ability to survey out to 20 ft water depths provides an accurate measurement profile in these depths—estimated at ±0.3 ft at the time the measurement is taken.

a. Great Lakes Dredge & Dock Co. currently operates CRABs on renourishment projects to obtain offshore survey data during beach construction. RTK elevation data at the upper platform is recorded on a Trimble Survey Controller. When pre- and post-fill sections are run at 100-ft spacing, typically, 30 to 50 sections can be run in one day. The CRAB can obtain some beach topo data but upland data to the dune line is obtained by traditional RTK topo methods.

b. The CRAB is typically operated by one person, who both drives the platform and performs the data acquisition. A second person may be required for safety reasons. Mob and demob costs are high; thus, the CRAB is most effective when deployed on long-term beach renourishment projects.

11-8. Survey Sled Methods. Sled survey systems were developed to collect continuous survey data from the dry beach, through the surf zone, and into the nearshore. Similar in concept to the

CRAB platform, sled surveys provide direct elevation measurements from the seabed. The system consists of a mast some 30 ft high with a cluster of reflective prisms or a GPS antenna at the top--see Figure 11-9. The mast is mounted to an aluminum frame sled. The sled is pulled along predetermined lines across the beach and into the nearshore by a LARC to a maximum

Figure 11-7. CRAB. Hydrographic survey platform used for research purposes by the ERDC Coastal and Hydraulics Laboratory research facility at Duck, NC. (ca 1980s)

depth of about 30 ft. A land vehicle may be necessary for winching the sled back onto the beach from the water. As the sled is being towed, a Total Station set over a LPCP is used to track the prism on top of the mast and record the horizontal and vertical positions at regular time intervals. Using GPS, a cable is extended from the sled to the LARC. Alternatively, the GPS positions can be broadcast to the shoreline via radio telemetry. The sled provides a relatively accurate method of collecting complete profile surveys. Approximately 25 - 30 minutes are required to sample along a 1,000 ft profile line. Thus, only 10 to 20 profiles can usually be obtained in one day. Sled surveys are now rarely performed by USACE districts.

a. Surveys can be conducted using this method in areas where the beach is easily accessible. Survey sleds do not perform well on irregular bottoms or areas where rock or reef outcroppings are prominent. Such conditions can cause the sled to tip over or become snagged. Sleds have been known to be stable in breaking waves up to 15 ft; however, since the sleds are typically towed by LARC through the surf, the working conditions are limited by that of the towing vessel.

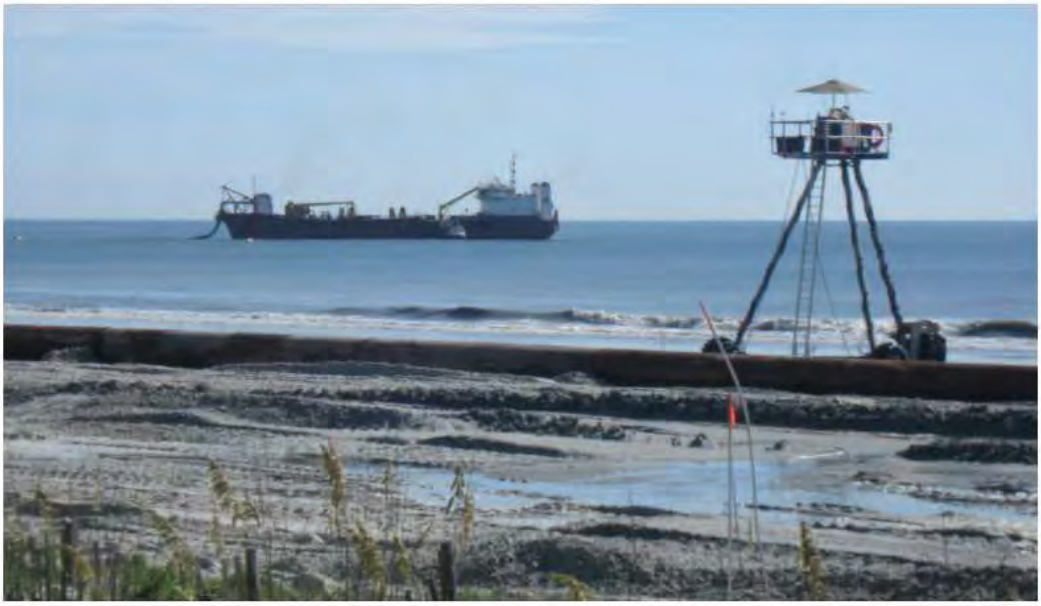

Figure 11-8. One of the CRABs operated by Great Lakes Dredge & Dock on a 2011 Beach Renourishment Project at Jacksonville Beach (Duval County), FL. The dredge in the background is shown at the beach pump-out site. (Jacksonville District).

b. Sled surveys are extremely labor intensive, requiring a crew of six (6) or more persons. Given the high survey cost, the Corps and a few A-E firms rarely utilize this survey method. Like the CRAB, the sled provides accurate elevation data in the surf zone where traditional single-beam hydrographic surveys degrade. Those specifying requirements for sled surveys must weigh the added costs versus the required profile accuracy.

11-9. Nearshore and Offshore Profile Acoustic Measurement Methods. Single beam hydrographic survey systems and methods outlined in Chapter 4 are used to obtain profile data offshore of the topographic survey limits. When possible, hydrographic surveys are performed at high tide in order to maximize overlap with the land topographic section. Survey or study requirements will normally specify the outer limit by distance (e.g., "3,000 ft from the baseline range monument") or to a maximum depth of closure (e.g., "-30 ft NAVD88").

Figure 11-9. Sled profiling system—LARC ("Lighter, Amphibious, Re-Supply, Cargo") with towed sled. Used to collect profile data through the surf zone and into the nearshore areas. (New York District)

a. Survey vessels. USACE Districts have used nearly every type of boat on beach profile surveys. These range from 12-ft open skiffs to 65-ft survey boats. In general, conventional survey boats in the 19- to 26-ft range are employed. The type of vessel selected is highly dependent on the surf zone depths and potential adverse wave actions at the near-shore end of each line. Due to the possibility of taking in water while broaching in the surf (and perhaps overturning), the vessel stability, power, and instrumentation must be designed to extricate and recover from such an event. Boat maneuverability in the surf zone turn is also a major factor—dual outboard engines are strongly recommended on larger vessels operating in these environments. For these and other reasons, recent trends have been to utilize smaller platforms to perform these surveys. These include use of jet skies and inflatable rafts.

b. Single Beam and multibeam systems. Since individual profiles are being surveyed in relatively shallow water, single beam systems are used almost exclusively for these surveys. If additional bottom coverage is required, multibeam systems may be used at maximum array width (e.g., 8 to 15 times water depth), recognizing that data on the outer arrays is marginal in shallow water. Both single beam and multibeam systems become marginal in surf zones with aeration in the water; thus, maximum coverage using topographic methods and direct measurement techniques is obtained in these surf zones in order to minimize acoustic coverage. Traditional single beam echo sounders are used on larger vessels—e.g., Ross, Odom, Reson. On smaller platforms portable systems specifically designed for shallow water surveys are often used—e.g., the Seafloor Systems, Inc. HydroLite system that has both positioning and depth measurement components in a compact unit.

Figure 11-10. Inflatable raft on left is used on near-shore beach profile surveys. Water-proofed shallow-water depth sounder, RTK, and a laptop running HYPACK are installed aboard the raft.The Corps survey vessel on right must have sufficient engine power to maneuver through surf zones during turns at the inshore end of each profile line.

c. Positioning and orientation systems. Survey vessels may be positioned using either code phase DGPS or carrier phase RTK methods. Kinematic positioning is the preferred method for determining water levels during the hydrographic portion of the survey because it is nearly impossible to obtain accurate water levels from a remote tide staff or automated gage. Larger boats may have POS/MV and IMU systems to correct for vessel motion; however, larger vessels may be limited in how close they can get to the surf zone. Inertial orientation systems may or may not be used on a smaller open raft or 'jet ski' type survey platform. Due to the dynamic nature of the surf zone, heave should be measured with an IMU, MRU, or RTK.

d. Data recording. Survey data are recorded on a survey controller or a laptop using HYPACK software. HYPACK is used to process and edit the data and merge land and water profile sections for subsequent applications. During processing, overlap points should be verified to meet specifications for the project. Whether the hydrographic or wading portion of the survey is done first, the distance from the reference baseline should be noted such that it can be used to ensure adequate overlap is being obtained.

11-10. LIDAR Bathymetry and Topography Methods. A state-of-the-art LIDAR system coupled with high precision carrier phase RTK and inertial positioning is a technology that can be utilized for conducting hydrographic and topographic beach surveys. An airborne hydrographic LIDAR system operates by emitting laser pulses from an airborne platform that travel to the water surface. For each laser pulse, some of the light is reflected from the surface to onboard receivers. The remaining energy propagates through the water column, reflects off the sea bottom, and returns to the airborne sensor. The time difference between the surface light return and the bottom return corresponds to water depth. The maximum depth detection is limited predominately by water turbidity. As a rule-of-thumb, the system is capable of sensing depths equal to two or three times the visible depth. Sounding densities can be adjusted by flying higher or lower at different speeds or by selecting multiple scan widths. With the ability

topographic and hydrographic survey data an airborne LIDAR system can simultaneously conduct complete beach and structure surveys above and below the waterline, and is particularly useful in areas where human access is difficult or restricted. The technology is also a useful tool for post-storm erosion assessments. Data acquired from LIDAR can be used to generate vertical profiles, cross sections, contours, and volumetric analysis.

a. Airborne LIDAR is capable of rapidly collecting relatively dense survey data over large areas in a short amount of time. However, the technology is highly dependent on water

clarity and should not be considered for areas with chronic high turbidity. Costs pertaining to system mobilization can be high and may be a limiting factor when considered for surveying small projects. It is beneficial to schedule surveys along with other projects in the same general vicinity to share and minimize mobilization costs. Users of LIDAR survey data should possess data processing equipment and software capable of handling large data sets.

b. LIDAR observations are not as accurate as profile data obtained from traditional topographic and acoustic survey systems described previously. LIDAR accuracy also degrades in the turbulent surf zone. Therefore, LIDAR systems are not used for construction measurement and payment purposes. However, they are far more efficient than traditional survey methods for broad area coastal studies. LIDAR accuracies are typically ±0.5 ft on land and ±1 ft under water. Increased accuracies are possible with lower altitude flights, such as from unmanned aircraft or helicopters.

c. Additional details on the principles of LIDAR measurements can be found in the IHO Manual of Hydrography (IHO 2005).

Figure 11-11. RTK measurement and payment surveys for beach renourishment projects.

SECTION II

Coastal Project Applications

This section contains examples of construction surveys on coastal projects. Beach fill measurement and payment techniques are described.

11-11. Beach Renourishment Measurement and Payment Surveys. During beach fill construction, profile surveys are continuously (i.e., daily) performed to monitor grade levels, both on the beach and into the water. As shown in Figure 11-12, beach profile sections are established from the profile templates and baseline control provided in the construction drawings. Each profile section (and template) is referenced to a point on the baseline and has a fixed azimuth—see Figure 11-13.

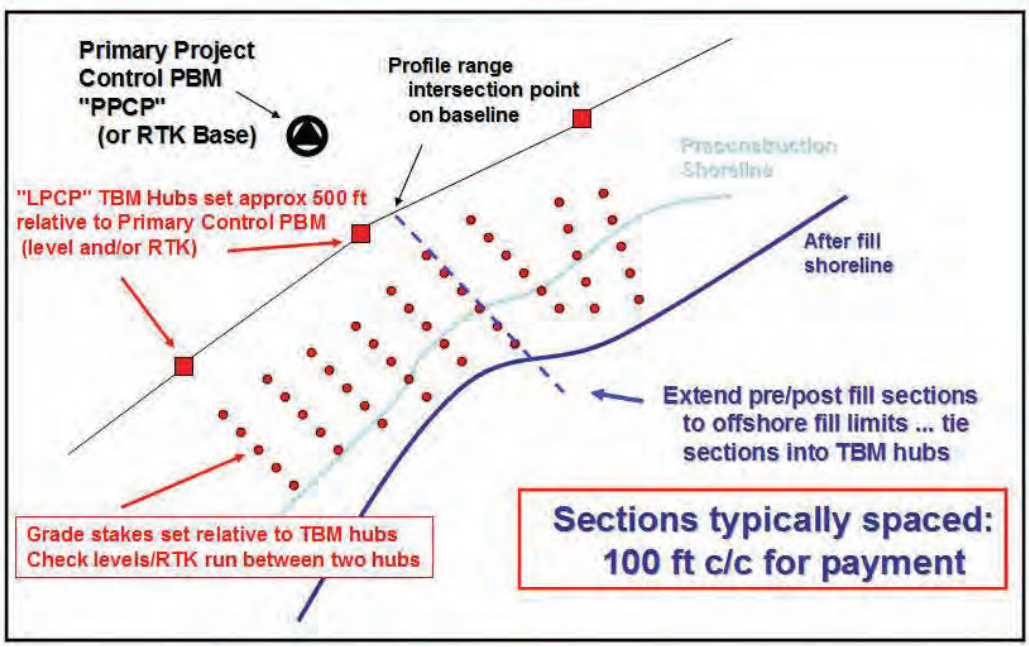

Figure 11-12. Profile sections for beach fill measurement & payment. Profile lines are defined in position and azimuth relative to established baselines and/or fixed PBMs.

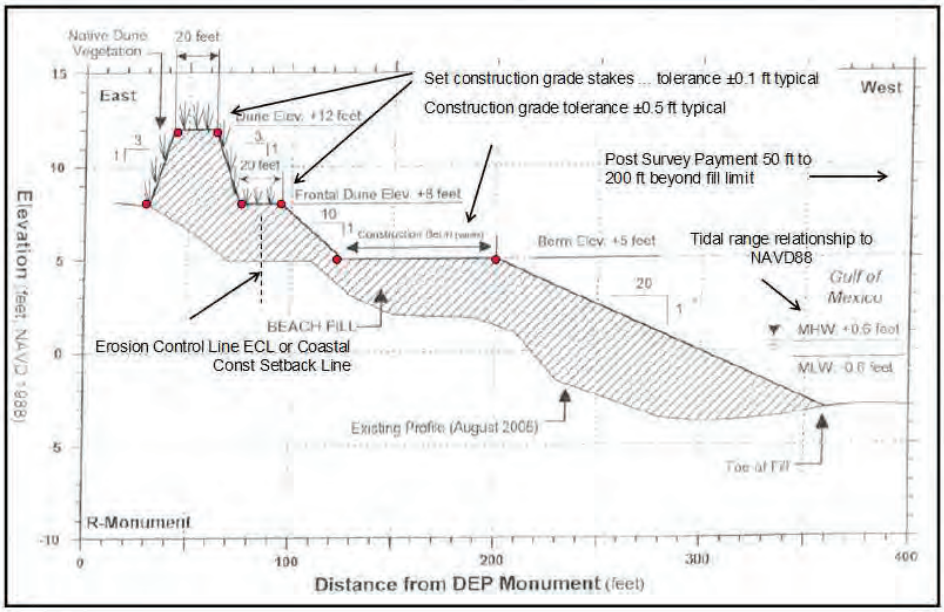

Figure 11-13. Typical beach profile template referenced to a permanent "DEP Monument." The X-Y location and range azimuth for the reference monument were shown on a separate table.

a. RTK control. Most renourishment projects now employ RTK for all operations. This includes not only the surveys but also dredging operations at the borrow site. An established RTN may be used or a permanent local RTK base station set up for the project. As in any survey, RTK site calibration is an essential QC requirement using either a RTN or local base station.

b. Grade staking. (Figure 11-14). A variety of grade stakes are used during beach fill contracts. In sandy conditions, long metal rods are often used with top flagging visible to the dozer operators. Grades and tolerances are marked with color-coded flagging on the rod. Any grade staking survey technique may be used to set the elevation on the grade stake relative to the profile template. This includes differential levels, total stations, or RTK. In general, RTK methods are now the most economical and efficient. Survey controllers are pre-loaded with each profile template on the project. Grade staking software and displays in the controller will automatically compute the required elevation at any point along the template and at breaks in grade. Grade staking can be minimized or eliminated if machine control systems are employed on the project.

c. Survey time requirements. Given the rapidly changing nature of a beach, surveys must be completed before and after placement. Pre-fill (i.e., "pre-dredge") surveys are normally performed within two (2) weeks of intended placement. Often weather delays will require a repeated pre-fill survey to stay within the two-week window. Erosion from a large storm may

require repeating the pre-fill survey prior to placement. Post-fill surveys are usually required as soon as possible after the material has been placed and graded—ideally the same or next day to verify grade before pipelines are relocated. If sections are not within tolerance these surveys are repeated. On site "field-finish" data processing and plotting is essential.

Figure 11-14. Setting a metal grade stake with driving hammer during active beach fill construction. Pre-drilling the stake hole with a portable auger makes for easier driving. RTK stake out observations are used to determine grade levels relative to the template along the profile range. Ft. Pierce Beach Renourishment Project. (Jacksonville District)

d. Volume computations. (Figures 11-15 to 11-18). Beach fill volumes for construction payment are generally computed using Average End Area routines. Surface–to-surface TIN methods have little application, other than perhaps in assessing quantities of material removed from an offshore borrow area. Although profile sections are run on 100-ft intervals, the sections are not necessarily perpendicular to the reference baseline; thus, each template is shifted relative to the next template. Range profile azimuths may not always be parallel. In addition, successive templates may change slopes or elevation grade intersects. This variability requires extreme care in setting up volume computations in software. Given the variability in template elevations and orientations, the "Standard HYPACK Method" of beach volume computations is recommended. (Refer to HYPACK User Manual, "Cross Sections & Volumes—CSV" (HYPACK 2012)). This Standard HYPACK Method is specifically designed for Average End Area volumes of sections that have different alignments (i.e., non-parallel) and different lengths, as is typical on beach fill sections non-perpendicular to the reference baseline.

e. Borrow area surveys. Borrow area surveys may be especially critical, especially in environmentally sensitive areas. Often sand sources are limited and dredging is restricted to specified locations and depths. In some cases, overdepth dredging penalties may be imposed. Both single beam and multibeam survey methods are used for these surveys. RTK control is recommended.

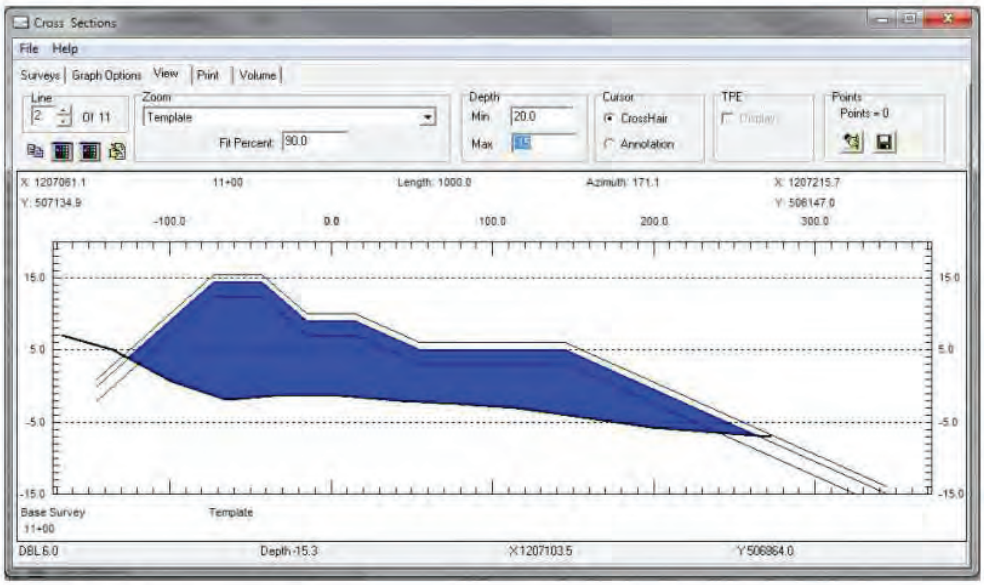

Figure 11-15. Pre- and Post-Fill beach profile templates in HYPACK "Cross Section & Volumes" program. Also shown are tolerance templates above and below grade.

11-12. Offshore Jetty, Breakwater, and Groin Surveys. Surveys for these structures are performed for design, construction, and maintenance. Traditional topographic survey methods entailed establishing a baseline atop the centerline of the structure (if above water), and cross-sections then run (by tag line, total station, or RTK) normal to the structure every 50 or 100 ft O/C, extending past the toe of the foundation stone (Figure 11-19). Depths are measured by lead line, level rod, or sounding pole at a relatively dense interval. Echo sounding (vertical single beam or multibeam) may be used if return signals are adequate in the rock structure. During stone placement, submerged areas may be surveyed using hydrographic single beam methods.

a. The above manual survey techniques are extremely labor intensive and often hazardous. They are only used when more modern survey methods are impractical.

b. Survey of offshore breakwaters or jetties are now more economically and accurately performed using a variety of remote sensing techniques. Multibeam sonar heads may be rotated to assess underwater conditions of the armor or foundation stone. On inaccessible or broken breakwaters, low-altitude airborne, vessel mounted mobile, or terrestrial LIDAR surveys may be conducted to map the rock placement and voids above the surface. The LIDAR topography and multibeam hydrography models may then be merged in order to evaluate the overall condition of the structure and estimate repair quantities needed. Examples of some USACE projects employing these technologies are shown in Figures 11-20, 11-21, and 11-22. Refer also to the underwater structure investigation survey examples in Chapter 9.

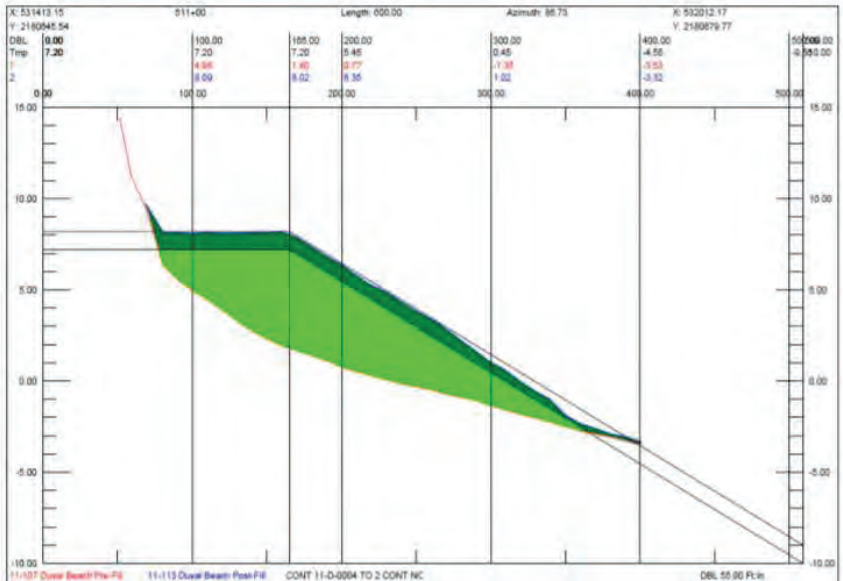

Figure 11-16. Pre- and post fill beach quantity computations. Output details material relative to the design template and the upper (1-ft) tolerance template. A slope sloughing compensation option (i.e., box cut) is calculated. Duval County beach renourishment, Station 511+00, August 2011. (Jacksonville District)

ST. JOSEPH PENINSULA EROSION CONTROL PROJECT
VOLUME SUMMARY - JANUARY 3, 2009

STATION 23+00 - 31+00

BD Station Name	BD Date	AD Station Name	AD Date	Total Req. Area (sf)	Total Req. Volume (cy)	Tolerance Area (sf)	Total Tolerance Volume (cy)	Additional Pay Area (sf)	Additional Pay Volume (cy)	Total Pay Volume (cy)	Accumulated Pay Volume (cy)	Non-Pay Area (sf)	Non-Pay Volume (cy)	Accumulated Non-Pay Volume (cy)
2300	12/29/08	2300	01/03/09	68.62	0.0	0.00	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0
2400	12/29/08	2400	01/03/09	464.79	985.9	22.82	42.2	4.2	7.7	1035.8	1035.8	0.00	0.0	0.0
2500	12/29/08	2500	01/03/09	503.76	1790.1	53.64	141.3	27.4	58.3	1969.8	3025.6	0.00	0.0	0.0
2600	12/29/08	2600	01/03/09	532.70	1915.6	57.63	261.1	21.3	90.0	2266.7	5292.3	0.89	1.6	1.6
2700	12/29/08	2700	01/03/09	576.71	764.8	95.92	129.8	23.3	31.5	946.2	6238.5	128.36	91.4	93.1
2800	12/29/08	2800	01/03/09	613.36	2190.0	67.54	337.6	17.0	74.1	2601.7	8840.2	184.14	575.1	668.1
2900	12/30/08	2900	01/03/09	523.72	2092.5	28.05	212.7	0.0	31.3	2336.5	11176.7	0.89	340.5	1008.6
3000	12/30/08	3000	01/03/09	133.76	1209.9	0.00	51.6	0.0	0.0	1261.5	12438.2	0.00	1.6	1010.3
3100	12/30/08	3100	01/03/09	0.00	246.1	0.00	0.0	0.0	0.0	246.1	12684.3	0.00	0.0	1010.3

Total Pay Volume (cy)	12,684.3
Total Non-Pay Volume (cy)	1,010.3
Total Placed Volume (cy)	13,694.6

Figure 11-17. Typical Beach Renourishment Project Volume Computations. 100-ft section accumulations for payment. Includes pay area quantities, tolerance area quantities, non-pay area quantities, and (not shown) slough/box cut allowance quantities. (Gahagan & Bryant, Inc.)

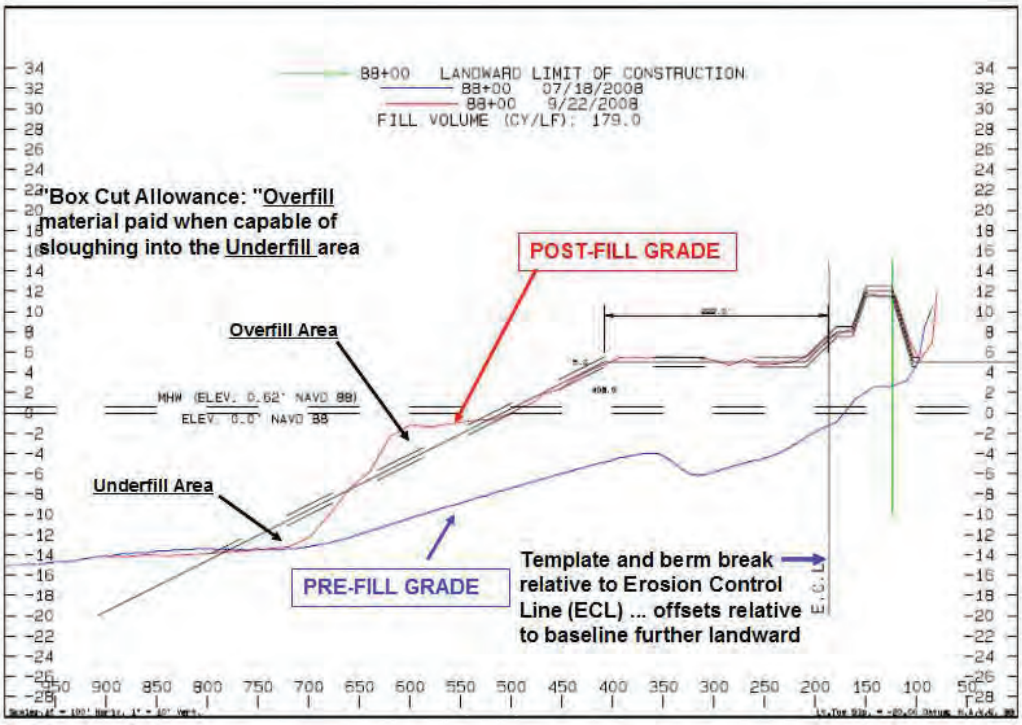

Figure 11-18. Typical pre-and post-fill sections with excess material placed at surf zone for eventual sloughing to equalize final section. (Manson Construction and Gahagan & Bryant, Inc.)

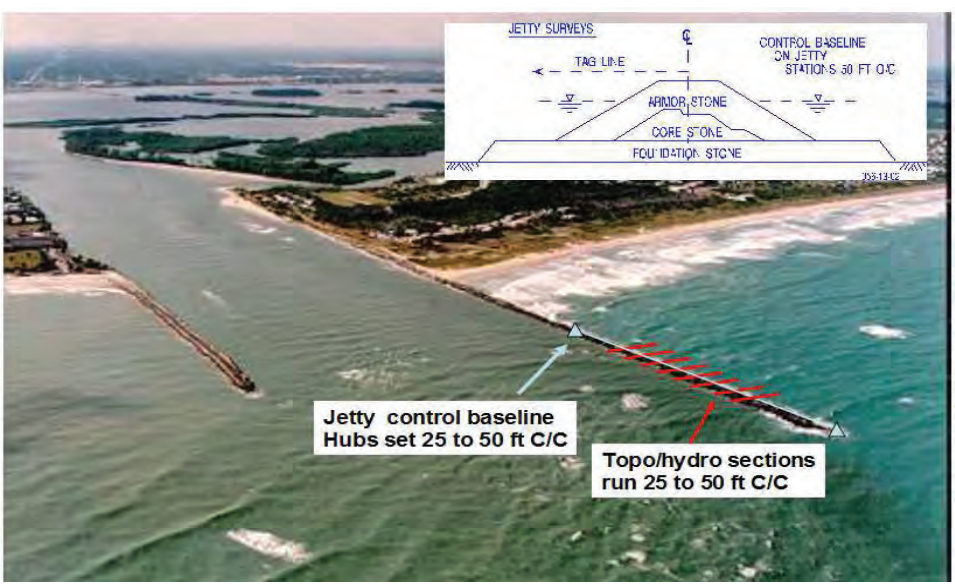

Figure 11-19. Jetty and breakwater surveys—traditional baselines set along structure for cross sectional surveys.

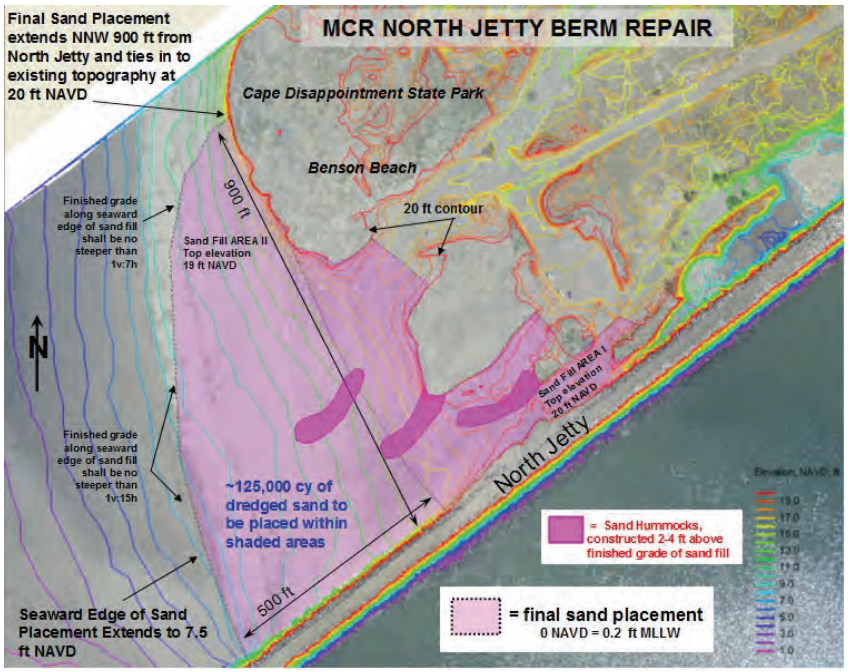

Figure 11-20. Surveys for North Jetty Berm Repair, Mouth of Columbia River (MCR). Surveys conducted for this project included vessel mounted multibeam to cover the underwater portions of the jetty, airborne LIDAR, beach profiles and jet ski single beam to cover the surf zone. (Portland District)

11-13. Subsurface Probings. Hydrographic survey crews are occasionally tasked to obtain either dry rod or washed offshore probings, often over potential sand sources for proposed beach renourishment projects, or to obtain depths to hard rock. When such geotechnical data are intended for use in contract plans and specifications, DGPS survey positional accuracy is required for the probe location and offshore elevation reductions. Sample field notes are shown in Figure 11-23.

Figure 11-21. Combined terrestrial laser scanner with multibeam hydrographic surveys of Harbor of Refuge Light - Lower Delaware Bay. (Philadelphia District)

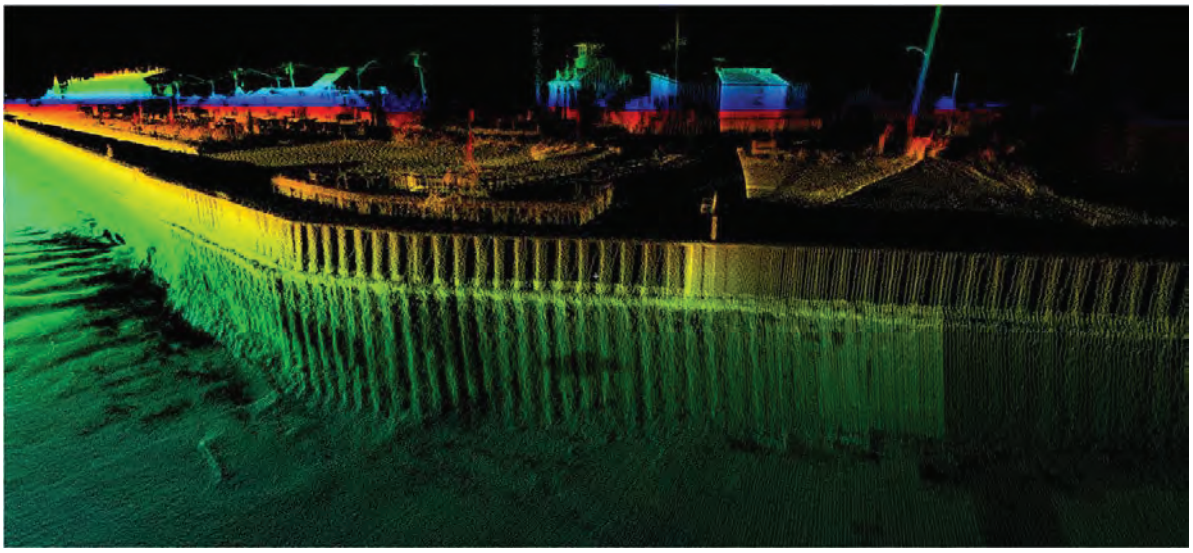

Figure 11-22. Combined vessel mounted mobile laser scanner with multibeam hydrographic surveys of sheet piling structure – Manasquan Inlet, NJ (Philadelphia District).

STA	+ ROD	H.I.	− ROD	SDG.	PROBE	ELEV		REMARKS:	10 MAY 70
BM-1						30.05			
	5.15	35.20							
10+00			5.6			29.6		TOP GROUND	
					0	29.6		TOP GROUND	
					12.2	17.4		TOP HARD MATERIAL, UNABLE	
								TO PENETRATE	
12+00			6.6			28.6		TOP GROUND	
					0	28.6		TOP GROUND	
					14.2	14.4		TOP ROCK	
			9.2			26.0		WATER SURFACE OF CANAL	
13+50				5.0		21.0		TOP WATER	
					0	26.0		BOTTOM CANAL	
					5.0	21.0		BOTTOM CANAL	
					16.0+	10.0		REQUIRED PROBING	
BM-2			5.05			30.13		PUB. ELEV = 30.13	
NOTE: THE FIELD NOTES WILL SHOW IF DRY									
ROD OR PUMP USED FOR PROBINGS. IF PUMP USED									
SEE CRITERIA FOR DRIVE BORINGS AND									
PROBINGS WHICH WILL BE FURNISHED									
WITH REQUEST FOR SURVEY.									

Figure 11-23. Probing field notes.

a. Sub-bottom profiling by seismic reflection methods. Seismic reflection systems operating between 400 Hz and 14.0 kHz are useful for continuous high-resolution profile recordings of the top 30 m of material below the sea floor. The high-energy signal will penetrate and reflect from interfaces between nonhomogeneous materials. The receiving package will detect the reflected signals and convert them into a profile recording. The display is real time with relatively high ship speeds of 10 to 12 knots. Typical resolution is 0.5 m. When properly calibrated, the systems can also be used for obtaining bathymetric profiles. Depth of sub-bottom penetration varies inversely with frequency. Sub-bottom depths over 200 ft have been recorded.

(1) Sub-bottom reflection data have been very useful in numerous investigations in which information pertaining to the sub-bottom strata is important. These include predredging investigations, pipeline route locations, and offshore foundation investigations.

(2) In operation, an instrument package is towed which contains both transducer and receiver. Outputs can be either analog strip charts or in digital form, which facilitates post-survey processing that enhances resolution. Other systems rely on ship-mounted transducer/receivers. For these, resolution can be reduced by ship heave, but accelerometer packages are available to measure heave for correction purposes.

b. Sub-bottom profiling by Ground Penetrating Radar (GPR). Recent experience with GPR indicates that under some conditions this technique can provide sub-bottom information. Radar designed to obtain subsurface information usually operate at frequencies between 20 and 500 MHz. To best resolve echoes from subsurface interfaces, broadband antennas are used to radiate a very short duration pulse. Low-frequency (20-100 MHz) antennas with high radiated power (0.5-2 kW) provide the greatest penetration and in most situations would be best suited for sub-bottom profiling. The depth that radar can penetrate is strongly limited by attenuation in the water and bed material, with greatest signal loss in electrically conductive water and sediment. High attenuation limits the use of this technique, making it best suited for surveys in low-conductivity fresh-water lakes and streams. On-site conductivity measurements should be taken before using radar equipment. These measurements will estimate the radar penetration. The radar frequency used will also be a trade-off between resolution and penetration. Plots of amplitude versus time for the returning pulses are usually compiled into a graphic display, producing an apparent profile of subsurface reflectors and interfaces. When the electrical properties (dielectric permittivity) of a layer are known, propagation time to the base of the layer can be converted to layer thickness, with resolution of about 0.5 m. More information on GPR techniques may be obtained from the US Army Cold Regions Research and Engineering Laboratory (CRREL).

11-14. Offshore Confined Placement or Borrow Area Surveys. Offshore material placement areas (Figure 11-24) are frequently surveyed during planning, design, construction, and maintenance phases of a project. The most frequent surveys are conducted during dredging operations and for subsequent general condition purposes. The purposes of these surveys are varied. Normally, offshore submergent areas are periodically surveyed to monitor material placement grade during construction--to ensure minimum depths and area limits are not exceeded. Surveys are also performed to locate any misplacement of dredged material outside the disposal area limits. Subsequent surveys may be required to monitor settlement or material movement. Offshore borrow area surveys are similar; however, they are used to monitor the amount of material removed from the site--usually a sand source for renourishment projects. Emergent disposal areas in offshore locations and upland confined disposal areas are periodically surveyed during construction and later to monitor settlement and available quantities for additional placement.

a. Submergent dredged material placement areas and borrow areas are typically cross-sectioned at 100- to 200-ft spacing. Survey lines are run 200- to 1,000-ft outside the disposal area limits to monitor for any misplaced material. Material quantities can be computed using either average-end-area or grid methods.

b. In the past, single, vertical beam echo sounders were used for disposal area surveys. For deep water disposal areas, multibeam survey systems are now recommended. Multibeam systems can be set at maximum beam width to obtain maximum swath widths of coverage. Note that high frequency multibeam systems may have limited depth ranges—around 150 to 200 ft on most systems. Therefore, low-frequency single-beam systems will have to be used to reach depths up to 2,000 ft.

c. During construction, offshore disposal areas may be surveyed weekly or biweekly. Subsequent monitoring surveys are performed at quarterly or annual intervals, depending on any environmental requirements/restrictions that may have been imposed on the use of the area.

d. Upland disposal areas are surveyed using standard topographic techniques. Fixed baselines are established along the top of the confining dikes and cross-sections are run internally within the disposal area and externally into the water. Total station or RTK survey methods may be employed. In cases where the confined material has not settled, a small skiff may be needed to obtain measurements. Extreme caution should be exercised when spoil material has only crusted on the top--the rodman should use a life jacket and/or lifeline should there be a danger of breaking through to water-suspended material. A sounding pole with a bottom plate may be needed in soft material.

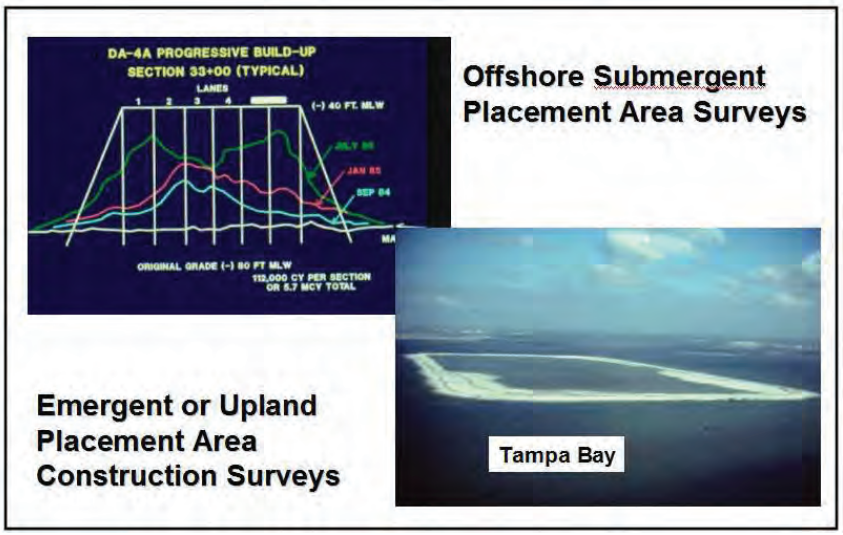

Figure 11-24. Submergent and confined disposal area surveys.

SECTION III

General Guidance on Survey Requirements for Coastal Engineering Studies

This section outlines some general planning considerations relating to coastal engineering studies and their supporting survey requirements. This guidance was developed in the 1990s by the Coastal Engineering Research Center (now the Coastal and Hydraulics Laboratory). Thus, some portions may refer to dated survey methods. It is applicable only to coastal studies—it does not apply to beach fill placement construction surveys.

11-15. Coastal Engineering Studies. Coastal project studies of all types typically require extensive and accurate beach and nearshore survey data. Acquiring such data is often a labor intensive, time consuming, and complex process, and it is often difficult to establish the success and quality of the data set after the fact. Part of this problem can be attributed to a lack of consistent guidance for planning, conducting, and properly evaluating coastal surveys. Guidance is lacking especially for defining survey requirements based on the eventual end-use of the data. Studies are performed to monitor completed beach renourishment projects along the Atlantic and Gulf Coast--common in Jacksonville, Philadelphia, Norfolk, Wilmington, and New York Districts (Figure 11-25). Surveys are performed during design to locate suitable offshore borrow area sand sources.

Figure 11-25. Beach renourishment project ca 1975--Miami Beach, FL (Jacksonville District).

a. The exact end use of a coastal study may vary, but the essential goal of most coastal survey projects is to characterize the features of a relatively large study area, often the equivalent of several square miles. The principal type of survey used to accomplish this has been a series of profile lines and this is the most familiar type of technology still in use. In addition, the same basic technology frequently can be used or applied in more than one way to produce results, which vary in accuracy, coverage density, time, cost and other factors. Interest in these approaches arises from concerns about the numerical inaccuracies of interpolating between traditional profile lines and the possibility of significant bathymetric anomalies being hidden in the blind areas between profiles. Alternate approaches that could provide denser data coverage even at the expense of having less precision in individual measurement points may produce an overall result that better represents those features important to the project.

b. It is important to match the surveying scope, including the selected technology and procedures, with the true requirements based on the eventual data use. It is essential that survey specifications originate from the project's functional requirements and that the requirements are realistic and economical. However, too frequently a survey method is pre-selected based on a combination of peripheral factors, and this selection, in effect, defines the type, accuracy and characteristics of the data. Surveying a coastal structure, for example, requires a different effort than documenting general changes on a dynamic beach several times a year; reconnaissance or condition surveys may be able to use less accurate, but broader covering, faster technologies than "payment" surveys. If numerical models require profile-type data eventually to be extrapolated and converted into gridded depths or contours, the data can be collected in that manner to start with if the need is identified as part of the surveying scope. Data end-users must have and be able to communicate a complete understanding of their needs.

c. A related issue is who should be responsible for specifying, defining, or otherwise deciding among choices for each technical question. In almost all cases the in-house survey branch will ultimately be responsible for accomplishing the work, but limitations on the number of in-house crews and their workload often result in the work being contracted. For most reconnaissance, planning, design, and similar projects, the surveys are performed by A-E or specialty surveying firms under task order contracts. For construction progress, as-builts, or pay measurement, especially on dredging-related projects, the surveys are often part of the construction contractor's scope of work and are spot-checked by in-house crews.

d. In both basic scenarios, however, a critical point is that the work is often done by outside personnel not under the direct supervision or coordination of the end users, e.g., the study manager. Once a survey request goes from the originator/end user into the survey branch/contract system, there is a danger that the originator no longer has control nor input, and the final surveying contract specifications and standards may not address the original requirements. This type of situation underscores the importance of ensuring a high level of awareness and communication on the part of all the people involved in the data collection planning and decision-making processes for a project.

11-16. Accuracy Requirements for Studies. The accuracy of beach and nearshore survey data is often stated as a major concern, but accuracy frequently means different things to different groups of surveyors. Accuracy should be broadly viewed as more than the ideal or theoretical accuracy associated with a particular instrument or system. It includes operational influences such as the site conditions, overall field collection and data reduction procedures used, and any constraints due to datum problems, lack of monuments or other control, or historical incompatibility. Project data planning goals should be less directed toward improving absolute or ideal accuracy and more toward properly understanding, characterizing, and communicating the errors and limitations in existing or proposed systems and procedures. The calculation and presentation of realistic error bands on all data is consistent with and supports the trend toward risk-based analyses in project design. Although they may recognize the need to do so, many end-users are unable to identify a specific use or type of analysis, which directly translates into a requirement for nearshore hydrographic survey accuracy, spacing or a similar standard. In addition, situations sometimes occur in which ambiguous project goals, together with the inherent lack of precision in many coastal engineering design tools and other inputs such as wave data, result in project personnel feeling that survey precision is not their highest priority. This point can be especially contrasted by surveys in the planning community with the requirement for 3rd order accuracy in real estate maps and the dramatic effect which inaccuracies in that type of data (i.e. building floor elevations and foundation positions) could have on the calculation of project storm damage reduction benefits. It is often recognized that a more formal, comprehensive error analysis to establish the effect of survey limitations on a particular project or calculation should be performed in order to better assess risk and uncertainty, but resources are not typically available for the necessary effort.

11-17. Data Density, Formats, Processing and Archiving. The issue of data density or coverage is closely related to accuracy and end-use. A general phrasing of the problem might be: "what changes, features or other data are really important?" Airborne LIDAR technologies are capable of rapidly collecting data over entire surfaces rather than profile-by-profile. However, the trade-off is in additional processing time and computing power, QA/QC difficulties in terms of checking such data, and very significant storage requirements. Procedures for intelligently editing or "decimating" can be developed, but the basic question is more one of knowing how much data is necessary to adequately characterize the site or problem of interest.

a. A negative aspect with the more highly pre-processed data is that the user is no longer directly involved in data reduction tasks such as corrections for datum, tides, or waves and does not develop an intuitive appreciation for the variability and limitations of the data. Because the raw survey data itself is no longer "handled" directly by the end users and survey data files often are not plotted and inspected for their own merit, major errors may not be noticed until problems subsequently develop while performing calculations or interpreting model results. By that point, the survey data has been so co-mingled with other potential data problems and issues that it may take considerable time and effort to identify the survey as the source of error.

b. Whether the ultimate purpose of a set of surveys is planning, design, construction or pay, the intermediate step in all projects is some type of volumetric change calculation. These

calculations are most often performed using a software program, which automates some type of algorithm involving interpolations, point-by-point differencing and extension of two-dimensional area changes to three-dimensional volumes.

11-18. Coastal Processes Affecting Surveys. The coastal margin is a unique physical environment and as a result, it presents unique challenges for collecting and interpreting all types of data including survey data. The coast is the triple interface of the atmosphere, ocean and land (EM 1110-2-1100). Surveying this interface cannot be done through the straightforward application of conventional terrestrial surveying principles; neither can adequate data be collected exclusively with traditional hydrographic surveying techniques. Both approaches - used with innovation, creativity and intuition - are necessary to properly characterize the beach and nearshore environment.

a. Unlike most terrestrial sites, the coastal margin changes and moves constantly, even within time frames as short as the time of the field survey itself. The coast is said to exist in a state of dynamic equilibrium. That is to say, it is shaped by a unique balance among wind, waves, tides and sediment characteristics (EM 1110-2-1100). The concept of dynamic equilibrium suggests that significant changes to one of these parameters can disturb the balance and produce a new system. Unfortunately for coastal engineers, planners and surveyors, sufficiently significant changes can occur within a time frame of hours, days and weeks.

b. Understanding the equilibrium condition at a particular site is further compounded by the fact that the natural forces producing the equilibrium may not be those observable on the survey day, or even the average condition observable over a short period of time. Often extreme events or perturbations in the average energy condition are responsible for the equilibrium profile or other features observed weeks or even months after the event. This phenomena may be more important to the analyst reviewing the data set and drawing conclusions for design, but it is useful knowledge for the surveyor planning the program and collecting data in the field as well. A sufficient familiarity with the natural process can ensure that modifications to a scope are made, if appropriate, in the field based on conditions observed and that any atypical events or features are noted which might make data interpretation more meaningful to the problem.

c. Very frequently in coastal planning and design, historical data is either sparse or of questionable accuracy. The reasons for this are varied, but certainly can include a lack of past interest or concern in a site and its problems, or a lack of attention to properly archiving and describing a collected data set. One result of this problem is that the coastal professional may be required to hindcast a historical condition from a very limited present or short-term past data set, and then use the hindcast condition for forecasting a future condition. This process of predicting the future based, not on the "true" past but on a "prediction" of the past is not unique to coastal projects, but is certainly more common than in most other fields of engineering design.

d. This section briefly summarizes those coastal processes that most affect the collection of survey data and is necessarily a very brief overview because of the complexity of the subject. In addition, while coastal processes occur at most sites, the range and significance vary greatly

from site to site and requires specific analysis of the local conditions as part of the scoping phase. In addition, the problems associated with the physical environment are made more complex by the fact that different data end uses may require different accuracies and density.

11-19. Overview of Coastal Processes. As noted, the coastal margin is a dynamic system that can change significantly during the time it takes to complete the field portion of a survey program. The survey program planner must have an understanding of those features most likely to change, the range of variation, and the time scales associated with each. Some aspects of time scales are straightforward and familiar to most people collecting and using coastal data. For example, it is well understood that if the water level itself is being used for a reference plane, as in most hydrographic segments of a coastal survey, that level must be continuously corrected for tidal variation if the survey extends over an appreciable portion of a tidal cycle. For most traditional surveying methods, in contrast however, wave height variations usually are not individually corrected.

a. Time scales. Classical oceanography introduced this same concept of a relationship between the length and time scales of various physical processes, called Lagrangian times and scales. Simply stated, the time frame over which a process is observed or measured should be consistent with the length scale over which the effect is felt. For example, a rough order of magnitude of the time scale for tidal cycles is $\sim 10^4$ sec. At typical water velocities, the length scale of this single cycle should also be very roughly 10^3 to 10^4 ft. This type of analysis would suggest, therefore, that if a mile-long section of shoreline would require more than three to four hours ($\sim 10^4$ seconds) to survey, tidal influences could be significantly different at the starting point of the survey than at the ending point. While the process time scale influence may not be important for every survey or site, it is necessary to perform some type of scale analysis in order to establish the level of importance. This is especially true in using newer surveying technologies for which the influence of various factors is either unknown or unfamiliar to many users.

b. Waves. At most sites wave energy is probably the primary natural forcing function responsible for shaping the bathymetry and shoreline alignment (EM 1110-2-1100). As waves approach the shore and move into shallower water depths, the water particles that have been set into orbital motion by the waves increasingly "feel" the sea floor. One effect of this is to transform a portion of the kinetic energy of the traveling waves into potential energy. The visible effect of this energy transformation is that the waves shoal or increase in height, growing steeper and more peaked, until finally they become unstable and collapse or break in the nearshore.

(1) A second equally important, but perhaps somewhat less obvious effect, is that the friction imparted to the sea floor by the transforming waves produces a shear stress which may be sufficiently great to lift sediment into the water column and make it available for transport and redistribution. The wave-induced shear is usually too transient and non-directional to drive the sediment very far. However, once it is lifted into the water, other background currents such as those resulting from the angle the waves make with the shoreline, from tides, or direct wind

stresses can take over and move the suspended sediment. In any case, the result is that the waves can move sufficient unconsolidated sediment to reshape the bathymetry. The altered bathymetry then produces a new set of water depths, which, in turn, transform the wave field differently. This iterative and continuous interaction between incoming waves and the nearshore bottom is one of the principal sources of complexity and dynamic change in the coastal environment.

(2) A further complicating factor in this process is that the waves are not constant either in height or period. For illustration and rough planning purposes, waves are often characterized as regular or "monochromatic," meaning that successive waves in the incoming field are assumed to have the same, constant height and period, and the wave form is sinusoidal in shape. These assumptions result in mathematical simplifications which allow for the use of linear wave theories. However, real waves exist in an irregular spectrum composed of inter-mixed heights, periods, translation speeds and steepness. To an observer at a fixed point in the water, the passing waves appear as a varying time series. In addition, the time series observed on one day, at one location may be very different the next day at the same point, or the same day, but a few thousand feet away. A detailed analysis of such waves requires statistical techniques and so-called non-linear or "higher order" wave theories.

(3) The reason such analyses are important and are performed in spite of their complexity is that wave energy and resulting sediment transport potential is proportional to the square of the wave height ($\sim H^2$). Alongshore variations in the wave time series cause gradients in energy that can be very significant in influencing local shoreline alignments and on the impact of any existing or proposed coastal structures or other alterations. In addition, because the water depth at which a wave begins to be influenced by bottom friction depends on the wave height and steepness, the different waves in the time series in a given section of shoreline will break over some cross-shore width (i.e. a range of depths) representative of the degree of variability in the wave series. This determines the width of the visible "surf zone" at any time and location, but is important because it may affect total sediment transport volumes and the position and prominence of features such as submerged bars or run-out channels.

(4) The wave climate at a particular location is a combination of locally generated wind waves and (usually) longer-period waves that have traveled over some appreciable distance of open water. Local seas respond rapidly to changes in local winds and the arrival timing of waves produced by distant events is unpredictable. As a result, the time scale for significant changes in wave energy and its effect on local bathymetry is often on the order of hours or days. Field work begun at a project site before a weather front moves in, and completed a day or two after it passes when the waves have laid down enough to resume work may be capturing very different and unrelated conditions.

(5) Because of the mathematical relationships among different components of all statistical distributions, even limited data or observations-- as long as they are consistently taken-- can provide insight into the entire wave climate at a site. One parameter often used is the significant wave height, "H_S," which is defined as the average height of the one-third highest waves in the series. This is a convenient approximate field measure because experience has

shown that this is the height an observer will tend to notice anyway when watching a variable time series. Accuracy can be improved by observing the waves for several minutes and comparing their heights, from trough to crest, to some reference object such as a range pole, rod, piling, pier, boat railing or similar. An associated representative wave period is determined by measuring the total time it takes for several waves (typically 20) to pass a fixed object and dividing the total by the number of waves. Several trials should be measured and compared. Lastly, a very rough approximation of the water depth (d) at which a wave will begin to shoal and break is a depth between three-quarters and one full wave height (i.e. solitary wave theory breaking limit, $H_b \sim 0.78$ d).

c. Currents. Along most sections of open coast, any sediment suspended by wave action typically is transported parallel to the shoreline by background currents. These currents most often result from the fact that the breaking wave crests form some angle with the shoreline. Waves surging obliquely toward the beach and reflecting at the complementary angle produce net alongshore water movements which are roughly proportional to the size of the approach angle and the square of the wave height. These currents may be either reinforced or opposed by other water movements resulting from tides, local wind shear on the water column, or any similar force, which results in a dynamic setup or mounding of the water surface differentially at one location compared to another.

(1) Although alongshore transport currents are relatively weak under average conditions, they are persistent and can be much stronger during storms when the wave heights are larger and the seas more directional. The result is that the total sediment transport integrated over the width of the nearshore zone and over a long time period can be very substantial. Average annual transport can range from as little as 30,000 to 40,000 cu yds to as much as 300,000 to 400,000 cu yds; values as large as 700,000 cu yds are not unheard of. The direct measurement of sediment transport has been attempted using traps and various optical instruments, but the techniques are cumbersome and results have been mixed. Most often transport is either predicted using one of several mathematical formulae based on wave height and angle (e.g. energy flux), or it is inferred from dredging records at nearby inlets, comparative surveys, or balancing sediment budgets.

(2) Because most sediment transport is related to the wave climate at a particular location and time, the instantaneous transport magnitude and even the direction may change as the wave field changes. The most common pattern of change is a seasonal one in which higher energy periodic winter storms approach a shoreline from a consistent direction (e.g. northeasters, etc.) which is different from the prevailing wave direction under average, milder summer conditions. In such cases there will be associated reversals in transport direction for varying lengths of time. The magnitudes of the transport in each direction are algebraically combined to produce values known as the net annual transport magnitude and direction. This approach is useful in many analyses, but can be misleading in others. As can be seen, if the transport is roughly balanced in both directions, the net value can be very small even though many hundred thousand cubic yards are actually moving in the system.

11-20. Profile Closure. Coastal project designs usually focus on that portion of the beach that is actively changing or fluctuating. This zone is defined by seeking to identify the opposite situation: those boundary points-- landward and seaward-- which appear to be stable, or at least changing very infrequently. Such a point on the seaward end of a beach cross-sectional profile is often referred to as the closure point or closure depth. To establish an accurate assessment of an entire beach system, surveys should extend from the dune crest seaward to depth of closure, which ranges from between 5 and 18 mdepending upon location. The coastal engineering community has been criticized recently for implying that this closure point is a point of 'no change' or one at which 'nothing' ever happens. Sediment actually may be transported offshore and onshore through the closure point, and other changes may be occurring over longer periods which are too subtle to be distinguished using typical surveying techniques. Perhaps a better perspective is that some point on the profile exists at which the net change is either not measurable or is of no engineering significance. In any case, it is desirable that surveys (using any technology) should extend seaward to the closure depth. The best method for determining this point is experience gained by looking at past data to assess any changes noticed. Because the bathymetry and profile shape is determined largely by the wave climate, there should be some theoretical relationship between closure depth and wave height. One such suggestion is that the limiting offshore depth can be approximated as twice the height of the extreme wave likely at the site. Obviously, judgment and experience must be applied to the manner in which the wave height is estimated.

11-21. Tides and Other Water Level Changes. Tidal fluctuations and other water level changes are of particular interest in coastal surveying when the water surface itself is used as a measurement reference plane. The basic procedures for accounting for water level variations, using tidal benchmarks and adjusting to specific datums are familiar to most survey personnel and are extensively discussed within this manual. Only two additional points will be mentioned in this chapter: project variability and vertical changes from other sources.

a. Most tidal reference stations are located in sheltered waters, not on the open coast. It can be challenging to correlate the water level data at an interior reference station to the fluctuations at a beach location. Tidal phase and amplitude shifts are related to hydraulic distances and not necessarily geographic proximity. For example, because of complexities in bathymetry, channel characteristics and frictional effects, beaches at the opposite ends of a barrier island may have very different, even anti-correlated, water level variations when compared to the same tide station equidistant between them on the bay side of the island. Simultaneous observations at several locations in the project area (over a short time period) may be the only feasible way to assess the variability and correlate station data.

b. Other factors may affect local water levels on the open coast. One such influence is the dynamic setup caused by mass transport of water shoreward by waves after breaking. The still water setup is proportional to the wave height and can be as great as 5% of the breaker height (e.g. ~ 0.3 ft of super-elevation for 6-ft waves). The real difficulty with dynamic setup is that it is not uniform. No setup is present outside the surf zone (a "setdown" effect may even occur), and the setup increases inside the breaking point the closer to shore the depth is

measured. It may not be practical to make sufficient simultaneous observations to correct for setup. It should, however, be recognized as a potential source of uncertainty when data are analyzed and reported.

11-22. Survey Planning Considerations. Planning a data collection program obviously should take place in advance of the field effort. The objective of the planning process should be to carefully think through the eventual uses for the data and the manner in which they will be analyzed, develop the equipment and procedural requirements and anticipate as thoroughly as possible what the site conditions might be and what the data should look like. However, in most cases over-planning and over-specifying the work is just as counter-productive as not planning at all. Situations will always arise in the field that requires judgment and flexibility. The planning goal should be to communicate among all interests the purposes and uses for the survey and the ranges or thresholds of "typical" data, so that atypical conditions are noted and evaluated, even by further discussion while field work is in progress. A survey program ideally should be developed as a team effort among the data users, a representative familiar with the available surveying technologies and procedures, and perhaps a contracting representative if work will be done by outside sources. It is extremely helpful for the team to research and have access to any existing data, past surveys or similar information about a particular site or project area. Existing or historic information is valuable in several ways. A principal use of such data is to allow for a pre-project, preliminary analysis of the area to identify any natural features, shoreline segments or coastal structures which are of particular interest or potential impact on the final project, research effort or monitoring assessment. This type of analysis may suggest areas in which the survey data, however it is collected, may need to be more densely spaced to evaluate an important feature, or can be relaxed to save time and money in more uniform, less critical sections. Another value in carefully reviewing all existing information during planning is to help estimate the likely ranges in the various coastal processes discussed previously and to assess what impact they might have on the field effort. This could include the basic approach to tide corrections, expected wave climate, influences of nearby inlets, and the offshore extent of the data (closure depth). The review can also provide a preliminary look at the existing horizontal and vertical control in the area and the need for any additional benchmarks and/or datum conversions.

a. Planning variables. There may be a number of other factors that the planning team might consider along with any existing data or information about the site and personal experience in order to select appropriate surveying methods and to optimize the data collection effort. The goal is to provide the planning team with information which will allow for matching requirements to capabilities. It is recognized that in some cases surveys may be performed and the data used for more than one purpose over the planning and engineering design cycles of a major project. One type of survey may be better at the preliminary stages of a project and a different type for similar data, but at a more detailed stage of the work. Similarly, different considerations may be appropriate for a Project Feasibility study if the principal design approach will be based on historic conditions, or if it will be based on extensive numerical modeling.

b. Summary. The recommended approach is that a team-based planning process take place prior to specifying a survey method or field procedure. That planning process should begin with a preliminary characterization of the coastal environment at the project site, and proceed by using a decision-guiding matrix, or other local adaptation, in combination with the technical information on various technologies presented below in order to better define and match the requirements to the capability.

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APPENDIX A

References

Section I
Required Publications

Public Law 92-582
Brooks Architect-Engineer Act; Public Law 92-582, as amended; 40 United States Code (U.S.C.) 1101-1104

Executive Order 12906
Coordinating Geographic Data Acquisition and Access: The National Spatial Data Infrastructure (NSDI)

WRDA 1992
Water Resources Development Act of 1992, (Rivers and Harbors Appropriation Act of 1915, 38 Stat. 1053; 33 U.S.C. 562)

WRDA 2000
Water Resources Development Act of 2000 (Section 554)

Office of Management and Budget (OMB) Circular A-16Coordination of Geographic Information and Related Spatial Data Activities

Engineer Regulation (ER) 1110-1-8156
Policies, Guidance, and Requirements for Geospatial Data and Systems

ER 1110-2-1150
Engineering and Design for Civil Works Projects

ER 1110-2-1404
Hydraulic Design of Deep-Draft Navigation Projects

ER 1110-2-8160
Policies for Referencing Project Elevation Grades to Nationwide Vertical Datums

ER 1130-2-520
Navigation and Dredging Operations and Maintenance Policies

EP 1130-2-520
Navigation and Dredging Operations and Maintenance Guidance and Procedures

EM 1110-2-1003
30 Nov 13

EM 1110-1-1003
NAVSTAR Global Positioning System Surveying

EM 1110-1-2909
Geospatial Data and Systems

EM 1110-2-1100
Coastal Engineering Manual

EM 1110-2-1202
Environmental Engineering for Deep-Draft Navigation Projects

EM 1110-2-1416
River Hydraulics

EM 1110-2-1611
Layout and Design of Shallow-Draft Waterways

EM 1110-2-1613
Hydraulic Design of Deep-Draft Navigation Projects

EM 1110-2-1810
Coastal Geology

EM 1110-2-4000
Sedimentation Investigations of Rivers and Reservoirs

EM 1110-2-5025
Dredging and Dredged Material Disposal

EM 1110-2-6056
Standards and Procedures for Referencing Project Elevation Grades to Nationwide Vertical Datums

ERDC/TN EEDP-04-37
"Overdepth Dredging and Characterization Depth to Recommendations," Tavolaro, J. F., J. R. Wilson, T. L. Welp, J. E. Clausner, and A. Y. Premo. June 2007 Technical Note. Vicksburg, MS: U.S. Army Engineer Research and Development Center.

HEC RD 26 1986
Hydrologic Engineering Center (HEC) Research Document 26 (HEC RD 26), Accuracy of Computed Water Surface Profiles, 1986, incl. Supplemental volumes.

Section II
Related Publications

Applanix 2005
“Hydrographic Surveying on the Ellipsoid with Inertially-Aided RTK,” by: Peter Canter, Director of Marine Products at Applanix Corporation, Toronto, Canada and Louis Lalumiere, Senior Analyst at Applanix Corporation, Toronto, Canada, 2005.

Calder and Mayer 2003
"Automatic Processing of High-Rate, High-Density Multibeam Echosounder Data," Calder, B. and Mayer, L., Center for Coastal and Ocean Mapping and Joint Hydrographic Center, University of New Hampshire. Geochemistry Geophysics Geosystems, Vol. 4, No 6, 1048, 2003.

DEP 2004
"Monitoring Standards for Beach Erosion Control Projects," State of Florida Department of Environmental Protection, Division of Water Resource Management, Bureau of Beaches and Coastal Systems, March 2004.

Druyts and Brabers 2012
Druyts, M., and Brabers, P., “Nautical Depth Sounding, the Rheocable Survey Method,” International Hydrographic Review, May 2012.

GeoAcoustics 2002
“GeoSwath Product Information Bulletin,” GeoAcoustics, Ltd., UK (November 2002).

HYDRO International 2011
"Rheology as a Survey Tool," (Stijn Claeys), HYDRO International Magazine, May/June 2011.

HYPACK 2011
"HYPACK User Manual," ("HYPACK Hydrographic Survey Software User Manual"), (1582 pages), 2011 Edition, HYPACK, Inc., Middletown, CT 06457. [Note: This manual is updated annually; users should obtain the current version from the HYPACK web site]

IHO 2000
Special Publication No. 57, “IHO Transfer Standard for Digital Hydrographic Data." Edition 3.1.

IHO 2005
Publication C-13, "Manual on Hydrography," 1st Edition, May 2005 (Corrected to February 2011).

IHO 2008
Special Publication No. 44, "IHO Standards for Hydrographic Surveys," 5th Edition, February 2008.

IHO 2010
Special Publication No. 52, "Specifications for Chart Content and Display Aspects of ECDIS," (March 2010).

JCGM 100 2008
"Evaluation of Measurement Data—Guide to the Expression of Uncertainty in Measurement," Joint Committee for Guides in Metrology (JCGM), International Bureau of Weights and Measures (BIPM), First Edition, September 2008.

L-3 SeaBeam 2000
"Multibeam Sonar Theory of Operation," L-3 Communications SeaBeam Instruments, 141 Washington Street, East Walpole, MA 02032, 2000.

LINZ 1999
"Provisional Swath Sonar Survey Specifications," John E. Hughes Clarke, Ocean Mapping Group, Department of Geodesy and Geomatics Engineering, University of New Brunswick, Canada, National Topographic and Hydrographic Authority, Land Information New Zealand (LINZ), Technical Report #2, August 1999.

McAnally 2007
McAnally, W., Friedrichs, C., Hamilton, D., Hayter, E., Shrestha, P., Rodriguez, H., Sheremet, A., and Teeter, A., (American Society of Civil Engineering (ASCE) Task Force on Management of Fluid Mud), "Management of fluid mud in estuaries, bay, and lakes. Present state of understanding on character and behavior," ASCE Journal of Hydraulic Engineering, Vol 133, No. 1, January 1, 2007.

NAVOCEANO/Hare 2001
"Error Budget Analysis for US Naval Oceanographic Office (NAVOCEANO) Hydrographic Survey Systems: Final Report for Task 2, FY 01," Hare, R., University of Southern Mississippi, Hydrographic Science Research Center, September 2001.

NOAA 2005
"The Navigation Surface and Hydrographic System Uncertainty at NOAA's Office of Coast Survey," Allen, S. and Ferguson, J., US Department of Commerce, NOAA. The Hydrographic Society of America, 2005.

NOS 2011
"NOS Hydrographic Surveys Specifications and Deliverables," NOAA, NOS, Office of Coast Survey, Silver Spring, MD, April 2011. [Note: This document is periodically updated--users should obtain the latest version from the NOAA NOS web site].

OCS 2011
"Field Procedures Manual," NOAA, NOS, Office of Coast Survey, Silver Spring, MD, May 2011. [Note: This manual is periodically updated--users should obtain the latest version from the NOAA OCS web site].

Odom 2008
"Odom Echotrac MKIII User Manual," Version 4.03, 23 May 2008; Odom Hydrographic Systems, 1450 Seaboard Avenue, Baton Rouge, LA 70810-6261.

PIANC 1997.
"Approach channels, a guide for design." General Secretariat of PIANC. Supplement to Bulletin No. 95. (1997), Brussels, Belgium.

POS/MV 2011
"POS/MV V5 Installation and Operation Guide," Revision 3, PUBS-MAN-004291, Applanix Corporation, 2011.

R2Sonic 2010
"R2Sonic Operation Manual," (Sonic 2024/2022 Operation Manual), Version 3, 2010; R2Sonic LLC, 1503-A Cook Place, Santa Barbara, California 93117

Sea Technology 2008
"Evaluation of Nautical Bottom Detection Techniques," (Stijn Claeys), Sea Technology Magazine, July 2008.

Teeter 1997
Teeter, A. M., "Development and verification of an intrusive hydrographic survey system for fluid mud channels," Dredging Research Program Technical Report DRP-97-1, June 1997, U. S. Army Engineer Research and Development Center, Vicksburg, MS.

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APPENDIX B

Manual Depth Measurement Techniques

B-1. General Scope and Applications. Manual depth measurement techniques are used for many under water engineering and construction applications. These methods include use of hand lead lines, topographic level rods, 2-m GPS poles, and sounding poles. Manual methods are generally used where more efficient acoustic methods cannot provide adequate depth data or sufficient detail. Examples include: surveys of areas adjacent to piers, bulkheads, and offshore pile structures; near locks, dams, power plants, and river control structures subject to turbulence; detailed surveys of rock jetties and breakwaters; beach and dune profile surveys; surveys in shallow detention or retention ponds or water conservation pools; surveys in shallow wetland areas with thick bottom vegetation or mangrove; and surveys in areas where unconsolidated sediments are present. Manual depth measurement techniques are simply a variation of conventional topographic survey methods. However, unlike land-based topographic surveys, the geophysical properties of the bottom are not always visible or consistent. Any type of positioning method may be used to locate the depth measurement device—tag lines, total stations, and RTK being the most common. This appendix provides general guidance and procedural criteria for manual hydrographic survey depth measurements on engineering and construction projects.

B-2. Lead Line or Sounding Disk Measurement. Prior to the accepted use of acoustic depth sounding methods in the 1950's, lead lines were the Corps standard for hydrographic survey depth measurement, as illustrated in Figure B-1. At one time they were used as the calibration reference for acoustic soundings. Lead lines are simply surveyor tapes (chains) with a weight attached to the end. The length of these lines was usually less than 100 ft, or near project depth; however, much longer lines were used for deep-water surveys. Lead lines may be operated by hand, suspended from a bicycle wheel, or operated by a power winch apparatus--see Figure B-2. The water surface is used as the reference datum for the observations, as shown in Figure B-1.

a. General uses. Lead lines are to be used in situations where use of electronic sounding would be impractical, impossible, or give faulty results. Lead line sounding is especially suited for underwater investigation of rock or concrete placement; on the slopes of jetties, groins, and revetments; and near bulkhead construction. In such areas, echo sounding may be inaccurate or contaminated with noise from side echoes. Lead lines are to be used in conjunction with acoustic or nuclear density techniques to corroborate echo soundings. Also, for silty bottoms containing "fluff" that would give questionable echo sounding readings, a lead line may be required in a construction contract.

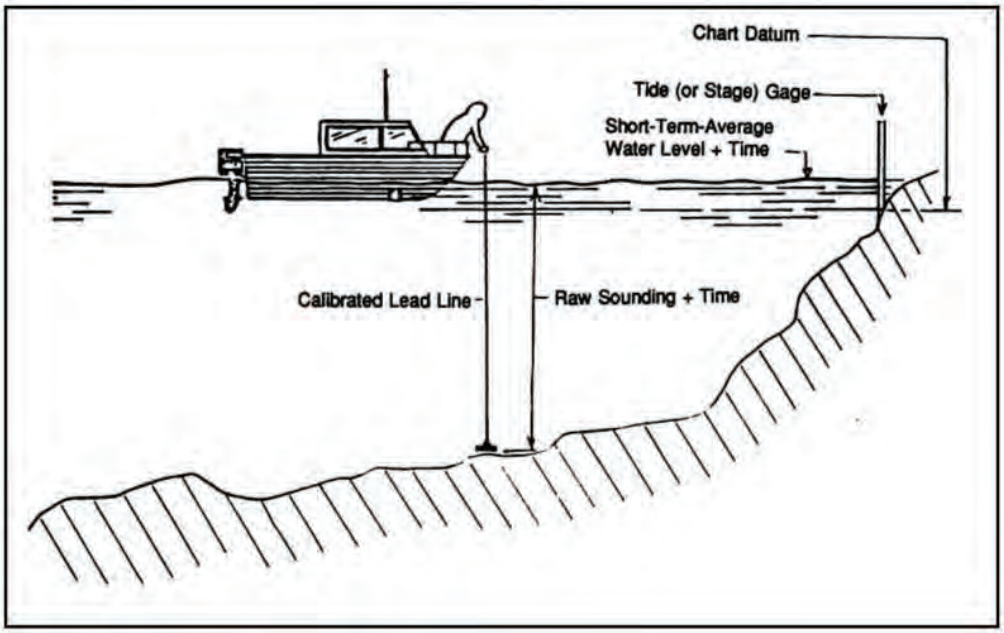

Figure B-1. Lead-line depth measurement

Figure B-2. Lead line measurements (Jacksonville District)

b. Line materials and dimensions. A variety of flexible metallic materials can be used to suspend a sounding lead. All must exhibit minimal stretch while under tension. Braided rope is never used for this reason. Standard 100-ft surveyor's chains/tapes have been configured into lead lines. Stainless steel wire rope, piano wire, and rubber-shielded electrical wire are often used. Since a lead line is rarely used in depths exceeding 50 ft, line stretching due to tension should be minimal. However, this should be checked when any type of braided material is used. For most USACE applications, lines need not be made any longer than 50 to 75 ft. Shorter lines may be made when used primarily on shallow-draft projects.

(1) The Coast and Geodetic Survey recommended use of a mahogany-colored tiller rope with a phosphor-bronze wire center (size 8 line--0.24-in. diameter). This type of braided line is suitable for continuous hand operation since the tightly woven cotton shroud prevents broken wire strands from protruding and causing hand injury. Procedures for seasoning and calibrating this type of line are covered in the NOAA Hydrographic Manual (1976).

(2) Flexible wire lines are best suited for mechanically reeled lead lines. A bicycle wheel rim (Figure B-2) or other large-diameter drum provides a rapid line payout velocity. A thin braided or solid core flexible wire is used for such devices.

c. Line marking. For most Corps applications, lines are usually marked at 0.1-ft intervals throughout their length. Lines marked at only 1-ft intervals make visual interpolation to a 0.1 ft precision difficult, especially in heavy seas. The zero reference is the bottom crown of the mushroom anchor or sounding disk, and the marking interval begins above the connection to the sounding line. The anchor/disk shank is not marked. Marking the 0.1-ft intervals is performed using a standard 100-ft surveyor's chain. These marks must be easily read. Care must be taken to ensure that the ring/swivel and shackle connection is free and clear and that the line is under adequate tension. Types of marks used depend on the line. Marks may be seized onto the line with small cord. Seizings should penetrate the wire braids to prevent slippage. Marks may be directly crimped onto braided or solid wire using standard wire rope crimping equipment, and identified by color-coded seizing cord or seized leather flags.

d. Lead type and dimensions. A consistent lead line weight shall be either a mushroom anchor or a flat sounding disk. A contract specified weight will help ensure uniformity of contract payment, especially in areas subjected to high-suspended sediment concentrations. Lead line types or weights should not be interchanged on the same project—i.e., use the same system for pre- and post-dredge measurements.

(1) Mushroom anchor. A mushroom anchor (Figure B-3) is commonly used as a lead weight on dredging projects. These anchors come in a variety of sizes and weights. A typical mushroom anchor used on Corps projects weighs between 7 to 8 lbs. and has upwards of a 6-in. diameter crown. This type of anchor may be purchased at most marine supply outlets. The lower end of the line should be attached to the anchor ring with a freely pivoting shackle. In

some cases, a permanent bight in the line may be end-spliced around the anchor ring's eye. Any variation from this typical lead weight shall be indicated in construction contract specifications.

Figure B-3. Mushroom anchor used as lead weight.

(2) Sounding disk. A typical sounding disk is a 6-in.-diameter circular stainless steel plate. A connecting shank (4- to 5-in. length) and swivel shall be welded to the center of the plate. Four 1-in.-diameter holes shall be drilled symmetrically around the plate. Total weight, including shank and attachment swivel, shall be about 8 lb. Again, any variation from this typical design shall be indicated in construction contract specifications.

(3) In some high-turbulence areas, a heavier lead weight may be required. Lead weights in excess of 100 lb. have been used to investigate scour rates below river control structures (e.g., New Orleans District Old River Control Structure).

e. Operational procedures. Normally, measurement is made upon free-fall to apparent refusal on the bottom. Proper care shall be taken to minimize line angle from the vertical due to strong currents or tidal flow. A bicycle wheel should be employed when rapid drops are necessary such as in project depths exceeding 40 ft with strong surface or subsurface currents are present. In soft-bottomed materials, the reading should be taken at apparent refusal or within some specified time (normally 5-sec) after apparent initial penetration. In payment areas where a lead continues to fall under its own weight, it is essential that contract specifications (or subsequent agreement) indicate the elapsed time before reading. To ensure consistency and equity of payment, the same lead line and leadsman operator should be used for both pre-construction and post-construction surveys. Leads should be thrown or mechanically dropped adjacent to the tag line mark or positioning reference. If lead casts are made to port/starboard and/or forward/aft of the positioning reference, an eccentric correction must be applied. The lead line is held taut for sufficient time to visually mean any sea state variation. Observed depths are recorded to the nearest 0.1 ft, either in a surveyor's field book, on a worksheet, or directly into a

portable data-logging device, or into HYPACK. Subsequent corrections are made for river/pool stage or tidal datum. Corrections resulting from periodic calibrations are also applied.

f. Calibration. Each lead line should be calibrated at intervals of time not exceeding those listed in Table B-1. Contractors are free to request that the lead line be checked before any payment survey. Calibration should be performed by comparison of marked intervals with a steel tape. Calibration data should be recorded in a standard field survey book or on a worksheet. Differences between true and marked intervals should be computed. Measurements in the interval band should be corrected accordingly. Maximum errors should not exceed the indicated allowable values. If so, marks exceeding this value shall be reset. If a constant index error is present, the line-anchor connecting assembly should be modified to remove the error.

B-3. Sounding Pole.

a. Uses. A sounding pole is basically a level rod which uses the water surface instead of a differential leveling instrument for reference. Depths are observed relative to the water surface. If a total station is used, direct absolute elevations may be observed and reduced to the water surface datum. Standard expandable level rods are often used for sounding poles. Sounding poles, like lead lines, are useful in certain situations in which an electronic echo sounding system is not practical or accurate. For example, areas with dense bottom vegetation or irregular jetty stone may give false signals electronically and must be sounded by hand. Next to instrumental leveling, a sounding pole is perhaps the most accurate hydrographic measuring device in shallow water depths. It is especially suitable for subsurface rock and concrete placement. Its light weight is useful in fluff areas where free-fall penetration must be minimized. Its uses are generally restricted to depths not exceeding 15 to 20 ft. Figures B-4 and B-5 are illustrations of the use of a sounding pole.

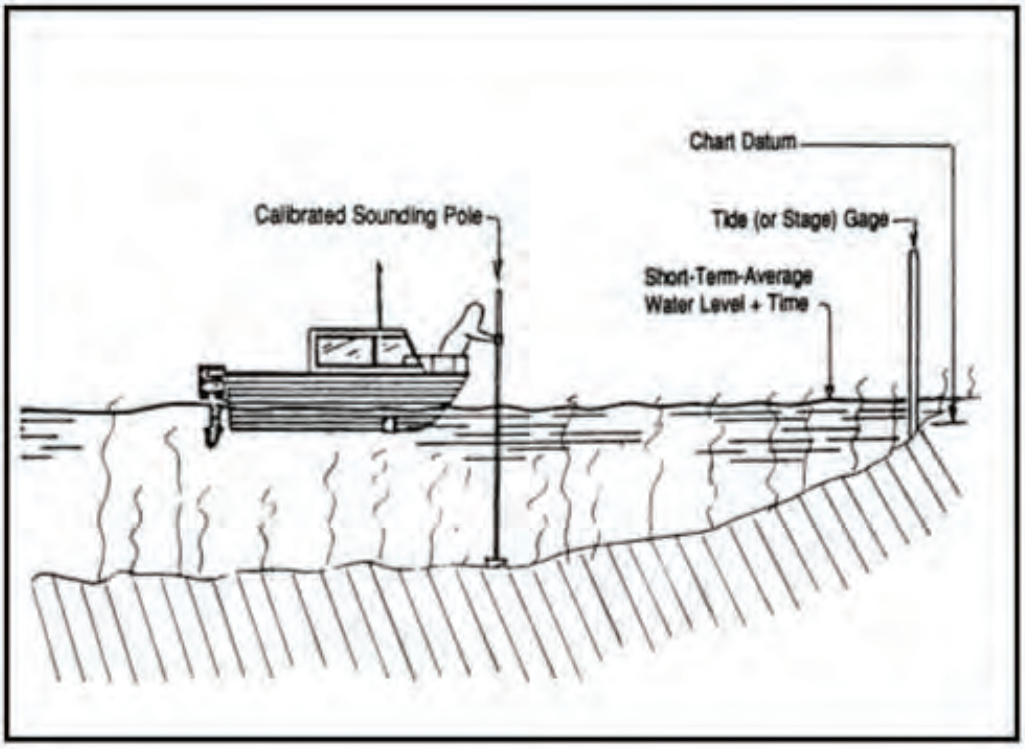

Figure B-4. Sounding pole depth measurement

b. Dimensions. Poles should generally not exceed 20 ft in length. An 8- to 15-ft-long pole is optimal for ease in handling and maintaining verticality. Wood or square tubular aluminum poles (1-in. dimension) are commonly used. Standard wooden/metallic and 25-ft expandable fiberglass level rods are also employed as sounding poles. In shallow water, a standard 2-meter GPS pole may be used. For other than subsurface rock, packed sand, concrete, or other hard bottom material depth measurement, the pole should have a 6-in.-diameter circular plate attached to the base of the pole. Overall weight of the pole (including base plate) should be less than 8 lb. In sand, 2-meter pole bases are attached to a 3-inch survey disc. As with a lead line, use of a particular pole should remain consistent throughout the duration of a contract/project. When conventional level rods or fiberglass rods are used, the base plate characteristics and overall weight should conform to a standard, such as that outlined above. Any deviation for a particular project shall be noted in the contract specifications.

Figure B-5. Sounding pole measurement from a small work boat (Jacksonville District)

c. Marking. Sounding poles are marked at 0.1-ft intervals. Rod divisions are referenced to the bottom of the base plate. Marks are usually painted and annotated in a manner identical with that used to paint and annotate conventional level rods.

d. Calibration requirements. Each sounding pole should be calibrated at periodic intervals and recorded in a standard field survey book. Pole calibration should be done by comparison with a steel tape or level rod whereby marked intervals are measured and recorded.

e. Operational procedures. In projects with hard bottom material, readings shall be taken at apparent refusal. In soft-bottomed materials, the reading shall be taken at apparent refusal or within some specified time (normally 5 seconds) after apparent initial penetration. In extreme low-density areas where the pole continues to fall under its own weight, it is essential that contract specifications (or subsequent agreement) indicate the time of reading. It is critical that no pressure be exerted in areas of highly suspended sediments. Observations are referred to the water surface and are corrected to the final datum by applying appropriate corrections, including

calibration corrections, if any. The pole must be kept as nearly vertical as possible especially in strong currents. A standard bulls-eye rod level may be attached to the pole if necessary. Depth measurements must be reduced for any horizontal eccentricities as described for lead line measurements.

B-4. Manual Depth Measurement Accuracy and Quality Control Criteria. Manual depth measurement accuracy depends on a number of factors: water depth, currents, sea state, and bottom consistency. In general, these devices are highly accurate in calm, shallow water where the device can quickly reach the bottom and depth readings can be easily interpolated from the water surface undulations. Accurate measurements require rapid estimation of the average wave action. Where feasible, direct total station elevation observations on the rod can eliminate the water surface interpolation error. However, this is usually not practical at distances beyond 500 ft from the instrument, and the water surface must be used as the reference elevation. Currents can adversely affect both lead line and sounding pole measurements, causing slope distances to be observed. In soft sediments, the reading accuracy is dependent on the ability to judge a point of refusal. This is likewise true in dense bottom vegetation or where mangrove roots are present.

a. Depth limitations. In general, the accuracy of manual depth measurement methods is limited to water depths of approximately 15 to 20 ft. Deeper measurements may be justified only in extremely calm, current-free, protected waters, with a nearby reference gage.

b. Quality control and assurance. QC techniques are basically limited to periodic calibrations of the line or rod intervals, restricting observation conditions (depth, current, sea state, etc.), and verifying tide/stage gage readings. Independent QA testing is not usually performed on manual survey methods; thus, adequate QC is essential. If distances from the reference tide/staff gage are significant, then comparisons and/or interpolations should be made from a second gage. A "significant" difference in gage observations would be water surface slope errors exceeding 50% of the required elevation accuracy--i.e., approximately + 0.1 ft for dredging and navigation surveys in less than 15 ft of water.

c. Criteria. Table B-1 describes general criteria for depth measurement observing, recording, and accuracy evaluation.

Table B-1. Recommended Manual Depth Measurement Quality Control Criteria

Recommended maximum depth:		
	Lead line	20 ft [up to 50 ft is of marginal accuracy]
	Pole	15 ft
Read/record/plot soundings to nearest		0.1 ft
Maximum currents generally NTE		4-5 kts
Reference water surface accuracy for depths < 15 ft		0.1 ft
Calibrate line/pole/rod to tape every		project [annually if rarely used]
calibrate to nearest		0.05 ft
Recommended lead line weight/type		7 to 8 lb mushroom anchor or 8 lb/6-in. diam. plate
Recommended pole/rod disc size/weight		6-in diam/8± lbs (in extremely soft material) 3.5-in survey disc on 2-mpole (sand/rock)

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APPENDIX C

Contracted Survey Procedures and Cost Estimates

C-1. General. This appendix outlines the procedures used for obtaining hydrographic surveys using A-E contracting methods. It includes examples of survey scopes of work for task orders and cost estimates for hydrographic surveying services. The primary focus is on the use of task orders issued under Indefinite Delivery/Indefinite Quantity (IDIQ) contracts. Section I covers basic IDIQ contract provisions and Section II covers IDIQ Task Order procedures.

a. Procedures for developing hydrographic survey contract specifications and cost estimates are performed similarly to those for A-E design services. Similar technical discipline scheduling and production factors are used to determine the ultimate cost of a task. In addition, the Cost Estimating Center of Expertise in USACE can assist in developing dredge estimating costs in construction projects. See the web site at:
http://www.nww.usace.army.mil/Missions/CostEngineering.aspx

b. For detailed guidance on A-E procurement policies and practices, refer to the appropriate procurement regulations, e.g., Federal Acquisition Regulation (including DOD, DA, and USACE Supplements), EP 715-1-7 Architect-Engineer Contracting in USACE, and the ULC PROSPECT course on A-E contracting.

C-2. Background. Prior to World War II, in-house forces primarily performed design and related surveying support services in the Department of Defense. In 1939, legislation was enacted which created an expanded military construction program and authorized contracting of A-E services. Surveying and mapping services are considered a subset of A-E services. This initial contract work for military design/construction spilled over into the Corps civil works programs after the war--for similar planning, design, and surveying services. Contracting for surveying services began to expand in the late 1950's and early 1960's--especially during the space program build-up. Hydrographic surveying was one of the last Corps field survey data acquisition functions to be contracted--mostly beginning in the 1970's. Prior to the 1970's, the Corps employed well over 200 in-house hydrographic survey crews, mostly using manual tagline/leadline survey methods. In the 1960's and 1970's, outsourced survey services increased, including transfer of construction quality control functions to contractors--e.g., dredging progress payment surveys. Approximately 25% to 40% of all the Corps hydrographic work is contracted--either directly using A-E contracts or indirectly under construction contracts. The expanded use of A-E firms and dredging contractors to perform hydrographic surveying has many positive elements. These firms not only supplement any declining in-house capabilities but also provide specialized expertise in technical areas not routinely performed by the Corps. Most importantly, however, these firms represent a nationwide service base for use in a national emergency. This asset was clearly evident during the Great Flood of 1993 in the Upper Mississippi & Missouri Basin. During this high-water

build up, many private hydrographic contractors were mobilized by the Corps to locate and map levee breeches and backwater flooding limits with multibeam survey equipment.

C-3. Brooks Architect-Engineer Act. In the Federal government, professional architectural, engineering, planning, and related surveying services must be procured under the Brooks Architect-Engineer Act, Public Law 92-582. The Brooks A-E Act requires the public announcement of requirements for surveying services, and selection of the most highly qualified firms based on demonstrated competence and professional qualifications. Cost or pricing is not considered during the selection process. After selection, negotiation of a fair and reasonable price for the work is conducted with the highest qualified firm. Hydrographic surveying supporting the Corps' research, planning, development, design, construction, or alteration of real property is considered to be a related or supporting architectural or engineering service, and must therefore be procured using Brooks A-E Act qualifications-based selection, not by bid price competition.

C-4. Contracting Processes and Procedures. Corps procedures for obtaining A-E services are based on a variety of Federal and DOD acquisition regulations. The following paragraphs synopsize the overall A-E process used in the Corps (see EP 715-1-7 for details on this process).

a. Types of contracts. Two types of A-E contracts are generally used for procuring hydrographic surveying services: Firm-Fixed-Price (FFP) contracts and Indefinite Delivery/Indefinite Quantity (IDIQ) contracts. FFP contracts are used for moderate to large mapping projects where the scope of work is known prior to advertisement and can be accurately defined during negotiations--typically for a large new project site. Due to variable channel shoaling and changing engineering and construction schedules (and funding), most mapping work in the Corps cannot be accurately defined in advance; thus, fixed-scope FFP contracts are rarely used, and nearly all surveying services are procured using IDIQ contracts. IDIQ contracts are commonly referred to as "Task Order Contracts" or "Indefinite Delivery Order Contracts."

b. Selection criteria. Federal and DOD regulations set the criteria for evaluating prospective surveying contractors. These criteria are listed in the public announcement in their order of importance and the selection process assigns descending weights to each item in that order.

c. Selection process. The evaluation of firms is conducted by a formally constituted Selection Board in the Corps district seeking the services. This board is made up of highly qualified professional employees having experience in architecture, engineering, surveying, etc. The board evaluates each of the firm's qualifications based on the advertised selection criteria and develops a list of at least three most highly qualified firms; from which one is selected.

d. Negotiations and award. The highest qualified firm ranked by the selection board is provided with a scope of work for the project, project information, and other related technical criteria, and is requested to submit a detailed price proposal for performing the work. In the typical case of IDIQ contracts where specific projects are not known, the scope of work simply itemizes required technical personnel (project managers, surveyors, etc.) and survey equipment requirements (e.g., single-beam, multibeam, side scan sonar, vessels, etc.). The A-E proposes rates for personnel and equipment to be used on subsequent task orders. An Independent Government Estimate (IGE) is developed concurrent with the A-E contractor's price proposal. Once a fair and reasonable price (to the government) is negotiated, the contract is awarded. Task orders are then issued against the basic IDIQ contract using the agreed upon rates for personnel and equipment.

e. IDIQ use. IDIQ contracts typically are developed with multiple option years (e.g., three to five years). Yearly funding limits are established based on the amount of anticipated work over the term of the IDIQ contract. Typical limits range from $1 to $5 million per year. IDIQ contracts awarded in a District may be shared by other districts if within the scope and geographic limits of the contract. Thus, it is common for a district to issue a Task Order under an IDIQ contract from another district in the same Division.

f. IDIQ Task Orders. IDIQ contracts have only a general scope of work--e.g., "Hydrographic surveying services in the South Atlantic Division." When work arises during the term of the IDIQ contract, task orders are written for performing that specific work. Task orders are negotiated using the unit rate "Schedule" developed and negotiated in the basic IDIQ contract. From the IDIQ schedule, a hydrographic survey crew and equipment is pieced together using the various line items--adding or deducting personnel or equipment as needed for a particular project. Thus, task order negotiations are focused on the level of effort and performance period. Task orders typically have short scopes of work--a few pages. The scope is sent to a contractor who responds with a time and cost estimate, from which negotiations are initiated. The entire process--from survey need to task order award--should routinely take only one to two weeks. Under emergency conditions (e.g., flood fights, hurricanes) contractors can be issued task orders verbally by the Contracting Officer, with the scope of work simply defined as a limiting number of days for the hydrographic survey crew at the contract schedule rate.

SECTION I

IDIQ Contract Specifications and Pricing Schedules

C-5. IDIQ Contract Technical Specifications. Technical specifications for hydrographic surveying services (including general items such as types of projects, procedural requirements, and accuracy requirements) are inserted in the appropriate section of the IDIQ contract (e.g., Statement of Work--Section C). Procedural and accuracy requirements are generally referred to

this engineer manual, as are any quality control criteria for the total (field-to-finish) execution of a hydrographic survey. This engineer manual should be attached to and made part of any A-E IDIQ service contract requiring hydrographic surveying. References to this manual will normally suffice for most USACE hydrographic survey IDIQ technical specifications. Variations in technical specifications are covered in the individual task order scopes of work. IDIQ technical requirements may be only generally written since detailed technical requirements will be covered in subsequent task orders. This is illustrated by the following excerpts from a basic IDIQ contract Statement of Work:

STATEMENT OF WORK SECTION C

C.1 GENERAL. THE CONTRACTOR, OPERATING AS AN INDEPENDENT CONTRACTOR AND NOT AN AGENT OF THE GOVERNMENT, SHALL PROVIDE ALL LABOR, MATERIAL, AND EQUIPMENT NECESSARY TO PERFORM THE PROFESSIONAL HYDROGRAPHIC SURVEYING *[AND MAPPING WORK] *[FROM TIME TO TIME] DURING THE PERIOD OF SERVICE AS STATED IN SECTION D, IN CONNECTION WITH PERFORMANCE OF *[_____] SURVEYS *[AND THE PREPARATION OF SUCH MAPS] AS MAY BE REQUIRED FOR *[ADVANCE PLANNING,] [DESIGN,] [MAINTENANCE DREDGING,] [DETERMINING PROJECT CONDITION,] [AND CONSTRUCTION] [or other function] [ON VARIOUS PROJECTS] {specify project(s) if applicable}. THE CONTRACTOR SHALL FURNISH THE REQUIRED PERSONNEL, EQUIPMENT, INSTRUMENTS, AND TRANSPORTATION, AS NECESSARY TO ACCOMPLISH THE REQUIRED SERVICES AND FURNISH TO THE GOVERNMENT REPORTS AND OTHER DATA TOGETHER WITH SUPPORTING MATERIAL DEVELOPED DURING THE FIELD DATA ACQUISITION PROCESS. DURING THE PROSECUTION OF THE WORK, THE CONTRACTOR SHALL PROVIDE ADEQUATE PROFESSIONAL SUPERVISION AND QUALITY CONTROL TO ASSURE THE ACCURACY, QUALITY, COMPLETENESS, AND PROGRESS OF THE WORK.

SPECIFIC PROCEDURAL, TECHNICAL, AND QUALITY CONTROL REQUIREMENTS FOR HYDROGRAPHIC SURVEYING *[AND MAPPING SERVICES] TO BE PERFORMED UNDER THIS CONTRACT ARE LISTED IN THE PARAGRAPHS BELOW. UNLESS OTHERWISE INDICATED IN THIS CONTRACT *[OR IN INDIVIDUAL TASK ORDERS THERETO], EACH REQUIRED SERVICE SHALL INCLUDE FIELD-TO-FINISH EFFORT PERFORMED IN ACCORDANCE WITH THE STANDARDS AND SPECIFICATIONS IN EM 1110-2-1003.

Figure C-1. Example IDIQ Specification for Hydrographic Surveying Services

C-6. IDIQ Contract Pricing Schedules. A number of methods are used for scheduling hydrographic survey rates in an IDIQ contract. The two most common methods are (1) daily rate and (2) cost per work unit rate.

a. Daily rate. The daily rate basis is the cost for a complete hydrographic field crew (including all instrumentation, transport, travel, and overhead) over a nominal 8-hr day. (Daily crew rates are derived from hourly labor and equipment rates. Either daily and/or hourly rates may be used in the IDIQ price schedule). This method is used on the vast majority of USACE IDIQ contracts. It provides the most flexibility for IDIQ contracts, especially when individual project scopes are expected to vary widely. It is, therefore, considered a more accurate method of determining costs for individual task orders. One disadvantage is that a more detailed independent government estimate (IGE) must be developed for each task order placed against an IDIQ contract. The estimator must be thoroughly familiar with the project and survey procedures.

b. Cost per work unit rate. The cost per work unit rate basis is effectively the daily rate divided by an average production rate for a specified item of survey work. Fixed rates can then be established for items such as river sections, overbank sections, 1,000-ft offshore cross sections, linear units (miles) of sounding, square units (square miles) of sounding, per traverse mile, or any other desired unit. Labor rate contracts may be based on either pricing method. Each of these unit pricing methods have advantages and drawbacks which need to be considered prior to determining which method to use. This unit price basis is by far the simplest to administer. It is, in effect, like a GSA Schedule catalogue that allows ordering of services based on simply computed quantities. If all task order projects have relatively constant scopes (i.e., project sites, surveying requirements, and access are similar), this method should yield similar costs to those of a daily rate basis. This pricing method assumes that hydrographic surveying productivity is constant (or will average out over the long term), regardless of project site constraints, weather, and other factors. This may or may not be a valid assumption. Unless such variations are accounted for in the price schedule, a modification to the basic contract may be required. Arriving at this rate basis requires an initial computation of the daily rate, then a determination of an average productivity rate for the field crew. Given all the project-dependent variables, development of average productivity rates is difficult and requires considerable expertise on the part of the government estimator. As a result, cost per work unit rate estimates tend to become worst-case costs that can be abnormally high in some instances. Consequently, work unit rates are rarely used in the Corps.

C-7. Preparing Independent Government Estimates for IDIQ Contracts. To develop the price schedule for IDIQ contracts, an independent government estimate (IGE) must be prepared for all technical disciplines, equipment, instrumentation, plant, travel, and other items that may be used during the term of the contract. For a FFP contract, the total of all these individual cost items is used to arrive at an overall project (contract) cost, and forms the basis for negotiating with the contractor. For an IDIQ contract, individual line items on the price schedule are estimated and negotiated with the contractor, and make up the contract schedule of prices. This IDIQ "Schedule" is then used for Task Order labor and equipment rates. The daily (or hourly) rate for a surveying crew may be estimated using the following outline. Other breakdowns may be employed to arrive at a cost per crew day, per crew hour, or per unit of work. The crew personnel size, floating plant, depth recorders, data processing systems, vehicles, etc., must be explicitly indicated in the draft contract specifications, with differences resolved during negotiations. Options to add additional specialized survey equipment (along with personnel and/or transport) must be accounted for in the estimate and unit price schedule. A contractor's cost proposal should follow the same general format used by the government's IGE, if possible. The following items are typically computed in an IGE.

a. Direct labor. Labor or salary costs of survey technicians, including applicable overtime or other differentials necessitated by the work schedule.

b. Overhead on direct labor.

c. General and Administrative (G&A) overhead costs.

d. Material costs. Include drafting supplies, field books, etc.

e. Travel and transportation costs. Crews' travel, per diem, etc., which includes all associated costs of vehicles used to transport personnel and floating plant to/and from the job site.

f. Other costs. Include floating plant costs and cost of survey equipment and instrumentation, such as hydrographic positioning systems and depth recorders. Instrumentation and equipment costs should be amortized down to a daily rate, based on average utilization rates, expected life, etc. Exclude any instrumentation and plant costs covered under General and Administrative (G&A) accounts--interest, maintenance contracts, etc.

g. Profit. (For IDIQ profit is either factored in the unit prices or computed separately for each task order).

C-8. Estimating Unit Cost Rates for IDIQ Contracts. IDIQ contracts for hydrographic survey services contain price schedules for the major line items that will be used in subsequent task orders. These line items may be broken out by individual labor and equipment and/or combined for a fully equipped survey crew. The method used is dependent on local preference or use. Most USACE commands tend to compute the daily rate for a complete survey crew and make minor adjustments to that rate, depending on the unique task order scope. Plant and equipment rental rates can represent the major cost item on a hydrographic survey team, especially if the automated survey instrumentation is factored into this rate. Often the plant rental costs far exceed survey crew labor costs. Daily costs (2013) for a survey vessel in the 40- to 65-ft-long range can run between $2,500 and $6,000 per day. Smaller launches (18 ft to 26 ft) are far less. Labor costs (2013) for survey crew personnel usually range between $1,500 and $3,000 per day, depending on number of party members, complexity of equipment operated, and geographical area. Thus, a fully automated hydrographic survey team can cost between $2,000 and $7,000 per day to field. In preparing an IGE for an IDIQ contract, unit costs may be determined from a variety of internal or external cost sources--see EP 715-1-7.

a. Labor rates. Field crew personnel costs include direct labor, fringe benefits, and G&A overhead costs. Estimates of labor rates may be obtained from a variety of publications that detail rates by geographical area--see EP 715-1-7. Equivalent General Schedule rates may also be used in estimating labor rates if they are representative of the private sector in the locality where the work is performed.

b. Travel costs. Normally, travel costs are computed for each task order based on the current GSA rates; thus, they are not normally computed in the IDIQ schedule. Vehicle costs may be included under this category or computed under "Other Costs."

c. Other costs.

(1) Floating plant rental rates. The costs of comparable Corps-owned plant may be used in arriving at an IGE for contracted work. Commercial vessel rental rates may also be used. In the Corps, the daily plant rental and survey equipment rental rates are developed at the time of purchase and are periodically updated based on actual utilization rates as charged against projects. Plant rental rates are recomputed at least annually, or more often if utilization changes significantly. Various Plant Replacement and Improvement Program (PRIP) costs make up this expense; however, such accounting methods are not used by private contractors. In addition, vessel operator labor rates are often incorporated into the plant rental rate. Corps field survey crew labor costs are separate expense items that may be used for comparable estimates.

(2) Survey instrumentation and equipment. Survey equipment--particularly major items such as complete multibeam systems and inertial-aided GPS orientation systems--are often broken out separately in the contract price schedule. Costs for each equipment item are reduced to a daily rate based on original purchase cost, depreciation, estimated annual utilization, operation and maintenance (O&M), and other factors. Associated costs, such as insurance, maintenance contracts, and interest, are presumed to be indirectly factored into a firm's G&A overhead account. If not, such costs must be directly added to the basic equipment depreciation rates shown. Other equally acceptable methods for developing daily costs of equipment may also be used, such as manufacturer or third-party vendor daily/monthly rental rates. Equipment utilization and life cycle estimates do represent a large variable in an IGE. Typically the IGE is subsequently revised (during negotiations), based on actual rates as determined from the contractor's proposal and from detailed cost analysis and field price support audits.

(3) The following example depicts a unit price IGE computation for a hydrographic survey crew equipped for multibeam and side scan surveys. Either the total (fully equipped) crew day rate or the rates for some selected items may be used for negotiating the final price schedule (e.g., "Schedule B") in a hydrographic survey services IDIQ contract. Similar computations would be performed for other major line items that would be included in the IDIQ contract, e.g., Project Manager, CADD Workstation Operator, Drafter, Hardware/software, etc.

(4) The example below is but one method that may be used to develop an IGE for hydrographic surveying services. Each USACE district will have unique project, survey instrumentation, survey vessel, and A-E personnel requirements, and should tailor the IGE accordingly. More detailed guidance and examples of IGE computations are found in EP 715-1-7 and in the A-E PROSPECT course manual.

(5) Note that all labor or equipment rates shown in this appendix are for illustrative purposes only.

SAMPLE IGE COMPUTATION FOR 3-MAN MULTIBEAM/SIDESCAN SURVEY CREW
NOTE: Rates and prices shown are based on ca 2000 costs and equipment rates.
Some survey equipment listed is now obsolete; thus, this example is for illustrative purposes only.

LABOR

Supervisory Survey Tech (Party Chief)		$42,776.00/yr	
Multibeam Operator			
	Overhead on Direct Labor (36%)	$15,399.36/yr	
	G&A Overhead (115%)	$49,192.40/yr	
	Total:	$107,367.76/yr	$411.57/day
Survey Technician		$35,355/yr	
	@ 151% O/H (36%+115%)	$88,741.05	$340.17/day
Survey Aid/Boat Operator		$23,332/yr	
	@ 151 % O/H	$58,563.32	$224.49/day

Total Labor Cost for 3-Man Multibeam Crew/day: **$976.23**

TRAVEL

[Optional to include this item in the IDIQ IGE – typically added to each Task order]
Per Diem (Nominal): 3 @ $ 88/day
(subject to JTR adjustment on task orders)

Total Travel Cost/day: $264.00

PLANT, FLOATING

Survey Vessel 32-foot:

$100,000 @ 5 yrs @ 100 d/yr	$ 200/day
Fuel, O&M, etc	$ 25/day

Total Plant Cost/day: **$ 225.00**

SURVEY INSTRUMENTATION & EQUIPMENT

Echo Sounder $30,000 @ 5 yrs @ 50 d/yr	$120/day
POS/MV Carrier Phase Positioning Sys $120,000 @ 4 yrs @ 100 d/yr	$300/day
Motion sensor $35,000 @ 5 yrs @ 100 d/yr	$ 70/day
Multibeam System (complete) $250,000 @ 5 yrs @ 100 d/y	$500/day
Side Scan Sonar (complete system) $75,000 @ 5 yrs @150 d/yr	$100/day
Total Station (RTK), rods, etc. $32,000 @ 5 yrs @ 120 d/yr (rental rate: $60/d)	$ 53/day
Tide Gage, Auto Telemetry (Manufacturer rental rate)	$ 22/day
Survey Vehicle $40,000 @ 6 yrs @ 225 d/yr plus O&M	$ 40/day
Misc Materials (field books, survey supplies, etc)	$ 25/day

Total Instrumentation & Equipment Cost/day: **$ 1,230.00**

Subtotal : $ 2,695.23
Profit @ 10.0% $ 269.52

Total Estimated Cost per Day -- 3 man Multibeam/Side Scan Survey Crew $ 2,964.75

Figure C-2. Sample IGE

C-9. IDIQ Contract Price Schedule. The various personnel, plant, and equipment cost estimates like those shown in the sample IGE above are used as a basis for negotiating fees for individual line items in the basic IDIQ contract. During negotiations with the A-E contractor, individual components of the IGE and the contractor's price proposal may be compared and discussed. Differences would be resolved in order to arrive at a fair and reasonable price for each line item. Computations similar to those shown in the above example would be performed for auxiliary home office direct support functions (e.g., drafter, CADD operator, etc.). The contract may also schedule unit prices based on variable crew sizes and/or equipment and may include non-hydrographic survey functions such as control surveys. An example of a negotiated IDIQ price schedule (i.e., Section B - Supplies or Services and Prices/Costs) is shown below. As indicated previously, each Corps district has its unique requirements and therefore line items used in schedules will vary considerably. The basic IDIQ contract specifications would contain the personnel and equipment requirements for each line item.

ITEM	DESCRIPTION	UNIT OF MEASURE	UNIT PRICE
1001	4-Man Topographic Survey Party	CD	$ 885.00
1002	5-Man Hydro Survey Party w/boat	CD	$1,382.00
1002a	4-Man Hydro Survey Party w/boat	CD	$1,200.00
1002b	3-Man Hydro Survey Party w/boat	CD	$1,000.00
1002c	2-Man Hydro Survey Party w/boat	CD	$ 784.00
1003	Survey Aid	CD	$ 144.00
1004	Per Diem (Florida)	MD	$ 78.00
1005	Project Manager	MD	$ 335.00
1006a	Project Manager (Per Diem-Florida)	MD	$ 78.00
1007	CADD Operator/Draftsman	MD	$ 300.00
1008	Computer (Person)	MD	$ 238.00
1011	Establish Control Monument	EA	$ 25.00
1012b	Extra Vehicle	DY	$ 100.00
1013	Air Boat (Florida w/operator)	DY	$ 130.00
1014	Marsh Buggy (Florida w/operator)	DY	$ 160.00
1016	Side Scan w/Operator	HR	$ 120.00
1018	Multibeam w/Operator	HR	$ 130.00
1019	Magnetometer w/Operator	HR	$ 120.00

NOTES:
Abbreviations: CD = Calendar Day MD = Man Day DY = Day EA = Each HR = Hour
Prices include overhead and profit.

NOTE: the above items and unit prices were developed ca 1995 and are shown for illustrative purposes only. They are not based on current (2013) survey procedures or equipment.

Figure C-3. Contract schedule B-hydrographic surveying services indefinite delivery/indefinite quantity contract

LABOR CLASSIFICATION	TOTAL DAILY RATE*
Hydrographic Survey Expert (Court Testimony)	$1,500.00
Senior Project Manager (RLS)	$800.00
Project Manager/ Senior Hydrographer (Field-Office)	$750.00
Hydrographic Party Chief (Field)	$600.00
Hydrographic Survey Technician (Field)	$400.00
Instrument Person/Survey Technician (Field)	$300.00
Tideperson/Rodperson/Survey Assistant (Field)	$250.00
Geophysicist/Analyst (Field)	$1,200.00
Senior CADD Operator/Survey Computer	$500.00
Digitizer/ Draftsperson	$300.00
Word Processor (Typist)	$250.00
Per Diem (per person)	$200.00

* Labor rates include a total Overhead of 150.00% and include a Profit of 10%.

DIRECT COST ITEMS:	TOTAL DAILY RATE
[Floating Plant: NOTE: Vessel rates do not include survey equipment or instruments]	
28-ft Survey Vessel with Trailer (no operator)	$600.00
50-ft Survey Vessel (w/boat operators)	$3,000.00
100-ft Survey Vessel (w/boat operators)	$8,000.00
210-ft Geophysical exploration vessel (w/boat operators)	$35,000.00
Air Boat (w/operator)	$130.00
Marsh Buggy (w/operator)	$150.00
Skiff, alum, 12-ft (no operator)	$50.00
[Hydrographic Survey Equipment]	
Hydrographic Computer Data Acquisition System-HYPACK MAX (Single or Multibeam Data Acquisition & Processing)	$155.00
Onboard plotter for survey computer system	$100.00
DGPS Code Phase Hydrographic Positioning System	$100.00
GPS Carrier Phase (RTK) Topo/Hydro Positioning System	$350.00
200 kHz Fathometer with digitizer (single beam)	$70.00
Multi-beam Sweep System (200 kHz); complete system	$1,000.00
Dual Frequency Fathometer with digitizer	$150.00
Side Scan w/Operator	$950.00
Magnetometer w/Operator	$950.00
Sound velocity profiler	$50.00
Inertial Motion Compensation Device (Heave/pitch/roll)	$200.00
Gyro Compass	$150.00
POS/MV GPS Attitude & Orientation System	$200.00
Automatic Water Level Recorder & Telemeter	$60.00
[Land Surveying Equipment]	
Total Station Surveying & Data Logging System; complete, w/tripods	$150.00
Level, Automatic w/rods, tripods	$50.00
Theodolite, Wild T-3; complete with tripods, targets, tribrachs	$30.00
Theodolite, Astronomic, Wild T-4	$80.00
Transit, Engineers, w/tripod	$20.00
[Transportation]	
Survey Vehicle (4X4) with towing capability	$75.00
Survey Vehicle, Standard Van	$50.00
ATV, dune/beach buggy	$50.00

ALL OTHER DIRECT COSTS WILL BE NEGOTIATED ON A TASK ORDER BASIS.

Figure C-4. Contract schedule B-hydrographic surveying services indefinite delivery/indefinite quantity contract

SECTION II

Task Order Time and Cost Estimates

C-10. Task Order Requests for Proposal. A scope of work for a specific project is provided to the A-E contractor, requesting a proposed time and cost to perform the work. The task order scope should clearly define the work along with specific deliverable requirements. Examples of task order Requests for Proposal are provided at the end of this Section. Upon receipt of the contractor's proposal, the USACE and contractor negotiate a fixed price for the task order.

C-11. Task Order Time and Cost Estimates. Once unit prices have been negotiated and established in the basic IDIQ contract schedule, as illustrated in Section I, each IDIQ task order is negotiated primarily for effort, i.e., time. The process for estimating the time to perform any particular survey function in a given project is highly dependent on the knowledge and personal field experience of the government and contractor estimators. The negotiated fee on a task order is then a straight mathematical procedure of multiplying the agreed-upon effort against the established unit prices in the IDIQ Price Schedule, plus an allowance for profit if not included in the unit rates. If a preliminary site investigation is scheduled for this project, any such adjustments should be investigated and resolved prior to negotiating subsequent task orders for the various phases of the work, to the maximum extent possible. As such, the negotiated costs for the subsequent work phases would be considered fixed price agreements. Any later adjustments to these agreed to prices would be issued in the form of modifications/amendments to task orders (i.e., change orders), and would have to be justified as significant, unforeseen changes in the scope. The A-E contractor would be expected to immediately notify the contracting officer (KO) or Contracting Officer's Technical Representative of the need for cost adjustments.

a. Factors to consider in estimating task order field survey effort. The following items are typically involved in developing time and cost estimates for an IDIQ Task Order for a specific hydrographic survey project.

- Mob/Demob
  Travel time from A-E home office.
  Set up time at job site.

- Preliminary work
  Set tide staffs/gages … leveling, set BMs.
  Set control points … traverses, RTK, etc.

- Survey project area
  Perform QC calibrations.
  Single-beam, multibeam, side-scan, other.Perform QA performance tests.

- Field data processing, editing, plotting, QA assessment.
- Potential resurveys … dredging projects.

- Allowances … weather, breakdowns, etc.

b. Task Order IGE computation. A task order IGE simply requires an estimate of the time required to perform the field survey and office data processing for a project. Given the time estimate, the total cost is determined using the IDIQ scheduled rates. Estimating field survey effort is described in other chapters of this Engineer Manual.

c. Example IGE. The example below illustrates a time and cost IGE for a multibeam survey task order under an IDIQ contract using the unit prices taken from the Price Schedule established in the IDIQ contract. The estimate for field survey effort (seven crew days) is not shown. This was based on the required miles of survey, vessel speed, etc. specific to the project—see examples of these computations in Chapter 2.

Estimated field survey time … 7 crew days
Mob/demob from home office … 4 crew days.
Set tide staff/gage … 1 crew day.
Field data processing, editing, QA … 1 crew day.
(Crew day rate includes plant, personnel, equipment, and per diem)

Office review, QA, CADD export, plotting … 2 man days.
Office professional supervision (PLS review) … 1 man day.

Task Order IGE:
($3,100 crew day rate includes plant, personnel, equipment, and per diem)

Total Crew Days:	13 days * $3,100/day	=	$40,300
Office CADD	2 days * $300/day	=	$ 600
Project Manager	1 day * $335/day	=	$ 335
TOTAL ESTIMATED TASK ORDER COST (IGE)			$41,235

Table C-1 Time and Cost IGE under IDIQ

d. Note that this is a simplified example. Other line items from the IDIQ Price Schedule might have been included in task order estimate. The contractor's proposal for this Task Order would follow a similar process. Subsequent Task Order negotiations would primarily focus on significant differences in time estimates for the various phases of the work. This assumes the scope of work is clearly defined in the Task Order Request for Proposal. Uncertain scopes would have to be resolved during negotiations and the IGE amended accordingly.

C-12. Task Order IGE Time Estimates. The USACE IGE time estimate must be based on solid facts regarding the performance capabilities of the contractor performing the work and the project site conditions. This would include reasonable allowances for unforeseen conditions. The IGE estimator must also be familiar with the survey equipment, calibration requirements, and production rates of that equipment. In cases where the A-E is unfamiliar with the project site conditions, the contractor's proposal may assume "worst-case" conditions. For example, in the above estimate, the A-E may propose 11 crew days of field survey time vice the 7 crew day IGE. Thus, during task order negotiations, the USACE estimator's experience is critical is resolving such a difference.

C-13. Labor Hour Task Orders for Construction Support Surveying Services. Fixed-price task orders under IDIQ contracts are effectively used to provide a substantial amount of surveying and mapping services in USACE. However, fixed-price task orders are not usually appropriate for quality assurance and payment surveys of ongoing dredging and construction projects since the duration of the survey work is not within the control of the survey contractor. The surveyor contractor's progress is dependent on the progress of the dredging or construction contractor, which in turn, depends on weather, equipment malfunctions, unforeseen site conditions, material availability, labor problems, and many other factors. In such cases, a labor-hour task order is a very useful contracting mechanism. Labor-hour task orders are appropriate when the uncertainties involved in contract performance do not permit costs to be anticipated with sufficient accuracy or confidence to use a fixed-price task order. The contractor is required to apply its best efforts, but is not obligated to complete the assigned work within the contract ceiling price. Hence, a higher level of surveillance is required by the Government to ensure the contractor is performing as efficiently as possible. No special approvals are required to use labor-hour task orders, but the contracting officer must execute a determination and findings for the contract file explaining why a fixed-price order was not suitable. There is no true negotiation, but rather an agreement on a realistic ceiling price considering the most likely conditions. All hourly costs for personnel and equipment (including overhead and profit) are already established in the basic IDIQ contract. The Government buys a certain amount of effort and has considerable control over how that effort is expended toward completion of the specified task. The Government can direct the contractor to start, pause, and stop work, within reasonable limitations. However, the Government bears the cost for disruptions in work. A labor-hour task order has the flexibility to follow the progress of the dredging or construction, without unfairly holding the survey contractor to a fixed price. The most cost-effective situation is where there is

more than one project in the same area that can be surveyed using one task order. If there is a delay on one project, the survey crew can relocate to another project and resume work with minimal lost time. The following is an example of a Labor Hour task order scope:

Furnish all personnel, plant, equipment, transportation and materials necessary to perform, process and deliver the survey data described herein for dredging payment surveys in the following work areas in accordance with the general instructions and conditions set forth in Contract DACWXX-XX-D-XXXX:

- [List projects or work areas. Attach marked-up maps if needed. Describe work.]

Since it is not possible to accurately estimate the extent or duration of this work, this order will be issued on an estimated, not-to-exceed basis. The estimated quantities and ceiling price in accordance with the established contract rate schedule are as follows:

3-Person survey crew @ $[____]/hour x [___] hours:	$_____
Project manager @ $[___]/hour x [___] hours:	$_____
Ceiling price:	$_____

It is estimated that this work will begin about [__(date)__] and be completed about [__(date)__]. The contracting officer's representative (COR) at the [_____] Project Office will advise the contractor at least [___] hours in advance of when work must begin. The contractor may be directed to stop work at any time due to circumstances beyond the Government's control. If work is stopped at a work area, the contractor may be directed to relocate and start (or continue) work at one of the other work areas covered by this order, or to demobilize and return to the contractor's office. The contractor will be compensated at the hourly contract crew rate while stopped, relocating to another work area, demobilizing, or remobilizing (if required). There will be no compensation while the contractor is demobilized. The COR will advise the contractor at least [___] hours in advance of when the contractor must remobilize and resume work.

The contractor will prosecute the work diligently and efficiently under the general direction and oversight of the COR. The contractor will provide a daily report, describing the work performed and hours worked, to the COR for certification. The daily reports will be used by the contractor to prepare monthly payment vouchers. With each monthly payment voucher, the contractor will estimate monthly and total earnings in the succeeding month, expressed both as total dollars and a percentage of the ceiling price.

The contractor will immediately notify the COR in writing when total estimated earnings reach 85 percent of the ceiling price. Also, if at any time the contractor projects that the total estimated earnings to complete the work will exceed the ceiling price, the contractor will promptly notify the COR and give a revised estimated total price with supporting reasons and documentation. The contracting officer will increase the ceiling price in writing if warranted or limit the work so as to remain within the current ceiling price. Exceeding the ceiling price is at the contractor's own risk.

[Insert technical requirements and deliverables.]

Figure C-5. Labor hour task order

C-14. Contract Quality Control and Quality Assurance. Under the Corps professional contracting system, contractors are responsible for performing all quality control (QC) activities associated with their work. The Corps is responsible for quality assurance (QA) oversight of the contractor's QC actions. Therefore, Corps QA or testing functions should be focused on whether the contractor meets the required performance specification (e.g., depth accuracy), and not the intermediate surveying or compilation steps performed by the contractor. As a result, for surveys procured using the Brooks A-E Act qualifications-based selection method, Corps representatives are not stationed aboard contractor survey vessels to observe work in progress (i.e., perform QC activities)--the contractor was selected as being technically qualified to perform the work;

including all QC associated with it. Corps-performed field testing of a contractor's work is an optional QA requirement, and should be performed only when technically and economically justified. Such Corps testing of a contractor's hydrographic survey data submittal rarely occurs in practice.

SAMPLE TASK ORDER REQUEST FOR PROPOSAL

Engineering Division
Design Branch

Subject: Contract No. DACW17-96-D-0017

EMC Inc.
101 West Market Street
Greenwood, Mississippi 38930-4431

Gentlemen:

Enclosed are marked drawings depicting the scope of work for the following project:

Canaveral Sand Bypass Phase II
Pre and Post Construction Survey
Canaveral, Florida (Survey No. 97-096)

General Scope. Furnish all personnel, plant, equipment, transportation, and materials necessary to perform and deliver the survey data required hereinafter in accordance with the instructions and conditions set forth in Contract No. DACW17-96-D-0017. Services not specifically described herein are nevertheless a firm requirement if they can be identified as an item, or items, commonly a part of professional grade work of a comparative nature. All work shall be accomplished in accordance with the manuals and TM's specified in your contract.

- Your attention is directed to the Site Investigation and Conditions Affecting the Work clause of your contract. After we have reached agreement on a price and time for performance of this work, neither the negotiated price nor the time for performance will be changed as a consequence of conditions at the site except in accordance with the clause. Costs associated with the site investigation are considered overhead costs which are reimbursed in the overhead rates included in your contract. Additional reimbursement will not be made.

a. Field Survey. Pre and After construction hydrographic and topographic beach survey data shall be collected for the borrow area and beach fill area. Enclosure 1 is the contract plans. Enclosure 2 is the control monument descriptions. Enclosure 3 is the technical requirements for the surveys.

The Contractor shall furnish one 4-Man hydrographic survey party. The task order shall be issued based on the estimated-not fixed-number of field crew days, project manager, CADD days, and computation days. When the assignment is completed the task order shall be adjusted to reflect the total cost. To certify the hours worked and progress, a daily report shall be furnished to Design Branch from the field party employed. Weekly submittal is acceptable. The Contractor's work hours and days may have to be adjusted to coincide with the Corps of Engineers request. The Contractor shall indicate on the daily report the survey party hours worked on that day. The Contractor shall be notified 24 hours in advance of any work assignment.

The points of contact are, Mr. Hank Rimmer, at 904-232-1606, and Mr. James Lanier at 407-783-8407. Any instruction given to the survey crew by the Atlantic Coast Area Office shall be coordinated with Mr. Rimmer before commencing.

b. Data processing. The Contractor shall make the necessary computations to verify the accuracy of all measurements and apply the proper theory of location in accordance with the law or precedent and publish the results of the survey.

c. CADD. The hydrographic and topographic features shall be translated or digital capture into Intergraph IGDS 3D design files according to the specifications furnished. The survey data (cover and section view sheets) shall be provided in Intergraph Microstation (PC or 32) Version 4.0 or higher, AT&T System V Unix, CLIX R3.1 Vr. 6.3.2 format as shown in the letter dated 30 September 1992.

Surveying shall be in strict compliance with the Technical Requirements for Surveying Mapping and Photogrammetric services manual and the Minimum Technical Standards set by the Florida Board of Land Surveyors and Mappers.

The completion date for this assignment is 90 days after the Notice to Proceed is signed by the Contracting Officer.

All material shall be returned to Design Branch upon completion of this assignment.

You must notify the Contracting Officer immediately when the work effort is 85% of the not to exceed amount. Contact Design Branch at 904-232-1613 for questions or assistance with your proposal.

You are required to review these instructions and make an estimate in writing of the cost and number of days to complete the work. Please mark your estimate to the attention of Chief, Survey Section.

This is not an order to proceed with the work. The Contracting Officer will issue this at a later date.

Figure C-6. Sample Task Order Request for Proposal

Example Task Order Scope of Work--Sand Bypass Project

CANAVERAL SAND BYPASS PHASE II PROJECT
PRE AND POST HYDROGRAPHIC AND TOPOGRAPHIC
BEACH CONSTRUCTION SURVEY
CANAVERAL, FLORIDA
SURVEY No.97-096

1. LOCATION OF WORK: The project is located at Canaveral, Florida.

2. SCOPE OF WORK:

2a. The services to be rendered by the Contractor include obtaining topographic and hydrographic beach survey data (x, y, z) for the borrow area from CCAFS-38 TO CCAFS-29, for the beach fill area from R-7-T to R-14 and CADD files as shown on Enclosure 1, contract plans and specifications.

2b. The services to be rendered by the contractor include all the work described below. Details not specifically described in these instructions are nevertheless a firm requirement if they can be identified as an item, or items, commonly a part of professional grade work of a comparative nature.

2c. The contractor shall furnish all necessary materials, labor, supervision, equipment, and transportation necessary to execute and complete all work required by these specifications.

2d. The Corps of Engineers, Design Branch shall be contacted the same day that the Contractor plans to commence the work. The points of contact are, Mr. Hank Rimmer, (CORPS OF ENGINEERS DISTRICT OFFICE) at 904-232-1606, and Mr. James Lanier (ATLANTIC COAST AREA OFFICE) at 407-783-8407. Any instruction given to the survey crew by the Atlantic Coast Area Office shall be coordinated with the Mr. Rimmer before commencing. A meeting with the Atlantic Coast Area Office, Mr. Lanier shall be arrange before commencing the surveys to establish the priority for the surveys.

2e. Rights-of-Entry must be obtained verbally and recorded in the field book before entering on the private property. Enter in the field book the name and address of the property owner contacted for rights-of-entry.

2f. COMPLIANCE: Surveying shall be in strict compliance with Engineering and Design Standards and Specifications for Surveys, Maps, Engineering Drawings, and Related Spatial Data Products and the Minimum Technical Standards set by the Florida Board of Professional Surveyors and Mappers.

2g. All digital data shall be submitted on CD ROM's.

3. FIELD SURVEY EFFORT: Topographic and hydrographic beach survey data shall be obtained for the borrow area from CCAFS-38 TO CCAFS-29, for the beach fill area from R-7-T to R-14 and CADD files as shown on Enclosure 1, contract plans and specifications. Enclosure 2 is the contract plans and specifications. Enclosure 3 is the control monument descriptions. Enclosure 4 is the Technical Requirements.

3a. CONTROL: The Horizontal datum shall be NAD 1927 and the vertical datum shall be N.G.V.D. of 1929. All control surveys shall be Third Order, Class II accuracy.

3a1. The basic control network can be accomplished using precise differential carrier-phase Global Positioning System (GPS). Differential GPS baseline vector observations shall be made in strict accordance with the criteria contained in the engineering manual EM-1110-1-1003 and with the Geometric Geodetic Accuracy Standards And Specifications For Using GPS Relative Positioning Techniques by Federal Geodetic Control Committee, version 5.0.

3a2. Network design, station and baseline occupation requirements, for static and kinematic surveys, satellite observation time per baseline, baseline redundancies, and connection requirements to existing networks, shall follow the criteria given in the above said engineering manual. A field observation log sheet shall be completed at each setup in the field.

3a3. GPS derived elevation data shall be supplied in reference to the above said datum. Existing benchmark data and stations shall be used in tandem in a minimally constrained adjustment program to model the geoid. All supporting data used in vertical adjustment shall be submitted.

3a4. Existing Corps of Engineers project control shall be utilized for establishing horizontal and vertical control. No control monuments shall be utilized that are not included in the control network shown in the contract plans. All established or recovered control shall be fully described and entered in a FIELD BOOK, in accordance with the Technical Requirements of this contract. Recover or establish horizontal and vertical control monuments at each profile line. The designations for new control monuments will be furnished when needed. All horizontal and vertical control shall be verified before using.

3a5. All horizontal and vertical control (double run forward and back) established shall be a closed traverse or level loop no spur lines, with third order accuracy. All horizontal and vertical control along with baseline layouts, sketches, and pertinent data shall be entered in field books.

3a6. All monuments, survey markers, etc., recovered shall be noted on the copies of control descriptions. Control points established or recovered with no description or out-of-date (5 Years old) description shall be described with sketches for future recovery use.

3a7. All original field notes shall be kept in standard pocket size field books and shall become the property of the Government. The first four pages of the field books shall be reserved for indexing and the binding outside edge shall be free of all marking. Design Branch will issue field book numbers upon submittal of field books for checking.

3b. TIDE STAFF: The survey data shall be collect on MLW datum which is 1.9 below N.G.V.D. located in vicinity of "CABLE SOUTH PORT" monument.

3c. BORROW AREA: Collect survey data (X, Y, & Z) for profile lines CCAFS-38 thru CCAFS-29. The profile lines shall start at the monuments (range 0) and extend seaward to range 1600 with data points at 25 foot range intervals and all breaks and 12.5 foot intervals in the water. The profile lines shall be ran on the azimuth shown in Enclosure 1. Establish a survey stake at 3.5 foot MLW elevation on each profile line. The survey stake shall be labeled with 3.5 MLW.

3d. BEACH FILL AREA:

3d1. BASELINE: Establish a baseline landside of the monuments with line of sight from R-7-T to R-14. The baseline shall be establish between elevation 9.5 MLW and the monuments. Establish POT's along the baseline at 100 foot intervals.

3d2. PROFILE LINES: Collect survey data (X, Y, & Z)
on 100 intervals with data points at 25 foot range intervals and all breaks for the land portions and 12.5 for the water portions, from the monuments (range 0) to range 1000 seaward. Establish a survey stake at 9.5 foot MLW elevation for each profile line. The survey stake shall be labeled with 9.5 MLW.

3e. BREAKLINE: Breaklines shall be located for all natural or man-made features as needed. The breaklines shall be located with X, Y, and Z and identified.

3f. DATA COLLECTION (RTK or TOTAL STATION): Data collection will be allowed for data points only, showing all instrument positions, calibration, backsites and closing readings in the field book. If RTK is utilized Q1 and Q2 files shall be furnished. Before using RTK, one session shall be performed around the expected survey area. After observation of the primary control (four monuments; one on each corner of the work area) the geoid model shall be prepared utilizing the four occupied monuments data.

4. DATA PROCESSING: The Contractor shall make the necessary computations to verify the accuracy of all measurements and apply the proper theory of location in accordance with the law or precedent and publish the results of the survey. Compute and tabulate the horizontal and vertical positions on all work performed. Review and edit all field data for discrepancies before plotting the final drawings.

4a. Furnish X, Y, Z, and descriptor ASCII file for each profile line and one X, Y, Z, and descriptor ASCII file with all profile lines included for each area.

5. CADD: The topographic and hydrographic features shall be translated or digital capture into Intergraph IGDS 3D design files according to the specifications furnished. The survey data (cover, control, site plan, plan sheets, and section drawings) shall be provided in Intergraph Microstation (PC or 32) Version 4.0 or higher, AT&T System V Unix, CLIX R3.1 Vr. 6.3.2 format as shown in the letter dated 30 September 1992. All CADD files shall be the same as shown in Enclosure 1.

5a. GLOBAL ORIGIN: The IGDS 3-D design file shall be prepared with a global origin of 0, 0, 2147483.65, Design file master units: FT., Sub units: 1,000, and positional units: 1. The file name shall be the survey number prefixed with an "Y", i.e. Y049sh1.DGN. All reference files name shall commence with the Y049**.DGN also.

5b. DIGITAL TERRAIN MODEL (DTM) DATA: The Contractor shall develop and deliver a surface model of each survey area using Intergraph compatible Digital Terrain Modeling software and the model file shall have the .dtm extension. The digital terrain model shall be developed from the collected data. Breaklines should include ridges, drainage, road edges, surface water boundaries, and other linear features implying a change in slope. The surface model shall be of adequate density and quality to produce a one-foot contour interval derived from the original DTM (Digital Terrain Model) file. The contour data shall be incorporated as a reference file into the final data set (DGN file). All data used to develop the DTM shall be delivered in Intergraph 3-D design files.

5b1. CONTOURS: The contours shall be developed in the digital terrain model (DTM). The contours shall be provided in one or more master (scale 1" = 200') DGN files, attached as a reference file to all sheet files utilizing clip bounds methods. Each contour shall be drawn sharp and clear as a continuous solid line, dashed contours are not acceptable. Every index contour shall be accentuated as a heavier line than the intermediate contour line and shall be annotated according to its actual elevation above MLW. Labeling or numbering of contours shall be placed on top of the contour line, so that the elevation is readily discernible, do not break contours. Labeling of intermediate contours may be required in areas of low relief.

5c. MASTER DGN FILES:

5c1. The survey data (DTM data points) points shall be provided in one or more master DGN file (scale 1" = 200'), attached as a reference file to all sheet files utilizing the clip bounds methods.

5c2. The contours shall be provided in one or more master DGN file (scale 1" = 200'), attached as a reference file to all sheet files utilizing the clip bounds methods. "DO NOT PLOT THE CONTOURS".

5c3. The breaklines shall be provided in one or more master DGN file (scale 1" = 200'), attached as a reference file to all sheet files utilizing the clip bounds methods, "DO NOT PLOT THE BREAKLINES".

5c4. The control points shall be provided in one or more master DGN file (scale 1" = 200'), attached as a reference file to all sheet files utilizing the clip bounds methods.

5c5. The baseline shall be provided in one or more master DGN file (scale 1" = 200'), attached as a reference file to all sheet files utilizing the clip bounds methods.

5d. COVER AND CONTROL SHEET: The first sheet shall be a cover sheet showing the control sketch, survey control tabulation, sheet layout or index, legend, project location map, survey notes, north arrow, graphic scale, grid ticks, large signature title block. Tabulate, plot, and list the control used for the survey on the final drawings.

5e. PLAN SHEETS: The plan sheets shall be prepared to a scale of 1" = 200', in the Corps of Engineers format (reference letter and instruction dated September 30, 1992) showing notes, title block, grid, north arrow, graphic scale, legend, sheet index, and D. O. File Number. Sheets shall be oriented with north to the top and designed to utilize the least number of sheets. The extreme right 7 inches of the sheet shall be left blank for notes, legends, etc. The first (cover) sheet shall have large signature block. The second sheet and all sheets following shall be a continuation sheet and shall have a minimum of two notes, note 1: See Drawing number 1 for notes, note 2: Refer to Survey No. 97-096. PAPER PLOTS ONLY".

6. MAP CONTENT:

6a. COORDINATE GRID (NAD 27): Grid ticks (English) of the applicable State Plane Coordinate System shall be properly annotated at the top, bottom and both sides of each sheet. Spacing of the grid ticks shall be five (5) inches apart.

6b. CONTROL: All horizontal and vertical ground control monuments shall be shown on the maps in plan and tabulated.

6c. TOPOGRAPHY: The map shall contain all representable and specified topographic features which are visible or identifiable.

6d. SPOT ELEVATIONS: Spot elevations shall be shown on the maps in proper position. In areas where the contours are more than 3 inches apart at map scale, spot elevations shall be shown. The horizontal distance between the contours and such spot elevations or between the spot elevations shall not exceed two (2) inches at scale of delivered maps.

6e. CONTOURS: The contours shall be developed in the digital terrain model (DTM). Each contour shall be drawn sharp and clear as a continuous solid line, dashed contours are not acceptable. Every index contour shall be accentuated as a heavier line than the intermediate and shall be annotated according to its actual elevation. Whenever index contours are closer than one-quarter (1/4) inch, and the ground slope is uniform, the intermediate shall be omitted. Labeling or numbering of contours shall be placed on top of the contour line, so that the elevation is readily discernible, do not break contours. Labeling of intermediate contours may be required in areas of low relief.

6f. MAP EDIT: All names, labels, notes, and map information shall be checked for accuracy and completeness. All buildings, roads and man made features shall be labeled with the type of construction, purpose and name. All residences shall be labeled with the type of construction.

6g. SHEET INDEX AND LEGEND: On plan drawings a small scale sheet index shall be shown on each sheet of the series; highlighting the sheets in the standard manner. Planimetric and topographic feature legends shall be shown on each sheet. Contractor logo shall be shown on each drawing.

6h. MAP ACCURACY: All mapping shall conform to the national map accuracy standards except that no dashed contours will be accepted.

7. OFFICE REVIEW AND COMPUTATIONS: The Contractor shall make the necessary computations to verify the correctness of all measurements and apply the proper theory of location in accordance with the law or precedent and publish the results of the survey.

8. DELIVERIES: On completion, all data required shall be delivered or mailed to Design Branch, Survey Section at the address shown in contract, and shall be accompanied by a properly numbered, dated and signed letter or shipping form, in duplicate, listing the materials being transmitted. All costs of deliveries shall be borne by the Contractor. Items to be delivered include, but are not limited to the following:

8a. GPS network plan.

8b. GPS raw data along with field observation log sheets filled out in field with all information and sketches.

8c. Computation files with Horizontal and Vertical abstracts along with any Q1 and Q2 files.

8d. Horizontal and Vertical Field Books.

8e. Furnish X, Y, Z, and descriptor ASCII file for each profile line and one merged with all data collected for each area.

8f. DTM File

8g. DGN files to a scale of 1" = 200.

8h. Advance paper plots of all plan sheets, cover sheet and control sheets for approval.

Figure C-7. Sample Task Order Scope of Work

Example Task Order Scope of Work--River Sections

PROPOSED TASK ORDER NO. 26
CONTINENTAL ENGINEERING, INC.
DACW66-97-D-0053

Scope of Work
1999 Mississippi River General Hydro Surveys
7 January 1999

1. General Scope The contractor shall perform General Hydrographic Surveys on the Mississippi River within the reaches described in the enclosures. The surveys shall include the development of digital maps reduced to the low water reference plane, color coded elevations (polyfill shapes vs triangles), checked for correctness, hard copy of each survey including the raster image, and a format developed to be directly inserted into the Regional Engineering Environmental Geographical Information System (REEGIS).

2. Survey Requirements and Specifications.

a. Miscellaneous. See Miscellaneous Survey and Specifications (MSRS), dated 4 March 1993, paragraphs 1 through 8 for A-E responsibilities in regard to Quality Assurance, Submission of Pay Estimates, Safety, Project Progress Reports, Damages, Coordination of Work, Datums, and Survey Field Notes.

b. Right of Entry. Verify right of entry with the QARs. See paragraph 9.b., MSRS dated March 1993.

c. Survey Limits. The limits for the surveys shall be the reaches as described in Encl. 1. The surveys shall extend from bank to bank at 1056-ft intervals unless otherwise required in the limit enclosure. Additional ranges shall be sounded upstream and downstream as near as safety considerations will allow to existing dikes. The ranges obtained near dikes should not be from bank to bank, but should extend a minimum of 200 feet beyond the riverward end of the dike. The data shall be obtained within the reaches described and sheets not split.Existing Horizontal Control. Adequate horizontal control exists within a reasonable distance of the survey limits to perform this project. The control consists of monuments used for all river work within the Memphis District. Horizontal control shall be supplied to the respective hydrographic survey party chiefs at the Memphis District Office prior to the start of the surveys.

d. New Baseline Control. No new baseline control shall be required for this project.

f. Horizontal Computations. All horizontal data developed for this project shall be computed on the North American Datum of 1983 (NAD 83) using Universal Transverse Mercator (UTM) Zone 15 or 16 plane coordinates in U.S. Survey Feet. See MSRS, paragraph 12 for other requirements. Azimuth orientation shall be from zero North.

g. Existing Vertical Control. Adequate vertical control exists within a reasonable distance of the survey limits to perform this project within the accuracy specified. Recovery of existing vertical control shall be documented as described in MSRS paragraphs 13.a., 13.b., 13.c., and 13.d.

g. New Vertical Control. No new vertical control shall be required for this project.

h. Monumentation. No new monumentation is required under this Scope of Work.

i. Digital Map. A digital map in a separate IGDS file for each hydrographic sheet shall be required at a scale of 1:10,000 with a five-foot contour interval. An ASCII file shall be provided that includes all hydrographic data collected and edited for erroneous soundings and positions. Soundings shall be collected at intervals no greater than 50 feet. A second ASCII file shall also be provided which contains an x,y,and z coordinate at least every 100 feet along each range.

A Microstation design file (.DGN) of each plotted "z" elevation at the "x" and "y" coordinate for each point found in the second ASCII coordinate file above shall be submitted. Soundings shall be on level 49, color coded elevations and buoys on level 52. The design file shall contain horizontal and vertical control used to develop the survey. An Intergraph digital terrain model (.DTM) file shall also be provided. For all work along the Mississippi River, the 1993 Low Water Reference Plane elevation shall be used as the zero contour. Digital sheets supplied by the Memphis District reflect true elevations but shall be reduced relative to the 1993 LWRP by the contractor. They shall be developed as three-dimensional graphic elements on level 57 to be loaded as breaklines to the .DTM file. Hydrographic survey shall be performed at the locations and intervals described in paragraph 2.c. and as described below:

(1) Ranges. The ranges shall extend from water's edge to water's edge. The coverage shall include all dike fields, chutes, sandbars and islands that can be surveyed hydrographically. In addition, all navigation buoys within the defined area shall be located by an x and y position and plotted on the maps.

(2) Sounding data (rounded to the nearest foot) shall be plotted at intervals of ± 100 feet using a text size of 80 (using Font 10). The contour interval shall be five feet and the contours shall extend from water's edge to waters edge. The zero contour shall be a dashed (---) line. The –10 contour shall be a solid line of heavier weight than the other contours. The hydrographic data may overlap with adjacent sheets. In these cases all hydro data shall be plotted on all overlapping sheets. All hydrographic maps shall be verified for accuracy by the contractor before final submittal to this office. All miscellaneous data (i.e. title blocks, gage data {furnished by Government}, slope diagrams, and data ranges were sounded) on the sheet shall be completed by the contractor.

(3) All hydrographic survey ranges are to be sounded as nearly normal to the channel as possible. Computer generated contours cannot be developed accurately if ranges are at any noticeable angle. Where some angle cannot be avoided, range spacing should be decreased.

(4) Each survey shall follow the REEGIS standards which are in the enclosure. Each survey shall use polyfill shapes for the color-coded contours instead of triangles.

(5) The following files shall be submitted .DGN, .DTM and .XYZ files for the NGVD Elevation **and** for the Low Water Reference Plane.

(6) A hardcopy plot of each completed hydrographic sheet shall be submitted containing the latitudinal and longitudinal grid, soundings, contours, color coded elevations, raster image, and title block.

(7) Level 63 information as contained in Miscellaneous Intergraph Requirements and Specifications, dated 10 September 1992 shall be included in all files.

3. DATA SUBMISSION. The data required by these surveys shall be developed and submitted by 12 February 1999. No formal SER shall be required for this scope of work.

Figure C-8. Example Task Order Scope of Work – River Sections

Example Task Order Scope of Work--Revetment Surveys

PROPOSED TASK ORDER NO. 33
EMC, INC.
DACW66-98-D-0007

Scope of Work
Revetment Before Construction Survey at Norfolk-Star, MS
Approximate River Mile 711L AHP

1. General Scope. The contractor shall perform a revetment before construction survey at Norfolk-Star Revetment, MS. The purpose of this survey is to gather information for the possible extension of Norfolk-Star Revetment. The survey will consist of baseline recovery from Norfolk-Star Revetment baseline station 84+00 to station 75+00 and the establishment of 6000 ft of new baseline upstream from station 75+00. Soundings from water's edge to 800 ft. beyond water's edge and bank sections from water's edge to 150 ft. behind top bank will also be required.

2. Survey Requirements and Specifications.

a. Miscellaneous. See Miscellaneous Survey and Specifications (MSRS), dated 4 March 1993, paragraphs 1 through 8 for A-E responsibilities in regard to Quality Assurance, Submission of Pay Estimates, Safety, Project Progress Reports, Damages, Coordination of Work, Datums, and Survey Field Notes

b. Right-of-Entry. Right-of-entry has been obtained by the Memphis District Corps of Engineers.

c. Survey Limits. The limits for baseline recovery shall be from Norfolk-Star Revetment baseline station 84+00 to station 75+00. Section limits shall be from baseline station 84+00 to 6000 ft. upstream of station 75+00. Lateral limits shall be from 150 ft. behind top bank to 800 ft. beyond water's edge. Sections shall be taken at 100-ft. intervals. A Site Map is provided in Encl. 1.

d. Existing Horizontal Control. The Norfolk-Star Revetment baseline shall be re-established from baseline station 75+00 to baseline station 84+00 in accordance with MSRS, paragraph 11.a, 11.b, 11.d, and 11.f. Paragraph 11.b shall be amended to Third Order Class 2. Adequate horizontal control exists as herein furnished within a reasonable distance of the survey limits to perform this survey to the required accuracy specifications. Existing Norfolk-Star Revetment baseline coordinates are provided in Encl. 2. Note that these coordinates are provided in NAD 83 Geographic Coordinates with Corpscon translated coordinates of Norfolk-Star Revetment baseline to NAD 83 UTM Zone 15, U.S. Survey feet.

e. New Horizontal Control. New baseline shall be established in accordance with MSRS, paragraph 11.a, 11.b, 11.d, and 11.f. Paragraph 11.b shall be amended to Third Order Class 2. The new baseline shall stem from existing baseline station 75+00 and run 6000 ft. upstream of station 75+00 along the bar at River Mile 926R AHP, to new baseline station 40+00.

f. Horizontal Computations. Horizontal data shall be computed on the North American Datum of 1983 (NAD 83) using Universal Transverse Mercator (UTM) Zone 15 plane coordinates in U.S. Survey Feet. See MSRS, paragraph 12 for other requirements.

g. Existing Vertical Control. Vertical control information is provided in Encl. 3. See MSRS, paragraph 13.a, 13.b, 13.c, and 13.d for requirements.

g. New Vertical Control. Third order vertical control shall be established on all Type G or Type F monuments and iron pins installed as described in MSRS, paragraphs 13.a and 13.d. All new vertical control documentation shall be submitted as hard copy and in digital form using previously supplied database software.

h. Monumentation. Monumentation shall be as described in MSRS, paragraph 14.a. through 14.g. and as follows:

(1). Each monument or iron pin (baseline) shall be designated by the stationing preceded by the following character:

BASELINE	DESIGNATION	EXAMPLE
Norfolk-Star	NS	NS 75+00

Note: There shall be a space between the prefix and the stationing, not a dash.

A River List monument/marker documentation form shall be completed in accordance with MSRS, paragraph 14.f (1) for each Monument installed. All existing and new horizontal and vertical control marks used to complete this survey shall be included in the final data submittal.

(2). Each iron pin shall be stamped as described in MSRS, paragraph 14.c.

i. Field Book Documentation.

(1) Recover/Re-establish Norfolk-Star Revetment baseline within the survey limits in accordance with MSRS, paragraphs 11.a, 11.b, 11.d, and 11.f.

(2) Establish new baseline from station 75+00 to 6000 ft. upstream of station 75+00 in accordance with MSRS, paragraphs 11.a, 11.b, 11.d, and 11.f.

(3). Obtain bank sections at 100-ft. intervals. Sections shall extend from water's edge to 150 ft. behind top bank.

(4) Obtain soundings at 100-ft. intervals. Soundings shall extend from water's edge to 800 ft. beyond water's edge.

(5 All elevations shall be referenced to National Geodetic Vertical Datum of 1929. All horizontal positions shall be referenced to the North American Datum of 1983, using UTM Zone 15 plane coordinates in U.S. Survey Feet.

(6 The 1993 Low Water Reference Plane shall be used for contouring which equals 168.40 at mile 711L AHP.

j. Digital Map. Digital maps shall be developed and provided in digital format as described in MSRS, paragraph 23.a.

3. DATA SUBMISSION. The delivery date for the final SURVEY ENGINEERING REPORT shall be 1 March 1999. See MSRS, dated 4 March 1993, paragraph 24, for additional requirements.

Figure C-9. Example Task Order Scope of Work--Revetment Surveys

Example Task Order Scope of Work--Project Condition Survey

TECHNICAL REQUIREMENTS
JACKSONVILLE HARBOR 30, 34, 38, & 42-FOOT PROJECT,
PROJECT CONDITION SURVEY, JACKSONVILLE,
DUVAL COUNTY, FLORIDA
(Survey No. 99-315)

1. LOCATION OF WORK. The project is located at Jacksonville Harbor, Jacksonville, Duval County, Florida.

2. SCOPE OF WORK.

2a. The service to be rendered by the Contractor includes obtaining hydrographic survey data as shown on Enclosures 1(Plan drawings), and 2. Enclosure 3 is the technical requirements and Enclosure 4 is control monuments descriptions.

2b. The services to be rendered by the Contractor include all the work described in these technical requirements. Details not specifically described in these instructions are nevertheless a firm requirement if they can be identified as an item, or items, commonly a part of professional grade work of a comparative nature.

2c. The Contractor shall furnish all necessary rights-of-entry, materials, labor, supervision, equipment, and transportation necessary to execute and complete all of the work required by these specifications.

2d. The Corps of Engineers, Survey Section shall be contacted the same day that the Contractor plans to commence the work.

2e. Rights-of-Entry must be obtained verbally and recorded in the field book before entering on the private property. Enter in the field book the name and address of the property owner contacted for rights-of-entry.

2f. COMPLIANCE. Surveying and Mapping shall be in strict compliance with EM-1110-1-1000 for Photogrammetric Mapping, EM-1110-1-1002 Survey Markers and Monumentation, EM-1110-1-1003 NAVSTAR Global Positioning System Surveying, EM-1110-1-1004 Deformation Monitoring and Control Surveying, EM-1110-1-1005 Topographic Surveying, EM-1110-2-1003 Hydrographic Surveying, EM-1110-1-2909 Geospatial Data and System, (Tri-Service) A/E/C CADD Standards, (Tri-Service) Spatial Data Standards, Related Spatial Data Products and Chapter 177, Chapter 472, and Chapter 61G17 of the Minimum Technical Standards set by the Florida Board of Professional Surveyors and Mappers.

2f1. STANDARDS FOR DIGITAL GEOSPATIAL METADATA.
Metadata are “data about data”. They describe the content, identification, data quality, spatial data organization, spatial reference, entity and attribute information, distribution, metadata reference, and other characteristics of data. Each survey project shall have metadata submitted with the final data submittal. Furnish a digital file using CORPSMET 95 (Metadata Software) with the appropriate data included. Enclosure 5 is an example of the metadata file printed. Point of contact in survey section is Mr. Bill Mihalik at 904-232-1462.

2g. All digital data shall be submitted on CD-ROM's.

3. FIELD SURVEY EFFORT. Obtain the hydrographic survey data for Cuts 3-19, Cuts 39-55, Terminal Channel, Cuts A, F & G as shown on Enclosures 1, and 2. Enclosure 3 is the control monument descriptions, Enclosure 4 is the technical requirements.

3a. CONTROL.

3a1. The Horizontal datum shall be NAD 1927. The vertical datum shall be NGVD 1929. All control monuments shall be verified both horizontally and vertically by a control survey. All control surveys shall be Third Order, Class II accuracy. All Positions will be tied to the state plane coordinate system, zone 0901 Florida East.

3a2. The basic control network shall be accomplished using precise differential carrier-phase Global Positioning System (GPS). Differential GPS baseline vector observations shall be made in strict accordance with the criteria contained in the engineering manual EM-1110-1-1003 and with the Geometric Geodetic Accuracy Standards And Specifications For Using GPS Relative Positioning Techniques by Federal Geodetic Control Committee, version 5.0.

3a3. Network design, station and baseline occupation requirements, for static and kinematic surveys, satellite observation time per baseline, baseline redundancies, and connection requirements to existing networks, shall follow the criteria given in the above said engineering manual. A field observation log shall be completed at each setup in the field.

3a4. GPS derived elevation data shall be supplied in reference to the above said datum. Existing benchmark data and stations shall be used in tandem in a minimally constrained adjustment program to model the geoid. All supporting data used in vertical adjustment shall be submitted.

3a5. Existing Corps of Engineers control data shall be tied into subject survey net. The GPS network shall commence from the control shown on Enclosure 2. All established or recovered control shall be fully described in accordance with the Technical Requirements of this contract. All control surveys shall be Third Order, Class II accuracy. The Contractor shall submit the field data and abstracts for the control networks to Survey Section for computation before commencing the mapping. The monument designations shall be furnished as requested. All horizontal and vertical control (double run forward and back) established shall be a closed traverse or level loop no spur lines, with third order accuracy. All horizontal and vertical control along with baseline layouts, sketches, and pertinent data shall be entered in field books. All monuments, survey markers, etc., recovered shall be noted on the copies of control descriptions. Control points established or recovered with no description or out-of-date (5 Years old) description shall be described with sketches for future recovery use. All original field notes shall be kept in standard (pocket size) field books and shall become the property of the Government. The first four pages of the field books shall be reserved for indexing and the binding outside edge shall be free of all marking.

3b. TIDE STAFF: Staff shall be located in the immediate vicinity of the work areas. The gauge shall be referenced MLW as shown on Enclosure 2 (Tide staff locations)

3c. The limits of the hydrographic survey are: Jacksonville Harbor, Cut-3 thru Terminal Channel, Cut-A, Cut-F & Cut-G. Take hydrographic cross-sections for the reaches listed below.

Cut	*Beginning Station*	*Ending Station*	*Azimuth*	*Sta. Interval*
3	0+00.00	300+00.00	96-53-41	100 feet
4	0+00.00	15+38.67	86-36-47	100 feet
5	0+00.00	13+58.23	66-17-49	100 feet
6	0+00.00	24+72.08	42-22-17	100 feet
7	0+00.00	28+21.83	21-18-33	100 feet
8	0+00.00	24+66.35	40-38-49	100 feet
9	0+00.00	24+23.63	65-36-03	100 feet
10	0+00.00	7+77.36	86-22-43	100 feet
11	0+00.00	6+08.86	98-23-01	100 feet
12	0+00.00	4+96.23	107-14-12	100 feet
13	0+00.00	18+14.83	116-51-38	100 feet
14/15	0+00.00	47+62.29	129-38-26	100 feet
16	0+00.00	13+31.28	120-17-44	100 feet
17	0+00.00	10+92.08	108-32-47	100 feet
18	0+00.00	8+98.59	91-46-22	100 feet
19	0+00.00	9+27.10	76-50-50	100 feet
39	0+00.00	36+57.85	60-42-50	100 feet
40	0+00.00	19+94.59	87-46-43	100 feet
41	0+00.00	29+54.53	114-28-25	100 feet
42	0+00.00	159+16.21	79-14-02	100 feet
43	0+00.00	21+57.00	112-50-00	100 feet
44	0+00.00	49+31.81	146-25-58	100 feet
45	0+00.00	40+47.22	136-44-10	100 feet
46	0+00.00	20+64.07	127-12-22	100 feet
47	0+00.00	14+95.67	107-30-00	100 feet
48	0+00.00	13+45.42	88-10-39	100 feet
49	0+00.00	20+41.57	68-43-49	100 feet
50	0+00.00	82+30.97	58-32-58	100 feet
51	0+00.00	58+57.42	16-40-20	100 feet
52	0+00.00	15+69.24	08-59-20	100 feet
53	0+00.00	12+92.85	342-49-45	100 feet
54	0+00.00	10+48.52	333-10-31	100 feet
55	0+00.00	40+11.32	309-07-42	100 feet
Term Ch	0+00.00	186+21.19	10-00-41	100 feet
A	0+00.00	53+10.21	161-45-23	100 feet
F	0+00.00	25+48.02	36-37-57	100 feet
G	0+00.00	149+36.21	17-11-17	100 feet

Coverage should extend a minimum of 200-feet outside channel limits, wideners, and turning basins in all directions. Ensure that lines extend sufficient distance to cover Coal Terminal and proposed settling basin (enclosure 2) which are both adjacent to Cut-42. Coverage in proposed settling basin should extend a minimum of 400-feet in all directions as shown on enclosure.

3d. Priorities are given for this project as follows:

1. Terminal Channel, from Sta. 164+56 to southern terminus.
2. Cut-42 to Sta. 164+56 of Terminal Channel.
3. Cut-14/15 to Cut-19.
4. Cuts A, F & G
5. Cut-19 to Cut-42
6. Bar Cut-3 to Cut-14/15.

Once a priority is completed, mapping should be done and submitted as stated above.

3g. NAVAIDS. All Navigation's Aids (NAVAIDS) shall be located with coordinate positions (GPS) in or adjacent project area. Fixed NAVAIDS shall be positioned four to five times and floating NAVAIDS shall be positioned one time, with wind and tide direction recorded. Note type and condition of NAVAIDS within the project limits. Warning signs, lights, and any existing regulatory markers, (information signs) within the project limits shall be positioned four to five times. Locate all NAVAIDS in the entrance channel.

3h. DGPS. The hydrographic positioning system shall be a Differential Global Positioning System utilizing the USCG Nav-beacon system as the reference station. The positioning system shall be checked with two control monuments and recorded along with setup data (input data to the GPS) in the field book. Hydrographic survey log sheets shall be filled out and submitted along with the field book.

3i. SOUNDING POLE 6" DISK. Utilize a 6 inch diameter disk attached to the bottom of the sounding pole or lead line at all times when collecting conventional soundings.

3j. Breakline. Breaklines shall be located for all natural or man-make features as needed. The breaklines shall be located with X, Y and Z and identified.

3k. DATA COLLECTION (TOTAL STATION). Data collection will be allowed for data points only, showing all instrument positions, calibration, backsites and closing readings in the field book.

4. DATA PROCESSING. The Contractor shall make the necessary computations to verify the correctness of all measurements and apply the proper theory of location in accordance with the law or precedent and publish the results of the survey. Compute and tabulate the horizontal and vertical positions on all work performed. Furnish X, Y, and Z points file for each profile line with descriptors shown for all land features located west of and including the monument at point collected, landward side (one file with land, one file with water, one with land and water data merged). Review and edit all field data for discrepancies before plotting the final drawings. Tabulate a list of the tide staff locations and bench mark designations used for the survey. Furnish ASCII X, Y, Z files with negative sign if elevation is negative.

5. CADD. The survey data shall be translated or digital capture into Intergraph IGDS 3D design files according to the specifications furnished. The survey data (cover, control, site plan, plan sheets, and section drawings) shall be provided in Intergraph MicroStation (PC or 32) Version 4.0 or higher, AT&T System V Unix, CLIX R3.1 Ver. 6.3.2 format as shown in the letter dated 30 September 1992.

5a. GLOBAL ORIGIN. The IGDS 3-D design file shall be prepared with a global origin of 0, 0, 2147483.65, Design file master units: FT., Sub units: 1,000, and positional units: 1. The file name shall be the survey number prefixed to an "A," i.e., A315.DGN. All reference file names shall commence with the A315 also.

5b. Digital Terrain Model (DTM) Data. The Contractor shall develop and deliver a surface model of the survey area using Intergraph compatible Digital Terrain Modeling software and the model file shall have the .dtm extension. The digital terrain model shall be developed from cross sections, spot elevations, and breaklines. Breaklines should include ridges, drainage, road edges, surface water boundaries, and other linear features implying a change in slope. The surface model shall be of adequate density and quality to produce a one foot contour interval derived from the original DTM (Digital Terrain Model) file. The contour data shall be incorporated as a reference file into the final data set. All data used to develop the DTM's shall be delivered in Intergraph 3-D design files.

5b1. Contours. The contours shall be developed in the digital terrain model (DTM). The contours shall be provided in one or more master data base DGN files, attached as a reference file to all sheet files utilizing the clip bounds methods. Each contour shall be drawn sharp and clear as a continuous solid line, dashed contours are not acceptable. Every index contour shall be accentuated as a heavier line than the intermediate and shall be annotated according to its actual elevation above NGVD Whenever index contours are closer than one-quarter (1/4) inch, and the ground slope is uniform, the intermediate shall be omitted. Labeling or numbering of contours shall be placed on top of the contour line, so that the elevation is readily discernible, do not break contours. Labeling of intermediate contours may be required in areas of low relief.

5c. MODEL DGN FILES (SCALE 1:1). The overall hydrographic data (collected data points) shall be provided in one or more master DGN file attached as a reference file to all sheet files utilizing the clip bounds methods. The project depth (30, 34, 38, & 42-foot) contours shall be provided in one or more master DGN file attached as a reference file to all sheet files utilizing the clip bounds methods. The control data points shall be provided in one or more master DGN file attached as a reference file to all sheet files utilizing the clip bounds methods.

5d. COVER AND CONTROL SHEET. The first sheet shall be a cover sheet showing the control sketch, survey control tabulation, sheet layout or index, legend, project location map, survey notes, north arrow, graphic scale, grid ticks, and large signature block. Tabulate, plot, and list the horizontal control used for the survey on the final drawings. In addition show a table on this sheet showing the X and Y coordinates, station and elevation for each point and monument.

5e. PLAN SHEETS. The plan sheets shall be prepared to a scale of 1"=100', in the Corps of Engineers format showing notes, title block, grid, north arrow, graphic scale, legend, sheet index, and D. O. File Number. The data shall be plotted at 12.5-foot intervals. The extreme right 7 inches of the sheet shall be left blank for notes, legends, etc. The second sheet and all sheets following shall be a continuation sheet and shall have a minimum of two notes, note 1: See Drawing number 1 for notes, note 2: Refer to Survey No. 99-315.

5f. Section Views. The sections shall be extracted and displayed from the digital terrain model (DTM OR TNT) utilizing INROADS OR INXPRESS. The sections shall be generated or extracted along the same azimuth as the section was collected in the field. The sections shall be displayed at a 10 to 1 vertical exaggeration. The planimetric lines (alignment of extraction), alignment, stations, and cross sections shall be displayed in one DGN file. Paper plots **"NOT REQUIRED".**

6. Map Content.

6a. Coordinate Grid (NAD 83). Grid ticks (English) of the applicable State Plane Coordinate System shall be properly annotated at the top, bottom and both sides of each sheet. Spacing of the grid ticks shall be five (5) inches apart.
6b. Control. All horizontal and vertical ground control monuments shall be shown on the maps in plan and tabulated.
6c. Topography. The map shall contain all representable and specified topographic features, which are visible or identifiable.
6d. Spot Elevations. Spot elevations shall be shown on the maps in the proper position.
6e. Contours. The contours shall be developed in the digital terrain model (DTM). The contours shall be provided in one or more master data base DGN files, attached as a reference file to all sheet files utilizing the clip bounds methods. Each contour shall be drawn sharp and clear as a continuous solid line, dashed contours are not acceptable. Every index contour shall be accentuated as a heavier line than the intermediate and shall be annotated according to its actual elevation above mean sea level. Whenever index contours are closer than one-quarter (1/4) inch, and the ground slope is uniform, the intermediate shall be omitted. Labeling or numbering of contours shall be placed on top of the contour line, so that the elevation is readily discernible, do not break contours. Labeling of intermediate contours may be required in areas of low relief.
6f. Map Edit and Accuracy. All names, labels, notes, and map information shall be checked for accuracy and completeness. All commercial buildings, roads and man made features shall be labeled with the type of construction, purpose and name. All residences shall be labeled with the type of construction. All mapping shall conform to the national map accuracy standards except that no dashed contour line will be accepted.

7. Office Review and Computations: The Contractor shall make the necessary computations to verify the correctness of all measurements and apply the proper theory of location in accordance with the law or precedent and publish the results of the survey. The contractor shall submit the original field notes and horizontal and vertical abstract (computation abstract) to Survey Section for final computation before mapping commences.

8. DELIVERIES: On completion, all data required shall be delivered or mailed to Design Branch, Survey Section at the address shown in contract, and shall be accompanied by a properly numbered, dated and signed letter or shipping form, in duplicate, listing the materials being transmitted. All costs of deliveries shall be borne by the Contractor. Items to be delivered include, but are not limited to the following:

8a. GPS network plan, (before GPS work commences).
8b. GPS raw data along with field observation log sheets filled out in field with all information and sketches.
8c. Computation files with Horizontal and Vertical abstracts along with any Q1 and Q2 files.
8d. Horizontal and Vertical Field Books.
8e. Furnish X, Y, and Z ASCII file for the longitudinal centerline.
8f. DTM Files (one overall and one per cut)
8g. DGN files. (scale 1" = 100')
8h. Plans plots at a scale of 1" = 1'00. 1 copy is requested with a contour shown inside channel at project depth. Project depth is 42-feet from Sta. 0+00 of Bar Cut-3 to Sta. 210+00 of Bar Cut-3, 38-ft from Sta. 210+00 of Bar Cut-3 to Sta. 164+56 of Terminal Channel, 34-feet from Sta. 164+56 of Terminal Channel to terminus of Terminal Channel, and 30-feet in Cut-A, F, G.
8i. Volumes: Perform necessary calculations to compute volume of material above project depth (plus 1 & 2-feet below) over surveyed area. Provide a spreadsheet showing computed results.

8j. Furnish a digital file using CORPSMET 95 (Metadata Software) with the appropriate data included.
8k. Raw HYPACK Log Files.

Enclosures (withdrawn in example)

Figure C-10. Example Task Order Scope of Work-Project Condition Survey

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APPENDIX D

General Background on Hydrographic Survey Accuracy Estimates

D-1. Purpose and Scope. This appendix provides supplemental background information on some of the statistical terms and depth error propagation issues covered in Chapter 3. It contains examples of techniques that may be used to estimate the accuracy of depth measurements. Some of the material in this appendix was incorporated from discussions at Multibeam User Group conferences held in the North Atlantic Division during the mid-2000's, and from the NOAA "NOS Hydrographic Surveys Specifications and Deliverables" manual (NOS 2011) and the NOAA "Field Procedures Manual,"(OCS 2011).

D-2. Definitions of Statistical Terms. Various statistical terms are used to describe the required or resultant "accuracy" of an observed depth. These include "error," "standard deviation," "uncertainty," "TPU," "confidence," "precision," and "repeatability." [1] Often these terms are misused, interchanged, and not always rigidly defined in specifications. Definitions of these statistical terms are provided in numerous texts and publications, such as those listed in Appendix A. The following definitions apply to the specific use of the terms in this manual.

a. Accuracy. Accuracy is a statistical terms that is often misused in specifications. It is classically defined as the "degree of closeness of a measurement to its true value." Since all depth measurements contain errors (uncertainties), the "true depth" measured at a point is rarely, if ever, absolutely known. This is especially true of underwater acoustic depth measurements in varying topography and sediments, along with often highly variable acoustic reflectivity, absorption, and refraction characteristics. Accuracy is traditionally used in a survey specification as requiring the measured depths to meet some type of "±" dispersion statistic, such as a standard deviation or TVU (e.g., ±1.0 ft); however, measuring or verifying that the survey actually met this type of "±" dispersion is extremely problematic.

b. Accuracy Standard. An "accuracy standard," as traditionally used in USACE engineering practice, is defined as meeting some statistical performance measure. This may be meeting some "repeatability" or "standard deviation" criteria based on calibration Performance Tests, or meeting some "TPU" dispersion level based on error budget estimates. For example, a required depth accuracy standard may specify that internal Performance Tests on a dredge clearance survey "should be repeatable to 0.2 ft. and that the 95% standard deviation not exceed

[1] Note that various international and national standards organizations have recommended replacing the terms "accuracy" and "error" with the somewhat equivalent term "uncertainty." This manual continues use of "accuracy" as it is recognized throughout USACE engineering practice. However, it is recommended that "uncertainty" be used to indicate data quality estimates on survey drawings furnished to the public or other federal organizations.

(±0.5 ft)." Alternatively, an accuracy standard may specify that a general project condition survey should be performed to meet an IHO "Special Order" TVU standard of ±0.8 ft.

c. Quality Control. Throughout this manual a variety of QC procedures are prescribed for survey instrumentation and data collection techniques in order to minimize systematic and random uncertainties in individual data points. QC procedures may include bar checks, velocity casts, patch tests, instrument alignment tests, vessel velocity limitations, multibeam beam-width restrictions, and maintaining overlapping coverage limits. Recommended single-beam and multibeam QC procedures are contained in their respective chapters in this manual, in equipment manufacturer's operating manuals, and in the NOAA "Field Procedures Manual" (OCS 2011). Performing all recommended QC procedures does not necessarily ensure that the resultant depth or elevation data will meet the standards in Table 3-1.

d. Performance Standard. A performance standard defines the minimal quality control (QC) calibration procedures and quality assurance (QA) tests (e.g., Performance Tests). The QC and QA performance standards recommended in this manual are not mandatory requirements—they should be modified as required to meet the required accuracy standard for a particular project.

e. Performance Tests. Repeatability is typically estimated from Quality Assurance Performance Tests—single beam cross-section checks (Chapter 4) or multibeam surface comparisons (Chapter 6). Poor repeatability indicates biases are present in the measurement system. Repeatability is a critical measure for dredge measurement and payment surveys.

f. Repeatability. Repeatability is defined as "the closeness of agreement between the results of successive measurements carried out under the same conditions of measurement" (JCGM 100 2008). These conditions include: the same measurement procedure, the same observer, the same measuring instrument used under the same conditions, the same site location, and repetition over a short period of time. For dredging measurement and payment surveys of a specific navigation project, these conditions of measured repeatability would include: using the same vessel, survey system, calibration procedures, tide/water level and geoid measurement methods, and performed over a short environmental time interval.

g. Bias. When multiple surveys are conducted over the same area (e.g., an acceptance section or in a small cell), the repeatability of these depth observations may be statistically estimated by computing the differences between the means of overlapping observations. The accumulated differences are an indication of a "bias" between the surveys. Repeatability is expressed as a bias difference between the comparison surveys—e.g., +0.03 ft or (-) 0.2 ft. For multibeam systems, the bias may vary by beam angle.

h. Repeatability versus Accuracy (Standard Deviation). A survey can show a high degree of repeatability but not be accurate. This is because accuracy (uncertainty or TPU) estimates

include many biases and errors that are not uncovered by Performance Tests run by the same vessel and system. These include datum uncertainties, calibration biases, bottom reflectivity characteristics, and acoustic signal processing biases. For example, a survey Performance Test in a deep-draft navigation project may show a repeatability of, say +0.05 ft, but have a 95% standard deviation of ±0.8 ft.

i. Reproducibility of depth measurements. Reproducibility is defined as "the closeness of the agreement between the results of measurements carried out under changed conditions of measurement" (JCGM 100 2008). For hydrographic surveys, changed conditions would involve depth measurements made over the same project area (or cell) by different vessels, different measurement systems, different environmental conditions, different calibration methods, different acoustic frequencies, different tidal conditions, different times (e.g., days apart), etc. A measure of reproducibility is observed when comparing surveys by two vessels survey of the same area, a common occurrence on dredging contracts when the government and dredging contractor's vessels survey the same acceptance section. Both vessels have differing error propagation estimates and differing precisions. Reproducibility is a better estimate of "repeatability" since Performance Test comparisons between different vessels/systems are more independent, and are more likely to uncover differing biases in each system.

j. Confidence. Survey confidence is roughly defined as the probability that the true value of a measurement will lie within some specified accuracy or uncertainty from the measured value. Confidence is specified as a "±" statistic at a 95% level and is derived from standard deviation or uncertainty error propagation estimates. It is usually based on the statistics from repeated sample standard deviations, i.e., the "standard error of the mean" statistic, which is not the same statistic as a 95% standard deviation, RMS, or TPU. However, in practice, confidence is often substituted for 95% standard deviation. Use of confidence statistics requires the same caution as that for TPU or standard deviation—the method by which it was computed (estimated) must be clearly defined. Confidence computations based on Performance Test comparisons obtained by the same vessel may contain unknown biases that may skew the "true" confidence of a clearance survey. Therefore, using the term "confidence" may incorrectly imply some absolute certainty in the data that is not correct—a "95% standard deviation" would be a more appropriate term. Computed confidence levels may be of some use in assessing "risk assessment" measures, such a channel clearance confidence. Commercial software, such as CUBE (Combined Uncertainty and Bathymetry Estimator) provides uncertainty hypotheses or "confidence" estimates for selecting a representative depth when multiple depths are observed in the same area.

D-3. Total Propagated Uncertainty. Total Propagated Uncertainty (TPU) is the result of uncertainty error propagation, when all contributing measurement uncertainties, both random and systematic, have been included in the propagation. Uncertainty propagation combines the effects of measurement uncertainties from several sources upon the uncertainties of derived or calculated parameters. These include, but are not limited to, uncertainties in the geodetic

framework (WGS84, GRS80, NSRS), vertical datum reference gage datum uncertainties (MLLW, MSL, LWRP), vessel motion (roll, pitch, heave, yaw), geoid model errors, tidal phase and range model errors, acoustic measurements, bottom reflectivity, etc. TPU estimates are derived using standard Mean Square Error (MSE) propagation methods. This includes treating minimized (by calibration) systematic errors (biases) as random variables (see JCGM 100 2008).

a. Total Horizontal Uncertainty (THU). THU is the component of total propagated uncertainty (TPU) calculated in the horizontal plane. THU is a two-dimensional quantity. The uncertainty of a horizontal position of an observed depth is the uncertainty at the position of the depth within the geodetic reference frame. The estimated positional accuracy is usually specified as a two-dimensional radial error at the 95% level. A measured/resolved depth typically represents the acoustic return over a relatively large horizontal area (footprint) on the bottom—the acoustic footprint can often be larger than a grid cell size being assessed for channel clearance. Depending on many factors, the horizontal position of the depth's footprint on the bottom can have uncertainties ranging from ±2 to more than ±10 ft.

b. Total Vertical Uncertainty (TVU). TVU is the component of total propagated uncertainty calculated in the vertical dimension. TVU is a one-dimensional quantity. Vertical uncertainty is to be understood as the uncertainty of the reduced (corrected) depths. In determining the vertical uncertainty, the sources of individual uncertainties need to be quantified. All uncertainties should be combined statistically (using Mean Square Error techniques) to obtain a total vertical uncertainty.

c. "IHO Standards for Hydrographic Surveys" (IHO 2008)) emphasizes that "…the adequacy of a survey is the end product of the entire survey system and processes used during its collection. The uncertainties outlined in IHO 2008 reflect the total propagated uncertainties of all parts of the system … simply using a piece of equipment that is theoretically capable of meeting the required uncertainty is not necessarily sufficient to meet the requirements of these [IHO] Standards. How the equipment is set up [calibrated], used and how it interacts with the other components in the complete survey system must all be taken into consideration ..." Section A.4 of IHO 2008 (at Appendix E) lists many of the error sources that make up the total propagated uncertainty of a multibeam survey system.

D-4. Hydrographic Survey Error Propagation. Figure D-1 illustrates how survey errors propagate through the positioning and depth measurement systems, resulting in an estimate of the three-dimensional (3D) error ellipsoid representing the Total Propagated Uncertainty of the measurement. These errors are described in the following paragraphs. For additional guidance on depth error propagation, refer to the NOAA "NOS Hydrographic Surveys Specifications and Deliverables" manual (NOS 2011) and the NOAA "Field Procedures Manual,"(OCS 2011).

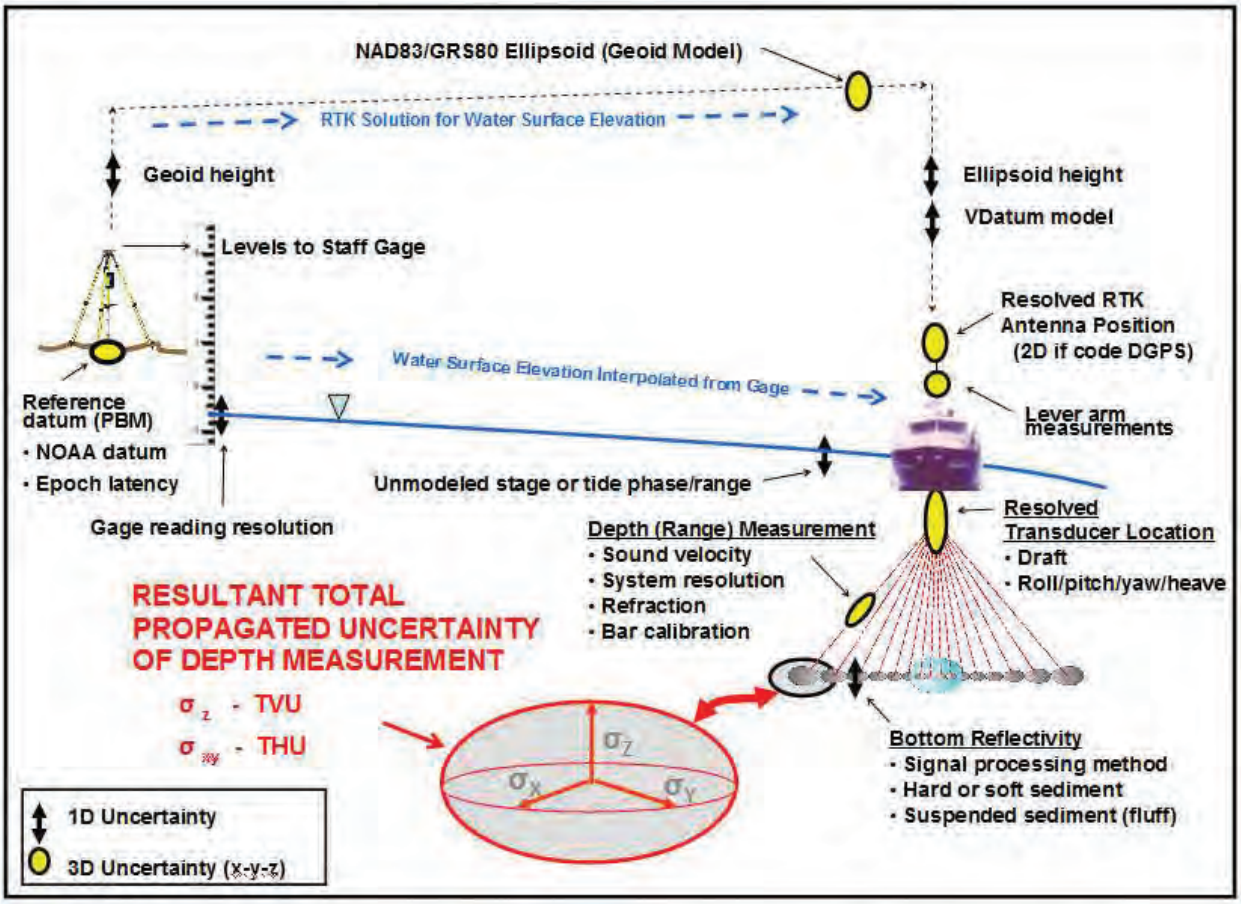

Figure D-1. Total Propagated Uncertainty of a multibeam depth. Major measurement system error components are indicated by arrows or ellipses. The elevation of the water surface at the vessel is determined by either (1) extrapolated gage reading or (2) RTK ellipsoid observations.

a. Reference benchmark uncertainties. Tidal benchmark elevations used to reference measurement, payment, and clearance surveys at a project are subject to uncertainties. The stability of the bench mark could be subject to regional settlement or uplift. The MLLW datum has an uncertainty dependent on the length of the time the gage was in place, the distance from a primary gage, and other factors. The uncertainty of the computed MLLW datum at a gage site can range from ± 0.1 ft to as much as ± 0.25 ft. It is also assumed that a primary reference bench mark (e.g., a "PPCP") is used to control all surveys performed at a given project site. If different bench marks are used, and inconsistencies between these bench marks are found to exist (height or MLLW datum), then these uncertainties would be propagated into the TPU estimates. An example would be uncertainties in a tidal zoning model.

(1) Biases in tidal models, tidal epoch latencies, reference datum biases, tidal bench mark settlement, sea level change, reference datum adjustments, geoid readjustments, and other largely indeterminate factors. These are biases that are difficult or nearly impossible to measure or correct for. They are generally not factored in dredge clearance assessment. This is because these biases are present in all repeated surveys over the project, assuming the same vertical reference tidal bench mark is used on a given project. They do, however, enter into the estimated uncertainty of a reported channel clearance to the public and cost estimates for dredging.

(2) For example, sea level rise occurring between NOAA tidal epoch updates at a project could be as much as 0.2 ft. Thus, the MLLW datum at the reference bench mark would have a constant bias of 0.2 ft and the reported channel clearance constantly off by that same amount. This equates to overdredging the project by a constant 0.2 ft, which may have significant budget impacts.

(3) The use of outdated or undefined local reference datums will also cause systematic biases in the maintained or reported project depth. Datum biases of upwards of 2 ft have been known to occur, resulting in incorrectly reported or interpreted channel clearance depths.

b. Reference water level staff gage resolution. The resolution of the gage reading will have additional uncertainty, especially on unstilled river or tidal staff gages where visual water surface estimates are made. RTK systems must be calibrated to this same staff gage. Depending on wave conditions at the gage, uncertainties in reading the gage can exceed ±0.1 ft.

c. Geoid uncertainties. Geoid undulations occurring over a project must be modeled if RTK methods are used to measure the water surface elevation. Geoid model uncertainties in coastal areas are typically at the 1 to 3 cm range, with predicted uncertainties slightly larger (5 cm) in offshore entrance channels. There are no practical methods of refining the model in offshore models; however, since these uncertainties are systematic to all users of the same model, survey repeatability (or more importantly, reproducibility) is not impacted.

d. Extrapolated or interpolated water surface elevation at project site. Hydrographic depth measurements are reduced and referenced to the local water surface at the time the measurement is made. This water surface is normally referenced to an on-shore reference benchmark or gage as shown in Figure D-1. The most significant error component involves the assumed stability (levelness) of the water surface between the on shore gage and the survey vessel. This stability is usually valid in most non-tidal lakes, impoundment reservoirs, and rivers where extensive stage surface modeling has been performed, and staff gages can be set at every 0.2- to 0.4-ft change in river slope. In these areas, interpolated (or extrapolated) vertical reference accuracies within ±0.1 ft may be attainable. However, on coastal navigation projects subject to tidal influences, any surface gradients between the gage and underway vessel must be corrected, using tidal models and/or in conjunction with inertial-aided RTK measurements.

(1) Estimating extrapolated surface elevation uncertainties. Extrapolated gage observations to an offshore location become more uncertain as the distance to the project site increases, especially in tidal waters with large phase and range variations. Interpolated river stages from distant gages also become uncertain over large distances. Estimating this extrapolation (or interpolation) error component is difficult—especially in areas with large tidal phase and range variations between the gage and project site. Estimating river gradient interpolation errors may also be difficult, especially where hydrodynamic surface variations exist between distant gages. Generally, a "worst case" estimate is used.

(2) Tidal zoning model uncertainties. Various tidal zoning models have been developed to estimate phase and range differences between the gage and the offshore project area. Since tidal gradient variations involve time and location-dependent parameters, on-line or after-the-fact correction may be difficult and time-consuming. Tidal zoning models contain numerous internal uncertainties, the largest being wind and current effects on the model. Estimating uncertainties in the zoning model due to these variations is difficult—again, a "worst case" estimate must be used.

(3) Tidal phase and range variations. Tidal datum phase and range variations over a project may be subject to uncertainties if not minimized by some form of hydrodynamic modeling. In tidal waters, the NAVD88-MLLW elevation difference (often termed a "KTD" file) may vary between the gage and project site. NOAA's "VDatum" models this variation. Any uncertainty in this KTD model is eliminated if all users apply the same model corrections. (VDatum is a software model developed by NOAA's National Geodetic Survey (NGS), Office of Coast Survey (OCS), and Center for Operational Oceanographic Products and Services (CO-OPS). VDatum transforms geospatial data among a variety of tidal, orthometric and ellipsoidal vertical datums.)

e. RTK surface elevation measurements. As indicated in Figure D-1, as an alternative to imprecise extrapolation methods, inertial-aided RTK techniques may be used to determine the water surface elevation at the vessel location. This is done by filtering long-term GPS observations to obtain an average surface elevation (i.e., "RTK Tide"). If RTK-derived water surface elevations are measured, coupled with inertial-aided GPS systems to correct vessel motions (e.g., POS/MV), then the uncertainty of the water surface elevation measurement at the project site may be minimized. RTK measurements contain numerous internal errors that must be factored into any uncertainty estimate. These include errors in the geoid model, RTK resolution, IMU drifts, and antenna-water surface-transducer lever arm measurements on board the survey boat. Corrected RTK surface measurement accuracies are typically at the ±0.2 ft level.

f. Vessel static and dynamic draft errors. Since echo sounding instrument calibrations are performed while the vessel is stationary, the “draft” index derived during that calibration may vary from the index occurring while the vessel is under way. This dynamic draft is due to

changes in the vessel's trim while under way. It is systematic and varies as a function of velocity through the water. A squat calibration is performed to measure the change of trim. However, the squat calibration process itself is not very precise, especially on smaller boats where personnel and loading characteristics (e.g., fuel usage) can vary between the time of the squat test and the time of the actual survey. Vessel loading changes may also occur during the course of an actual survey. Errors due to inadequate compensation for the varied index, loading, and dynamic draft variations are systematic and can be significant, especially on small boats with side-mounted transducers. If not calibrated, these errors can approach ±0.5 ft in some instances. (See Chapter 4 for details.) Use of RTK for vertical water level corrections helps minimize these errors.

g. Vessel stability and orientation errors. Sea conditions obviously impact the ability to reference a depth measurement to the uniform water surface alongside the survey vessel with precision. This applies to difficulties in correcting the superimposed effects of sea roll, pitch, and heave on a depth measured with an echo sounder. Thus, depending on the severity of sea conditions, an individual elevation (or sounding) contains an error component resulting from this source. If no motion compensation is used these errors can be ±1 ft or more. Inertial-aided GPS systems are used minimize this error. A number of internal errors are associated with inertial-aided GPS motion compensation systems, such as lever arm measurements, IMU biases, latencies, etc. These internal errors must be estimated in any uncertainty analysis. Refer to additional guidance in NOAA 2011.

h. Depth measurement system errors. All the various measurement errors (e.g., velocity and refraction) associated with the acoustic measurement system propagate downward to the bottom, as shown in Figure D-1. At the bottom surface, other acoustic reflectivity factors propagate into the error budget, such as the signal processing and analysis of the apparent acoustic reflection return. These errors are described in Chapters 4 and 6. In areas with suspended sediments, determining the depth of a return signal from a given material density becomes complex (See Appendix P). The precision of any depth measurement will, in general, degrade as a function of water depth, and slope distance on multibeam systems. This is due to a number of electronic and physical factors inherent in the sound travel-time measurement process, i.e., changes in water temperature, salinity, etc. Multibeam depth measurement uncertainty typically degrades (increases) over the outer beams on the array, depending on the type of depth determination method employed (amplitude, phase, interferometric) and the bottom characteristics or reflectivity. Beam refraction (ray bending) can also be a problem if sound velocity measurements are not correct. These errors are minimized by frequent calibration of the echo sounding equipment.

i. Echo sounder calibration. Errors and uncertainties associated with calibrating acoustic systems were described in Chapters 4 and 6. These include errors in the bar check calibration, velocity profiles, and Patch Tests.

j. Bottom material density variations. The relative density of the bottom material affects all depth measurement methods, especially echo sounding instruments that are highly dependent on finite density changes (acoustic impedance changes) to distinguish between and record acoustical returns. On sounding poles, sounding disks, and lead lines, the surface area, weight, and drop velocity determines their stopping or refusal points. In many instances, these points are difficult to establish, especially when these devices continue to free-fall under their own weight in low-density sediments. Echo sounding returns are dependent on the frequency of the acoustic pulse, receiver sensitivity settings, and distinct density (impedance) changes in the subsurface material. Bottom material densities may even vary across a single multibeam swath. Other difficulties arise in areas with suspended sediments (fluff) present, such as naturally occurring fluff or disturbed sediments from dredging operations. Small variations in sensitivity (or signal gain) settings on the echo sounder can cause large variations in the return point. These errors are systematic, and no definitive methods exist to fully compensate for them; let alone estimate error uncertainties for them.

D-5. Resultant Total Propagated Uncertainty. The resultant TPU ellipsoid shown in Figure D-1 will typically be elongated in the X-Y plane (THU) due to a higher uncertainty in the horizontal location of the depth observation.

a. Total Horizontal Uncertainty (THU). The horizontal uncertainty is dependent on the positioning system accuracy (DGPS or RTK). This positioning error propagates down from the vessel antenna, through the system orientation sensors, to the bottom. Horizontal uncertainty increases with acoustic footprint size, which, in turn, is dependent on beam width and depth (and location on a multibeam array). Obviously, a single beam depth or multibeam nadir depth in 10 ft of water will have a much smaller horizontal footprint than a multibeam depth 45 deg from nadir in 50 ft of water. Note also that the THU shown in Figure D-1 includes uncertainty in the NSRS horizontal datum. This is usually negligible (<2 cm) when published NSRS/CORS points are used to control the survey.

b. Total Vertical Uncertainty (TVU). As illustrated in Figure D-1, depth uncertainty is dependent on the propagating errors outlined above. The vertical uncertainty will normally be less that ±1 ft (95%) under average conditions. It can be as small as ±0.2 ft when surveying hard bottom in non-tidal waters a few hundred ft from a reference gage. It can be as large as ±2 ft when surveying in unmodeled tidal waters 10 miles distant from a reference gage. As with THU, TVU includes any uncertainty in the vertical datum at the reference gage, such as published NOAA NWLON tidal datums or inland low water reference planes (LWRP).

c. Minimizing TPU. Some of the error components shown in Figure D-1 will be minimized (and even eliminated) when the same vessel and acoustic system is used at a project site. Uncertainty in the reference datum at the gage is such an example—the X-Y-Z coordinates are assumed absolute regardless of NSRS datum uncertainty. Likewise, the MLLW datum model at the project site will be assumed constant (e.g., from a VDatum model) as will any geoid

model height uncertainty. If the bottom has a consistent density, and the processor sensitivity and gain settings are kept constant during repeated surveys, then some of these variables will be considered constant within this particular measurement system. This will result in repeated comparisons surveys in a given area agreeing with one another at less than the 0.1 ft level—i.e., "repeatability" not "accuracy." Use of inertial-aided RTK from a "fixed" reference datum (gage) will have a major effect in reducing relative accuracy levels down to < 0.1 ft repeatability levels. (Repeatability is assessed by comparing intersecting or overlapping points from two different surveys (e.g., Performance Tests), and computing the mean deviation of all the differences. Individual points may differ by large amounts in irregular bottoms (e.g., ±1 or more ft); however, if the mean or average deviation between the thousands of overlapping points is small (e.g., < 0.1 ft), then a good repeatability measure is indicated. This would also indicate minimal biases exist between the surveys.)

D-6. Estimating a Survey Uncertainty Allowance on USACE Navigation Projects. Estimating the uncertainty or TPU is complex, and must include individual error estimates for the numerous measurement system and environmental condition variables outlined above. These error estimates can be based on known uncertainties in each system component, from those provided by the individual sensor manufacturers, or obtained in guidance from other agencies (e.g., NOAA). Other error estimates may be gained from repeated observation experience, such as sound velocity or draft calibration consistency, and Performance Tests.

a. Required dredging grade uncertainty allowance. The design navigation grade or required dredging template should contain an allowance for uncertainties in the reference datum, tidal models, and survey accuracies. This allowance is dependent on a statistical analysis of the entire measurement system, along with estimated hydrodynamic, meteorological, geomorphological, and environmental conditions occurring at a specific project site. This uncertainty assessment should be performed during the feasibility or PED phase, and reviewed when developing construction plans and specifications for new work or maintenance dredging.

b. Survey uncertainty tolerance. This survey uncertainty allowance may be factored in the tolerances used in the original studies that determine the authorized navigation depth for a project—see EM 1110-2-1613, Hydraulic Design of Deep-Draft Navigation Projects. This uncertainty allowance (or tolerance) can also play in the evaluation of dredge clearance survey data and in the significant figure (rounding) resolution of recorded depths and clear grades. Figure D-2 illustrates the uncertainty allowance estimate relative to (i.e., above and below) a nominal or required clearance grade. This uncertainty may or may not be significant on soft bottom maintenance dredging projects; however, on new work or rock-cut channels, this allowance may need to be applied to the overdepth allowance to provide additional confidence that the final channel clearance is to grade. Any survey uncertainty allowance must consider the survey system intended for use on the project; especially variations in beam angle accuracies of multibeam systems.

c. Due to the difficulty in estimating some of the error components in a formal TPU computation, practical engineering judgment must often be used in establishing an uncertainty tolerance for a navigation project. Thus, a constant “tolerance" (i.e., confidence) may be estimated from a TPU evaluation for a specific navigation project, and that tolerance used for the entire survey or dredging contract. The survey tolerance may also be estimated from past results, such as from deviations and biases in past Performance Tests.

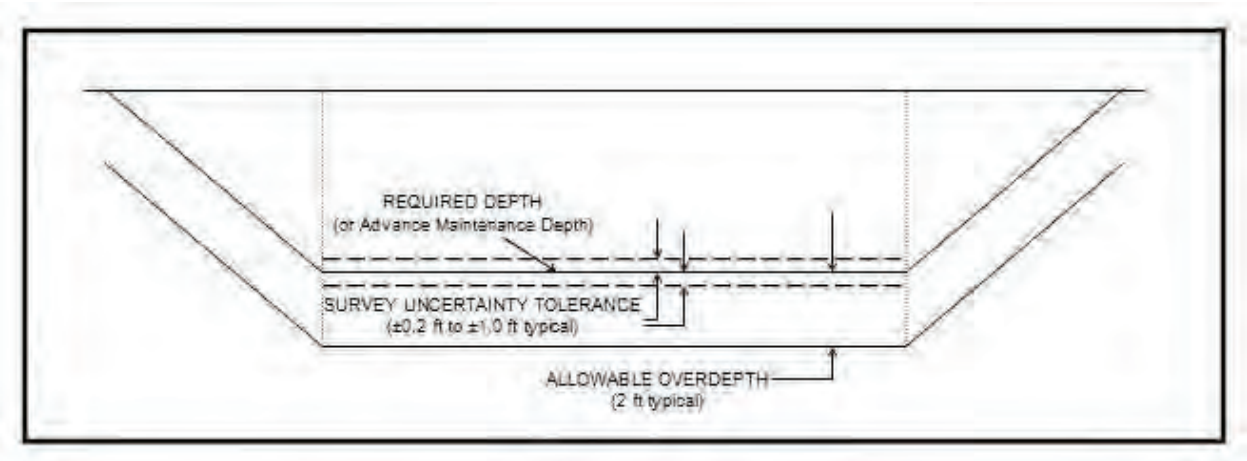

Figure D-2. Survey uncertainty allowance on a typical maintenance dredging template.

D-7. Examples of TPU Estimates for USACE Navigation Projects. The following paragraphs and tables contain simplified examples of TPU estimates for navigation projects. Typical error ranges are also listed for the major system components.

a. Coastal navigation project depth measurement uncertainties (Table D-1). This list differentiates between the survey procedures used to measure the water surface at the offshore project site—(1) unmodeled surface elevation extrapolation from a shore-based tide gage or (2) direct RTK surface elevation measurement at the project site—see Figure D-1. This example is not inclusive of all the measurement factors that make up a depth measurement.

Table D-1. Estimated Depth Measurement Uncertainties in a Typical Coastal Navigation Project. (From EM 1110-2-6056)

Measurement Factor	Uncertainty Range
Reference Datum:	
Tidal gage MLLW reference datum accuracy (NOAA)	0.1 - 0.2 ft
Tidal epoch latency (update lag during 19-year period)	0.05 - 0.1 ft
Tide staff leveling accuracy	0.02 – 0.05 ft

Tide staff visual reading resolution	0.02 – 0.1 ft
Acoustic depth measurement system uncertainties:	
includes sound velocity, refraction, reflectivity, bar calibration uncertainties, etc.	
Depths < 15 ft	0.05 – 0.1 ft
Depths 15 ft to 40 ft	0.1 – 0.3 ft
Depths > 40 ft	0.3 – 0.5 ft
Heave-Pitch-Roll uncertainties:	0.1 – 0.5 ft
Draft uncertainties (Static/Dynamic):	0.05 – 0.2 ft
Extrapolated Water Surface Elevation from Gage:	
MLLW range gradient (unmodeled/estimated)	0.05 - 0.3 ft
Tidal phase lag (gage to work site)	0.2 - 2 ft +
or	
RTK Water Surface Elevation:	
RTK geoid/ellipsoid uncertainty	0.05 - 0.2 ft
RTK accuracy	0.1 - 0.15 ft

(1) The applicable uncertainties in Table D-1 are statistically propagated to determine the resultant uncertainty of a depth measurement and uncertainty in the dredged clearance estimate.

(2) As an example, given a Gulf Coast 45-ft deep-draft navigation project located 5 miles distant from the reference tide gage. The reference gage datum computation was based on 90 days of observations 30 years ago. The tide readings at the gage are extrapolated out to the project site without any tide range or phase correction. A 1-ft swell exists at the staff gage and the work site. No heave-pitch-roll correction is applied. The mean tide range is 8 ft at the offshore project site and 6 ft at the gage. The phase lag between the project site and gage is estimated at 45 minutes. The TPU of the measured grade would be estimated as follows:

Estimated Uncertainty Factor in TPU [Visual Tide Gage Observations]	Uncertainty in ± ft (95%)	
Tidal gage MLLW datum accuracy	0.2 ft	(NOAA estimate)
Tidal epoch latency (update lag)	0.05 ft	(1993 to 2009)

Tide staff setting accuracy	0.02 ft	(leveling)
Tide staff visual resolution	0.05 ft	(gage observer)
Extrapolated (projected) surface from gage:		
MLLW range gradient	0.2 ft	(unmodeled MLLW reference)
Tidal phase lag (average ebb/flood)	0.7 ft	(average random deviations)
Heave-pitch-roll	0.3 ft	
Draft	0.05 ft	
Acoustic depth measurement	0.3 ft	(from above table)
Total Propagated Uncertainty:	0.9 ft	RMS (95%)

(3) If the above example project is modified to use RTK for determining the water surface elevation, VDatum is used to establish the offshore datum, and an inertial-aided heave-pitch-roll system is used, the above TPU estimate will be reduced as follows:

Estimated Uncertainty Factor in TPU	Uncertainty in ± ft (95%)	
[RTK Tide Observations]		
Tidal gage MLLW datum accuracy	0.2 ft	(NOAA estimate)
Tidal epoch latency (update lag)	0.05 ft	(1993 to 2009)
Tide staff setting accuracy	0.02 ft	(leveling)
Tide staff visual resolution	0.05 ft	(RTK calibration)
Extrapolated (projected) surface RTK:		
RTK resolution	0.15 ft	
Lever arm measurements	0.1 ft	
MLLW range gradient	0.01 ft	(VDatum modeled MLLW)
Tidal phase lag (average ebb/flood)	0.0 ft	(average random deviations)
Heave-pitch-roll (IMU)	0.05 ft	
Draft	0.05 ft	
Acoustic depth measurement	0.3 ft	(from above table)
Total Propagated Uncertainty:	0.4 ft	RMS (95%)

b. Approximate estimates of uncertainties in deep-draft navigation projects. Table D-2 provides another example of some general estimates for survey uncertainties under nominal deep-draft project conditions, accounting for various measurement conditions largely dependent on the water surface measurement correction. These ranges may be used to estimate the TPU for a specific navigation project. Given the main variable in the table is dependent on the gage location relative to the project site (non-RTK measurements) the magnitude of this uncertainty needs to be estimated based on actual tidal range and phase conditions.

Table D-2. Estimated TPU Allowances for Deep-Draft Navigation Projects.
(From EM 1110-2-5056)

Typical TPU	Water Surface Elevation Measurement Procedure	Tidal regime hydrodynamically modeled
Hard Bottom Materials		
± 0.20 ft	Determined from carrier phase GPS (RTK)	Yes
± 0.25 ft	Determined from carrier phase GPS (RTK)	No
± 0.20 ft	Estimated from gage less than 1 mile from project site	Yes
± 0.25 ft to ± 0.50 ft	Estimated from gage 1 to 5 miles from project site	No
± 0.50 ft to ± 1.0 ft	Estimated from gage > 5 miles from project site	No
± 0.50 ft to ± 2.0 ft	Estimated from gage > 10 miles from project site	No
Soft Bottom Materials (Maintenance Dredging)		
± 0.25 ft	Determined from carrier phase GPS (RTK)	Yes
± 0.25 ft to ± 1.0 ft	Estimated from gage 1 to 10 miles from project site	No
± 0.50 ft to ± 2.0 ft	Highly variable acoustic reflectivity due to suspended sediment, fluff, dense bottom vegetation, etc.	Yes

c. Accuracy of tidal reference datums with Vdatum coverage. Table D-3 (from EM 1110-2-6056) outlines recommended accuracies of reference tide gage datums and the tidal and geoid models at a coastal navigation project site. Uncertainties relative to the NSRS/NWLON are minimized when a specific tide gage and VDatum model are specified for a given navigation project. Details on these relationships are covered in Chapter 4 of EM 1110-2-6056.

Table D-3. Recommended Accuracies for Tidal Reference Datums on Navigation Projects with VDatum Coverage. (From EM 1110-2-6056)

	Accuracy (95%)	Relative to Datum
Absolute accuracy of tidal datum relationship at gage	± 0.25 ft	MLLW Regional NWLON
Relative accuracy of local tidal model	± 0.2 ft	Local MLLW at PPCP Gage

Tidal-geoid model numerical resolution:	nearest 0.01 ft
Model 1D or 2D density in navigation channel:	100 to 500 ft (varies with tidal range)
Geoid model:	use latest available at time of study (currently Geoid 09)
Tidal-geoid model format:	1D or 2D (1D for linear navigation channels)

NOTE: The above standards are believed representative for most CONUS navigation projects. Exceptions may exist in extreme tide ranges or in parts of Alaska. See VDatum uncertainty models on NOAA VDatum web site.

D-8. Total Propagated Uncertainty Estimates in Superseded Versions of EM 1110-2-1003. The 2002 version of this manual developed an error budget analysis for single-beam depth measurements under various conditions, as shown in Table D-4 below. This analysis was, in effect, a Total Propagated Uncertainty estimate. (The term "TPU" was not used back in 2002.) This error budget analysis was used, in part, to develop "mandatory" survey specifications in the 2002 manual. Extracts from those 2002 standards are shown in Table D-5. These 2002 "mandatory" standards, which were developed based on single-beam survey TPU error estimates,

did not account for any significant variations in the project's environmental conditions. These previous standards were, and still are, valid TPU targets, and they do not differ much from the recommended tolerances in Table 3-1; the only difference being the older standards were based on RMS (i.e., TPU) estimates and Table 3-1 is based on Performance Test results.

Table D-4. EM 1110-2-1003 (2002) Single-Beam Uncertainty Estimates.

Quantitative estimate of acoustic depth measurement accuracy in different project conditions

Single-beam 200 kHz echo sounder in soft, flat bottom
USCG DGPS vessel positioning accurate to ± 2 m RMS
All values in ± feet

	Inland Navigation	Turning basin	Coastal entrance	Coastal offshore
	Min river slope	2 ft tide range	4-ft tide range	8-ft tide range
	Staff gage < 0.5 mile	Gage < 1 mile	Gage < 2 mile	Gage > 5 mile
	12-ft project	26-ft project	43-ft project	43-ft project
	<26-ft boat	<26-ft boat	<26-ft boat	65-ft boat
Error Budget Source	No H-P-R	No H-P-R	No H-P-R	H-P-R corrn
Measurement system accuracy	0.05	0.05	0.1	0.2
Velocity calibration accuracy	0.05	0.1	0.1	0.15
Sounder resolution	0.1	0.1	0.1	0.1
Draft/index accuracy	0.05	0.1	0.1	0.1
Tide/stage correction accuracy	0.1	0.15	0.25	0.5
Platform stability error	0.05	0.2	0.3	0.25
Vessel velocity error	0.05	0.1	0.1	0.15
Bottom reflectivity/sensitivity	0.05	0.1	0.1	0.2
RMS (95%)	**± 0.37 ft**	**± 0.66 ft**	**± 0.90 ft**	**± 1.32 ft**
Allowed (2002 Standards)	**± 0.5 ft**	**±1.0 ft**	**± 1.0 ft**	**± 2.0 ft**

a. The above uncertainty estimate attempted to assign error components under various (but limited—only four) "average" or "typical" project conditions. It does illustrate the complexity in estimating depth uncertainty (TPU) for any specific project. Items such as "tide/stage correction" and "bottom reflectivity characteristics" are highly subjective. In addition, the above analysis did not include any multibeam system uncertainties.

b. The RMS (TPU) estimates in Table D-4 were factored into the "mandatory" accuracy standards specified back in 2002 (Table D-5). No allowance was made for "non-average" project conditions; however, the 2002 version did note that "… it is fully recognized that exceptions to these standards will exist for some applications, or as technological advances occur …" As stated in Chapter 3, some of the criteria in Table D-5 do not differ significantly from the revised tolerances, QC, and QA procedures in this updated manual.

Table D-5. Superseded EM 1110-2-1003 (2002) Accuracy Standards.

Minimum Performance Standards for Corps of Engineers Hydrographic Surveys (Mandatory)

PROJECT CLASSIFICATION		Navigation & Dredging Support Surveys Bottom Material Classification Hard	Soft	Other General Surveys & Studies (Recommended Standards)
RESULTANT ELEVATION/DEPTH ACCURACY (95%)				
System	Depth (d)			
Mechanical	(d<15 ft)	± 0.25 ft	± 0.25 ft	± 0.5 ft
Acoustic	(d<15 ft)	± 0.5 ft	± 0.5 ft	± 1.0 ft
Acoustic	(15>d<40 ft)	± 1.0 ft	± 1.0 ft	± 2.0 ft
Acoustic	(d>40 ft)	± 1.0 ft	± 2.0 ft	± 2.0 ft
QUALITY CONTROL & ASSURANCE CRITERIA				
Sound velocity QC calibration		> 2/day	2/day	1/day
Position calibration QC check		1/day	1/project	1/project
QA performance test		Mandatory	Required (multibeam)	Optional
Maximum allowable bias		± 0.1 ft	± 0.2 ft	± 0.5 ft

[Note that the "maximum allowable bias" (i.e., repeatability) shown in the 2002 table should not have been indicated as a "±" statistic.]

c. These sections taken from the 2002 manual are intended to illustrate the difficulty in estimating TPUs for surveys, and in defining a uniform Corps-wide "required" accuracy standard, given the variability in survey equipment, methods, and project conditions.

D-9. TPU Calculator. An estimate of the TPU may also be computed using algorithms developed by Rob Hare of the Canadian Hydrographic Service (CHS)—see "Error Budget Analysis for US Naval Oceanographic Office (NAVOCEANO) Hydrographic Survey Systems," NAVOCEANO/Hare 2001. A TPU computation calculator, based on these algorithms, is available in HYPACK software—see HYPACK 2011. A screen capture of this TPU calculator is shown in Figure D-3. This TPU calculator requires user input of the estimated accuracies of over 40 parameters making up the total depth error budget.---far more so than the dozen or so

parameters used in the simplified TPU examples in this appendix. This TPU calculator is applicable to either multibeam or single-beam systems.

Other software acquisition and processing systems (e.g., Caris) can compute TPU estimates for each depth observation, including each depth on a multibeam array. Thus, each observed depth will have a TPU "quality factor" along with its X-Y-Z values. NOAA and its contractors utilize these options on their surveys to determine a most likely representative depth in cells or regions.

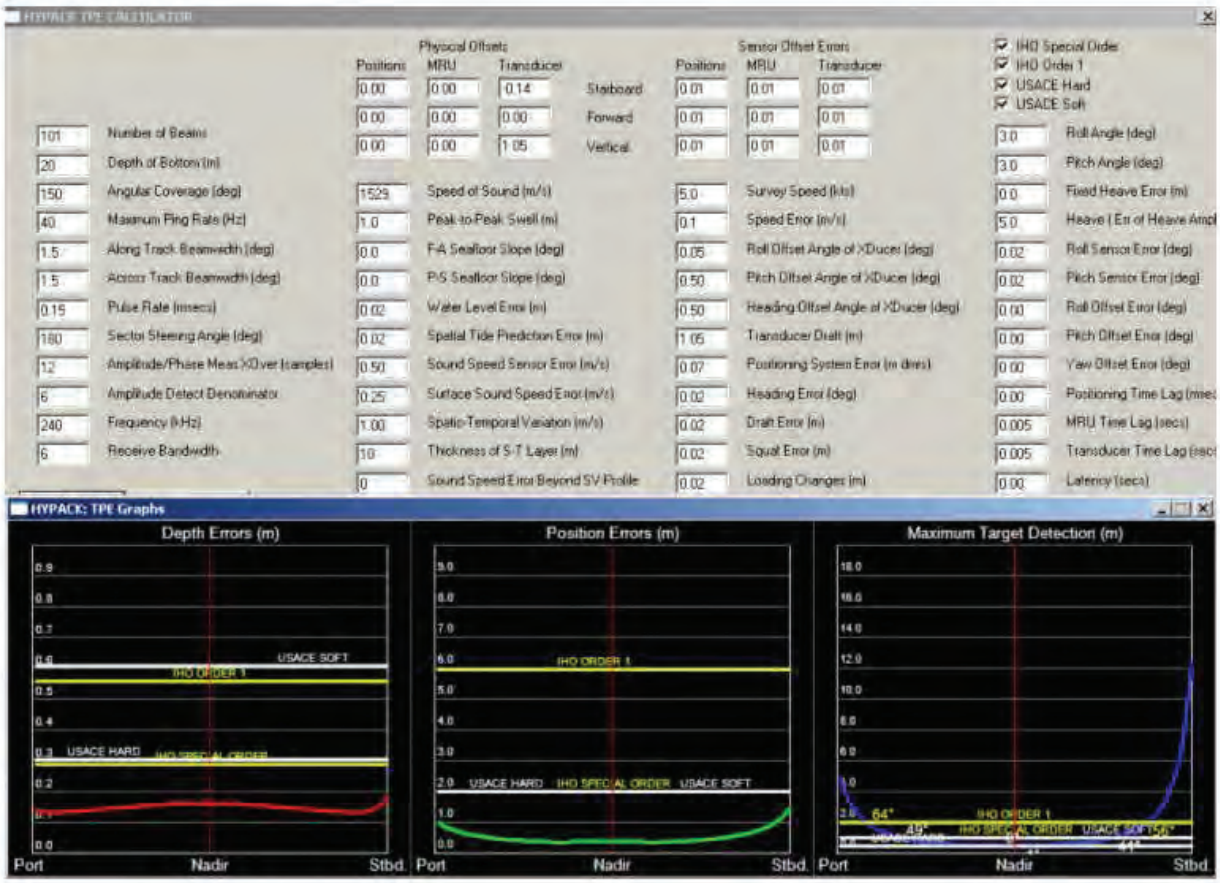

Figure D-3. HYPACK Total Propagated Uncertainty calculator for depth, position, and object detection. Values shown are for example only—users must insert estimated uncertainties for each parameter specific to their survey systems, procedures, and project. (USACE standards shown have been superseded).

APPENDIX E
IHO Standards for Hydrographic Surveys (S-44)

INTERNATIONAL HYDROGRAPHIC ORGANIZATION

IHO STANDARDS FOR HYDROGRAPHIC SURVEYS

5th Edition, February 2008

Special Publication No. 44

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INTERNATIONAL HYDROGRAPHIC ORGANIZATION

IHO STANDARDS FOR HYDROGRAPHIC SURVEYS

5th Edition, February 2008

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PREFACE

This publication, "Standards for Hydrographic Surveys" (S-44), is one of the series of standards developed by the International Hydrographic Organization (IHO) to help improve the safety of navigation.

Formal discussions on establishing standards for hydrographic surveys began at the VIIth International Hydrographic Conference (IHC) in 1957. Circular Letters to Member States in 1959 and 1962 reported on the views of Member States and the VIIIth IHC in 1962 established a Working Group (WG) comprising 2 members from the USA, 1 from Brazil and 1 from Finland. The WG communicated by mail and held two meetings in conjunction with the IXth IHC in 1967 and prepared the text for Special Publication N^{o} S-44.

The 1st Edition of S-44 entitled "Accuracy Standards Recommended for Hydrographic Surveys" was published in January 1968 the Foreword to which stated that "…hydrographic surveys were classed as those conducted for the purpose of compiling nautical charts generally used by ships" and "The study confined itself to determining the density and precision of measurements necessary to portray the sea bottom and other *features* sufficiently accurately for navigational purposes."

Over subsequent years technologies and procedures changed and the IHO established further WGs to update S-44 with the 2nd Edition published in 1982, the 3rd in 1987 and the 4th in 1998. Throughout these revisions the basic objectives of the publication have remained substantially unchanged and this remains so with this 5th Edition.

The Terms of Reference for the WG established to prepare the 5th Edition of S-44 included inter alia: a desire for clearer guidance regarding sea floor *features* and listed a number of concerns including system capabilities for detecting *features* and the characteristics of *features* to be detected. The WG concluded that S-44 sets minimum standards for surveys conducted for the safety of surface navigation. The WG considered it to be the responsibility of each national authority to determine the precise characteristics of *features* to be detected relevant to their organization and to determine the ability of particular systems and their procedures to detect such *features*. The WG further concluded that the design and construction of targets used to demonstrate system detection capabilities is the responsibility of national authorities. The reference to cubic *features* > 1 or 2 metres in size used in these Standards provides a basis for understanding that *features* of at least this size should be detected.

The principal changes made from the 4th Edition are:

The division of Order 1 into 1a where a *full sea floor search* is required and 1b where it is not required. The removal of Order 3 as it was considered that there was no longer a need to differentiate this from Order 2.

The replacement, in most cases, of the words *"accuracy"* and *"error"* by *"uncertainty". Errors* exist and are the differences between the measured value and the true value. Since the true value is never known it follows that the *error* itself cannot be known. *Uncertainty* is a statistical assessment of the likely magnitude of this *error.* This terminology is increasingly being used in measurement: see ISO/IEC 98: 1995 "Guide to the expression of uncertainty in measurement" (due to be updated in 2008) and ISO/IEC 99:2007 "International Vocabulary of Metrology – Basic and general concepts and associated terms (VIM).

The Glossary has been updated and some terms which the WG consider fundamental to the understanding of these Standards are repeated in the Introduction.

The WG considered that information on "How to Survey" was not appropriate to these Standards and this information has been removed from the 5th Edition. However the WG acknowledges the usefulness of this guidance and the information has been retained in two annexes. The WG recommends that this information should be transferred to IHO Publication M-13 (Manual on Hydrography) at which time the annexes should be removed from S-44.

A minimum spot spacing for bathymetric LIDAR has been included in Table 1 for Order 1b surveys where *full sea floor search* is not required.

Finally it was the view of the WG that S-44 provides "Standards for Hydrographic Surveys" and that it is the responsibility of individual Hydrographic Offices / Organizations to prepare "Specifications" based on these Standards. Specifications will be more system specific and as such will be quite dynamic as systems change.

INTRODUCTION

This publication is designed to provide a set of standards for the execution of hydrographic surveys for the collection of data which will primarily be used to compile navigational charts to be used for the safety of surface navigation and the protection of the marine environment.

It must be realised that this publication only provides the **minimum** standards that are to be achieved. Where the bathymetry and expected shipping use requires it, hydrographic offices / organisations wishing to gather data may need to define more stringent standards. Also, this publication does not contain procedures for setting up the necessary equipment, for conducting the survey or for processing the resultant data. These procedures (which are a fundamental part of the complete survey system) must be developed by the hydrographic office/organisation wishing to gather data that is compliant with these Standards. Consideration must be made of the order of survey they wish to achieve, the equipment they have at their disposal and the type of topography that they intend to survey. Annexes A and B provide guidelines for *Quality control* and Data Processing and it is intended that these will be moved to the Manual on Hydrography (IHO Publication M-13) which provides further guidance on how to perform hydrographic surveys.

There is nothing to stop users adopting these Standards for other uses. Indeed, such a broadening of the use of these Standards is welcomed. However, users who wish to adopt

these for other means must bear in mind the reason why they were written and therefore accept that not all parts may be suitable for their specific needs.

To be compliant with an S-44 Order a survey must be compliant with ALL specifications for that order included in these Standards.

It is also important to note that the adequacy of a survey is the end product of the entire survey system and processes used during its collection. The *uncertainties* quoted in the following chapters reflect the total propagated *uncertainties* of all parts of the system. Simply using a piece of equipment that is theoretically capable of meeting the required *uncertainty* is not necessarily sufficient to meet the requirements of these Standards. How the equipment is set up, used and how it interacts with the other components in the complete survey system must all be taken into consideration.

All components **and their combination** must be capable of providing data to the required standard. The hydrographic office / organisation needs to satisfy itself that this is so by, for example, conducting appropriate trials with the equipment to be used and by ensuring that adequate calibrations are performed prior to, as well as during and, if appropriate, after the survey being carried out. The surveyor is an essential component of the survey process and must possess sufficient knowledge and experience to be able to operate the system to the required standard. Measuring this can be difficult although surveying qualifications (e.g. having passed an IHO Cat A/B recognised hydrographic surveying course) may be of considerable benefit in making this assessment.

It should be noted that the issue of this new edition to the standard does not invalidate surveys, or the charts and nautical publications based on them, conducted in accordance with previous editions, but rather sets the standards for future data collection to better respond to user needs.

It should also be noted that where the sea floor is dynamic (e.g. sand waves), surveys conducted to any of the Orders in these Standards will quickly become outdated. Such areas need to be resurveyed at regular intervals to ensure that the survey data remains valid. The intervals between these resurveys, which will depend on the local conditions, should be determined by national authorities.

A glossary of terms used in this publication is given after Chapter 6. Terms included in the glossary are shown in the text in italic type and in the electronic version are hyperlinked to their definition. The following "Fundamental Definitions" from the glossary are considered essential to the understanding of these Standards.

FUNDAMENTAL DEFINITIONS

Feature detection: The ability of a system to detect *features* of a defined size. These Standards specify the size of *features* which, for safety of navigation, should be detected during the survey.

Full sea floor search: A systematic method of exploring the sea floor undertaken to detect most of the *features* specified in Table 1; utilising adequate detection systems, procedures and trained personnel. In practice, it is impossible to achieve 100% ensonification / 100% bathymetric coverage (the use of such terms should be discouraged).

Reduced depths: Observed depths including all *corrections* related to the survey and post processing and reduction to the used vertical datum.

Total horizontal uncertainty (THU): The component of *total propagated uncertainty* (TPU) calculated in the horizontal plane. Although THU is quoted as a single figure, THU is a 2 Dimensional quantity. The assumption has been made that the *uncertainty* is isotropic (i.e. there is negligible correlation between *errors* in latitude and longitude). This makes a Normal distribution circularly symmetric allowing a single number to describe the radial distribution of *errors* about the true value.

Total propagated uncertainty (TPU): the result of *uncertainty propagation*, when all contributing measurement *uncertainties*, both random and systematic, have been included in the propagation. *Uncertainty* propagation combines the effects of measurement *uncertainties* from several sources upon the *uncertainties* of derived or calculated parameters.

Total vertical uncertainty (TVU): The component of *total propagated uncertainty* (TPU) calculated in the vertical dimension. TVU is a 1 Dimensional quantity.

CHAPTER 1 – CLASSIFICATION OF SURVEYS

Introduction

This chapter describes the orders of survey that are considered acceptable to allow hydrographic offices / organizations to produce navigational products that will allow the expected shipping to navigate safely across the areas surveyed. Because the requirements vary with water depth and expected shipping types, four different orders of survey are defined; each designed to cater for a range of needs.

The four orders are described below along with an indication of the need that the order is expected to meet. Table 1 specifies the minimum standards for each of these orders and **must** be read in conjunction with the detailed text in the following chapters.

The agency responsible for acquiring surveys should select the order of survey that is most appropriate to the requirements of safe navigation in the area. It should be noted that a single order may not be appropriate for the entire area to be surveyed and, in these cases, the agency responsible for acquiring the survey should explicitly define where the different orders are to be used. It should also be noted that the situation discovered in the field by the surveyor may differ sufficiently enough from what was expected to warrant a change of order. For instance in an area traversed by Very Large Crude Carriers (VLCCs) and expected to be deeper than 40 metres an Order 1a survey may have been specified; however if the surveyor discovers

shoals extending to less than 40 metres then it may be more appropriate to survey these shoals to Special Order.

Special Order

This is the most rigorous of the orders and its use is intended only for those areas where under-keel clearance is critical. Because under-keel clearance is critical a *full sea floor search* is required and the size of the *features* to be detected by this search is deliberately kept small. Since under-keel clearance is critical it is considered unlikely that Special Order surveys will be conducted in waters deeper than 40 metres. Examples of areas that may warrant Special Order surveys are: berthing areas, harbours and critical areas of shipping channels.

Order 1a

This order is intended for those areas where the sea is sufficiently shallow to allow natural or man-made *features* on the seabed to be a concern to the type of surface shipping expected to transit the area but where the under-keel clearance is less critical than for Special Order above. Because man-made or natural *features* may exist that are of concern to surface shipping, a *full sea floor search* is required, however the size of the *feature* to be detected is larger than for Special Order. Under-keel clearance becomes less critical as depth increases so the size of the *feature* to be detected by the *full sea floor search* is increased in areas where the water depth is greater than 40 metres. Order 1a surveys may be limited to water shallower than 100 metres.

Order 1b

This order is intended for areas shallower than 100 metres where a general depiction of the seabed is considered adequate for the type of surface shipping expected to transit the area. A *full sea floor search* is not required which means some *features* may be missed although the maximum permissible line spacing will limit the size of the *features* that are likely to remain undetected. This order of survey is only recommended where under-keel clearance is not considered to be an issue. An example would be an area where the seabed characteristics are such that the likelihood of there being a man-made or natural *feature* on the sea floor that will endanger the type of surface vessel expected to navigate the area is low.

Order 2

This is the least stringent order and is intended for those areas where the depth of water is such that a general depiction of the seabed is considered adequate. A *full sea floor search* is not required. It is recommended that Order 2 surveys are limited to areas deeper than 100 metres as once the water depth exceeds 100 metres the existence of man-made or natural *features* that are large enough to impact on surface navigation and yet still remain undetected by an Order 2 survey is considered to be unlikely.

CHAPTER 2 – POSITIONING

2.1 Horizontal Uncertainty

The *uncertainty* of a position is the *uncertainty* at the position of the sounding or *feature* within the geodetic reference frame.

Positions should be referenced to a geocentric reference frame based on the International Terrestrial Reference System (ITRS) e.g. WGS84. If, exceptionally, positions are referenced to the local horizontal datum, this datum should be tied to a geocentric reference frame based on ITRF.

The *uncertainty* of a position is affected by many different parameters; the contributions of all such parameters to the *total horizontal uncertainty* (THU) should be accounted for.

A statistical method, combining all *uncertainty* sources, for determining positioning *uncertainty* should be adopted. The position *uncertainty* at the 95% *confidence level* should be recorded together with the survey data (see also 5.3). The capability of the survey system should be demonstrated by the THU calculation.

The position of soundings, dangers, other significant submerged *features*, navaids (fixed and floating), *features* significant to navigation, the coastline and topographical *features* should be determined such that the horizontal *uncertainty* meets the requirements specified in Table1. This includes all *uncertainty* sources not just those associated with positioning equipment.

CHAPTER 3 – DEPTHS

3.1 Introduction

The navigation of vessels requires accurate knowledge of the water depth in order to exploit safely the maximum cargo carrying capacity, and the maximum available water for safe navigation. Where under-keel clearances are an issue the depth *uncertainties* must be more tightly controlled and better understood. In a similar way, the sizes of *features* that the survey will have or, more importantly, may not have detected, should also be defined and understood.

The measured depths and drying heights shall be referenced to a vertical datum that is compatible with the products to be made or updated from the survey e.g. chart datum. Ideally this *sounding datum* should also be a well defined vertical datum such as, LAT, MSL, a geocentric reference frame based on ITRS or a geodetic reference level.

3.2 Vertical Uncertainty

Vertical *uncertainty* is to be understood as the *uncertainty* of the *reduced depths.* In determining the vertical *uncertainty* the sources of individual *uncertainties* need to be

quantified. All *uncertainties* should be combined statistically to obtain a *total vertical uncertainty* (TVU).

The maximum allowable vertical *uncertainty* for *reduced depths* as set out in Table 1 specifies the *uncertainties* to be achieved to meet each order of survey. *Uncertainty* related to the 95% *confidence level* refers to the estimation of *error* from the combined contribution of random *errors* and residuals from the correction of systematic *errors*. The capability of the survey system should be demonstrated by the TVU calculation.

Recognising that there are both depth independent and depth dependent *errors* that affect the *uncertainty* of the depths, the formula below is to be used to compute, at the 95% *confidence level*, the maximum allowable TVU. The parameters "a" and "b" for each order, as given in Table 1, together with the depth "d" have to be introduced into the formula in order to calculate the maximum allowable TVU for a specific depth:

$$\pm\sqrt{a^2 + (b \times d)^2}$$

Where:

a	represents that portion of the *uncertainty* that does not vary with depth
b	is a coefficient which represents that portion of the *uncertainty* that varies with depth
d	is the depth
b x d	represents that portion of the *uncertainty* that varies with depth

The vertical *uncertainty* at the 95% *confidence level* should be recorded together with the survey data (see also 5.3).

3.3 Reductions for Tides / Water-level Observations

Observations sufficient to determine variations in the water level across the entire survey area must be taken for the duration of the survey for the reduction of soundings to the relevant *sounding datum.* These may be determined either by direct measurement of the water level (i.e. by using a gauge) and if necessary carried across the survey area by co-tidal *corrections* or by 3D positioning techniques linked to the required *sounding datum* by a suitable separation model.

Tidal / water-level reductions need not be applied to depths greater than 200 metres if TVU is not significantly impacted by this approximation.

3.4 Depth measurement

All anomalous *features* previously reported in the survey area and those detected during the survey should be examined in greater detail and, if confirmed, their position and least depth determined. If a previously reported anomalous *feature* is not detected refer to Chapter 6 for

disproving requirements. The agency responsible for survey quality may define a depth limit beyond which a detailed sea floor investigation, and thus an examination of anomalous *features*, is not required.

For wrecks and obstructions which may have less than 40 metres clearance above them and may be dangerous to normal surface navigation, their position and the least depth over them should be determined by the best available method while meeting the depth *uncertainty* standard **of the appropriate order** in Table 1.

Side scan sonar should not be used for depth measurement but to define areas requiring more detailed and accurate investigation.

3.5 Feature detection

When a *full sea floor search* is required, the equipment used to conduct the survey must be demonstrably capable of detecting *features* of the dimensions specified in Table 1. Additionally, the equipment must be considered as part of a system (includes survey / processing equipment, procedures and personnel) that will ensure there is a high probability that these *features* will be detected. It is the responsibility of the hydrographic office / organisation that is gathering the data to assess the capability of any proposed system and so satisfy themselves that it is able to detect a sufficiently high proportion of any such *features.*

The Special Order and Order 1a *feature detection* requirements of 1 metre and 2 metre cubes respectively are minimum requirements. *Features* may exist that are smaller than the size mandated for a given order but which are a hazard to navigation. It may therefore be deemed necessary by the hydrographic office / organization to detect smaller *features* in order to minimise the risk of undetected hazards to surface navigation.

It should be noted that even when surveying with a suitable system 100% detection of *features* can never be guaranteed. If there is concern that *features* may exist within an area that may not be detected by the Survey System being used, consideration should be given to the use of an alternative system (e.g. a mechanical sweep) to increase the confidence in the minimum safe clearance depth across the area.

3.6 Sounding Density / Line Spacing

In planning the density of soundings, both the nature of the seabed in the area and the requirements of safe surface navigation have to be taken into account to ensure an adequate *sea floor search.*

For Special Order and Order 1a surveys no recommended maximum line spacing is given as there is an overriding requirement for *full sea floor search.*

Full sea floor search is not required for Orders 1b and 2 and Table 1 recommends maximum line spacing (Orders 1b and 2) and bathymetric LIDAR spot density (Order 1b). The nature of the seabed needs to be assessed as early as possible in a survey in order to decide whether the line spacing / LIDAR spot density from Table 1 should be reduced or extended.

CHAPTER 4 - OTHER MEASUREMENTS

4.1 Introduction

The following observations may not always be necessary but if specified in the survey requirement should meet the following standards.

4.2 Seabed Sampling

The nature of the seabed should be determined in potential anchorage areas; it may be determined by physical sampling or inferred from other sensors (e.g. single beam echo sounders, side scan sonar, sub-bottom profiler, video, etc.). Physical samples should be gathered at a spacing dependent on the seabed geology and as required to ground truth any inference technique.

4.3 Chart and Land Survey Vertical Datums Connection

IHO Technical Resolution A2.5, as set out in IHO Publication M-3, requires that the datum used for tidal predictions should be the same as that used for chart datum. In order for the bathymetric data to be fully exploited the vertical datum used for tidal observations should be connected to the general land survey datum via prominent fixed marks in the vicinity of the tide gauge/station/observatory. Ellipsoidal height determinations of the vertical reference marks used for tidal observations should be made relative to a geocentric reference frame based on ITRS, preferably WGS84, or to an appropriate geodetic reference level.

4.4 Tidal Predictions

Tidal data may be required for analysis for the future prediction of tidal heights and the production of Tide Tables in which case observations should cover as long a period of time as possible and preferably not less than 30 days.

4.5 Tidal Stream and Current Observations

The speed and direction of tidal streams and currents which may exceed 0.5 knot should be observed at the entrances to harbours and channels, at any change in direction of a channel, in anchorages and adjacent to wharf areas. It is also desirable to measure coastal and offshore streams and currents when they are of sufficient strength to affect surface navigation.

The tidal stream and current at each position should be measured at depths sufficient to meet the requirements of normal surface navigation in the survey area. In the case of tidal streams, simultaneous observations of tidal height and meteorological conditions should be made and the period of observation should ideally be 30 days.

The speed and direction of the tidal stream and current should be measured to 0.1 knot and the nearest 10º respectively, at 95% *confidence level.*

Where there is reason to believe that seasonal river discharge influences the tidal streams and currents, measurements should be made to cover the entire period of variability.

CHAPTER 5 – DATA ATTRIBUTION

5.1 Introduction

To allow a comprehensive assessment of the quality of survey data it is necessary to record or document certain information together with the survey data. Such information is important to allow exploitation of survey data by a variety of users with different requirements, especially as requirements may not be known when the survey data is collected.

5.2 Metadata

Metadata should be comprehensive but should comprise, as a minimum, information on:

- the survey in general e.g. purpose, date, area, equipment used, name of survey platform;
- the geodetic reference system used, i.e. horizontal and vertical datum including ties to a geodetic reference frame based on ITRS (e.g. WGS84) if a local datum is used;
- calibration procedures and results;
- sound speed *correction* method;
- tidal datum and reduction;
- *uncertainties* achieved and the respective *confidence levels*;
- any special or exceptional circumstances;
- rules and mechanisms employed for data thinning.

Metadata should preferably be an integral part of the digital survey record and conform to the "IHO S-100 Discovery *Metadata* Standard", when this is adopted. Prior to the adoption of S-100, ISO 19115 can be used as a model for the *metadata.* If this is not feasible similar information should be included in the documentation of a survey.

Agencies responsible for the survey quality should develop and document a list of *metadata* used for their survey data.

5.3 Point Data Attribution

All data should be attributed with its *uncertainty* estimate at the 95% *confidence level* for both position and, if relevant, depth. The computed or assumed scale factor applied to the standard deviation in order to determine the *uncertainty* at the 95% *confidence level*, and/or the assumed statistical distribution of *errors* should be recorded in the survey's *metadata.* (For example, assuming a Normal distribution for a 1 Dimensional quantity, such as depth, the scale factor is 1.96 for 95% confidence. A statement such as "*Uncertainties* have been computed at 95% confidence assuming a standard deviation scale factor of 1.96 (1D) or 2.45 (2D), corresponding to the assumption of a Normal distribution of *errors*," would be

adequate in the *metadata*.) For soundings this should preferably be done for each individual sounding; however a single *uncertainty* estimate may be recorded for a number of soundings or even for an area, provided the difference between the individual *uncertainty* estimates and the collectively assigned *uncertainty* estimate is negligible. The attribution should, as a minimum, be sufficient to demonstrate that the requirements of these Standards have been met.

5.4 Bathymetric Model Attribution

If a *Bathymetric Model* is required, *metadata* should include: the model resolution; the computation method; the underlying data density; *uncertainty* estimate/*uncertainty surface* for the model; and a description of the underlying data.

5.5 Report of Survey

The Report of Survey is the principal means by which the Surveyor in Charge approves the contents of all survey records. It must give a clear and comprehensive account of how the survey was carried out, the results achieved, the difficulties encountered and the shortcomings. Emphasis should be placed on the analysis of achieved accuracies and whether the survey specifications have been met.

CHAPTER 6 - ELIMINATION OF DOUBTFUL DATA

6.1 Introduction

To improve the safety of navigation it is desirable to eliminate doubtful data, i.e. data which are usually denoted on charts by PA (Position Approximate), PD (Position Doubtful), ED (Existence Doubtful), SD (Sounding Doubtful) or as "reported danger". To confirm or disprove the existence of such data it is necessary to carefully define the area to be searched and subsequently survey that area according to the standards outlined in this publication.

6.2 Extent of Area to be Searched

No empirical formula for defining the search area can cover all situations. For this reason, it is recommended that the search radius should be at least 3 times the estimated position *uncertainty* of the reported hazard at the 95% *confidence level* as determined by a thorough investigation of the report on the doubtful data by a qualified hydrographic surveyor.

If such report is incomplete or does not exist at all, the position *uncertainty* must be estimated by other means as, for example, a more general assessment of positioning and depth measurement *uncertainties* during the era when the data in question was collected.

6.3 Conducting the Search

The methodology for conducting the search should be based on the nature of the *feature,* the area in which the doubtful data is reported and the estimated danger of the potential hazard to surface navigation. Once this has been established, the search procedure should be that of conducting a hydrographic survey of the extent defined in 6.2, to the standards established in this publication.

6.4 Presentation of Search Results

Doubtful data shall be replaced with actual data collected during the search if the hazard has been detected. If not detected, the agency responsible for the survey quality shall decide whether to retain the hazard as charted or to delete it.

TABLE 1 Minimum Standards for Hydrographic Surveys (*To be read in conjunction with the full text set out in this document.*)

Reference	Order	Special	1a	1b	2
Chapter 1	**Description of areas.**	Areas where under-keel clearance is critical	Areas shallower than 100 metres where under-keel clearance is less critical but *features* of concern to surface shipping may exist.	Areas shallower than 100 metres where under-keel clearance is not considered to be an issue for the type of surface shipping expected to transit the area.	Areas generally deeper than 100 metres where a general description of the sea floor is considered adequate.
Chapter 2	**Maximum allowable THU 95% *Confidence level***	2 metres	5 metres + 5% of depth	5 metres + 5% of depth	20 metres + 10% of depth
Para 3.2 and note 1	**Maximum allowable TVU 95% *Confidence level***	a = 0.25 metre b = 0.0075	a = 0.5 metre b = 0.013	a = 0.5 metre b = 0.013	a = 1.0 metre b = 0.023
Glossary and note 2	***Full Sea floor Search***	Required	Required	Not required	Not required
Para 2.1 Para 3.4 Para 3.5 and note 3	***Feature Detection***	Cubic *features* > 1 metre	Cubic *features* > 2 metres, in depths up to 40 metres; 10% of depth beyond 40 metres	Not Applicable	Not Applicable
Para 3.6 and note 4	**Recommended maximum Line Spacing**	Not defined as *full sea floor search* is required	Not defined as *full sea floor search* is required	3 x average depth or 25 metres, whichever is greater For bathymetric lidar a spot spacing of 5 x 5 metres	4 x average depth
Chapter 2 and note 5	**Positioning of fixed aids to navigation and topography significant to navigation. (95% *Confidence level*)**	2 metres	2 metres	2 metres	5 metres
Chapter 2 and note 5	**Positioning of the Coastline and topography less significant to navigation (95% *Confidence level*)**	10 metres	20 metres	20 metres	20 metres
Chapter 2	**Mean position of floating**	10 metres	10 metres	10 metres	20 metres

Reference	Order	Special	1a	1b	2
and note 5	**aids to navigation (95% *Confidence level*)**				

Notes:

1: Recognising that there are both constant and depth dependent *uncertainties* that affect the *uncertainty* of the depths, the formula below is to be used to compute, at the 95% *confidence level*, the maximum allowable TVU. The parameters "a" and "b" for each Order, as given in the Table, together with the depth "d" have to be introduced into the formula in order to calculate the maximum allowable TVU for a specific depth:

$$\pm\sqrt{a^2 + (b \times d)^2}$$

Where:

a represents that portion of the *uncertainty* that does not vary with depth
b is a coefficient which represents that portion of the *uncertainty* that varies with depth
d is the depth
b x d represents that portion of the *uncertainty* that varies with depth

2: For safety of navigation purposes, the use of an accurately specified mechanical sweep to guarantee a minimum safe clearance depth throughout an area may be considered sufficient for Special Order and Order 1a surveys.

3: A cubic *feature* means a regular cube each side of which has the same length. It should be noted that the IHO Special Order and Order 1a *feature detection* requirements of 1 metre and 2 metre cubes respectively, are minimum requirements. In certain circumstances it may be deemed necessary by the hydrographic offices / organizations to detect smaller *features* to minimise the risk of undetected hazards to surface navigation. For Order 1a the relaxing of *feature detection* criteria at 40 metres reflects the maximum expected draught of vessels.

4: The line spacing can be expanded if procedures for ensuring an adequate sounding density are used.
"Maximum Line Spacing" is to be interpreted as the:
- Spacing of sounding lines for single beam echo sounders, or the

- Distance between the useable outer limits of swaths for swath systems.

5: These only apply where such measurements are required for the survey.

GLOSSARY

Note: The terms defined below are those that are most relevant to this publication. A much larger selection of terms are defined in IHO Special Publication S-32 (Hydrographic Dictionary) and this should be consulted if the required term is not listed here. If a term listed below has a different definition in S-32, the definition given below should be used in relation to these standards.

Accuracy: The extent to which a measured or enumerated value agrees with the assumed or accepted value (see: *uncertainty*, *error*).

Bathymetric Model: A digital representation of the topography (bathymetry) of the sea floor by coordinates and depths.

Blunder: The result of carelessness or a mistake; may be detected through repetition of the measurement.

Confidence interval: See *uncertainty.*

Confidence level: The probability that the true value of a measurement will lie within the specified *uncertainty* from the measured value. It must be noted that confidence levels (e.g. 95%) depend on the assumed statistical distribution of the data and are calculated differently for 1 Dimensional (1D) and 2 Dimensional (2D) quantities. In the context of this standard, which assumes Normal distribution of *error*, the 95% confidence level for 1D quantities (e.g. depth) is defined as 1.96 x standard deviation and the 95% confidence level for 2D quantities (e.g. position) is defined as 2.45 x standard deviation.

Correction: A quantity which is applied to an observation or function thereof, to diminish or minimise the effects of *errors* and obtain an improved value of the observation or function. It is also applied to reduce an observation to some arbitrary standard. The correction corresponding to a given computed *error* is of the same magnitude but of opposite sign.

Error: The difference between an observed or computed value of a quantity and the true value of that quantity. (NB The true value can never be known, therefore the true error can never be known. It is legitimate to talk about error sources, but the values obtained from what has become known as an error budget, and from an analysis of residuals, are *uncertainty* estimates, not errors. See *uncertainty.*)

Feature: in the context of this standard, any object, whether manmade or not, projecting above the sea floor, which may be a danger for surface navigation.

Feature detection: The ability of a system to detect *features* of a defined size. These Standards specify the size of *features* which, for safety of navigation, should be detected during the survey.

Full sea floor search: A systematic method of exploring the sea floor undertaken to detect most of the *features* specified in Table 1; utilising adequate detection systems, procedures

and trained personnel. In practice, it is impossible to achieve 100% ensonification / 100% bathymetric coverage (the use of such terms should be discouraged).

Integrity monitor: Equipment consisting of a GNSS receiver and radio transmitter set up over a known survey point that is used to monitor the quality of a Differential GNSS (DGNSS) signal. Positional discrepancies are continuously monitored and timely warnings are transmitted to users indicating when the system should not be used.

Integrity monitoring: This is the ability of a system to provide timely warnings to users when the system should not be used.

Metadata: Information describing characteristics of data, e.g. the *uncertainty* of survey data. ISO definition: Data (describing) about a data set and usage aspect of it. Metadata is data implicitly attached to a collection of data. Examples of metadata include overall quality, data set title, source, positional uncertainty and copyright.

Quality assurance: All those planned and systematic actions necessary to provide adequate confidence that a product or a service will satisfy given requirements for quality.

Quality control: All procedures which ensure that the product meets certain standards and specifications.

Reduced depths: Observed depths including all *corrections* related to the survey and post processing and reduction to the used vertical datum.

Sea floor search: A systematic method of exploring the sea floor in order to detect *features* such as wrecks, rocks and other obstructions on the sea floor.

Sounding datum: The vertical datum to which the soundings on a hydrographic survey are reduced. Also called 'datum' for sounding reduction.

Total horizontal uncertainty (THU): The component of *total propagated uncertainty* (TPU) calculated in the horizontal plane. Although THU is quoted as a single figure, THU is a 2 Dimensional quantity. The assumption has been made that the *uncertainty* is isotropic (i.e. there is negligible correlation between *errors* in latitude and longitude). This makes a Normal distribution circularly symmetric allowing a single number to describe the radial distribution of *errors* about the true value.

Total propagated uncertainty (TPU): the result of *uncertainty* propagation, when all contributing measurement *uncertainties,* both random and systematic, have been included in the propagation. *Uncertainty* propagation combines the effects of measurement *uncertainties* from several sources upon the *uncertainties* of derived or calculated parameters.

Total vertical uncertainty (TVU): The component of *total propagated uncertainty* (TPU) calculated in the vertical dimension. TVU is a 1 Dimensional quantity.

Uncertainty: The interval (about a given value) that will contain the true value of the measurement at a specific *confidence level.* The *confidence level* of the interval and the assumed statistical distribution of *errors* must also be quoted. In the context of this standard the terms uncertainty and *confidence interval* are equivalent.

Uncertainty Surface: A model, typically grid based, which describes the depth *uncertainty* of the product of a survey over a contiguous area of the skin of the earth. The uncertainty surface should retain sufficient *metadata* to describe unambiguously the nature of the *uncertainty* being described.

ANNEX A

GUIDELINES FOR QUALITY CONTROL

NOTE: it should be noted that the information contained in Annexes A and B provide some guidance on *quality control* and data processing. These Annexes are **not** an integral part of the S-44 Standards and will be removed when the information therein is fully incorporated into IHO Publication M-13.

A.1 Introduction

To ensure that the required *uncertainties* are achieved it is necessary to monitor performance. Compliance with the criteria specified in this document has to be demonstrated.

Standard calibration techniques should be completed prior to and after the acquisition of data and after any major system modification takes place.

Establishing *quality control* procedures should be a high priority for hydrographic offices / organizations. These procedures should cover the entire system including navigation sensors, data collection and processing equipment and the operators. All equipment should be confirmed as functioning within its calibration values and the system should be assessed to ensure that the relevant *uncertainties* in Table 1 can be met. Other parameters, e.g. vessel motion and speed, which can affect the quality of the collected data, should also be monitored.

The processing procedures used prior to the introduction of Multi Beam, Echo Sounders (MBES) and bathymetric LIDAR systems are inefficient, in terms of both manpower and the time required to process the high volume of data gathered by these systems. Processing procedures are needed that allow the reduction, processing and production of the final data set within acceptable manpower and time constraints while maintaining data integrity. As hydrographic offices / organizations continue to be responsible (liable) for their products, these processing procedures should be well documented.

The original survey data (raw data from the different sensors) should be conserved adequately before commencing with the processing of data. The final processed data set should also be conserved. The long-term storage of data, in this era of rapidly changing electronic systems, needs careful planning, execution and monitoring.

Each office is responsible for the definition of its long-term conservation policy for both raw and processed data sets.

A.2 Positioning

Integrity monitoring for Special Order and Order 1a/b surveys is recommended. When equipment is installed to determine or improve the positioning of survey platforms (e.g. Global Navigational Satellite Systems (GNSS) *corrections*), the *uncertainty* of the equipment position relative to the horizontal datum must be included in the calculation of THU.

A.3 Depth Data Integrity

Check lines or overlapping swaths indicate the level of agreeability or repeatability of measurements but do not indicate absolute *accuracy* in that there are numerous sources of potential common *errors* (see A.4) between data from main lines and check lines. The *quality control* procedure should include statistical analysis of differences and the consideration of common *errors* to provide an indication of compliance of the survey with the standards given in Table 1. The effect of spikes and *blunders* should be eliminated prior to this analysis. Remaining anomalous differences should be further examined with a systematic analysis of contributing *uncertainty* sources. All discrepancies should be resolved, either by analysis or re-survey during progression of the survey task.

The ability to compare surfaces generated from newly collected data to those generated from historical information can often be useful in validating the quality of the new information, or alternatively, for notifying the collecting agency of an unresolved systematic *uncertainty* that requires immediate attention.

A.3.1 Single-beam Echo Sounders (SBES)

Check lines should be run at discrete intervals. These intervals should not normally be more than 15 times the spacing of the main sounding lines.

A.3.2 Swath Echo Sounders

An appropriate assessment of the *uncertainty* of the depths at each incidence angle (within each beam for a MBES) should be made. If any of the depths have unacceptable *uncertainties*, the related data should be excluded. A number of check lines should be run. Where adjacent swaths have a significant overlap the spacing between check lines may be extended.

A.3.3 Sweep Systems (multi-transducer arrays)

It is essential that the distance between individual transducers and the acoustic area of ensonification should be matched to the depths being measured to ensure full sea floor coverage across the measurement swath. A number of check lines should be run.

Vertical movements of booms must be monitored carefully as the sea state increases, especially where the effects of heave on the transducers are not directly measured (e.g. decoupled booms systems). Once the heave on the transducers exceeds the maximum allowable value in the *uncertainty* budget, sounding operations should be discontinued until sea conditions improve.

A.3.4 Bathymetric LIDAR

Hazards to navigation detected by bathymetric LIDAR should be examined using a bathymetric system capable of determining the shallowest point according to the standards set out in this document. A number of check lines should be run.

A.4 Error Sources

Although the following text focuses on *errors* in data acquired with swath systems, it should be noted that it is in principle applicable to data acquired with any depth measurement system.

With swath systems the distance between the sounding on the sea floor and the positioning system antenna can be very large, especially in deep water. Because of this, sounding position *uncertainty* is a function of the *errors* in vessel heading, beam angle and the water depth.

Roll and pitch *errors* will also contribute to the *uncertainty* in the positions of soundings. Overall, it may be very difficult to determine the position *uncertainty* for each sounding as a function of depth. The *uncertainties* are a function not only of the swath system but also of the location of, offsets to and accuracies of the auxiliary sensors.

The use of non-vertical beams introduces additional *uncertainties* caused by incorrect knowledge of the ship's orientation at the time of transmission and reception of sonar echoes. *Uncertainties* associated with the development of the position of an individual beam must include the following:

a) Positioning system *errors*;
b) Range and beam *errors*;
c) The error associated with the ray path model (including the sound speed profile), and the beam pointing angle;
d) The error in vessel heading;
e) System pointing *errors* resulting from transducer misalignment;
f) Sensor location;
g) Vessel motion sensor *errors* i.e. roll and pitch;
h) Sensor position offset *errors*; and
i) Time synchronisation / latency.

Contributing factors to the vertical *uncertainty* include:

a) Vertical datum *errors*;

b) Vertical positioning system *errors*;
c) Tidal measurement *errors*, including co-tidal *errors* where appropriate;
d) Instrument *errors*;
e) Sound speed *errors*;
f) Ellipsoidal / vertical datum separation model *errors*;
g) Vessel motion *errors*, i.e. roll, pitch and heave;
h) Vessel draught;
i) Vessel settlement and squat;
j) Sea floor slope; and
k) Time synchronisation / latency.

Agencies responsible for the survey quality are encouraged to develop *uncertainty* budgets for their own systems.

A.5 Propagation of Uncertainties

TPU is a combination of random and bias based *uncertainties*. Random and short period *uncertainties* have to be recognised and evaluated both in horizontal and vertical directions.

The propagated *uncertainty* may be expressed as a variance (in meters^2) but is more often reported as an *uncertainty* (in meters) derived from variance with the assumption that the *uncertainty* follows a known distribution. In the latter case, the level of confidence (e.g., "at 95% *confidence level*") and the assumed distribution shall be documented. Horizontal *uncertainties* are generally expressed as a single value at a 95% level, implying an isotropic distribution of *uncertainty* on the horizontal plane.

In the hydrographic survey process it is necessary to model certain long period or constant factors related to the physical environment (e.g. tides, sound speed, dynamics, squat of the survey vessel). Inadequate models may lead to bias type *uncertainties* in the survey results. These *uncertainties* shall be evaluated separately from random type *uncertainties*.

TPU is the resultant of these two main *uncertainties*. The conservative way of calculating the result is the arithmetic sum, although users should be aware that this may significantly overestimate the total *uncertainty*. Most practitioners, and the appropriate ISO standard, recommend quadratic summation (i.e., summation of suitably scaled variances).

ANNEX B

GUIDELINES FOR DATA PROCESSING

NOTE: it should be noted that the information contained in Annexes A and B provide some guidance on *quality control* and data processing. These Annexes are **not** an integral part of the S-44 Standards and will be removed when the information therein is fully incorporated into IHO Publication M-13.

The text of this annex originates from IHB CL 27/2002 entitled "Guidelines for the processing of high volume bathymetric data" dated 8 August 2002. Sections 2, 3.1 and 4 of

these guidelines have been incorporated into the main body of the 5th Edition of S-44 whilst the remaining sections, with a few amendments, are reproduced below.

B.1 Introduction

The following processing guidelines concentrate on principles and describe **minimum requirements.** The processing steps outlined below are only to be interpreted as an indication, also with regard to their sequence, and are not necessarily exhaustive. Adaptations may be required due to the configuration of the survey as well as the processing system actually used. In general, processing should strive to use all available sources of information to confirm the presence of navigationally significant soundings.

The following workflow should be followed:

B.1.1 Position

This step should comprise merging of positioning data from different sensors (if necessary), qualifying positioning data, and eliminating position jumps. Doubtful data should be flagged and not be deleted.

B.1.2 Depth corrections

Corrections should be applied for water level changes, measurements of motion sensors, and changes of the draught of the survey vessel (e. g. squat changing with speed; change over time caused by fuel consumption). It should be possible to re-process data for which *corrections* were applied in real-time.

B.1.3 Attitude data

Attitude data (heading, heave, pitch, roll) should be qualified and data jumps be eliminated. Doubtful data should be flagged and not be deleted.

B.1.4 Sound speed correction

Corrections due to two-way travel time and refraction should be calculated and applied during this step. If these *corrections* have already been applied in real-time during the survey, it should be possible to override them by using another sound speed profile.

B.1.5 System Time Latencies

Time latencies in the survey system may include both constant and variable components. The acquisition system or the processing system should check for latency and remove it whenever practicable.

B.1.6 Merging positions and depths

For this operation the time offset (latency) and the geometric offsets between sensors have to be taken into consideration.

B.1.7 Analysis of returning signal

When a representation of the time series of the amplitude of the returning signal is available, this information may be used to check the validity of soundings.

B.1.8 Automatic (non-interactive) data cleaning

During this stage, the coordinates (i.e. positions and depths) obtained should be controlled automatically by a programme using suitable statistical algorithms which have been documented, tested and demonstrated to produce repeatable and accurate results. When selecting an algorithm, robust estimation techniques should be taken into consideration as their adequacy has been confirmed. Many high-density bathymetry processing packages have built-in statistical processing tools for detecting and displaying outliers. Generally speaking, higher-density data sets with large amounts of overlap between lines provide an increased likelihood of detecting *blunders*. In addition to statistics, threshold values for survey data can be used to facilitate the detection of *blunders*. Each agency is responsible for the validation of the algorithm used and the procedures adopted.

All *blunders* and erroneous and doubtful data should be flagged for subsequent operator control. The type of flag used should indicate that it was set during the automatic stage.

B.1.9 Manual (interactive) data cleaning

Following automated processing procedures, there is a requirement for an experienced and responsible hydrographer to review the automated results and validate those results and/or resolve any remaining ambiguities.

For this stage the use of 3-D visualisation tools is strongly recommended. Decision making about whether to accept or reject apparently spurious soundings can often be enhanced by viewing combined data sets in three dimensions. These tools should allow viewing the data using a zoom facility. The interactive processing system should also offer different display modes for visualisation, e.g. depth plot, *uncertainty* plot, single profile, single beam, backscatter imagery etc. and should allow for the visualisation of the survey data in conjunction with other useful information e.g. shoreline, wrecks, aids to navigation etc. Editing the data should be possible in all modes and include an audit trail. When editing sounding data, it can often be useful to understand the spatial context of the examined data points. What may appear to be bad soundings (*blunders*) out of context may be recognised as real sea floor artefacts (submerged piles, wrecks, etc.) when viewed in the context of a chart backdrop for example. If feasible, data displays should be geo-referenced. The ability to compare surfaces from newly collected data to ones generated from historical information can often be useful in validating the quality of the new information, or alternatively, for notifying the collecting agency of an unresolved systematic *uncertainty* that requires immediate attention.

If feasible, these tools should include the reconciliation of normalised backscatter imagery with bathymetry and, provided that automated object detection tools were used, the display of flagged data for both data modes should be possible.

The rules to be observed by operators during this stage should be documented.

The flags set during the automatic stage, which correspond to depths shallower than the surrounding area, should require explicit operator action, at least, for Special Order and Order 1 a/b surveys. If the operator overrules flags set during the automatic stage, this should be documented. If a flag is set by the operator, the type of flag used should indicate this.

B.2 Use of *uncertainty surfaces*

Many statistical bathymetry processing packages also have the ability to generate an *uncertainty surface* associated with the bathymetry using either input *error* estimates or by generating spatial statistics within grid cells. Displaying and codifying these *uncertainty surfaces* is one method of determining whether the entire survey area has met the required specifications. If some areas fall outside the specifications, these areas can be targeted for further data collection or use of alternative systems in order to reduce the *uncertainty* to within an acceptable tolerance. When performed in real-time, the sampling strategy can be adapted as the survey progresses, ensuring the collected data are of an acceptable quality for the intended use. Each agency is responsible for the validation of these processing capabilities prior to use.

B.3 Validation Procedures

The final data should be subject to independent in-house validation employing documented *quality control* procedures.

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APPENDIX F

Multibeam Quality Control and Quality Assurance Procedures (North Atlantic Division Multibeam User Group)

F-1. This appendix contains examples of quality control and quality control criteria used by districts in the North Atlantic Division. Much of the recommended QC and QA guidance in this appendix was developed during periodic North Atlantic Division (NAD) "Multibeam User Group (MUG)" meetings held in the early to mid 2000's in Atlantic City, NJ.

a. Section I contains QC and QA procedural criteria established by the New York District for dredge measurement, payment, and clearance surveys applicable to new work deepening projects in rock cuts.

b. Section II illustrates Philadelphia District Performance Test methods and results on the S/V Shuman's Reson Seabat 8101 multibeam system.

c. Section III describes Patch and Performance Tests on the Philadelphia District S/V Cherneski's Reson 7125 multibeam system.

d. Section IV illustrates a Performance Test between independent survey vessels over a full dredging acceptance section.

e. Section V contains a table of recommended QC and QA practices for multibeam surveys developed during the NAD MUG meetings.

SECTION I

New York District Quality Control and Quality Assurance Requirements for Dredging Measurement and Payment Surveys

F-2. The following checklist lists minimum QC and QA steps that are performed daily by each survey vessel in New York District. This checklist was especially developed for work on the New York/New Jersey Deepening Project, much of which involved critical contract clearance and acceptance surveys over rock cut channels.

F-3. Definitions:

a. Caven Point" is the New York District Operations Division Marine Terminal in Jersey City—the location of the RTK base station covering navigation projects in the Port of New York

& New Jersey, a Corps-operated water level (tide) gage, and a nearby Performance Test site with a baseline Reference Surface established by multiple survey vessels and survey systems.

b. A “Float Test” is a gage comparison (i.e., "check") with an observed “RTK Tide” while the vessel is dead in the water near the gage.

Multibeam Payment Work QC and QA
(Minimum Required)

Caven Point:

- □ Check Hardware/System Set-Up
  - Ensure correct INI files are loaded and PPS is functioning correctly
  - Check Orthometric Height
- □ Measure, Record, and Apply Draft Correction
- □ Perform Horizontal Calibration Check / Verify Results
- □ Log Float Test—Caven Point Gage (minimum 60 secs)
- □ Review and Record Float Test Results
  - (In Stage 1 of the edit, make sure you are looking at where the white line intersects the red line. The red line is the average, but the white line is the value shown on the screen. If there is confusion, go to Stage 2 of the edit and view the tide in the “Sounding Info” screen)
- □ Start True Heave File

Caven Point Quality Assurance Performance Test Site:

- □ Perform QC Velocity Cast
- □ Run multibeam Performance Test “Check Surface”
- □ Review and Record Performance Test Results
  - (Look at overlapping passes as well as single beam test)
  - (Compare results to current Reference Surface)

Project Site (work area):

- □ Log Float Test near project reference gage (minimum 60 secs)
  - The Float Test should be conducted in the vicinity of the tide staff. There may be jobs where logging near the staff is not practical; for these jobs you should log as close to the staff as possible. In these circumstances, if you do not match the staff, you must prove out that your tide is correct.
- □ Review and Record Float Test Results
- □ Perform QC Velocity Cast

□ Perform Ball Check

RUN SURVEY

□ Additional Velocity Casts – if sound velocity conditions change such that additional casts are needed
□ Perform Final Velocity Cast in work Area
□ Perform Final Ball Check
□ Log Final Float Test (minimum 60 secs)
□ Review and Record Float Test Results

Caven Point Quality Assurance Performance Test Site:

□ Perform QC Velocity Cast
□ Run multibeam Performance Test "Check Surface"
□ Review and Record Performance Test Results
(Look at overlapping passes as well as single beam test)
(Compare results to current Reference Surface)

Caven Point:

□ End True Heave File
□ Measure and Record Draft Correction
□ Log Float Test (Caven Point Gage) (minimum 60 Secs)
□ Review and Record Float Test Results

It is the Party Chief's responsibility to ensure all QC and QA work. If QC or QA checks show results that are not typical, the Party Chief will confer with office personnel to decide if work can proceed.

SECTION II

Performance Tests on S/V Shuman (Philadelphia District)

F-4. This section describes a series of Performance Tests run on the S/V Shuman Reson Seabat 8101 multibeam system in August 2004. A Trimble 4000 DGPS was used for code phase positioning. Vessel motion and alignment was controlled by a TSS MAHRS Gyro/MRU.

a. Reference Point and Mounting Offsets. Because the S/V Shuman is a catamaran, using the boat center of gravity (CG) as the reference point causes problems (static roll rotations due to loading that are not about the CG). The MAHRS system has been mounted as near as practical to the sonar and selected as the reference point.

Device	Offset	Starboard	Forward	Vertical	Latency
Trimble 4000	Antenna	-4.3’	0.0’	-15.0’	0.85 S
Seabat 8101	Sonar Head	-4.3’	0.0’	2.7’	0.00 S
TSS MAHRS	Gyro	0.0’	0.0’	0.0’	0.00 S
TSS MAHRS	MRU	0.0’	0.0’	0.0’	0.00 S

b. MRU Roll and Pitch Corrections. To achieve a static value of 0.0 degrees pitch and roll, the following offsets were entered in Hysweep Hardware:

Pitch Offset = 0.85 degrees,
Roll Offset = -0.40 degrees.

Patch Test: Latency Offset = 0.85 s (No patch testing was done for latency because the Trimble 4000 DGPS latency is known to be 0.85 seconds).

Trial 1 = 0.1 degrees, trial 2 = 0.2, trial 3 = 0.1, trial 4 = 0.15

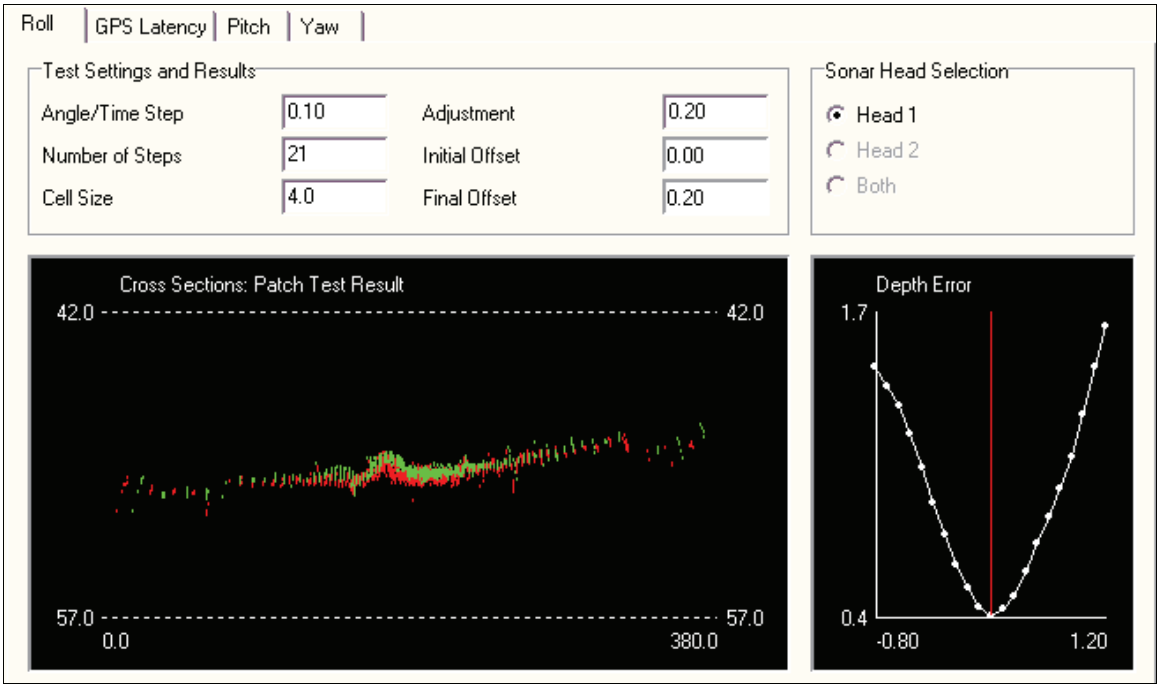


Figure F-1. Preliminary Patch Test: Roll Bias = 0.15 degrees:

Trial 1 = -1.5 degrees, trial 2 = -2.0, trial 3 = -4.0, trial 4 = -1.5

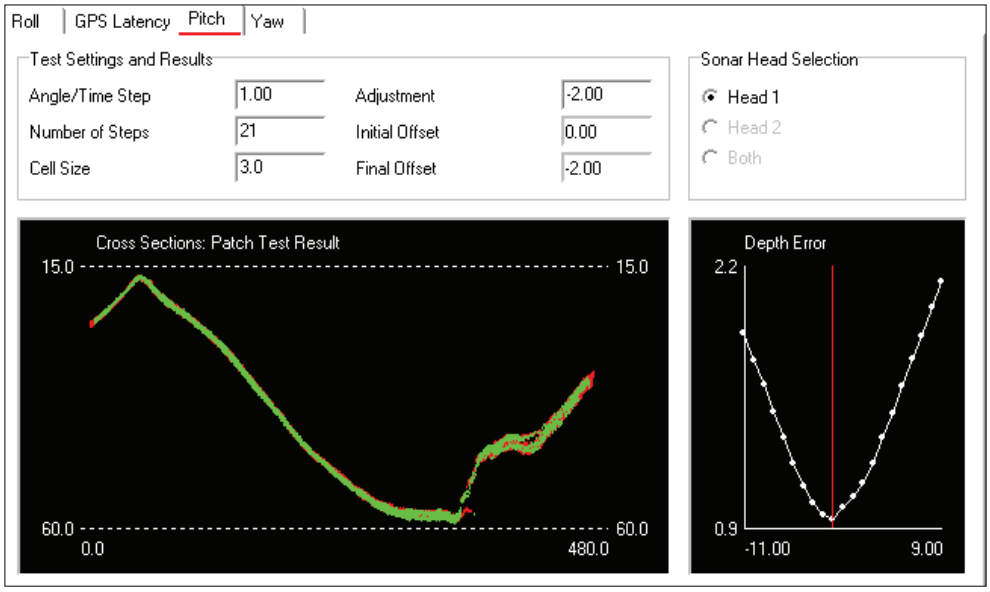


Figure F-2. Preliminary Patch Test: Pitch Bias = -2.0 degrees

:

Trial 1 = 0.0 degrees, trial 2 = 2.0, trial 3 = 2.0, trial 4 = 0.0

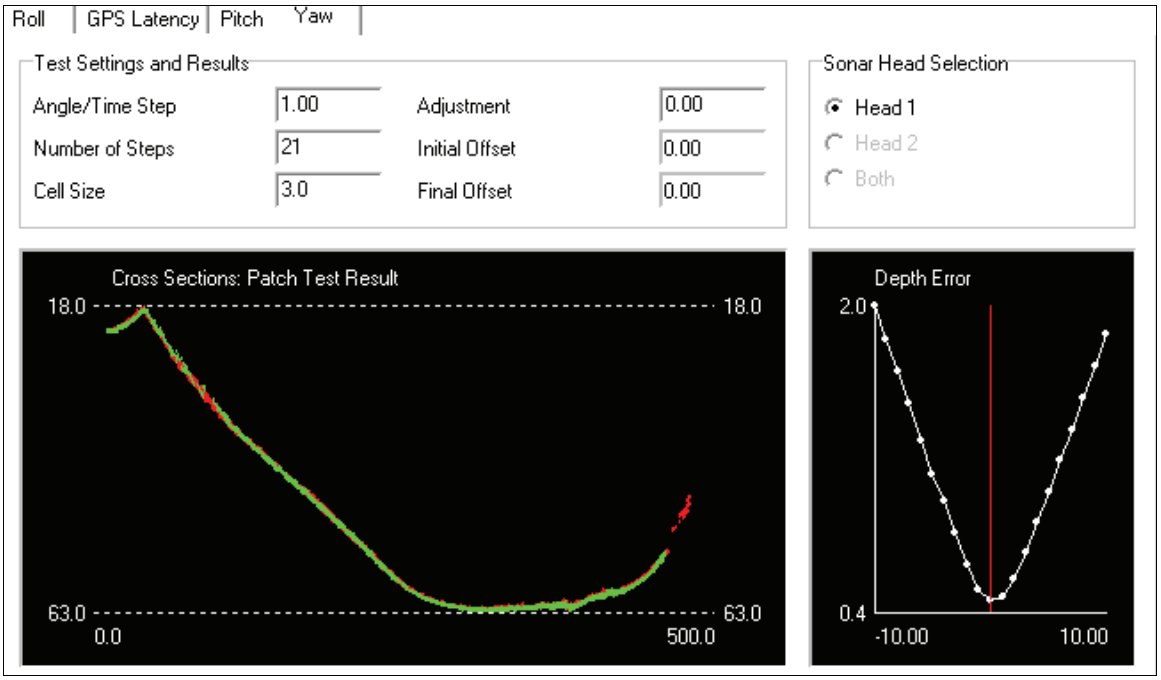


Figure F-3. Preliminary Patch Test: Yaw Bias = 1.0 degrees

Four bar checks were done but the first was thrown out due to a questionable sound velocity profile. Results are with the final Seabat draft constant (vertical offset) of 2.7'

Depth / Direction	Bar Check 2	Bar Check 3	Bar Check 4
20' Down	20.1	19.95	20.1
30' Down	30.0	30.0	29.9
40' Down	40.0	40.05	39.9
30' Up		29.9	30.0
30' Up		20.0	20.0

c. Multibeam Performance Test Results. The survey system is shown to be repeatable to 0.2' at the 95% confidence level (see comparison below). Starting at 45 degrees, a bias is seen between the reference surface and check lines that must be resolved. The most likely cause of the bias is an error in the sound velocity profile. At 45 degrees, all comparisons (Max Outlier, Mean Difference, Std. Deviation and 95% Confidence) fall well within USACE limits for dredging and aid to navigation surveys (see Details tab in the screen shot below).

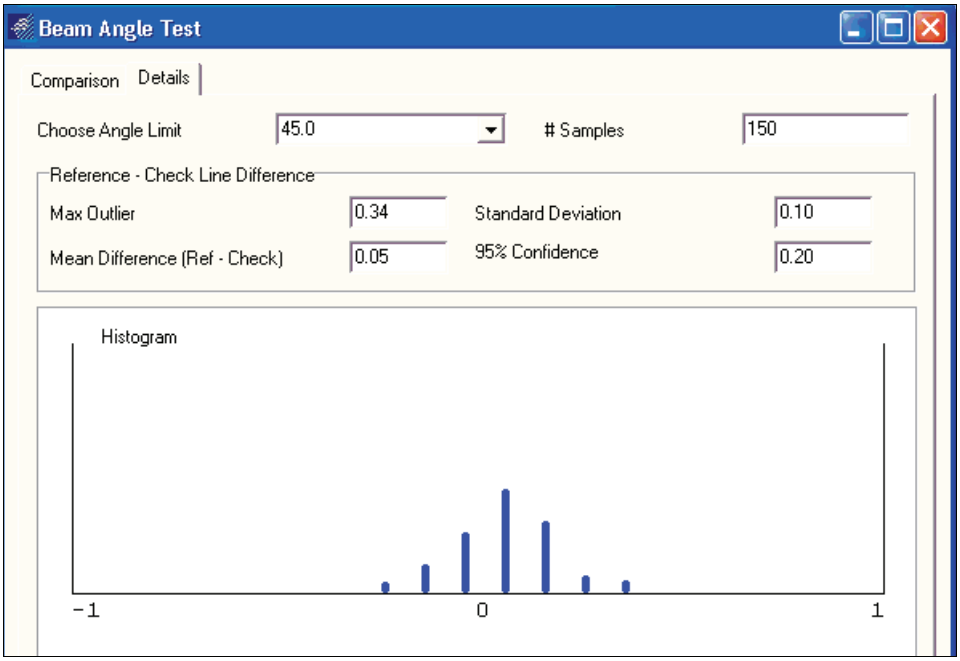


Figure F-4. Multibeam Angle Test

d. Single Beam Comparisons. The Single Beam Test of MBMAX is used to find depth bias between the Shuman multibeam and various single beam systems.

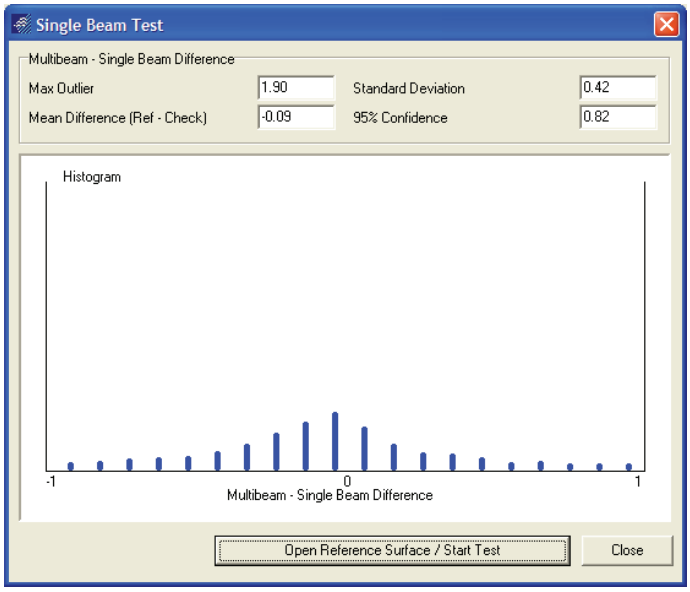


Figure F-5. Shuman Multibeam vs. Shuman Single Beam: Single Beam 0.09' deeper.

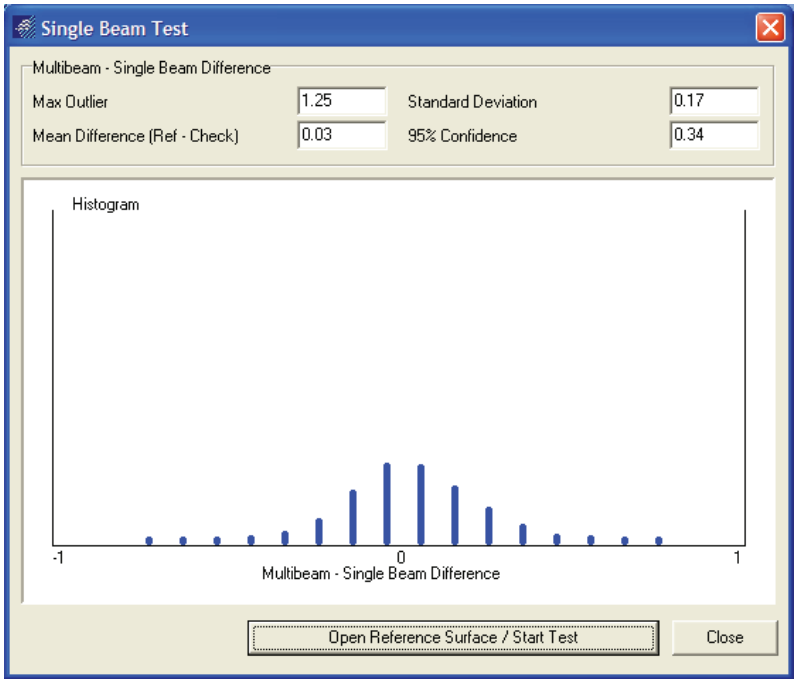


Figure F-6. Shuman Multibeam vs. S/V Cherneski Single Beam: Single beam 0.03' shoaler.

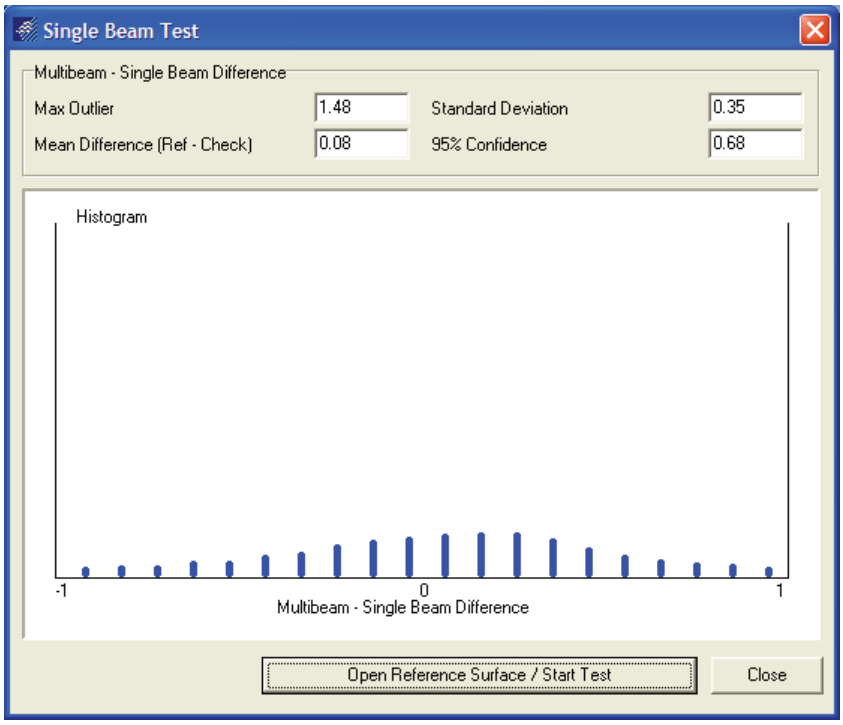


Figure F-7. Shuman Multibeam vs. S/V Essayons Single Beam: Single Beam 0.08 ft shoaler.

SECTION III

Patch / Performance Tests Performed on the S/V Cherneski (Philadelphia District).

F-5. This section is a report on a series of Patch and Performance Tests run on the S/V Cherneski in August 2011. A Reson 7125 multibeam system was combined with an Applanix POS/MV which was used for positioning, vessel motion, and alignment. An SVP 70 was used for sound velocity at the head and an Odom Digibar was used for the sound velocity profile.

Table F-1 Multibeam Calibration

No	Description	Acceptance Criteria	Accepted
2	Determine residual sonar misalignments in roll, pitch and heading. A positioning latency check shall be performed also. • Water depth: approx 50 feet for determining misalignment angles. • Seabed type: Flat and steeply sloping • Min 4 Transits, 300 feet length at 6kts for misalignment angles and min 4 transits . • Beam-forming mode: 256 Equi-Distant • Roll Stabilization on	• Sufficient data shall be collected to perform independent calculation of each misalignment twice (min 6 data sets).	

a. Summary of Patch Test Results

A summary of the accepted patch test results, to be applied for both frequencies, is presented in the following table.

Table F-2 Patch Test Results

Method	Latency	Roll	Pitch	Yaw
Patch Test Results	**Zero**	**-0.11**	**-0.75**	**1.38**

Following completion of the patch test, the results were applied in the Sonar offsets tab in Hysweep hardware. Initially patch tests were carried out with each frequency; however, results proved to be equivalent.

Table F-3. Sound Velocity Profile Criteria

No	Description	Acceptance Criteria	Accepted
1	Prior to and during all sea acceptance tests a sound velocity profile shall be performed. The sound velocity at the transducer face shall be compared with that from the profiling sound velocity probe at the corresponding depth.	• The sound velocity measurements shall agree to within 1m/s.	

b. Sound Velocity Results

The following sound velocity profile was observed using the Odom Digibar prior to the commencement of the calibration and subsequent grid survey. The sound velocity at the transducer depth (approx 2.99ft) was be observed as being 4718 ft/sec (1438m/sec), the SVP 70 at the head read 4717 ft/sec (1437.7 m/sec) . The figure below shows the profile applied for ray tracing on the right and the values read at the sonar on the right.

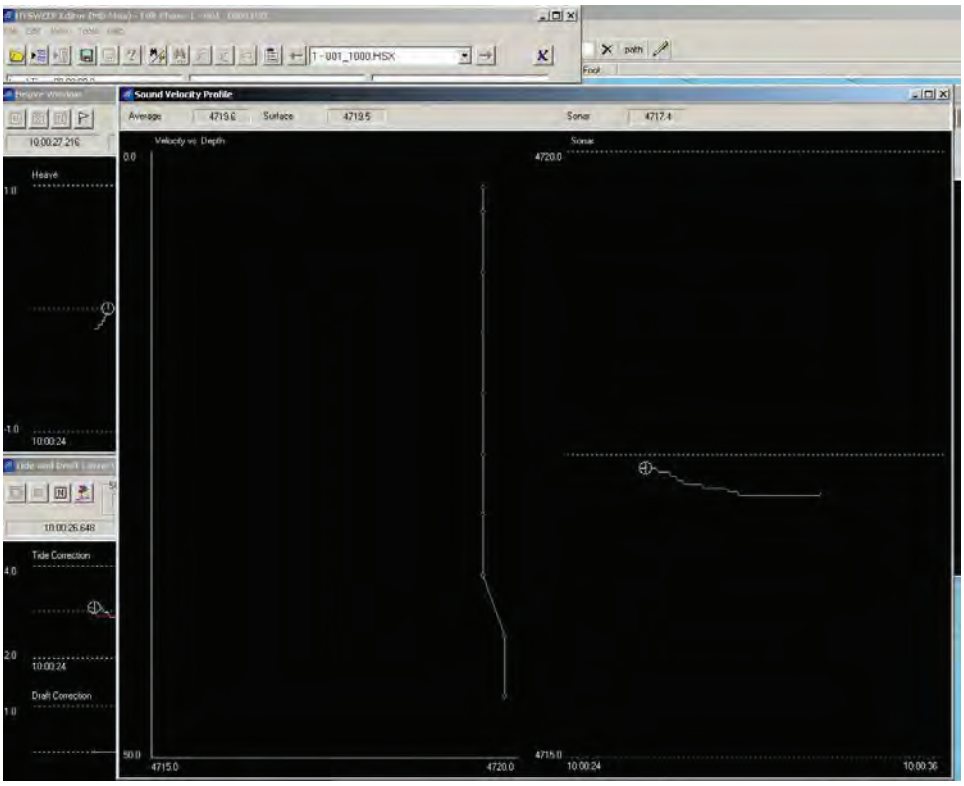


Figure F-8 Sound Velocity Profile

The profile was used for all data collected as the water column properties did not change for the duration of the tests.

c.Latency Check

The latency checks were carried out over a slope ranging from approximately 50 feet to 33 feet. As shown below a number of tests were carried out and successive values of a latency of zero were calculated.

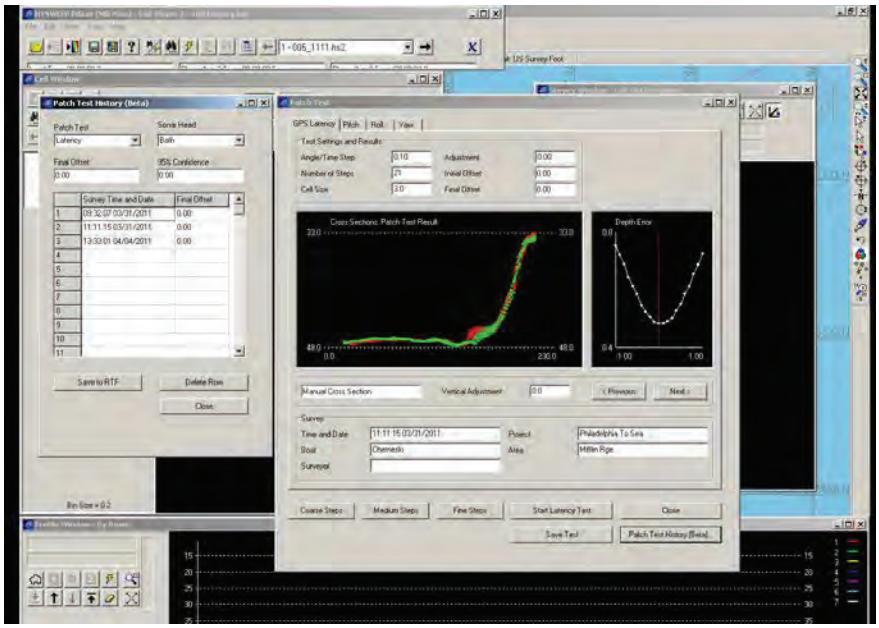


Figure F-9. Latency Check display

Note that the Hypack data acquisition software is synchronized to UTC via the POS MV network time tags. The sonar in turn is synchronized via the ZDA string and 1PPS (Pulse per Second) being issued by the POS MV. RTK positioning was used during these tests to insure data integrity.

c. Roll Calibration

The roll calibration was performed over a flat section of the riverbed at around 50 ft depth, using the same line run in opposite directions. A table of successive roll results was generated and an average of the roll values calculated as to for pitch and yaw.

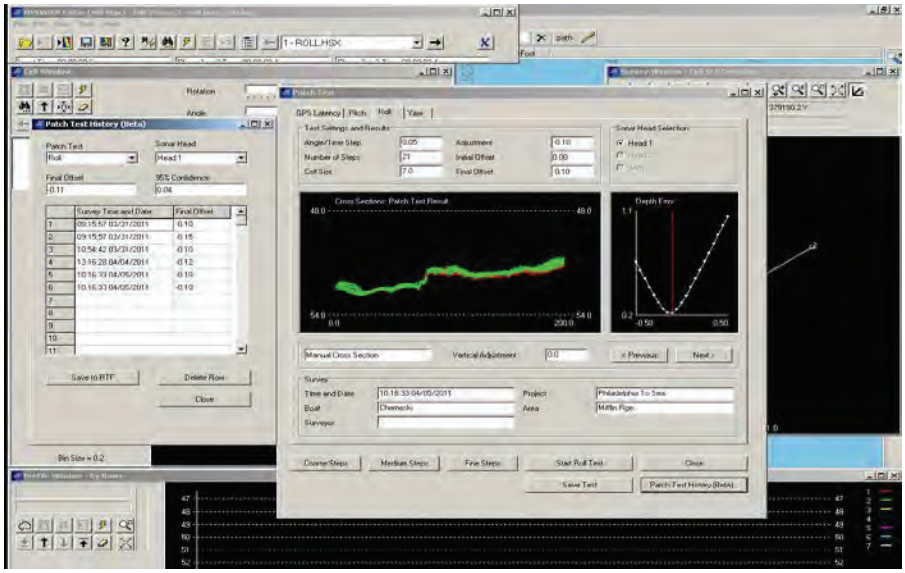


Figure F-10. Roll Calibration Display

d. Pitch Calibration

The pitch calibration was performed using a nadir profile over a slope (the same used for latency), using the same line run in opposite directions.

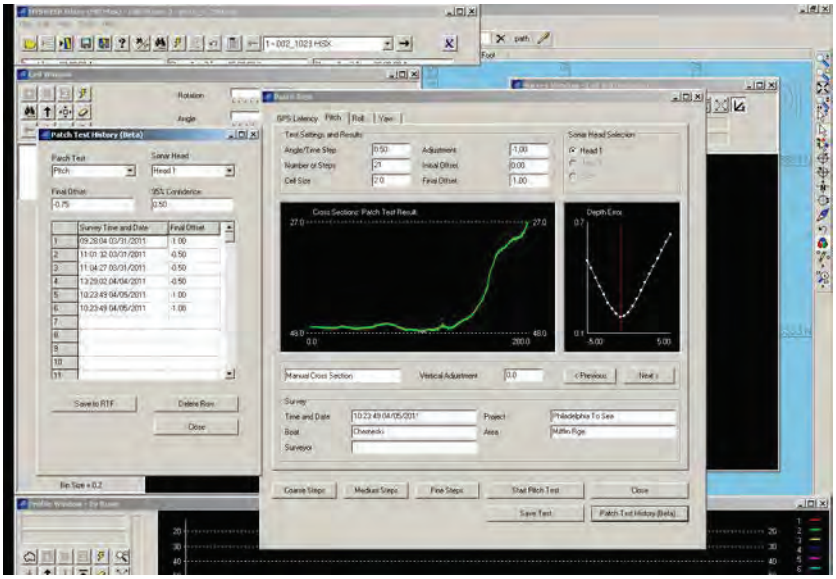


Figure F-11. Pitch Calibration Display

e. Yaw Calibration

The yaw was performed over a profile taken in the overlap region of two adjacent lines over the same slope. The lines were run in the same direction.

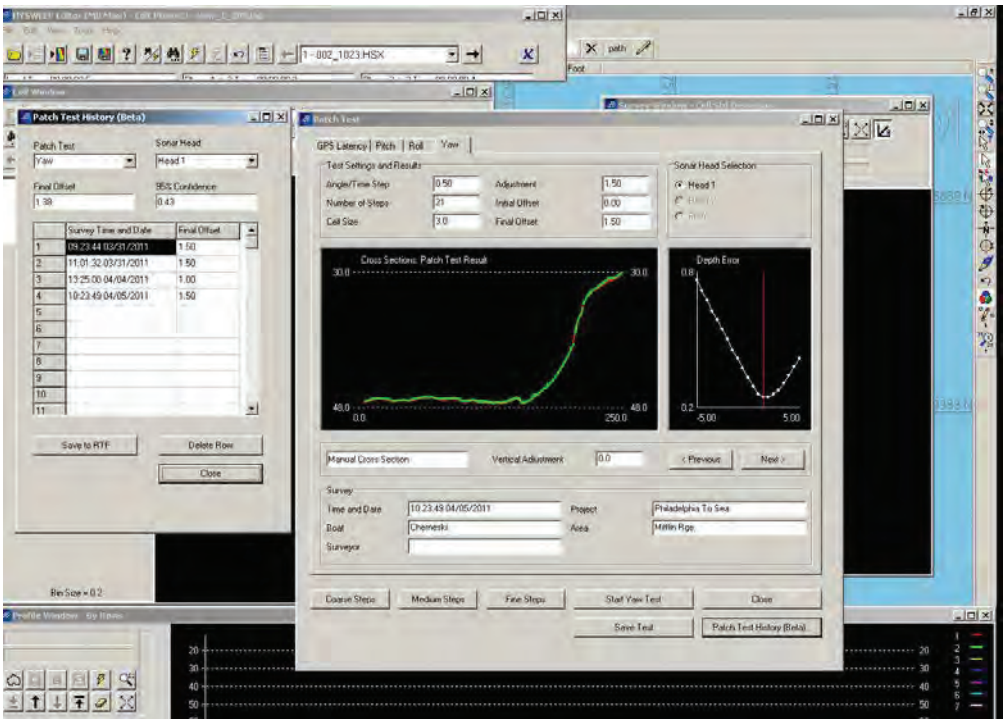


Figure F-12. Yaw Calibration Display

No	Description	Acceptance Criteria	Accepte
3	The Grid Survey shall show that the calibration results are acceptable such that the system is repeatable, independent of direction, with respect to the contracted performance criteria. • Water depth: approx 50 feet • Seabed type: flat • A minimum of 3 lines in one direction and 3 three lines over the same area in the perpendicular direction shall be sailed • Speed: contracted survey speed. • Beam-forming mode: 256 and 512 Equi-Distant (frequency dependent). • Roll Stabilization: on	• The standard deviation of geo-referenced grid cells shall be within the contracted performance criteria. • Depth differences between geo-referenced grid cells from lines run in perpendicular directions shall be within the contracted performance criteria.	

Figure F-13. Grid Survey Tests (Performance Tests)

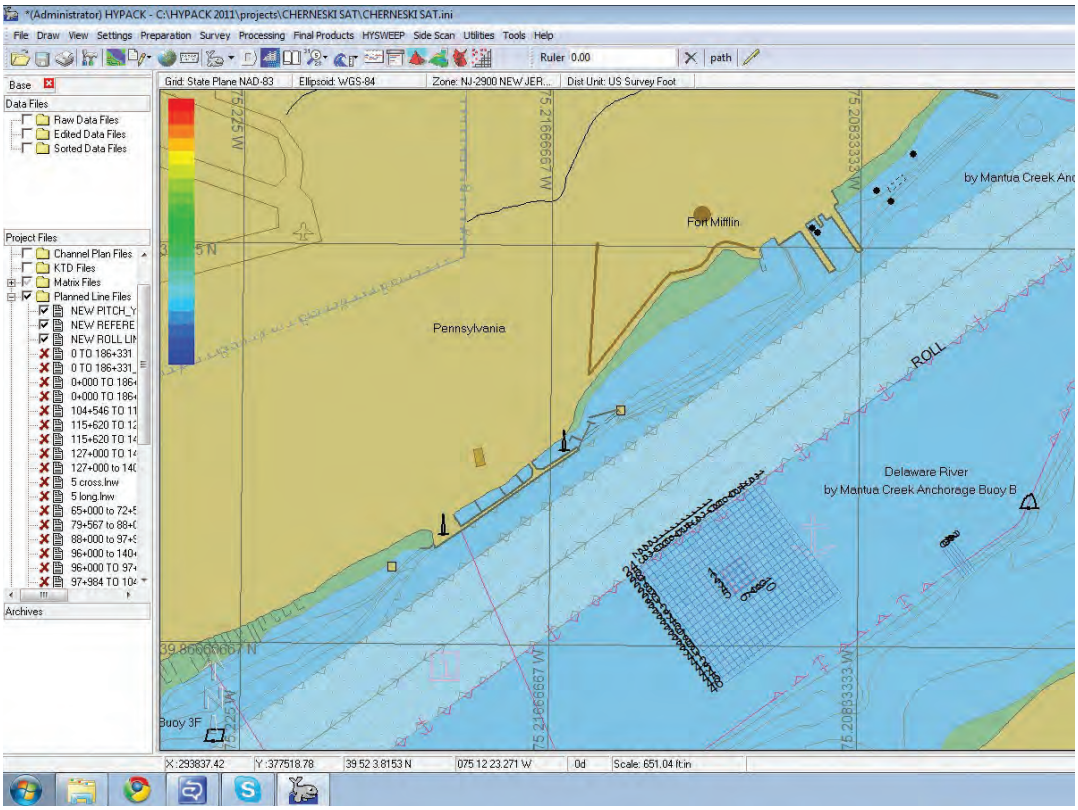


Figure F-14 Performance Test Area

Grid Survey				
Sonar / Mode	SeaBat 7125		**Depth**	50 feet
Vessel Name	*Sv Cherneski*		**Power / Gain / Pulse**	220 / 20 / 35
Mounting Method	Hull Mount		**TVG Abs / Spr**	60 db / 30 db
Survey Date	2011-04-06		**Roll Stabilization**	On
Location	Delaware River, Fort Mifflin.		**Swath Sector**	90
Area Name	Reference Survey		**Cell Size**	1ft
Speed / Dir	6kts		**Contract Tolerance**	**0.82 ft (0.25m) IHO Special Order.**
Comments	Data initially was to be collected within the 1000X1000ft grid shown below. However on consultation a 300X300 ft grid was used (shown within larger grid) consisting of 5 vertical and 5 perpendicular lines. Note: patch test area was directly adjacent to grid area.			

Figure F-15. Survey Parameters

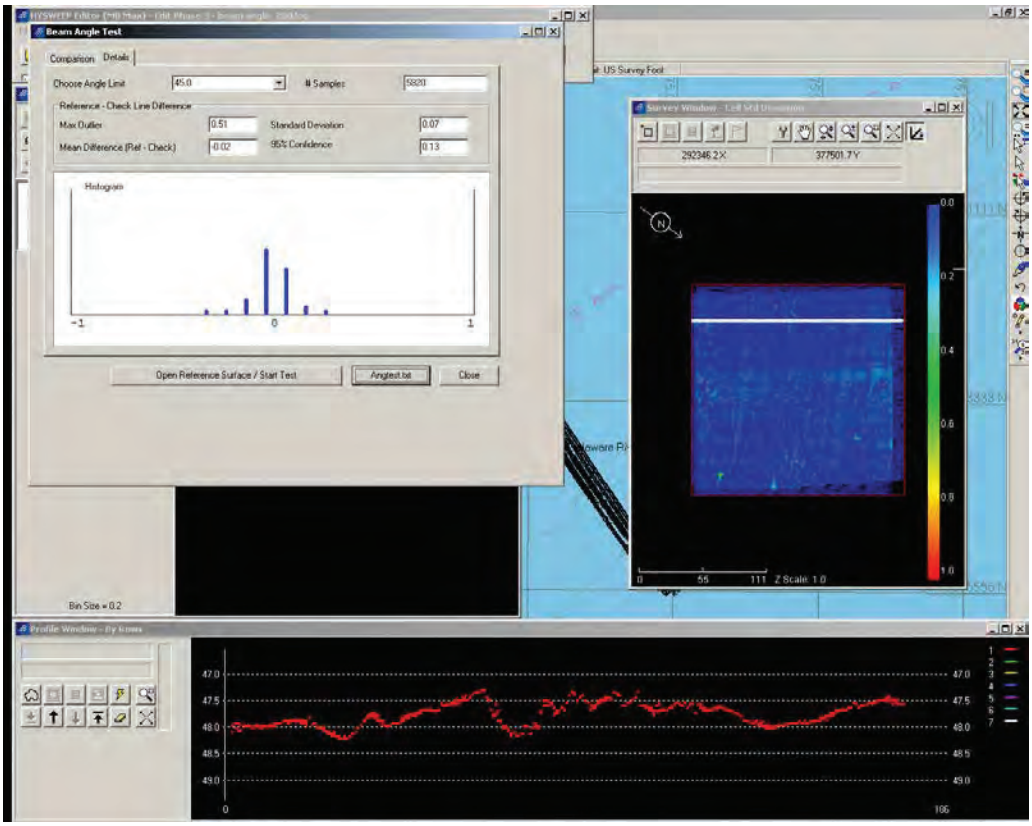
F-6 200 kHz Test

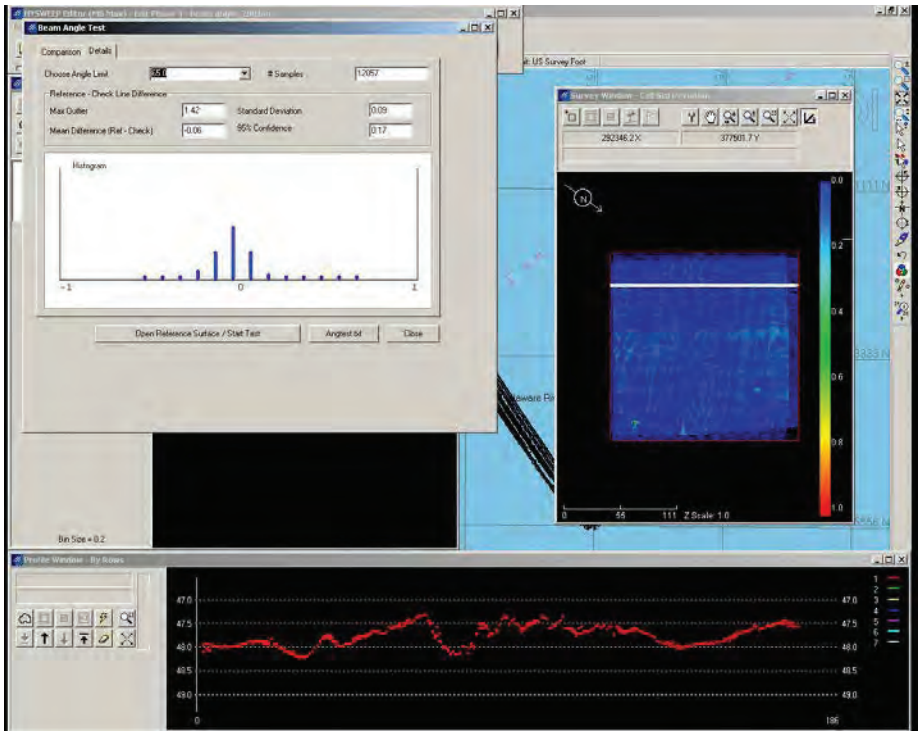
a. Reference Grid.

Grid Survey				
Sonar / Mode	SeaBat 7125 200kHz 256 ED		**Depth**	50 ft
Vessel Name	*Sv Cherneski*		**Power / Gain / Pulse**	220 / 20 / 35
Mounting Method	Hull Mount		**TVG Abs / Spr**	60 db / 30 db
Survey Date	2011-04-06		**Roll Stabilization**	On
Location	Delaware River, Fort Mifflin		**Swath Sector**	90
Area Name	Reference Survey		**Cell Size**	1ft
Speed / Dir	6kts		**Contract Tolerance**	**0.82 ft (0.25m) IHO Special Order.**
Comments	The data example shows the 300X300 ft reference survey area from a total of 10 lines run 5 vertical and 5 perpendicular. The depth variation over the entire area is less .2 feet. Note the overlap of the lines, each shown as a different color at the bottom of the screen. When collecting this data a 45 filter is applied (as per USACE dredge requirements).			

b. Beam Angle Test at 45 deg.

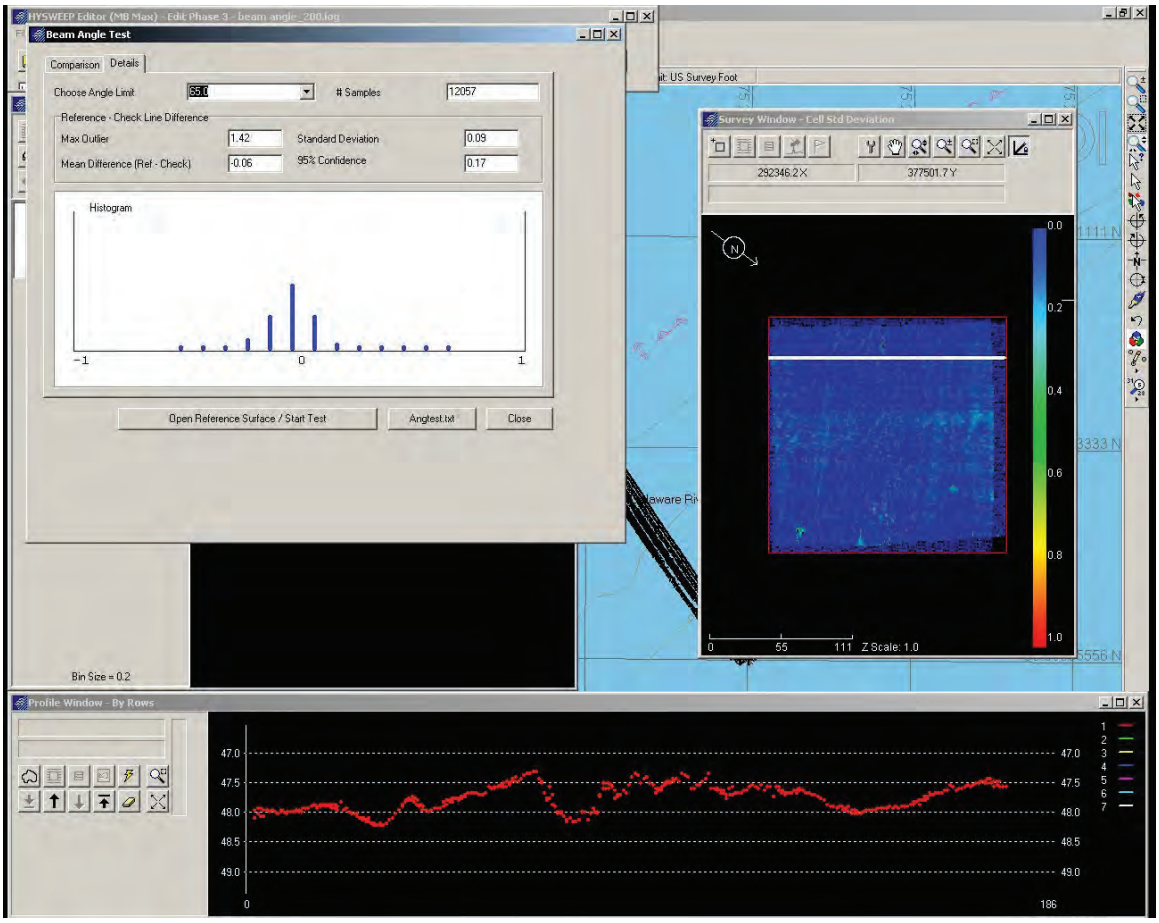
Grid Survey – Beam Angle test at 45				
Sonar / Mode	SeaBat 7125 200kHz 256 ED		**Depth**	50 ft
Vessel Name	*SV Cherneski*		**Power / Gain / Pulse**	220 / 20 / 35
Mounting Method	Hull Mount		**TVG Abs / Spr**	60 db / 30 db
Survey Date	2011-04-06		**Roll Stabilization**	On
Location	Delaware River, Fort Mifflin.		**Swath Sector**	90°
Area Name	Reference Survey		**Cell Size**	1ft
Speed / Dir	6kts		**Contract Tolerance**	**0.82 ft (0.25m) IHO Special Order.**
Comments	The test below shows that when two single crosslines (with 45 port/starboard filters being applied) are compared with the reference surface a mean depth difference of -.02 ft is observed (.006 m).			


Beam Angle Test
Comparison
Details
Choose Angle Limit
45.0
Samples
Reference - Check Line Difference
Max Outlier
0.51
Standard Deviation
0.07
Mean Difference (Ref - Check)
-0.02
95% Confidence
0.13
Histogram
Open Reference Surface / Start Test
Angtest.txt
Close
Bin Size = 0.2
Survey Window
Profile Window - By Rows


Beam Angle Test
Comparison
Details
Choose Angle Limit
Samples
Reference - Check Line Difference
Max Outlier
1.42
Standard Deviation
0.09
Mean Difference (Ref - Check)
-0.06
95% Confidence
0.17
Histogram
Open Reference Surface / Start Test
Angtest.txt
Close
Bin Size = 0.2
Survey Window
Profile Window - By Rows

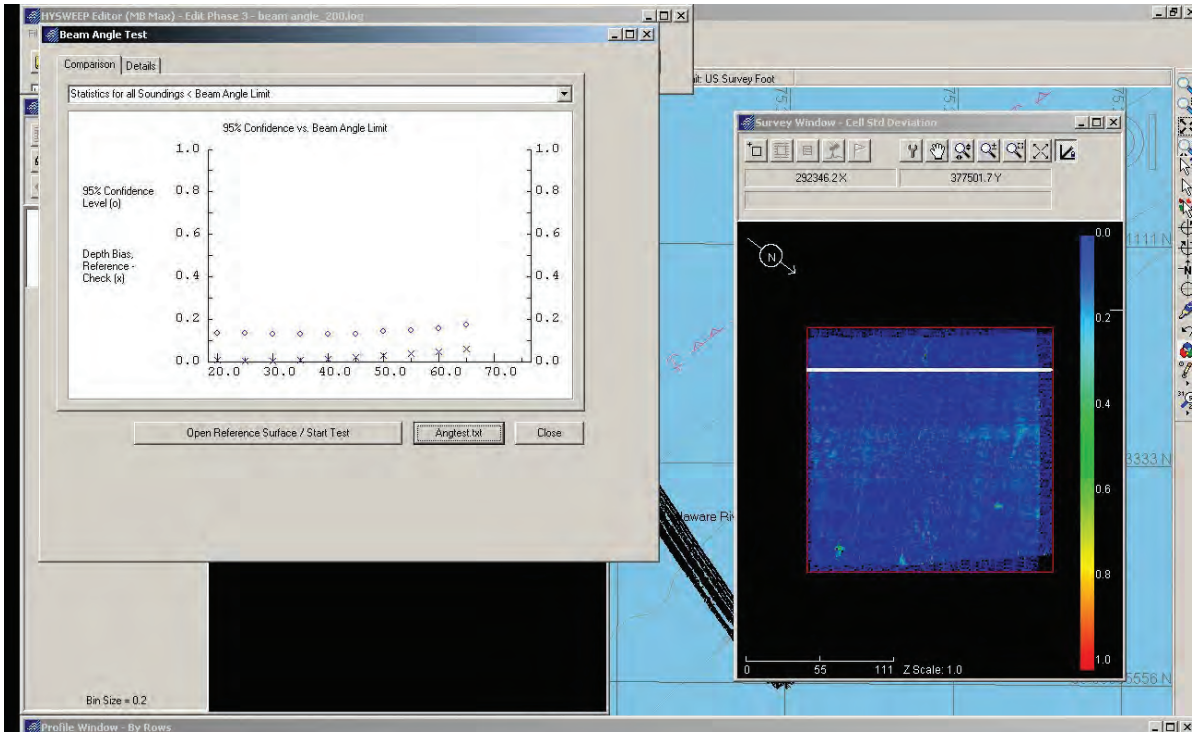
f. Beam Angle Test at full Swath.

Grid Survey – Beam Angle test at full swath.				
Sonar / Mode	SeaBat 7125 200kHz		**Depth**	50 ft
Vessel Name	*SV Cherneski*		**Power / Gain /**	220 / 20 / 35
Mounting	Hull Mount		**TVG Abs / Spr**	60 db / 30 db
Survey Date	2011-04-06		**Roll**	On
Location	Delaware River, Fort		**Swath Sector**	128°
Area Name	Reference Survey		**Cell Size**	1ft
Speed / Dir	6kts		**Contract**	**0.82 ft (0.25m) IHO Special**
Comments	The test below shows that when two single crosslines (with **no** port/starboard filters being applied i.e. full swath) are compared with the reference surface a mean depth difference			



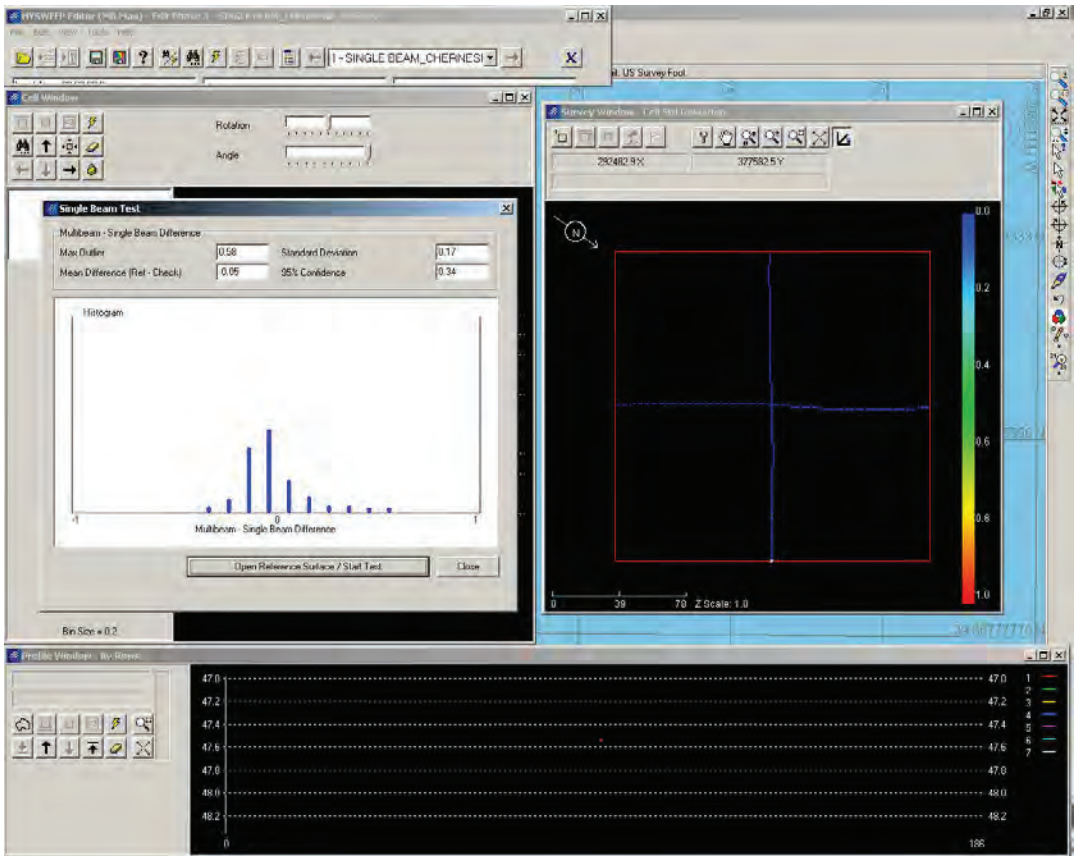
g. Beam Angle Limit Test at 45 deg.

Grid Survey – Beam Angle Limit test at full swath.				
Sonar / Mode	SeaBat 7125 200kHz 256 ED		**Depth**	50 ft
Vessel Name	*SV Cherneski*		**Power / Gain / Pulse**	220 / 20 / 35
Mounting Method	Hull Mount		**TVG Abs / Spr**	60 db / 30 db
Survey Date	2011-04-06		**Roll Stabilization**	On
Location	Delaware River, Fort Mifflin.		**Swath Sector**	128°
Area Name	Reference Survey		**Cell Size**	1ft
Speed / Dir	6kts		**Contract Tolerance**	**0.82 ft (0.25m) IHO Special Order.**
Comments	The test below shows that when two single crosslines (with **no** port/starboard filters being applied i.e. full swath) are compared with the reference surface a mean depth difference is observed of 0 starting at nadir to approx .05 ft (.015m) at the outermost beam. This is well within the 95% repeatability of between 0.12-0.2 ft.			



h. Single Beam Comparison.

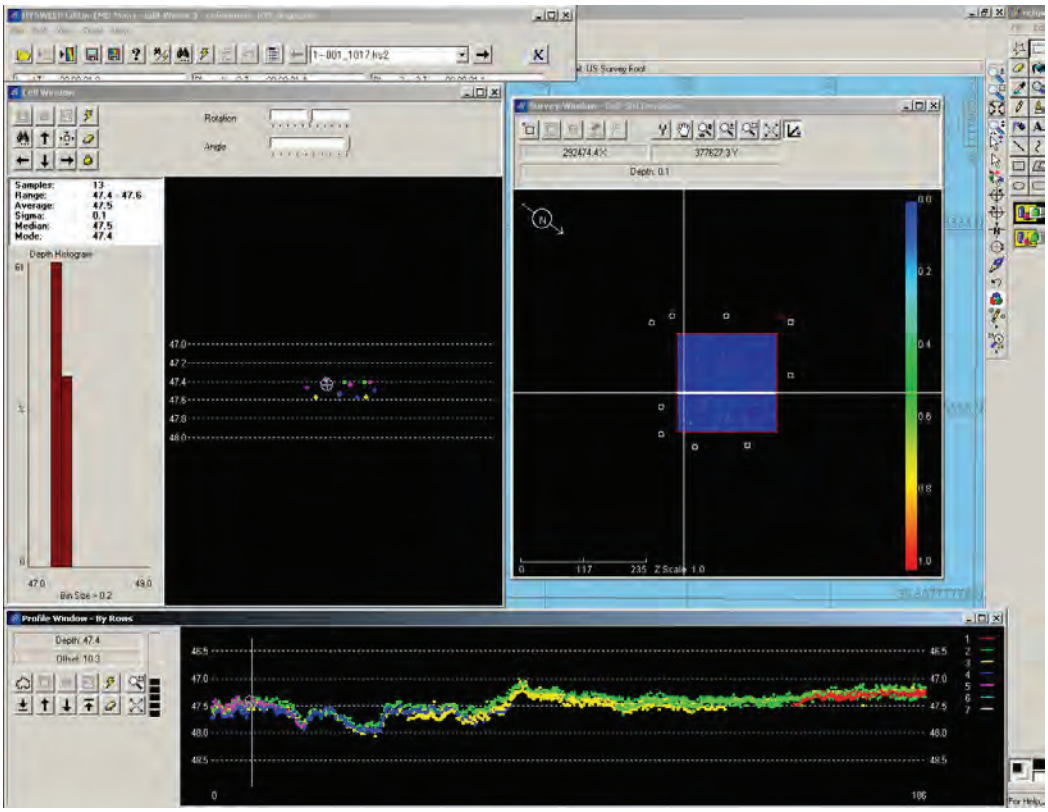
Grid Survey – Single beam comparison.				
Sonar / Mode	SeaBat 7125 200kHz 256 ED		**Depth**	50 ft
Vessel Name	*SV Cherneski*		**Power / Gain / Pulse**	220 / 20 / 35
Mounting Method	Hull Mount		**TVG Abs / Spr**	60 db / 30 db
Survey Date	2011-04-06		**Roll Stabilization**	On
Location	Delaware River, Fort Mifflin.		**Swath Sector**	90°
Area Name	Reference Survey		**Cell Size**	1ft
Speed / Dir	6kts		**Contract Tolerance**	**0.82 ft (0.25m) IHO Special Order.**
Comments	The test below shows a comparison of cross lines run with a 200kHz single beam with the reference area (as per USACE customer requirements). This shows a mean depth difference of -.05 ft (.015 m)			



F-7 400 kHz Test

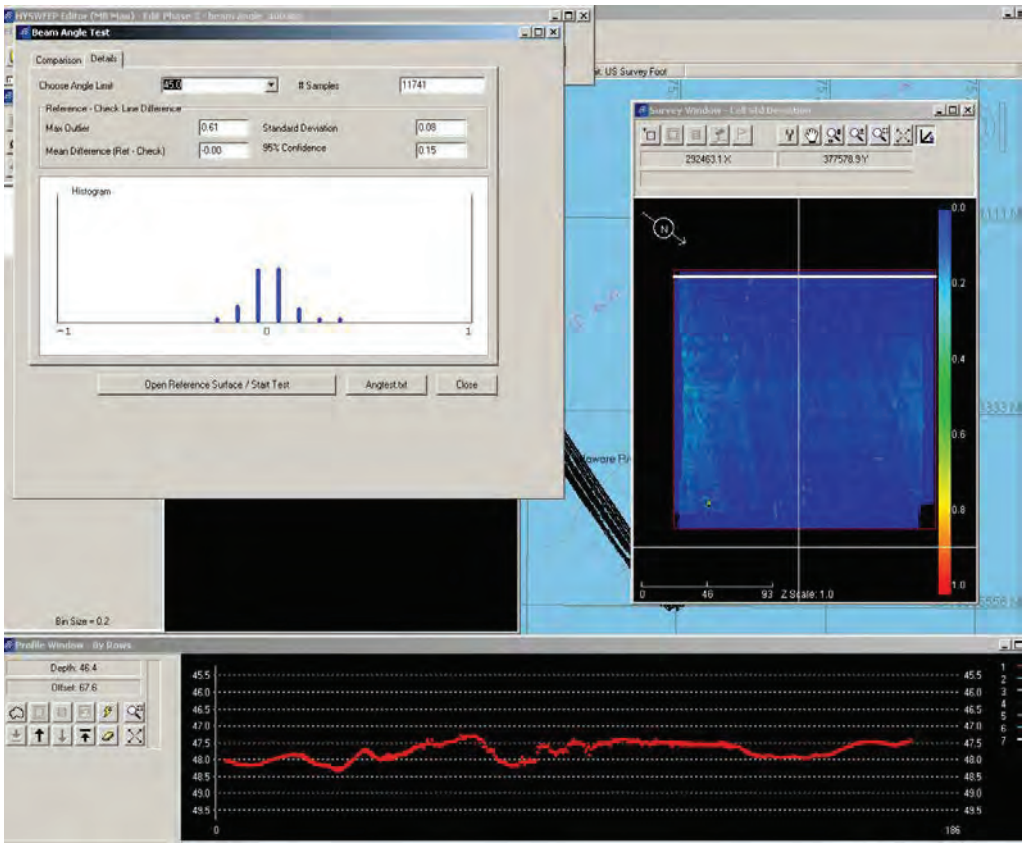
a. Reference Grid.

Grid Survey				
Sonar / Mode	SeaBat 7125 400kHz 512 ED		**Depth**	50 ft
Vessel Name	*SV Cherneski*		**Power / Gain / Pulse**	220 / 20 / 35
Mounting Method	Hull Mount		**TVG Abs / Spr**	60 db / 30 db
Survey Date	2011-04-06		**Roll Stabilization**	On
Location	Delaware River, Fort Mifflin.		**Swath Sector**	90°
Area Name	Reference Survey		**Cell Size**	1ft
Speed / Dir	6kts		**Contract Tolerance**	**0.82 ft (0.25m) IHO Special Order.**
Comments	The data example shows the 300X300 ft reference survey area from a total of 10 lines run 5 vertical and 5 perpendicular. The depth variation over the entire area is less .1 feet. Note the overlap of the lines, each shown as a different color at the bottom of the screen. When collecting this data a 45 filter is applied (as per USACE dredge requirements).			



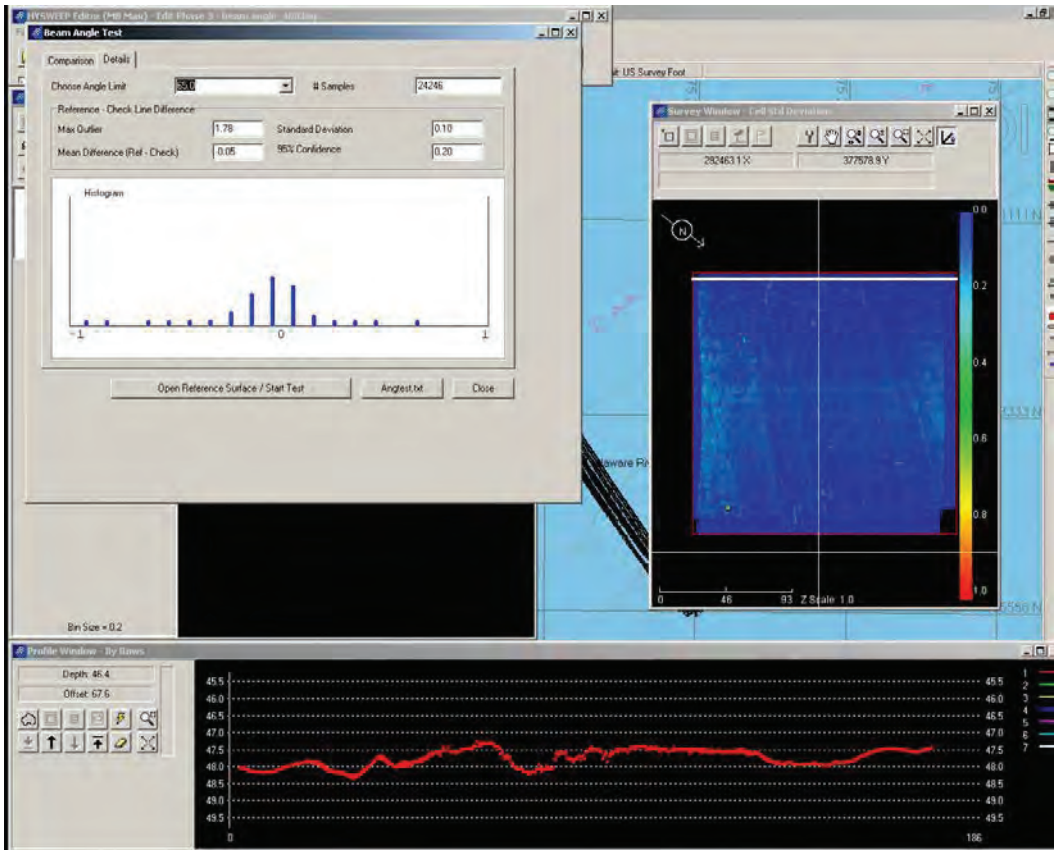
Beam Angle Test at 45 deg.

Grid Survey – Beam Angle test at 45				
Sonar / Mode	SeaBat 7125 400kHz 512 ED		**Depth**	50 ft
Vessel Name	*SV Cherneski*		**Power / Gain / Pulse**	220 / 20 / 35
Mounting Method	Hull Mount		**TVG Abs / Spr**	60 db / 30 db
Survey Date	2011-04-06		**Roll Stabilization**	On
Location	Delaware River, Fort Mifflin.		**Swath Sector**	90°
Area Name	Reference Survey		**Cell Size**	1ft
Speed / Dir	6kts		**Contract Tolerance**	**0.82 ft (0.25m) IHO Special Order.**
Comments	The test below shows that when two single crosslines (with 45 port/starboard filters being applied) are compared with the reference surface a mean depth difference of 0 ft is observed (.0 m).			



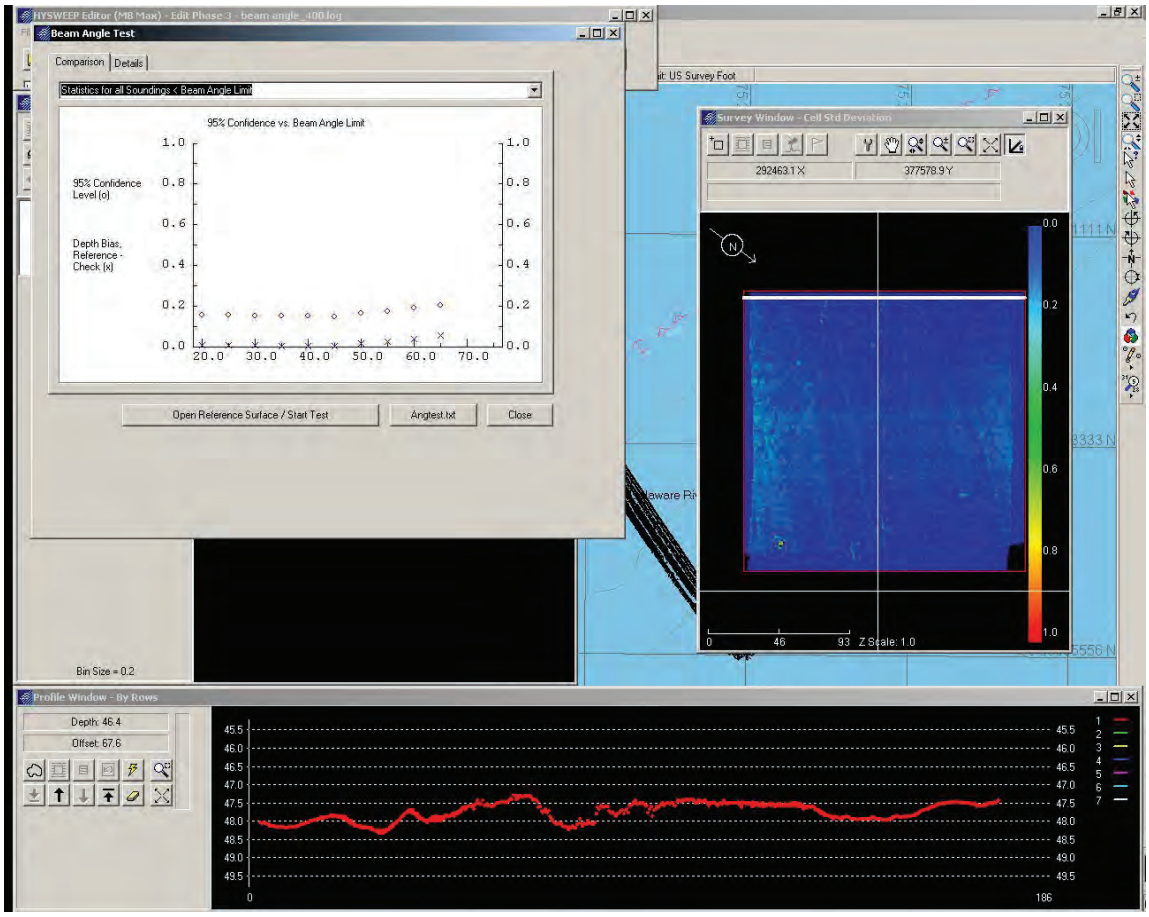
b. Beam Angle Test at Full Swath.

Grid Survey – Beam Angle test at full swath.				
Sonar / Mode	SeaBat 7125 400kHz 512 ED		**Depth**	50 ft
Vessel Name	*SV Cherneski*		**Power / Gain / Pulse**	220 / 20 / 35
Mounting Method	Hull Mount		**TVG Abs / Spr**	60 db / 30 db
Survey Date	2011-04-06		**Roll Stabilization**	On
Location	Delaware River, Fort Mifflin.		**Swath Sector**	128°
Area Name	Reference Survey		**Cell Size**	1ft
Speed / Dir	6kts		**Contract Tolerance**	**0.82 ft (0.25m) IHO Special Order.**
Comments	The test below shows that when two single crosslines (with **no** port/starboard filters being applied i.e. full swath) are compared with the reference surface a mean depth difference of - .05 ft is observed (.015 m).			



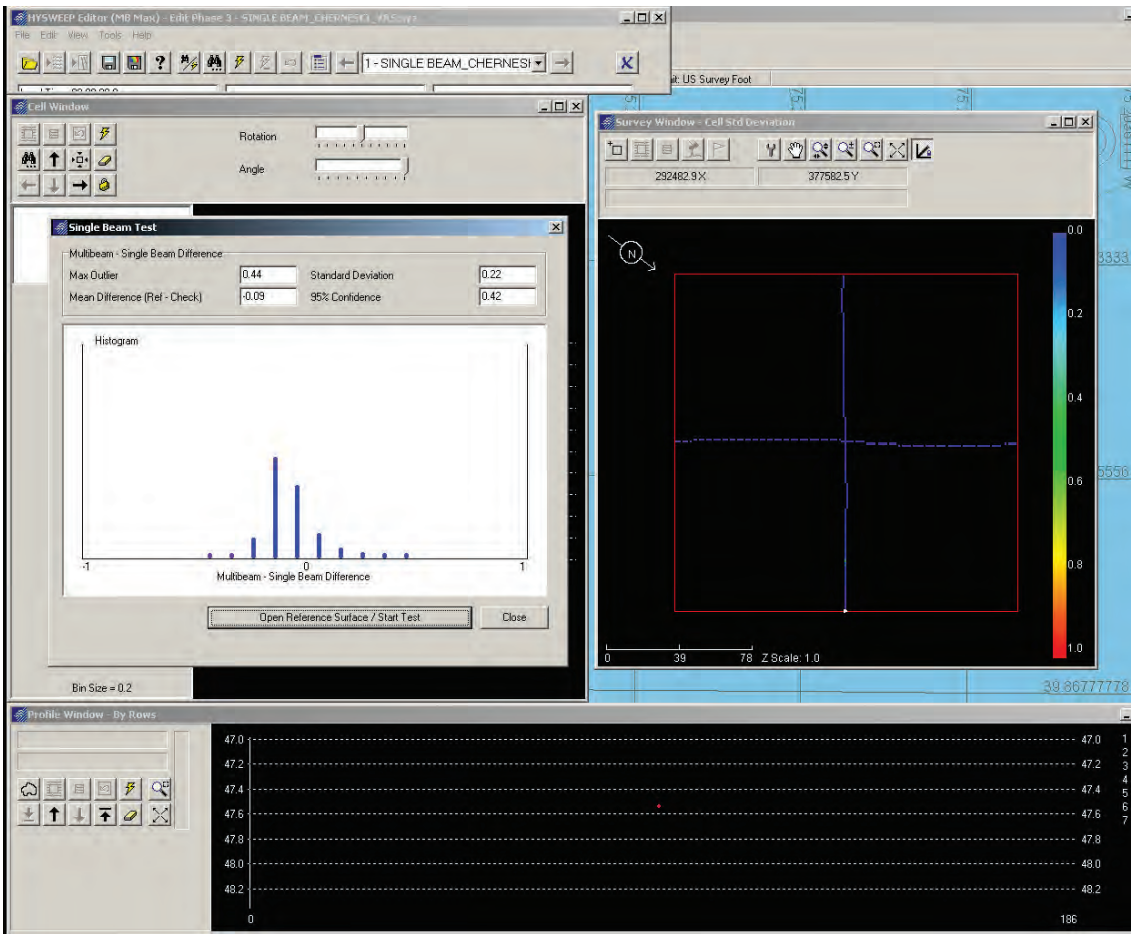
c. **Beam Angle Limit Test at Full Swath.**

Grid Survey – Beam Angle Limit test at full swath.				
Sonar / Mode	SeaBat 7125 400kHz 512 ED		**Depth**	50 ft
Vessel Name	*SV Cherneski*		**Power / Gain / Pulse**	220 / 20 / 35
Mounting Method	Hull Mount		**TVG Abs / Spr**	60 db / 30 db
Survey Date	2011-04-06		**Roll Stabilization**	On
Location	Delaware River, Fort Mifflin.		**Swath Sector**	128°
Area Name	Reference Survey		**Cell Size**	1ft
Speed / Dir	6kts		**Contract Tolerance**	**0.82 ft (0.25m) IHO Special Order.**
Comments	The test below shows that when two single crosslines (with no port/starboard filters being applied i.e. full swath) are compared with the reference surface a mean depth difference is observed of 0 starting at nadir to approx .05 ft (.015m) at the outermost beam. This is well within the 95% repeatability of between 0.15-0.2 ft.			



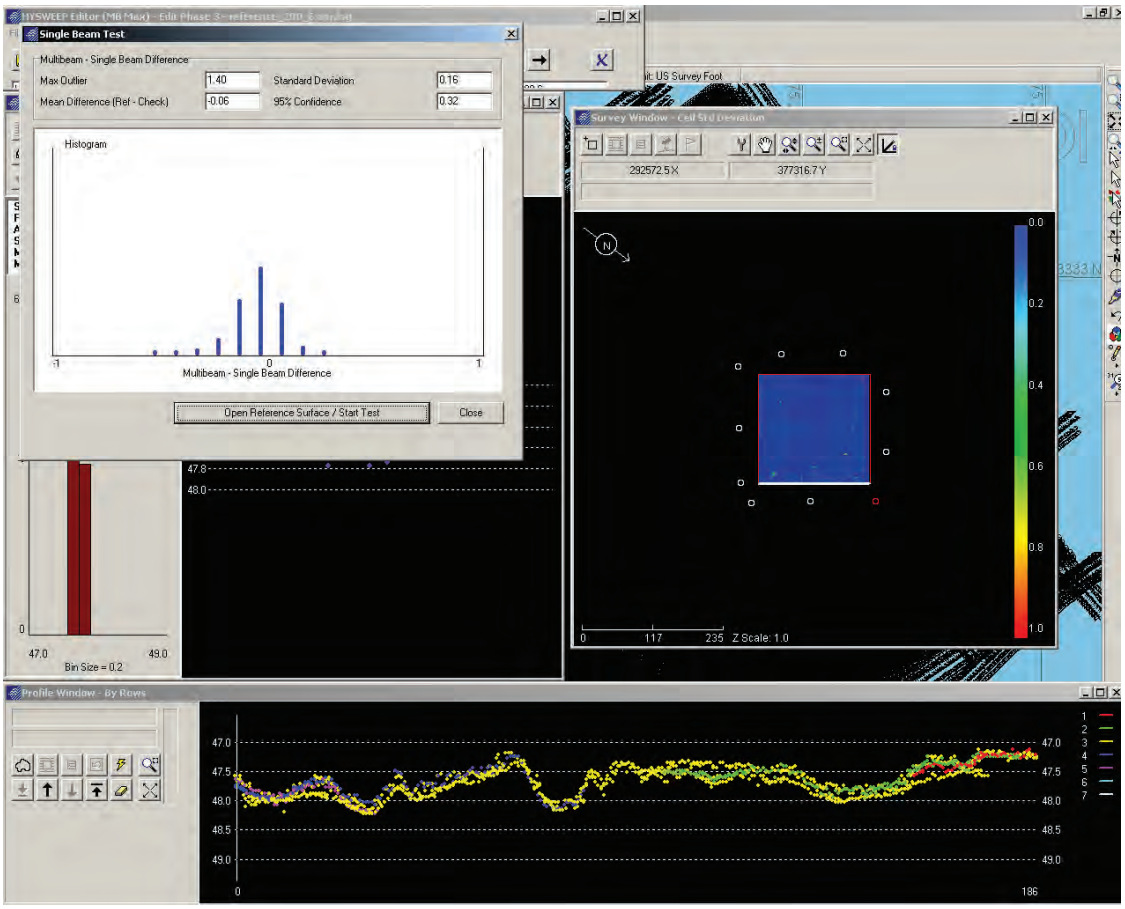
d. **Single Beam Comparison.**

Grid Survey – Single beam comparison.				
Sonar / Mode	SeaBat 7125 400kHz 512 ED		**Depth**	50 ft
Vessel Name	*SV Cherneski*		**Power / Gain / Pulse**	220 / 20 / 35
Mounting Method	Hull Mount		**TVG Abs / Spr**	60 db / 30 db
Survey Date	2011-04-06		**Roll Stabilization**	On
Location	Delaware River, Fort Mifflin.		**Swath Sector**	90°
Area Name	Reference Survey		**Cell Size**	1ft
Speed / Dir	6kts		**Contract Tolerance**	**0.82 ft (0.25m) IHO Special Order.**
Comments	The test below shows a comparison of cross lines run with a 200kHz single beam with the reference area (as per USACE customer requirements). This shows a mean depth difference of -.09 ft (.027 m).			



e. 200 kHz to 400 kHz Grid Comparison

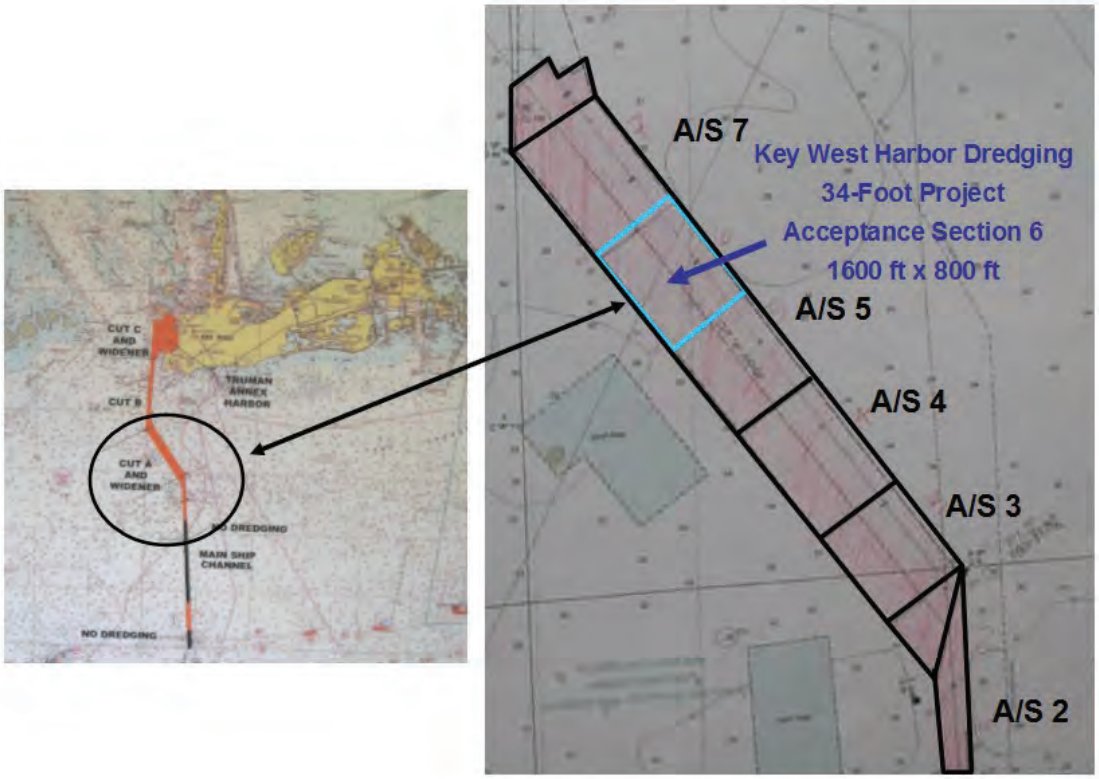
Grid Survey – 200kHz to 400kHz comparison.				
Sonar / Mode	SeaBat 7125 200kHz 256 ED		**Depth**	50 ft
Vessel Name	*SV Cherneski*		**Power / Gain / Pulse**	220 / 20 / 35
Mounting Method	Hull Mount		**TVG Abs / Spr**	60 db / 30 db
Survey Date	2011-04-06		**Roll Stabilization**	On
Location	Delaware River, Fort Mifflin.		**Swath Sector**	90°
Area Name	Reference Survey		**Cell Size**	1ft
Speed / Dir	6kts		**Contract Tolerance**	**0.82 ft (0.25m) IHO Special Order.**
Comments	Although not strictly necessary, a comparison of the two grids (200 and 400 kHz) was made and a mean depth difference of -.06 ft (.018 m) was observed.			



SECTION IV

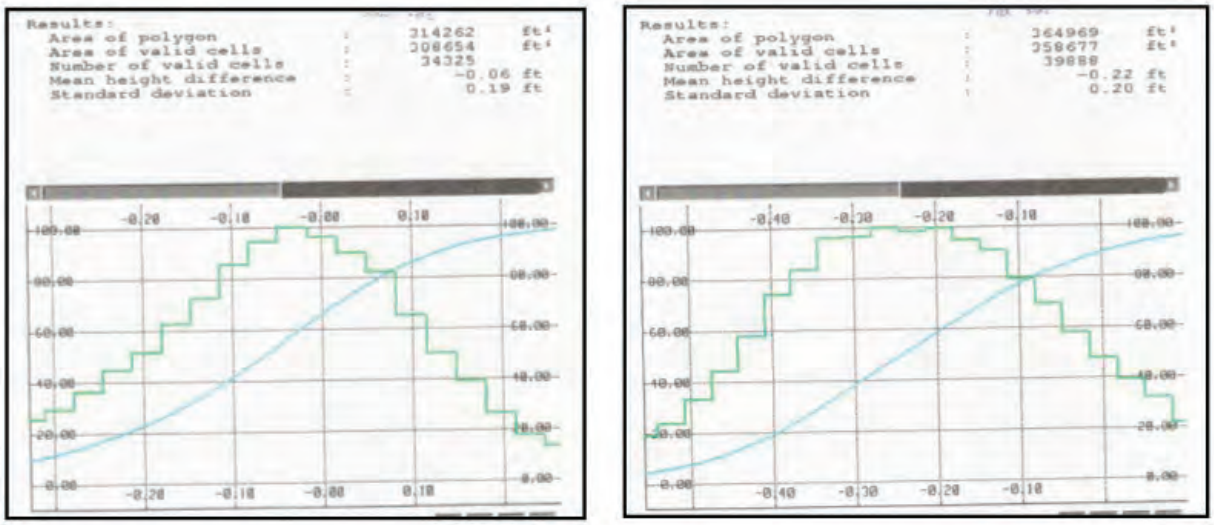
Performance Tests between Independent Survey Vessels over a Dredging Acceptance Section

F-8. An ideal QA procedure compares observed X-Y-Z coordinate dataset values with coordinate values obtained from an independent source of higher accuracy for the same identical points. Obtaining an independent, higher-accuracy test area is usually difficult. A lock chamber may provide an independent reference surface; however, the acoustic return from the chamber sill may differ from the softer bottom at the project site. Thus, a preferred hydrographic QA performance test compares two nearly independent sets of elevation data collected over the same area—ideally over the actual project site. The following example compares "nearly independent" data sets collected from different multibeam survey boats, each with independent positioning, orientation, water level measurement, and depth measurement systems



Key West, FL Main Ship Channel

The above figure shows the 2004 Jacksonville District deepening of the Main Ship Channel into Key West Harbor. Acceptance Section 6 was surveyed (after dredging clearance and payment) by two different vessels (Corps and dredge contractor). Each multibeam vessel had independent RTK base stations for reducing tide levels. All internal data collection, orientation, and processing systems were of different manufacturers. Both vessels surveyed the area at the same time. Both vessels used the same geoid model and performed RTK calibrations at a NOAA gage in Truman Basin (Key West). Due to strikes above grade, the area was resurveyed again on a later date.



The above figure shows statistical comparisons between the two vessels. These comparisons and frequency plots were computed by the dredging contractor (Bean Stuyvesant); thus comparing their survey with the Government's survey.

The first comparison survey (on the left) indicated a "mean height difference" (i.e., "bias") between the surveys of -0.06 ft. This was based on a comparison of 34,325 overlapping points. This result is well within acceptable tolerances, and indicates there are no appreciable biases in either survey. The standard deviation (±0.19 ft one-sigma or ±0.4 ft at 95%) is also well within tolerances. This is expected given the relatively hard and flat channel bottom in this section.

The later resurvey (above figure on the right) did not yield an acceptable comparison test between the two vessels. A bias of -0.22 ft was observed between the 39,888 overlapping points, which is outside tolerances. (The standard deviation was the same as the first survey.)

The dilemma with the -0.22 ft bias is determining which vessel has the bias, and why. It could be a combination of non-offsetting biases on both vessels. The only practical solution in such a case was to re-calibrate all equipment and perform additional comparison surveys during subsequent clearance re-excavations.

This example illustrates that the need to test for and resolve any survey biases is critical, especially on channel clearance surveys in this example project where minimal overdepth dredging was performed, and small 0.1 ft and 0.2 ft strikes above the 34-ft grade were observed on the Government survey. As would be expected, the contractor's survey was 0.22 ft deeper than the Government's survey, eliminating most of the strikes. The impact of a 0.22 ft bias on contract payment is also significant. In this project's 800x1600 ft acceptance section, a 0.22 ft bias equated to $584,000 ($56/cy unit rate).

SECTION V

Summary of NAD QC and QA Criteria for Dredging Measurement and Payment Surveys.

The table below summarizes criteria for conducting multibeam surveys. This table was developed during NAD MUG meetings in the early 2000s and incorporated into EM 1110-2-1003 in 2004. The measurement, alignment, calibration, quality assurance, and data processing criteria are based on procedures followed by a variety of government and commercial sources; and especially from actual NAD experience on dredging projects since the late 1990s. The guidance in this table is applicable to measurement and payment surveys of deep-draft navigation projects. Some of it may be dated due to improved multibeam QC methods and data processing technology. The recommended calibrations and tolerances shown in this table are for general guidance only. They are not intended for Corps-wide application.

a. Frequency of tests and checks. QC and QA checks, calibrations, and other tests are recommended at beginning of all critical dredging projects, and on all surveys where high quality assurance is required (e.g., a project clearance survey in dispute). Depending on documented stability of a system, and user experience and confidence, the frequency of calibrations and performance tests may be locally modified from the indicated intervals.

b. Calibration, QC, and QA documentation. Project or contract files should contain documentary evidence that all calibration and performance tests were performed. This would include a written log (or equivalent digital record) of sensor offset and alignment measurements, patch test calibration results, sound velocity measurements, bar checks, squat calibrations, tide/stage observations, performance test results, etc. Original records of such calibrations should be retained in a permanent, bound surveyor's field book aboard the boat.

c. Other Surveys and Studies. Specific criteria for multibeam surveys outside navigation projects are not listed in the table. It is recommended that the general QC and QA procedures for dredging surveys be followed. For general underwater topographic surveys, many of these requirements can be significantly relaxed based on user experience with a particular system. This would include unlimited beam width restrictions and far less frequent calibrations. However, for detailed underwater structural investigations, more demanding criteria than that shown in the table might be warranted.

Table F-2. Quality Control and Quality Assurance Criteria for Multibeam Surveys (2004 NAD MUG)

Criteria	PROJECT CLASSIFICATION Navigation & Dredging Surveys Bottom Material Classification Hard	Soft	Notes
QUALITY ASSURANCE PERFORMANCE TEST			
Perform Calibration	1/project	1/project	Test should be performed at the beginning of each new project (e.g., a pre or post dredge survey), and periodically during a longer-term project, such as a Project Condition Survey. The time interval needed between QA Performance Tests will depend on the consistency of test results.
Perform comparison with different vessel multibeam and/ or single beam	Periodically	Periodically	
Location of test	at project site	at project site	
Perform tests over same and different tidal phases	Recommended	Recommended	Tests should be conducted over same and different tidal phases to check for tidal model biases.
Maximum outliers between data set comparison points	1 ft	1 ft	
Maximum bin size for comparison data sets	1 ft sq	1 ft sq	Use averaged depth in bin for Reference Surface
Mean bias between data sets	< 0.1 ft	< 0.2 ft	The maximum mean bias computed between two data sets should not exceed the indicated tolerances
POSITION QUALITY ASSURANCE CHECK	1/day	1/project	Check different DGPS beacons, known point, etc.

Table F-2 (cont) Quality Control and Quality Assurance Criteria for Multibeam Surveys (2004 NAD MUG)

Criteria	PROJECT CLASSIFICATION Navigation & Dredging Surveys Bottom Material Classification Hard	Soft	Notes
SOUND VELOCITY CALIBRATION			
Perform velocity probe calibration	> 2/day	2/day	Velocity casts should be taken at the indicated intervals. They should be taken directly in the work area and at a density such that the water column is adequately modeled. More frequent calibrations may be needed in conditions where temperature or salinity are variable, or where Performance Test data indicates large variances are present.
Location of calibration	In project site	In project site	
Record velocity to nearest	1 fps	1 fps	
Record velocities in water column every	5 ft	5 ft	
Perform internal (distilled water) probe calibration	Weekly	Monthly	
BAR or BALL CHECK ON CENTER (NADIR) BEAM	Quarterly	Quarterly	A QC Bar Check should be made as near to the nadir beam as possible. This periodic check is used to verify/calibrate any index or draft error in the system.
SQUAT TEST CALIBRATION PERFORMED	Annually	Annually	
PLATE CHECK ON OUTER BEAMS	Daily	Daily	Perform before each survey as QA "blunder" check if possible.
RECORD SHORT TERM VESSEL DRAFT VARIATIONS	2/day	2/day	

Table F-2 (cont) Quality Control and Quality Assurance Criteria for Multibeam Surveys (2004 NAD MUG)

Criteria	PROJECT CLASSIFICATION Navigation & Dredging Surveys Bottom Material Classification Hard	Soft	Notes
OBJECT DETECTION CONFIDENCE CHECK (for specialized search surveys only)	Daily	Daily	Similar to side scan confidence check Verify hits on multiple passes over object
MAXIMUM BEAM ANGLE	90-deg	90-deg Meas & Pay Surveys 120-deg Proj Cond Surveys	Beam/swath width should generally not exceed the indicated values, unless independent QA performance test results indicate depth accuracies can be achieved with wider arrays. The beam angle may be further reduced for critical object detection-due to footprint expansion and poorer return from outer beams--or should QA performance test results indicate poor correlation in the outermost portion of the array.
BEAM OVERLAP	50%	10%	In navigation projects, a 50% side overlap (i.e., 200% bottom coverage) is strongly recommended when sweeping for rock shards or other hazardous objects remaining above project grade. Two or more overlapping passes on different aspects of the beam are recommended in shoal areas--to confirm hits above grade.
MAXIMUM SURVEY SPEED	2-5 kts	6-12 kts	Recommended speeds are prescribed to

ensure data integrity and minimize latency errors. Further limitations may be required for multibeam or side-scan systems to ensure 100% or greater forward (along-track) coverage or object detection.

Table F-2 (cont) Quality Control and Quality Assurance Criteria for Multibeam Surveys (2004 NAD MUG)

Criteria		PROJECT CLASSIFICATION Navigation & Dredging Surveys Bottom Material Classification Hard	Soft	Notes
INSTRUMENT ALIGNMENT/OFFSET MEASUREMENTS				
Measure Antenna-Transducer-Inertial system relative coordinates to nearest		0.05 ft	0.05 ft	Alignment measurements are performed on installation or change of equipment.
PATCH TEST BIAS CALIBRATIONS				
Perform test		as needed	as needed	The time interval required between Patch tests is dependent on Quality Assurance Performance Test results -- usually when mandatory QA Performance Tests indicate data is not meeting standards. No specific interval is recommended.
Patch Test Bias Repeatability (individual test)				
	Roll	0.1 deg	0.1 deg	Corrections should be averaged over a long series of Patch Tests, rather than using the results from a single test. Enter data to one decimal point better than repeatability.
	Pitch	1 deg	1 deg	
	Yaw	1 deg	1 deg	
	Latency	0.1 sec	0.1 sec	

Resolution in system	0.1 deg/sec	0.1 deg/sec	Significant figure of correction
HEAVE CORRECTIONS (MRU)			
Measure heave to accuracy of	5%	5%	or 5% of heave amplitude
MRU/RTK update rate at least	20 Hz	20 Hz	

Table F-2 (cont) Quality Control and Quality Assurance Criteria for Multibeam Surveys (2004 NAD MUG)

Criteria		PROJECT CLASSIFICATION Navigation & Dredging Surveys Bottom Material Classification Hard	Soft	Notes
MISCELLANEOUS CRITERIA				
MINIMUM PROJECT DEPTH (Dredging Surveys)		> 10 ft	> 10 ft	Limiting depth is system dependent. Multibeam systems are recommended for dredge measurement, payment, and acceptance purposes in project depths greater than those shown.
ACOUSTIC FREQUENCY	Project Option	[< 20 KHz to > 500 KHz]		A nominal 200 kHz frequency is recommended for most USACE navigation projects; however, different frequency systems may optionally be used if needed for better beam definition on objects (e.g., 450 KHz) or to penetrate suspended sediments in a particular project area (e.g., 24 KHz). The same frequency should be consistently used for a specific project and specified in dredging contracts.

Table F-2 (cont) Quality Control and Quality Assurance Criteria for Multibeam Surveys (2004 NAD MUG)

Criteria	PROJECT CLASSIFICATION Navigation & Dredging Surveys Bottom Material Classification Hard	Soft	Notes
RECOMMENDED DEPTH SELECTION AND DATA PROCESSING/THINNING BIN MATRIX LIMITS			
Dredging Measurement & Payment Surveys and Project Condition Surveys (including those used for contract Plans & Specifications)			
Bin/Cell size--Recommended maximum	3 ft sq	5 ft sq	The X-Y coordinate origin of the matrix should be specified.
Depth Selection--Method used to select representative depth from multiple depths in a cell for use in volume computations	Average of all depths in 3x3 cell	Average of all depths in 5x5 cell	Average depth is truncated to nearest 0.1 ft and located at the cell centroid X-Y coordinate. (Median depth in cell may alternately be used)
Volume computation method	Full DTM/TIN binned matrix	Full DTM/TIN binned matrix AEA optional	Volumes should be computed using the selected representative depths from the entire 3 x 3 or 5x 5 ft sq dataset matrix. AEA cross section spacing should be appropriate to channel topography.
Depth Plot (Plan)--Method used to select depths from cell matrix for a generalized hard copy display of individual depths/elevations	Randomly selected 3x3 ft cells containing representative shot depth	Randomly selected 5x5 ft cells containing representative shot depth	Density of plotted data dependent on output drawing scale. Plotted depths are generalized representations of the full multibeam dataset and should not be used for quantity computations. Shot depth may be shifted to center of 3x3 or 5x5 ft cell.

Contour or Color-Coded Plot-- Method used to select depths from a cell matrix for generating contours or DTM color-coded plots	Use all 3x3 cells containing representative shot depth	Use all 5x5 cells containing representative shot depth	Full edited database used.

Table F-2 (cont) Quality Control and Quality Assurance Criteria for Multibeam Surveys (2004 NAD MUG)

Criteria	PROJECT CLASSIFICATION Navigation & Dredging Surveys Bottom Material Classification Hard	 Soft	Notes
RECOMMENDED DEPTH SELECTION AND DATA PROCESSING/THINNING BIN MATRIX LIMITS (Continued)			
Dredge Clearance & Acceptance Surveys (Shoal/Strike detection) and Minimum Channel Clearance Condition Reports			Surveys using “minimum” or “shoal biased” depths should not be used for Plans & Specs or volume computations.
Depth Selection--Method used to select representative “shoalest” depth from multiple depths in a cell	Shoalest of 3 confirmed depth hits above project grade in 3x3 cell	Shoalest of 3 confirmed depth hits above project grade in 5x5 cell	Individual cells must be assessed to determine multiple hits above grade.
Number of confirmed "hits" above grade required per cell	3 hits	3 hits	Based on a single pass or multiple passes. Hits on multiple passes provide better confidence.
Depth Plot (Plan)--Method used to select plotted depths from cell matrix for a generalized hard copy display of the shoalest individual depths above grade	Selected cells containing representative shoalest confirmed depth	Selected cells containing representative shoalest confirmed depth	Density of selected cells that can be plotted dependent on output drawing scale. .

Contour or Color-Coded Plot-- Method used to select depths from cell matrix for generating contours or DTM color plots	Use all 3x3 cells containing representative shoalest depth	Use all 5x5 cells containing representative shoalest depth	Full edited database matrix used.
Tabular Report of Channel Conditions (ENG Form 4020/4021) Method used to select minimum controlling depth for channel reach	Least recorded depth in 3x3 ft cells containing representative shoalest confirmed depth	Least recorded depth in 5x5 ft cells containing representative shoalest confirmed depth	Select least controlling depth from all the cells contained over a given channel reach. Selected controlling depth should be shown on plan of condition survey if submitted.
Record minimum controlling depth to nearest	1 ft	1 ft	

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APPENDIX G

Terrestrial (Non-GPS) Positioning Methods

G-1. General Scope and Applications. This appendix covers general procedural guidance and quality control criteria for visual, mechanical, electronic, and microwave positioning methods used to control surveys of river and harbor projects. Terrestrial positioning methods include traditional land-based techniques such as sextant resection, triangulation, tag lines, microwave electronic distance measurement (EDM) systems, and electronic total stations. Since the early 1990's most of these terrestrial positioning methods have been largely replaced by satellite-based positioning methods, namely code phase differential GPS (DGPS) and carrier phase RTK.

a. The positioning methods in this appendix were developed in the 1980s prior to the use of GPS. It was included in the first version of EM 1110-2-1003 in 1991. It is largely unchanged since that original version.

b. Some of these terrestrial methods covered in this appendix are obsolete (e.g., microwave positioning, triangulation, sextant positioning). They are retained in this Appendix for archival purposes. Other methods are still occasionally employed by USACE districts and their contractors, such as Total Station and tag line positioning. (Updated Total Station survey methods are included in EM 1110-1-1005, Control and Topographic Surveying.)

c. There may be isolated project areas where satellite GPS methods may be inaccessible or impractical, and one of the traditional terrestrial survey methods covered in this appendix may be needed to provide survey control. Examples of such cases may include: (1) small dredging or marine construction projects where only a limited amount of depth coverage is required, (2) areas under bridges, in deep-draft harbor berths, or near dams where GPS satellite view is blocked, (3) intermittent, low-budget projects where traditional positioning methods may prove more economical than equipping a fully automated GPS-based hydrographic survey system, or (4) rough reconnaissance surveys where meeting a specific positional accuracy standard is not required. Procedural methods and quality control (QC) criteria for some of these older survey techniques are retained in this manual primarily for reference purposes.

d. The following topics are covered in this appendix:

Section I:	Sextant Resection Positioning
Section II:	Triangulation/Intersection Positioning
Section III:	Visual Positioning Methods
Section IV:	Tag Line Positioning Methods
Section V:	Total Station (Range-Azimuth) Positioning Methods
Section VI:	Terrestrial Electronic Positioning Systems

G-2. Positional Accuracy. All the positioning methods described in this appendix will generally meet USACE positional accuracy requirements, provided that distances from the shore-based reference point and the vessel are kept within tolerable limits. The "tolerable limit" will vary with the type of positioning method, procedures employed, and accuracy of the instrumentation used. In general, the positional accuracy of all systems will degrade as a function of distance from the baseline reference points--some faster than others. For example, a poorly conducted tag line survey may exceed accuracy standards 300 feet from the baseline whereas an electronic total station could be extended 1000 ft or 2000 ft from the reference point. Sextant, triangulation, and range-range EDM are extremely geometry dependent; thus the accuracy of such methods will vary widely over a project area. Terrestrial-based positioning methods should only be employed where GPS positioning is not available. Users must also fully assess and evaluate the resultant accuracy of any positioning method, including GPS. Some visual or mechanical positioning methods can, under some limited conditions, exceed DGPS or RTK accuracies.

SECTION I

Sextant Resection Positioning

G-3. General Applications. Sextant positioning involves the simultaneous observation of two horizontal angles between three known objects from which the position of an offshore platform is resected--see Figure G-1. Although sextant resection positioning was once one of the most widely used methods of positioning hydrographic survey vessels, channel sweep rafts, and dredges, it is now rarely, if ever, used. Sextant positioning was also widely used to calibrate medium frequency hyperbolic, range-range, and microwave positioning systems. Until the mid 1990s, sextant positioning was the primary method used by the US Coast Guard to locate and place buoys. Sextant positioning is totally performed aboard the survey vessel. It is not dependent on electronics, communications, or shore-based support. Under restricted conditions (i.e., close in on targets and near static position fixes), it can be relatively accurate when properly executed. In general, however, sextant positioning under dynamic vessel conditions is no longer considered accurate for most navigation or dredging applications. Currently, inexpensive hand-held GPS (autonomous) receivers will typically provide accuracies that far exceed sextant positioning accuracies.

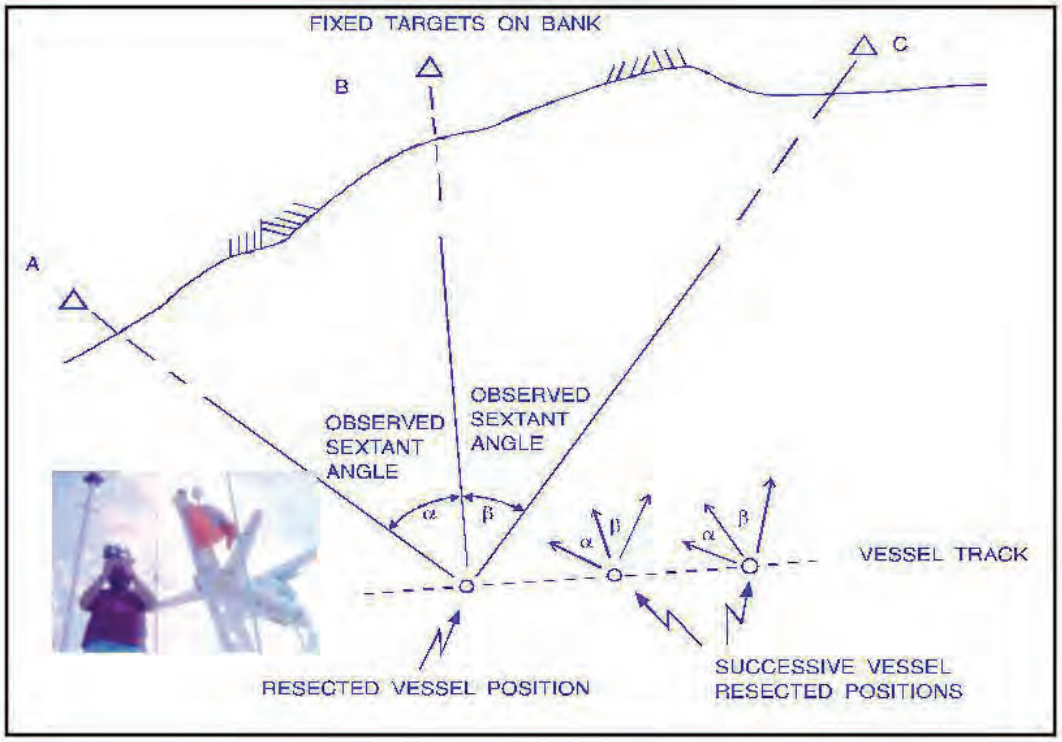


Figure G-1. Sextant resectioning.

G-4. Sextant Resectioning Procedures. Two sextant observers aboard the vessel are required. Sextant "fix" angles are usually taken at some even time interval or as called for by the depth observer (lead line or echo sounder). These angles are called or radioed to the recorder/plotter, along with depth information from that observer. Observed sextant angles are recorded with their times and, if applicable, depth data. These data can be recorded on a worksheet form or in a standard field survey book, or they can be directly input into a data logging device. The vessel's position is determined at the time of the fix by manual plotting with a three-arm protractor. Preconstructed constant sextant angle curves can also be drawn on a plotting sheet for on-line manual plotting. Alternatively, the two observed angles can be input into a computer containing standard survey resection software. Formulas for performing such computations are found in any standard surveying or geodesy textbook. The density of position fix updates varies with the timing and speed of the sextant observers and plotter/computer input. Overall, the process is extremely labor-intensive, requiring a boat operator, two sextant observers, a depth recorder operator, and a data logger/plotter. In extreme cases, these functions can be doubled or even tripled up (i.e., one of the sextant observers could also perform the recording and plotting function).

a. Hopper dredge positioning. A single sextant angle may be used in conjunction with a fixed range line of position, as shown in Figure G-2. In years past this was a common technique for locating hopper dredges. Preplotted sheets showing the intersecting sextant angles and ranges were drawn up for each channel. A single sextant angle would quickly locate the dredge running along a constant channel range. Figure G-3 depicts sextant angle curves used for positioning sweep rafts in Detroit District prior to the 1980s.

b. Redundant sextant resectioning. On stable offshore vessels and other platforms, multiple sextant angles can be observed to several targets. The resultant fix can be adjusted by onboard software using least squares adjustment techniques. This adjustment will provide an assessment of the positional accuracy. The results of a multiple resection can be quite accurate, and can be less than +1 m in some isolated cases. The US Coast Guard used this technique on buoy tenders.

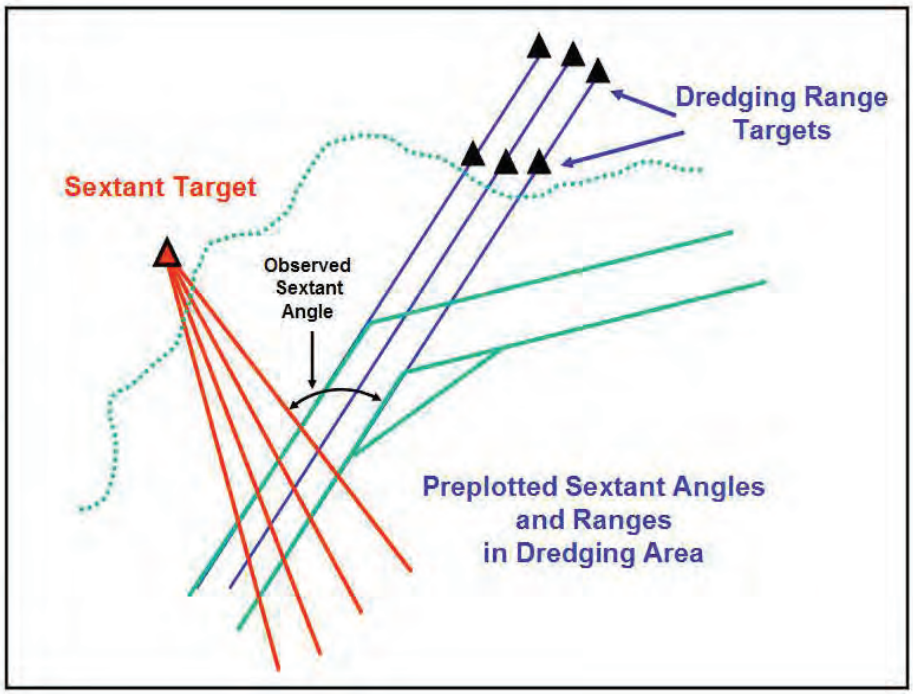


Figure G-2. Hopper dredge control using combined visual ranges and sextant angles.

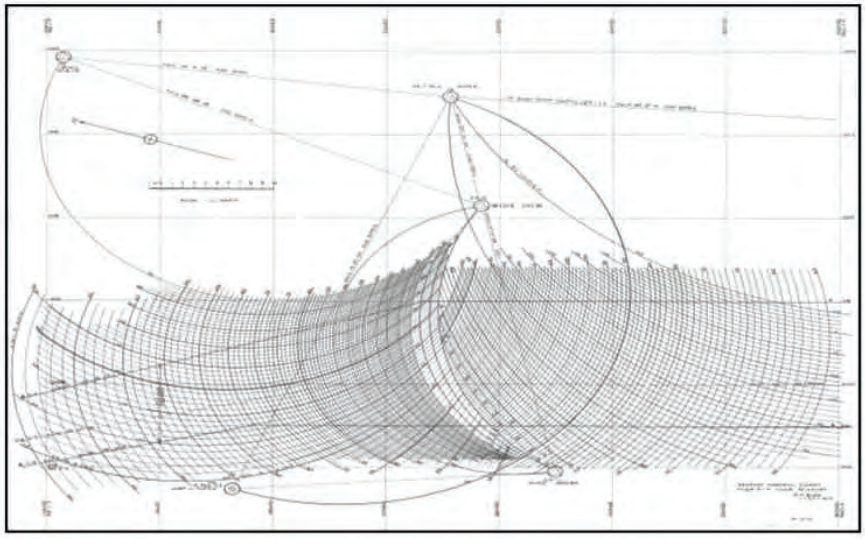


Figure G-3. Pre-plotted sextant curves for bar sweep on the St. Marys River, MI. (Detroit District)

G-5. Accuracy and Quality Control of Sextant Resection Positioning. The two observed sextant angles form the loci of circles, the intersection of which is the vessel's position. Each angle forms a circle defined by three points: the two shore control points/targets and the vessel. The geometry of these two intersecting circles is a primary factor in determining the strength of a sextant resection. As the two intersecting circles converge on each other, the resultant position weakens drastically. This is often termed the "swinger" since a three-arm protractor will swing along this arc to any position. As a result, the accuracy of a sextant position varies significantly with the geometrical location relative to the targets. In the best conditions, dynamic positional accuracies rarely exceeded 5 m (95% RMS). Average accuracies were generally in the 10 to 20 meter range.

a. Determining the accuracy of a resected position. Historically, various numerical formulas were developed to depict the relative accuracy of a resected position. Constant error contours could also be drawn for any given target configuration. The simplest method for estimating resection accuracy at any point is to move each angle by its estimated accuracy and assess the resultant change in position. This is readily done when automated resection computing software is available, or by noting the position shift in a three-arm protractor. Positional accuracy needs to be accessed at various points in the work area.

b. Quality control factors. In performing sextant resection positioning the following QC factors must be considered. All impact the overall accuracy of a resected position.

(1) Precision of sextant angles. This is a function of the instrument's resolution, sharpness

of the shore-based targets, relative rate of angular change, and, most importantly, the skills of the observers. Estimating the standard error of a sextant angle observed on a moving vessel is difficult--a range of ±1 to ±5 minutes of arc is typical. Sextant angles are usually recorded to the nearest minute of arc and, in some cases, to the nearest 0.1 minute of arc.

(2) Observer synchronization. Both angles must be observed simultaneously and from the same point. This is usually not feasible in practice, and observer eccentricities are accepted errors.

(3) Plotting errors. Plotting sextant fixes with a three-arm protractor aboard a moving vessel is not an exact process, and significant inaccuracies can result.

(4) Velocity and motion of the vessel. Vessel motion affects the ability of the observers to maintain angles on both targets. Slow vessel velocities are essential in performing accurate sextant surveys.

(5) Observer fatigue. Continuous sextant surveying is extremely fatiguing for the observers and plotter. Data quality usually degrades during the course of a survey due to fatigue.

(6) Targets. Sextant angle targets may include water tanks, lights, daymarks, beacons, etc. When natural targets with coordinated points are not available, temporary targets must be constructed and surveyed. The type of target (and its distance away when fog or haze is present) affects the sextant pointing accuracy.

c. Sextant calibration. Due to design and handling, internal sextant instrument calibration is not particularly stable. Observers must continuously check the calibration of their sextants. This is usually done periodically during the survey--typically at the end of each survey line.

d. Quality assurance. Few opportunities existed to perform QA checks on sextant positioning. When more than three targets were visible, different resection positions could be compared at an anchored position.

SECTION II

Triangulation/Intersection Positioning

G-6. General Applications. An offshore vessel or platform can be positioned (triangulated) by transit or theodolite angles observed from base line points on shore. This method was also once commonly used to calibrate microwave positioning systems when fixed points were inaccessible

to the vessel (e.g., dredges, drill barges). Intersection techniques are no longer employed in dynamic hydrographic surveying practice; however, the technique may have application in areas where electronic positioning systems cannot be deployed or where increased positional accuracy is required. As with sextant surveying methods, angular intersection positioning techniques are labor-intensive. As indicated in Figure G-4, two (or more) shore-based transit or theodolite observers are required, along with either visual or radio communication equipment with which to transmit the observed angles (or direction azimuths) to the offshore vessel for on-line recording, plotting, and/or calibration analysis. Due to the higher precision and stability of the instruments, the resultant positional accuracy can be quite good, provided observing procedures are properly executed. Theodolite angular observations to align static platforms are extremely accurate, and triangulation techniques are often used to supplement electronic distance measurement (EDM) or RTK positioning of fixed offshore structures (piers, bridges, rigs, etc.)--both during construction and subsequent deformation monitoring.

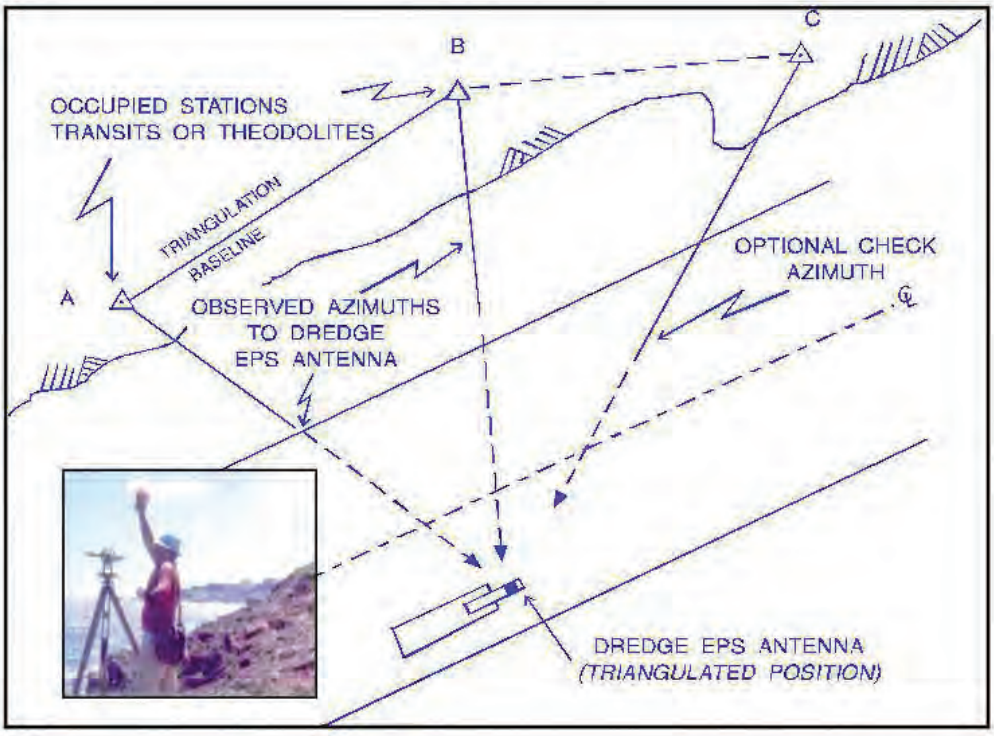


Figure G-4. Vessel location using triangulation/intersection positioning methods.

G-7. Intersection Positioning Procedures. A wide variety of angle or azimuth direction measuring instruments may be used. These include standard surveying transits, geodetic theodolites, and total stations. Instruments have been designed with hand cranks to facilitate continuous tracking of a moving vessel. The shore-based direction measuring instruments are set over known control monuments and aligned/referenced to one another or other positioned targets or landmarks. Two backsight check points are recommended, and frequent rechecks of the backsight orientations should be made during the course of the survey (normally every half-hour). Backsight orientations may be set to zero (resultant direction observations to the boat are then angles) or aligned to the grid azimuth between the occupied point and reference backsight (resultant directions to the boat are direct grid azimuths). The selected orientation depends on the onboard position computation/plotting method employed. Simultaneously observed positional "fixes" are usually called for from the boat by radio (or by visual flags where radio communication is unavailable). Fixes may be at equal time intervals or as called for on a random or as-needed basis. Advance warning is made of upcoming fix events so that observers can initiate precise tracking of the boat. A defined point aboard the vessel is tracked. This well-marked point should be centered over the echo sounder transducer or may be the positioning system antenna in the case of calibration work. In some instances, a preset alignment of an offshore platform is required. In this case, the precomputed alignment is set into each of the instruments and the platform is "walked" into position by the observers.

G-8. Data Recording and Plotting. Angles/direction azimuths are observed to units commensurate with the instruments and relative distance and velocity of the offshore vessel. Normally the nearest minute (or 0.01 deg) is adequate for dynamic hydrographic applications. Static observations will use repeated directions to increase accuracy to the ±1 second of arc level if needed. Angular data are relayed to and recorded aboard the boat and, in cases in which communications are erratic, at the instrument point also. Data may be recorded on worksheet forms or standard field survey books or input into a data logging device. Intersection data may be plotted aboard a dredge or survey vessel using standard drafting machines or preplotted azimuth array sheets. Neither of these methods is considered highly accurate, but each is adequate for visual navigation purposes

G-9. Accuracy of Triangulation/Intersection Positioning. As in conventional land surveying triangulation work, the accuracy of a point intersected by two azimuth directions depends on the precision of the instruments (their tracking accuracy) and the geometrical strength of the intersection. The positional accuracy, therefore, varies throughout the project area. An overall error analysis is complex since the angular standard errors for each instrument vary as a function of distance between the instrument and the vessel. Thus, determining the dimensions of the resultant error ellipse is more difficult.

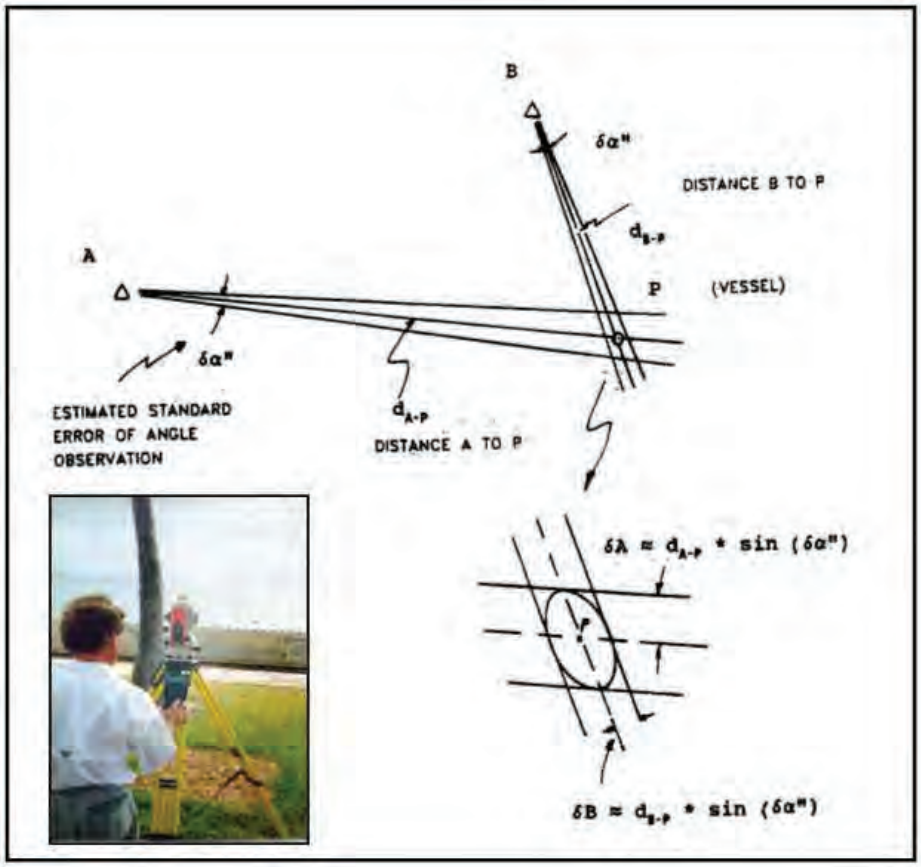


Figure G-5. Estimating accuracy of intersected angles.

a. A practical (but only approximate) estimate of the accuracy of an intersected position may be made by averaging the standard errors of each azimuth displacement at the offshore location, using the computed distances from each observing point. Given the theodolite/transit observing points A and B, and distances dA-P and dB-P to the offshore platform (Figure G-5):

$$\delta_A = d_{A\text{-}P} \cdot \sin(\delta\alpha'')$$

$$\delta_B = d_{B\text{-}P} \cdot \sin(\delta\alpha'') \qquad \text{(Eq G-1)}$$

$$\text{then,} \quad \sigma_{Avg} = (\delta_A + \delta_B) / 2$$

where

σ_{Avg} = estimated standard error of an azimuth displacement at the offshore point

δ_α'' = estimated angular tracking accuracy of the particular instrument used

(assumed the same for both instruments)

b. The RMS error (at either 1-σ or 95%) can be estimated using Equation G-2:

$$\text{RMS } (1\text{-}\sigma) = 1.414 \;.\; \sigma_{AVG} \;.\; \text{cosec } A \qquad \text{(Eq G-2)}$$

or at 95% confidence level;

$$\text{RMS } 95\% = 2.447 \;.\; \sigma_{AVG} \;.\; \text{cosec } A$$

where A is the angle of intersection between the two transit/theodolite azimuths at the offshore point.

c. The above computation may also be performed graphically. The left page in Figure G-6 depicts a sample field computation of the accuracy of a static intersected point (i.e., spudded dredge) using the above approximate formulas. The right page shows an alternate method of computing the RMS accuracy when the distances are simply averaged.

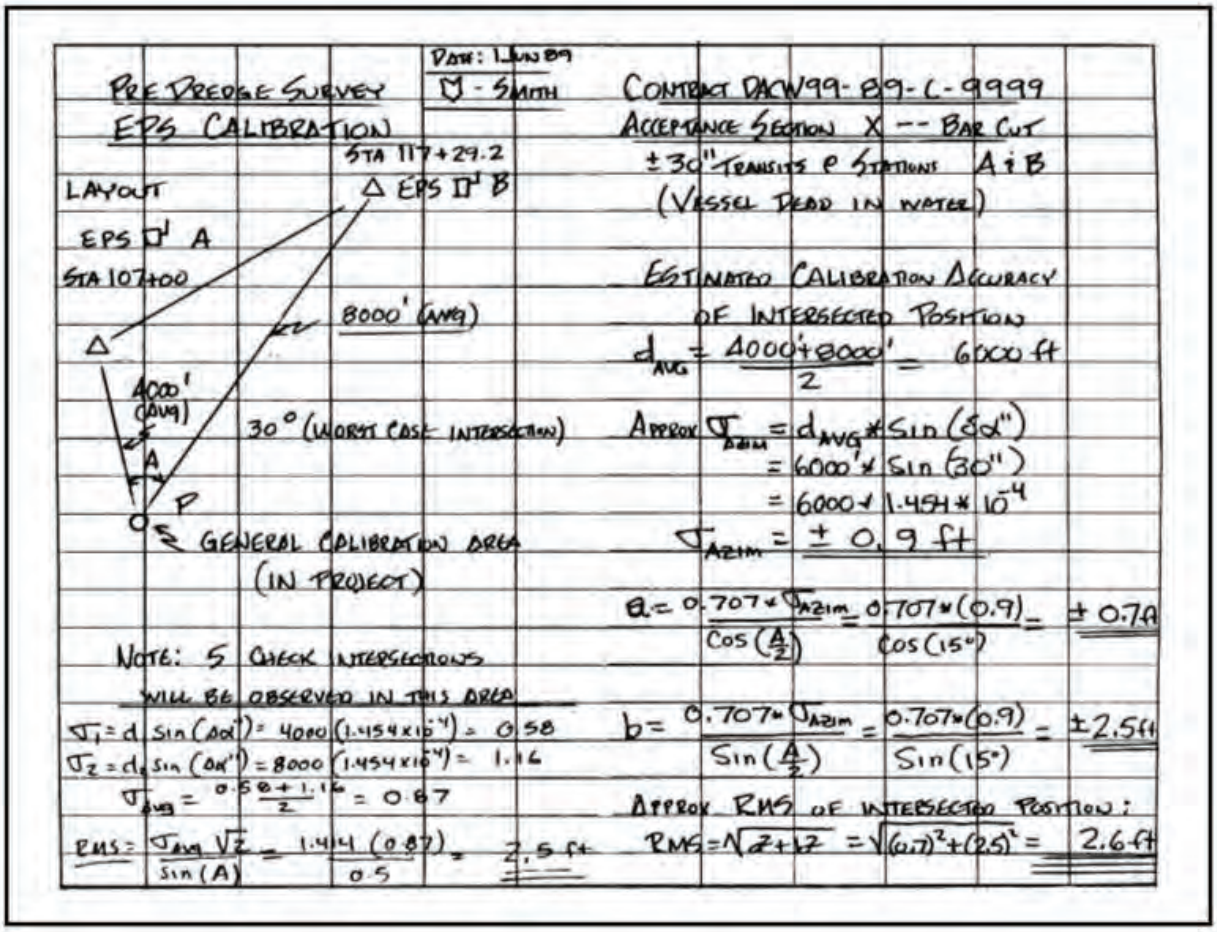


Figure G-6. Field computation of intersected position accuracy.

d. Multiple azimuth intersection techniques. To increase the accuracy of a triangulated point, additional shore stations are occupied in such a manner that each vessel position has three or more azimuth observations. This procedure provides redundancy and allows for an on-line assessment of the accuracy of the resultant position. Normally, a least-squares adjustment technique is performed on computers aboard the vessel. In aligning offshore structures during construction, or monitoring subsequent deformations, redundant theodolite azimuths are normally required. Theodolite (or total station) directions are repeatedly observed to increase accuracy. These azimuth alignments are combined with concurrent EDM or static GPS baseline distance observations in a properly weighted least-squares adjustment.

G-10. Quality Control and Quality Assurance. Periodic backsight checks should be made during the course of the survey. Like sextant survey methods, observer and plotter fatigue can impact quality. A third instrument provides the only semblance of an independent QA check on intersected point; however, this was rarely practical in practice.

SECTION III

Visual Positioning Methods

G-11. General Applications. Visual location relative to known shore features or flags was once a common hopper dredge positioning method. Few applications remain today, other than for construction--e.g., horizontal and vertical alignment of construction equipment, rigs, barges, etc. Dynamic hydrographic survey positioning by intersecting visible ranges and other identifiable objects is now rarely performed, given the wide availability of DGPS, RTK, or RTN control. Relative visual positioning is generally suitable only for non-navigation reconnaissance work where identifiable features on the furnished drawing, navigation chart, or map will be assumed to be accurate for this type of survey. These include navigational aids, beacons, day markers, bridges and other structures or map features. For some dredging and other investigative work, additional range poles, flags, and/or lasers are set ashore, as shown in Figure G-7. Fixes are typically taken when the boat is abeam or lateral of an identifiable object and a constant speed is maintained to the next identifiable object or range intersection. Intermediate soundings are interpolated between the two fixes. The plotted features are presumed to be error-free, and a constant vessel speed is assumed to have occurred between the control features. Ranges established by sighting across such features or additional shore points may be intersected for position determination. Accuracies of such surveys are considered marginal, at best. All drawings depicting these surveys should caution users concerning the approximate nature of the data and warn against their use in design or construction.

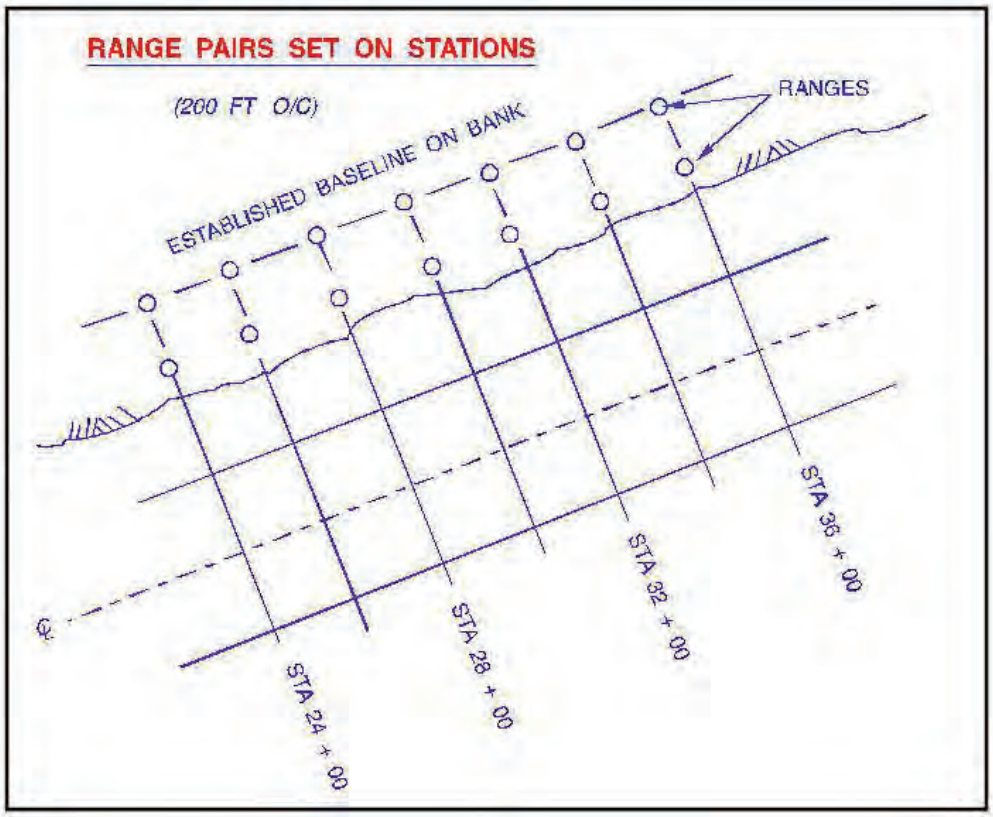


Figure G-7. Typical visual dredging range configuration.

G-12. Construction/Dredging Control Using Ranges. Offshore construction platforms, including dredges, can be effectively (and often accurately) controlled from visual ranges. Directional lasers are often used in place of range targets, and can provide both horizontal and vertical alignment to construction vehicles. In some hopper dredge work, alignment control is required only lateral to the project axis--see Figure G-7. Sets of range pairs are typically set along a canal bank or bulkhead or at the projected end of the channel. Existing sailing ranges may also be used. Normally, range pairs are established at fairly dense intervals (e.g., 100 ft O/C). The limiting factor is the distance offshore relative to the range spread. A common rule-of-thumb is that the ratio should not exceed 10 to 1. For canal or other limited area construction projects, visual alignment accuracies can be quite accurate.

G-13. Uncontrolled Project Centerline Surveys. Approximate visual positioning was once commonly used in running centerline check surveys over uncontrolled recreational projects of relatively shallow project depth. The vessel is maintained relative to the approximate center of the project using local visual navigation aids, taken from a map or other source. The lateral error is a function of the ability of the boat operator to estimate the project's center. The accuracy of the resultant profile depends on the distance between identifiable features, chart scale, constant

vessel velocity, and numerous other factors. Errors could approach 100 m. However, since these relative surveys are intended for reconnaissance purposes only, such inaccuracies may be tolerable. Any shoals encountered during these reconnaissance surveys that warrant a more detailed investigation would be developed using electronic or satellite positioning techniques. Survey data from visually controlled surveys are normally plotted in either plan or profile format, and not at a larger scale than that used to control the survey.

G-14. Accuracy and Quality Control. The accuracy of visual positioning techniques is difficult to access. Laser guided horizontal and vertical alignment can be highly accurate at reasonable distances from the target. Visual range-pair alignment accuracy is a function of the distance from the targets and the range pair spread. Positioning relative to existing map features varies with the map scale, interpolations, and feature accuracy. For these reasons, visual techniques are no longer used for navigation and dredging drawings. QA checks are rarely performed on visual positioning.

SECTION IV

Tag Line Positioning Methods

G-15. General Applications. Tag line positioning employs a calibrated wire rope stretched perpendicular from hubs on a baseline to the survey boat (Figure G-8). Up until the 1970s dozens of Corps survey crews used tag line survey methods to monitor dredging progress of navigation projects. In addition to traditional channel cross-section surveys, tag lines were employed to position floating platforms (barges) used in subsurface investigation for channel obstructions, core borings, jet probings, and channel clearance sweep surveys. In the 1970s, tag line methods were largely replaced by microwave EDM and range-azimuth techniques, which in turn were replaced by DGPS positioning in the mid-1990's. A few USACE districts have maintained a tag line survey capability for critical site investigation work; typically in areas where GPS signals are blocked, such as around berthing areas. Usually, however, an electronic total station is preferred for such surveys. A tag line survey requires no electronics or communication devices. Within limited distances off the baseline, and with proper execution, a tag line controlled survey is an accurate and stable method of performing hydrographic surveys and other investigative work for marine design and construction.

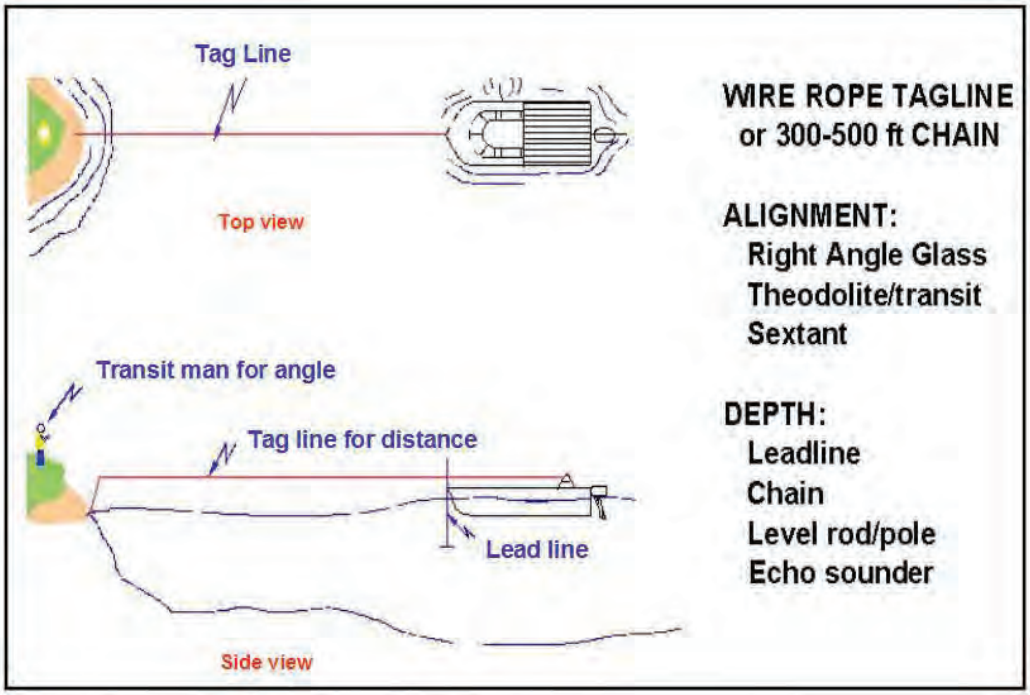


Figure G-8. Tag line surveys.

G-16. Tag Line Measurement Procedures. A tag line survey is simply a hydrographic method of running cross sections from a fixed baseline. Except for the boat and use of wire rope instead of chain, the same survey procedures are used as in highway cross-sectioning. The most accurate tag line distance measurements are conducted while the survey boat is stationary and holding constant tag line tension and alignment. Tag line surveys run dynamically (using echo sounders) are not as accurate as those conducted statically. Depths are observed with lead lines, sounding poles, level rods, or acoustically.

a. Static observations. Tag line length observations are made when the boat is properly aligned on the section and the wire is pulled taut to minimize sag. The zero end of the tag line must be firmly anchored on the baseline and held with a pole of sufficient leverage to withstand the pull from the boat. The tag line is payed out over the bow with the boat in reverse, and the winch clutch braked for each reading. The line is stopped when the interval mark is precisely at the depth measuring point on the boat (bow or transducer). The boat operator must maneuver the boat onto the proper cross-section alignment. This may be directed from ashore by hand signals or radio. Once on line, and with the tag line winch fully braked, the boat motor speed is regulated to hold the line taut out of the water and with only minimal apparent sag, at which time the depth is observed. Depending on the vessel power available and the weight of the line, the distance a tag line can be pulled fully taut will vary--pulls up to and exceeding 2,000 ft are

possible. The accuracy of a tag line measurement will degrade drastically once the vessel is no longer able to provide sufficient power to suspend the line out of the water.

b. Dynamic or continuous tag line surveys. Some tag line surveys are conducted in a continuous (dynamic) mode using analog echo sounders. The boat is not stopped at tag line intervals, but the echo sounder is “fixed” at observed intervals as the reel pays out. Controlling alignment and tag line tension is not assured when this survey method is used.

c. Baseline boat tag line extension methods. Tag lines may be anchored to a floating vessel (baseline boat) that has previously been positioned by tag line or other means. Due to the compounding accumulation of error, such techniques are highly inaccurate. Since right angle prisms are typically used to hold the alignment of both the baseline boat and extended tag line boat, resultant positional errors of +50 m or more are not uncommon.

d. Other tag line survey methods. A tag line may be used to maintain a constant range from the baseline hub. The line is held taut and the boat traverses along the constant tag line arc. Position fixes along the arc may be taken with a sextant or transit. Radial tag line surveys may be conducted from a single point on the baseline, with the survey vessel progressing outward along constant radials. Substituting an electronic ranging device for a tag line provides a better distance accuracy at extended ranges. In addition to normal cross-sectioning of harbors and canals, this survey method is commonly used in running-river cross sections and offshore sections for beach renourishment studies. The electronic positioning device and orientation instrument are moved to each incremental hub along the baseline. In some cases, a radial pattern may be run from one station. The survey vessel is guided along a constant azimuth in the same manner used in tag line work. Along-track (section) distance fixes are taken visually from an automated positioning system display. The accuracy of these distance readings is a function of the positioning system's stability, its update cycle, and the velocity of the boat. Higher accuracy surveys are obtained at slower velocities.

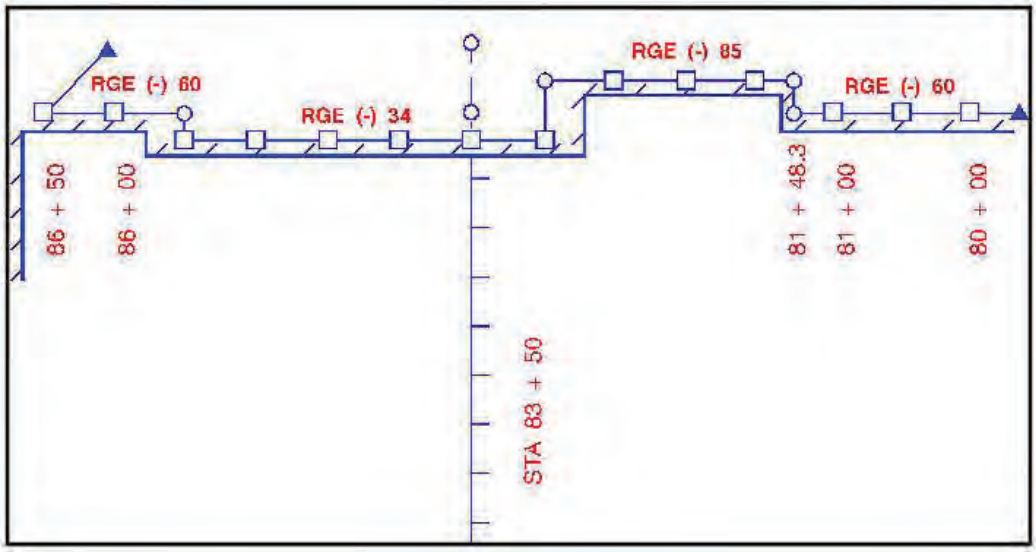


Figure G-9. Typical baseline layout along bulkhead.

e. Baseline layout for tag line surveys. Baselines for controlling tag line work are set using standard construction survey techniques and standards. Intermediate points (i.e., hubs) are surveyed at the line spacing required, usually 25, 50, or 100 ft O/C. These baselines should ideally be tied to USACE 3rd Order, Class II project control. However, 4th Order procedures may be used in setting intermediate control points along the baseline. Standard chaining or total station methods are used to lay out baselines. Baselines are normally aligned to the project's local coordinate system (station-range/offset) rather than a state plane system. See Figure G-9.

(1) Intermediate points, or hubs, may be set for permanent or temporary use. Intermediate hubs can be marked by stakes, PK nails, flagging, or any other method. Back range hubs are established behind the baseline if needed. Project stationing and range offsets should be marked on the stakes and/or painted on bulkheads facing seaward for offshore identification. Baseline hubs must be located at points that are unobstructed to seaward and where the tag line end can be firmly secured.

(2) Baselines can be established in shallow water by staking with 2- by 2-in. wooden stakes, iron pipe, rebar, etc., for tagging locations. Baselines staked in shallow water can be used by small shallow-draft workboats (outboard motor or inboard/outboard motor propulsion). The chain/weight used on the end of the tag line forming a loop will hold the tag line at the base of the stake/pipe/rebar when tension is applied to the line by the motor and braking assembly on the power/manual reel or winch. In far offshore projects, piles have been driven adjacent to the channel in order to establish a baseline.

f. Tag line alignment methods. Lateral alignment control of the survey boat can be the weakest link in the performance of tag line surveys, especially if strong currents are present. The method used to project the desired cross-section alignment (usually 90 degrees) off the baseline is also critical. Poor alignment techniques will limit the distance that a tag line cross section can be reliably projected from the baseline. Methods for holding alignment include visual range flags, right angle prisms, transits, theodolites, sextants, and total stations. The use of visual range poles or flags presumes an adequate range base is established. Right angle prisms shall generally not be used beyond 200 or 300 ft unless only rough reconnaissance surveys are being performed.

g. Data recording procedures. Tag line survey and related depth measurements may be recorded on worksheets or in a standard field survey book (Figure G-10). Survey data are plotted in either site plan or section formats.

	STA.	16+00	CUT	S -	19
RGE.	SDG.	TIDE	RED.	TIME	
-75	7.2	+0.9	6.3	1:50	
-50	7.4		6.5		
-25	7.5		6.6		
0	7.6		6.7		
25	7.5		6.6		
50	11.7		10.8		
75	11.7		10.8		
100	11.7		10.8		
150	11.8		10.9		
175	11.9		11.0		
200	11.5		10.4		
225	8.0		7.1		
250	7.8		6.9		
275	7.8		6.9		
300	7.7		6.8		

	STA.	37+65.94	CUT	S-19	
RGE.	SDG.	TIDE	RED.	TIME	
-75	7.0	+0.9	6.1	10:24	
-50	7.2		6.3		
-25	7.1		6.2		
0	8.6		7.7		W. LIMIT
25	9.3		8.4		
50	10.4		9.5		
75	11.2		10.3		
100	11.7		10.8		
150	10.8		9.9		
162	6.3		5.4		Rock
175	10.9		10.0		
200	7.7		6.8		
225	7.5		6.6		
256	7.4		6.5		E. LIMIT
250	7.4		6.5		
275	7.3		6.4		

Figure G-10. Field book recording of depths at 25-ft tag line marks.

h. Survey boats. Any size and type of boat may be used for performing tag line surveys. The most common types used in USACE are open workboats of rugged hull construction. Open boats provide ease and flexibility of tag line measurement and allow maintenance to the tag line power winches. Typical boat lengths range from 16 to 25 ft. Drafts of less than 1 ft are essential in order to work in shallow areas and to provide ease of beaching. Reinforced hulls are necessary since many tag line surveys are conducted adjacent to revetments, stone jetties, and other structures. An experienced boat operator is essential to the accurate and safe execution of a tag line survey. The operator must simultaneously maintain lateral alignment in currents, control the tag line tension, and, in some cases, operate the power winch mechanism. Lead line, sounding pole, or echo sounding depth observations are taken and recorded at the boat operator's signal. In cases in which tag line surveys are performed in navigable waters with heavy shipping traffic, the boat operator may have to release tag line tension to allow the wire to lower and rest on the channel bottom while a vessel passes.

G-17. Tag Line Equipment. Tag line surveys can be conducted using any type of continuous measuring device. Over short distances, tag line surveys may be performed using 50-ft cloth tapes or 100- to 300-ft surveyor's chains. Revolution-counting payout gages/meters are also employed. For greater distances, however, a lightweight, stainless steel (corrosion-resistant), braided cable, or wire rope (7 strand (+), 7/32-in. diameter or larger, depending on use of the tag line) is normally used. Wire rope tag line lengths vary from 500 ft to over 5,000 ft, and baseline boat tag lines from 5,000 ft to 15,000 ft long. A 2-ft loop of galvanized chain (5/8- to 3/4-in.) with a galvanized clevis and swivel should be used to connect the tag line wire to the chain.

a. Marking. The tag line cable is marked at any desired interval, usually every 25 ft. A variety of methods are used to mark and code the intervals along the tag line. Leather or plastic flagging or galvanized sleeves may be firmly crimped to the line using wire splicing/crimping tools--see Figure G-12. Strands of polypropylene rope may also be inserted through the sleeves prior to crimping. Marks are coded by color and/or size. These marks and the coding system must be readily identified to prevent reading blunders, a common problem on tag line work.

b. Swivels. Corrosion-resistant swivels are inserted along the tag line at intermediate points, usually at the 100-ft mark, the 500-ft mark, and at subsequent 500-ft intervals thereafter. The swivels help in eliminating loops (pig tails) in the wire when continuous tension is not maintained. When the line becomes slack, wire rolls and loops appear, causing crimps and breaks in the wire. The swivels also serve as checks for incremental, even, 500-ft distances.

c. Power winches. Power winches are used to reel and control tag line payout. The winches are permanently mounted amidships and may be manually, electrically, or gasoline powered. Clutching and braking assemblies in the power winches regulate tag line payout. Line payout can be alternated over the bow or stern. A guide or fair lead is used for maintaining control during payout and reeling in of the line. Hand reels or manual winches are normally used

on sounding boat tag lines because of the shorter or limited wire lengths deployed. Power reels/winches are commonly used on baseline boats due to the longer amounts of line involved. Power reels should have manual hand crank backup capability in case of power failure. Figure G-11 depicts a typical installation of a power winch aboard an open workboat.

Figure G-11. Tag line equipment aboard small 19-ft workboat. (Jacksonville District)

G-18. Accuracy, Calibration, and Quality Control Requirements.

a. Accuracy. Tag line surveys are highly accurate only within finite limits. Critical limitations include the length of extended line off the fixed baseline hub, the ability to measure and hold vessel alignment in strong currents, and the ability (power) of the boat to maintain a taut (sag-free) line over a given distance. The positional accuracy of a point positioned by tag line may be computed using the estimated accuracy of the alignment and distance measurements; similarly to that done with range-azimuth survey methods. Up to about 1,000 ft from the baseline, a tag line will maintain acceptable accuracy for dredging and navigation surveys; provided that it is pulled taut and accurate azimuth alignment is held.

b. Calibration. Flagged tag line intervals must be periodically calibrated every 3 to 6 months against a chained or EDM distance. The tag line should also be recalibrated after breaks have been respliced. Wire rope splicing must be performed so the original length is maintained as closely as possible. Calibration is done by comparing distances of the marked intervals with corresponding distances measured with a tape or instrument of higher accuracy (Figure G-12). This is most easily performed along a pier or wharf where the tag line can be fully extended and compared with taped or EDM distances. At each marked interval on the tagline, a difference shall be observed and recorded in a field book.

c. Quality assurance. Independent checks on tag line surveys were rarely performed in practice. Occasionally, when baselines could be set on opposite canal banks, duplicate (overlapping) cross-sections could be run from opposing baselines as a check.

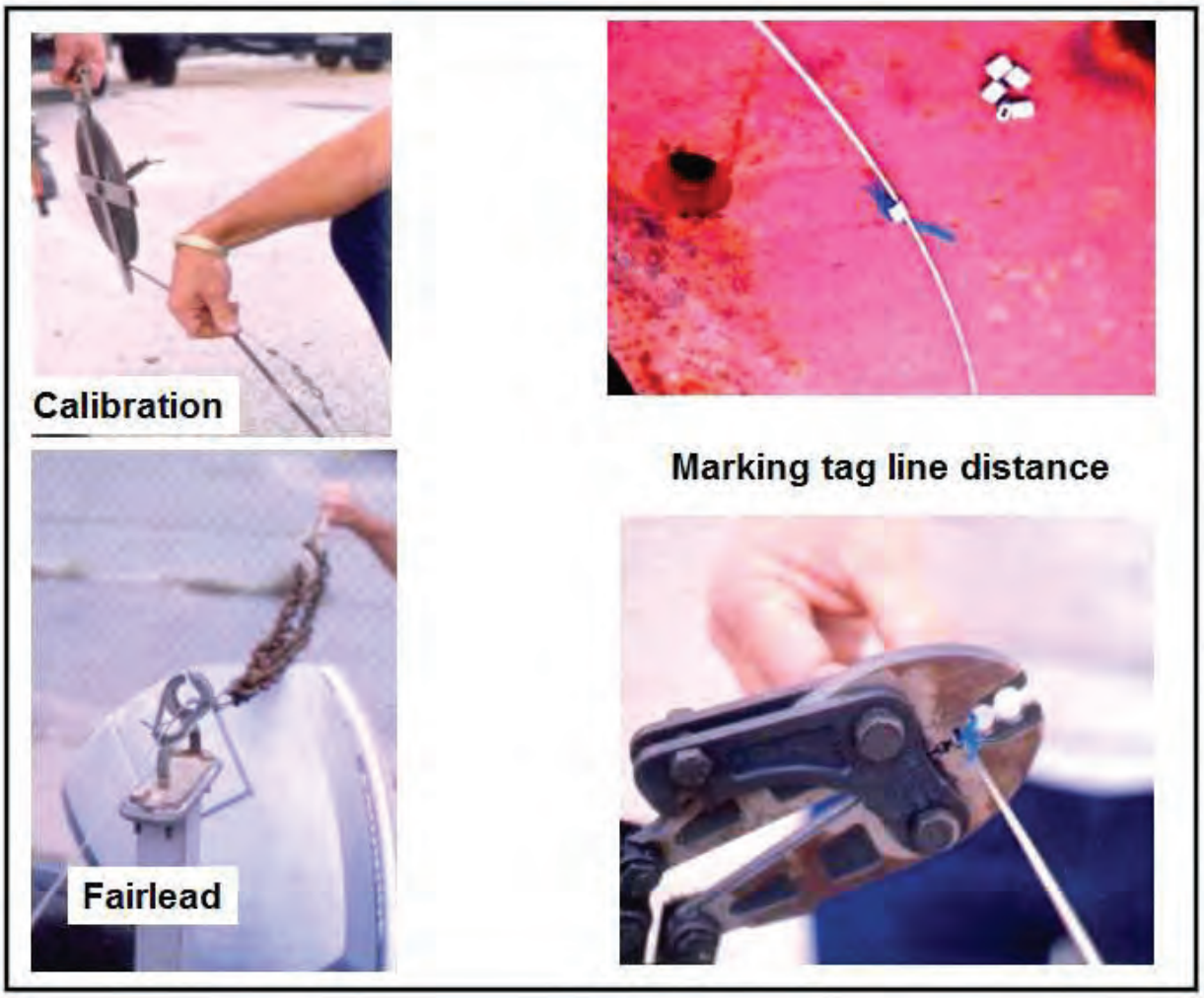


Figure G-12. Tag line marking and calibration.

SECTION V

Total Station (Range-Azimuth) Positioning Methods

G-19. General Applications. Range-azimuth positioning is most simply a forward traverse computation, based on the intersection of an angular and a distance observation, normally generated from the same shore-based reference station--Figure G-13. Angular azimuth to the offshore vessel is observed by transits, theodolites, or manually or automated tracking total stations. The angular data can be manually observed and voice-relayed to the boat by radio or digitally recorded and transmitted to the boat. The distance measurement can be made by any number of EDM devices, such as microwave, laser EDM, and infrared light EDM. Although once a widely used positioning method, range-azimuth techniques are now employed only where GPS positioning cannot be obtained—usually due to satellite blockage. Today range-azimuth surveys are mostly performed using electronic digital theodolites--i.e., total stations. Range-azimuth positioning is typically used on projects located within four miles of a shoreline or riverbank. Depending on the type of equipment used, range-azimuth surveys have high relative accuracies. Because range-azimuth positioning is nonredundant, periodic calibration is essential. This survey method is relatively efficient. Only a two- or three-man crew is required to perform the survey. Any type of boat may be used, but open or enclosed workboats 17 to 26 ft long are common. This section covers hydrographic range-azimuth positioning methods where angles and distances are obtained visually or electronically, using alidades, transits, theodolites, EDM and full electronic total stations.

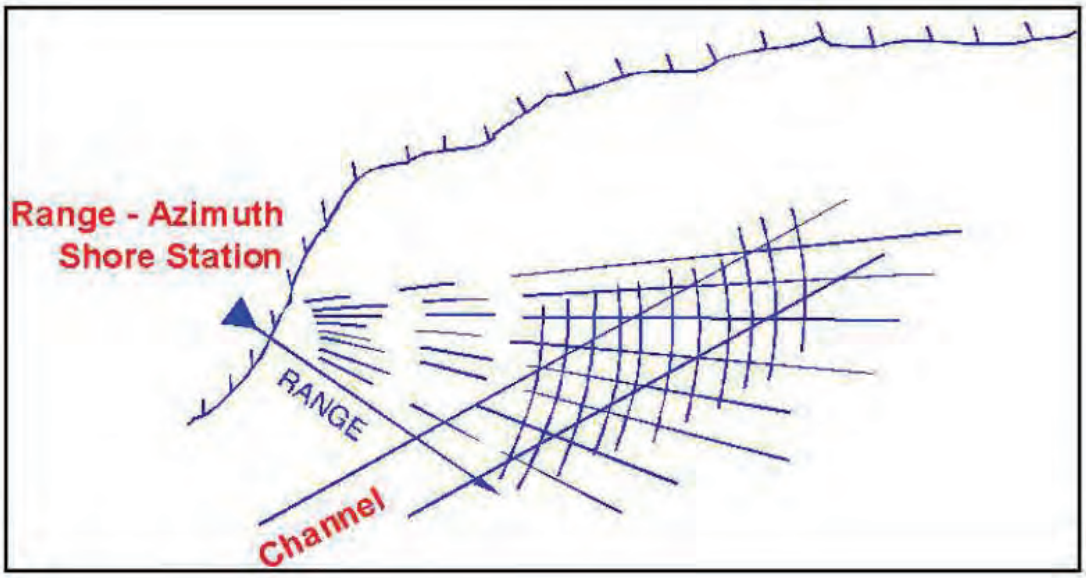


Figure G-13. Range-Azimuth positioning.

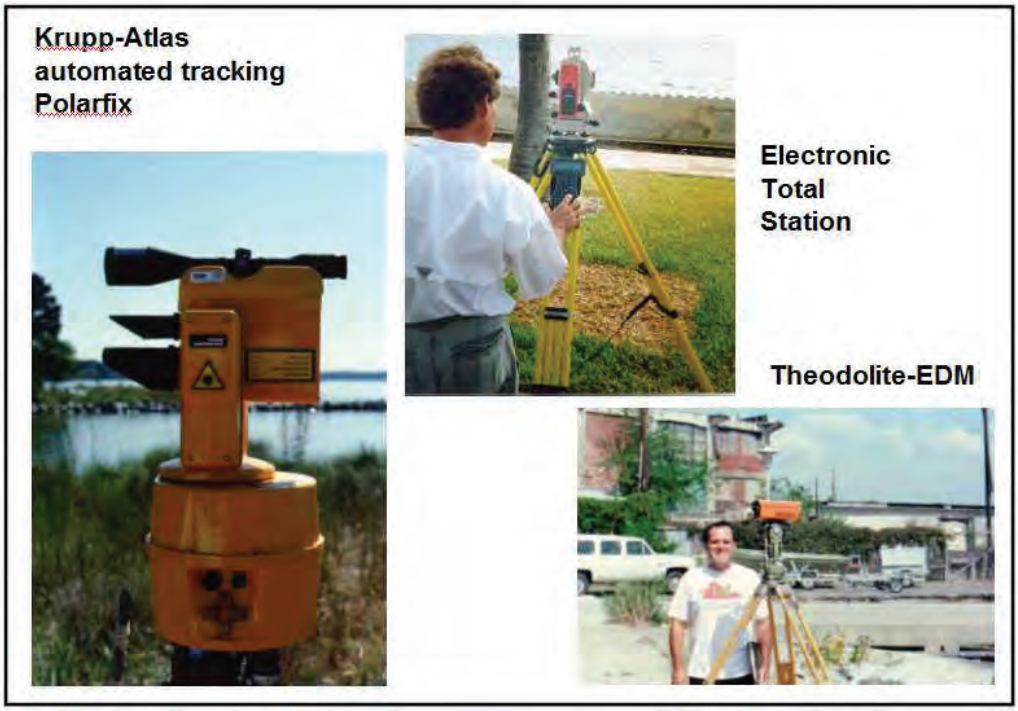


Figure G-14. Various Range-Azimuth positioning instruments used in Corps. (Norfolk District)

G-20. Range-Azimuth Survey Procedures. Total stations, theodolites, transits, or plane tables (i.e., alidades) are aligned on the local project datum in a manner similar to that described for triangulation intersection positioning (Section II). Thus, observed directions to the survey vessel are oriented in true grid azimuth reference for ease in plotting. Distances from the same point to the vessel are likewise observed, either visually (i.e., stadia) or electronically. Figure G-14 depicts some of the systems used in the Corps.

a. Manual range-azimuth tracking procedures. It is usually easiest for the tracking instrument operator to call the shot or fix events to the survey boat. The analog echo sounder record is fixed at each shot and the azimuth recorded. Constant azimuth increments may be computed based on the distance offshore. The angular spacing should conform (roughly) to the desired position fixing interval, i.e., 50, 100, or 200 ft depending on the type/class of survey. These increments are usually rounded to a convenient even value (1 min of arc or 0.01 deg) for ease of setting in the instrument. The azimuth is set in the instrument, and the vessel is tracked only for the period it is within the scope. The fix is called to the survey boat when the boat's antenna crosses the vertical crosshair. Alternatively, the survey vessel may call the fix/shot; however, this procedure requires constant tracking by the instrument man.

b. Constant range tracking. Constant circular range arcs may be tracked with fixes taken at prescribed angular (azimuth) intercepts. The boat operator follows a constant range using the microwave system display. Ranges are incremented based on the line spacing coverage desired. Azimuth intercepts to the boat are either observed at regular angle intercepts or called for by the survey boat. The observer manually tracks the boat throughout the survey and calls the observed azimuths to the boat by radio. Digital theodolites or total stations may be configured to telemeter the angular data directly to the boat. Angular intercept increments are designed to provide positions at roughly constant distances (e.g., every 100 ft) along the circular track. Thus, the angular increment will decrease as the distance offshore increases. Because the resultant data plot is along circular sections, which may not be aligned to the project, the data may not be suitable for quantity takeoffs unless DTM quantity-estimating techniques are available. This is, however, an excellent and efficient method of obtaining coverage over a given project area.

c. Separated range-azimuth reference points. The angular and distance measuring instruments need not be situated at the same point. For instance, a microwave system remote unit may be located on a sailing range structure and the tracking theodolite located at a more stable place ashore. The angle of intersection is no longer 90 deg in this case. To avoid degradation in geometry of intersection, the intersection angle should be kept larger than 45 deg within the project area. Manual tracking and positioning are accomplished in the same manner as described above.

d. Stadia distance measurement. Most traditional survey instruments are capable of determining slope/horizontal distances by tachymetric methods, i.e., using fixed cross-hair stadia intercepts. In many transits and levels with constant stadia intercept ratios, distances can be directly observed and rapidly computed by the instrumentman. Alidades typically reduce slope distances to horizontal--not required for most hydrographic applications. Visually observed stadia distances are relatively accurate over short distances--typically + 5 to +10 ft out to 300 foot distances on a dynamic platform. Beyond 300 ft to 500 ft, accuracy rapidly degrades. Ranges beyond 500 ft can be observed using "half-stadia" interval readings, and doubling the intercept value. Either level rods or painted "stadia boards" may be used for observing stadia distances. Level rod divisions are usually too difficult to read, so normally 8 to 12 ft long stadia boards are used. Boards are painted in with large black & white divisions, usually at 0.1-foot intervals, although larger intervals could be used if longer stadia distances are needed. The accuracy of observed stadia readings also degrades as vessel motion increases and visibility of the stadia board intercepts becomes obscured at longer ranges.

e. Data recording and plotting. Distances and azimuths are simultaneously observed by the instrumentman and recorded in a standard survey field book or electronic log by fix or time event. Radio contact with the vessel is maintained with the vessel normally calling for fix observations at prescribed intervals. The depth sounder is event-marked at the same time.

Position data may be plotted either ashore or on the survey boat; or post plotted if real time navigation or coverage information is not required. Plane table observations are directly plotted ashore as observed. Transit-stadia observations may be plotted at either location, using drafting machines or preplotted range-azimuth sheets. If navigation guidance is needed aboard the survey vessel, then position data must be relayed to the vessel for on board plotting. The position update interval is limited by the instrument observer's and plotter's expertise in observing, transferring, and plotting. Typically, 45 to 60 sec fix intervals are the best that can be performed in real time; thus, these methods are best for shot point depth observations under more static conditions. Total stations will typically compute and log vessel positions at a rapid update rate; however, in order to obtain real-time navigation aboard the vessel the position data must be relayed to the vessel. Manual plotting of range-azimuth surveys can be performed using a drafting machine and beam compass to lay out the azimuth and circular range arrays provided that the project area and reference station fall on the plotting sheet. If the project area is beyond the reach of these mechanical devices, the azimuth/circular array must be computed and drawn with spline curves. Angular position fixes are plotted along the constant range arc, and depth data are plotted relative to these points. Intermediate depth data points between fixes are interpolated between the fix events on the analog record. Range-azimuth position and depth data may also be encoded/digitized and plotted using automated techniques.

G-21. Total Station Range-Azimuth Surveys. Electronic total stations can be configured to provide highly accurate hydrographic positioning. The latest generation total stations can provide direct, real-time X-Y-Z coordinates on the vessel. If reflector-transducer offsets are applied, the X-Y-Z coordinate of the bottom can be computed/reduced in real-time. Robotic total stations can automatically track the vessel. A fully automated systems like the Krupp-Atlas Polarfix, contains a communications link that transmits the measured azimuth and distance to the boat. This communications data link is often the weak point in the system; care should be taken to ensure that there is no interference from other sources. These data are transformed to a local project coordinate system (station-offset, beach/river profiles, etc.) which is used for vessel operator steering guidance on a digital or analog left-right indicator. Topographic or construction total stations must be modified for hydrographic tracking applications if the beam width is not large enough to track the vessel. Philadelphia District has modified conventional topographic total stations for hydrographic survey purposes. Topographic total stations must also be configured to relay navigation data (via radio communication link) to the survey vessel processor for navigation and data logging purposes. Without on board navigation links, total stations are usually set up over established ranges--a common procedure for beach sections.

G-22. Range-Azimuth Accuracy. The accuracy of a range-azimuth position can be estimated from the following equation:

$$\text{RMS } 95\% = 1.73 \cdot \text{sqrt}\left[a^2 + (d \cdot \tan b)^2 \right] \qquad \text{(Eq G-3)}$$

where

a = estimated standard error (1-sigma) of the distance measuring system (e.g., tag line, EDM, stadia)

d = distance offshore

b = estimated standard error (in arc-sec) of azimuth measuring system (e.g., total station, right angle glass, transit, sextant)

Within a few hundred feet from the instrument, theodolite/EDM/total station range-azimuth systems are highly accurate for dredging and navigation surveys. Microwave based EDM will rarely meet current 2 m or 5 m positional accuracy standards. Dynamic alidade or transit stadia distances are accurate to 5 m within ranges of only 100-200 ft, depending on conditions.

G-23. Quality Control Requirements.

a. Angular orientation. The tracking instrument should be referenced to the grid azimuth for the project. This is accomplished by setting the lower plate to the grid azimuth of the reference backsight. The farthest or most reliable point should be selected as the reference orientation. Additional reference points should be pointed on to verify orientation. All available visible control should be sighted on, and any error or discrepancy resolved onsite. All orientation checks (including grid azimuth computations) must be recorded on a worksheet or field book.

b. Periodic orientation checks. During the course of the survey, the initially set orientation should be periodically checked to ensure that no movement in the instrument has occurred. Periodic orientation checks should be noted in instrument operator's field book. These checks are normally done at the end of each survey line. The instrument should be readjusted and releveled as required during these checks. If significant movement has occurred, all work done since the last orientation check was made should be rejected and rerun.

c. Quality assurance checks. Like most visual survey positioning methods, independent positional checks on range-azimuth positions are rarely available. When the vessel can be maneuvered to another project control monument, a check on the position can be made. This should always be done for critical navigation surveys.

SECTION VI

Terrestrial Electronic Positioning Systems

G-24. General Scope. Use of electronic distance measurement (EDM) techniques to position hydrographic survey vessels derived from hyperbolic aircraft navigation systems first developed during World War II. The Corps first began using hyperbolic and range-range electronic positioning during the mid 1950's--in Detroit and Norfolk Districts. A variety of systems have

been used since that time; most of which became quickly obsolete when GPS became fully operational. However, the basic operating concepts behind land-based EDM and related trilateration positioning (including GPS) have not significantly changed. This section describes these electronic distance measurement and positioning principles of these older land-based electronic positioning systems; including procedural criteria for using such systems. Land-based (or terrestrial) positioning systems are distinguished from satellite (extra-terrestrial) positioning systems. All these systems use time difference and trilateration techniques to determine a position. The main focus of this section is on land-based microwave positioning systems as opposed to now nearly obsolete low- or medium-frequency hyperbolic systems such as LORAN-C.

G-25. Types of Electronic Positioning Systems. One method of classifying electronic positioning systems is by their operating frequencies. The frequency generally determines operating range and accuracy, and, in turn, a system's applicability for a particular type of work. Figure G-15 lists some types of electronic positioning systems by their bandwidths. In general, the higher the frequency of the electronic positioning system, the more accurate the resultant position determination. Systems in the medium frequency range and below are typically hyperbolic phase/pulse differencing, and can reach far beyond the visible or microwave horizons. These systems were more suited for long-range navigation purposes or far offshore geophysical exploration work. Only those systems operating above the medium frequency bandwidth range had any practical application to USACE construction work. Microwave systems in the Super High Frequency (SHF) range were most commonly used to precisely control offshore survey vessels and dredges. Operating distances for these systems are generally limited to line of sight, which is adequate to cover most river, harbor, and coastal construction applications. Modulated lightwave and infrared spectrum electronic distance measurement instruments (e.g., electronic total stations) can be used over relatively limited distances, usually less than 3 to 5 miles offshore. These systems provide the highest distance accuracy measurements.

Bandwidth	Symbol	Frequency	System
Very Low Frequency	VLF	10-30 KHz	Omega
Low Frequency	LF	30-300 KHz	LORAN-C
Medium Frequency	MF	300-3000 KHz	Raydist, Decca
High Frequency	HF	3-30 MHz	Fundamental Earth Frequency 10.23 MHz
Very High Frequency	VHF	30-300 MHz	VOR Aircraft Navigation
Ultra High Frequency	UHF	300-3000 MHz	Del Norte
L-Band			NAVSTAR GPS
Super High Frequency	SHF	3-30 GHz	(Microwave EPS)
C-Band			Motorola
S-Band			Cubic
X-Band			Del Norte
Visible Light			EDM*
Laser Light			EDM
Infrared Light			EDM, Polarfix

Figure G-15. Frequencies of various positioning systems used for hydrographic surveying (1950 to date).

a. Medium-frequency positioning systems (RAYDIST/DECCA). Raydist and Decca positioning systems were first deployed by Corps districts in the mid 1950's and were used up to the early 1970's. They are no longer used. Systems in this frequency range operated by time/phase differencing methods--resulting in either circular or hyperbolic lattices (time differences). These systems required repeated calibration to resolve whole-wavelength (lane) ambiguities and continual monitoring during the course of the survey to resolve lane, or cycle, slips--no different than integer ambiguity determination requirements for modern day carrier phase GPS observations. Onsite calibration was essential to maintain accuracy. However, given the far offshore uses of these systems, calibration was often impossible. Many of the visual positioning techniques described in previous sections were used to calibrate these systems.

b. Low-frequency positioning systems (LORAN-C). LORAN-C is a low-frequency time-differencing hyperbolic system and has been the primary marine and airborne navigation system for over 40 years. It is suitable only for general navigation or reconnaissance surveys; and perhaps for general dredge/dump scow monitoring. Daily near-site or onsite calibration is critical if any semblance of absolute accuracy is to be maintained. (This is not the same as relative accuracy.) Without onsite calibration, absolute positional accuracy of LORAN-C is

+ 0.25 mile at best. Recently developed differential Loran-C has a much higher accuracy. LORAN-C is expected to be decommissioned by the US Coast Guard in the early 2000's.

G-26. EDM Measurement Process. Most EDM systems operate either by resolving two-way travel phase delays of a modulated electromagnetic carrier pulse/wave between the offshore vessel and shore-based reference transmitter or by measuring the two-way travel time of a coded electromagnetic pulse between these points. GPS operates in a similar manner to the conventional systems except the travel distances from the satellites are one-way. Code-phase GPS is similar to microwave coded pulse systems, and carrier phase GPS operates on the carrier wave (phase differencing) used to transmit coded information. Phase differencing techniques are also used on land surveying EDM instruments, with the carrier being a visible laser or infrared light. Microwave pulsing type systems (Motorola, Del Norte, Micro-Fix, etc.) measure the round-trip travel time of a pulse generated at the offshore vessel, to the shore repeater station, and back to the vessel. The remote shore stations are variously referred to as transponders (XPDR), trisponders (TPDR), or responders (RPDR), depending on the manufacturer. They receive, process, and retransmit the signal. Some microwave systems use passive radar reflectors. For a pulsing system, the round-trip distance is computed by multiplying the measured elapsed time (less internal system time delays) by the assumed velocity of propagation of electromagnetic energy. The distance, or range, is computed by the following equation:

$$d \text{ (meters)} = c \cdot (t_m - t_d) / 2 \qquad \text{(Eq G-4)}$$

where

c = assumed velocity of propagation (m/sec)
t_m = measured round-trip travel time (sec)
t_d = internal system delays (sec)

a. Distance determination. Under ideal conditions, and with repeated measurements, the travel time (tm) can be measured fairly accurately (to better than the 1-nsec (1-ft) level) and far more accurately (sub-centimeter) when modulated phase comparison techniques are employed, such as on infrared and some microwave systems. However, all three factors on the right side of Equation G-4 are subject to both random and systematic errors. The only way to minimize these errors is by external and internal calibration of the equipment. Internal system delays (td) can be controlled relatively effectively on some modern pulsing systems. Such control is often termed "self-calibrating." The assumed velocity of propagation (c = speed of light) and other local anomalies or inherent system measurement instabilities cannot be controlled or corrected by the measurement system. Thus, an independent, on-site calibration must be performed if errors due to these sources become significant, which is normally the case (i.e., ambient project conditions different from nominal conditions). As a result, a calibrated microwave positioning system operating in a dynamic hydrographic survey environment can measure a range to an accuracy ranging between + 3 m and + 10 m (95% RMS).

b. Velocity of propagation variations. Variations in the velocity of propagation in air are caused by changes in air density due to temperature, humidity, and air pressure. The effect on land-based microwave positioning systems is more pronounced than on light waves. A factory-calibrated microwave system may be operated in atmospheric conditions differing significantly from the nominal calibration conditions. A change of 50 to 75 ppm could result, or 0.5 to 0.75 m in 10,000 m. Although such a variance may not be significant in operations 6 miles offshore, it is a systematic error, which could be compensated for by proper calibration. Assumed stability in the pulsing system time (tm - td) or phase measurement process cannot be guaranteed. Periodic independent calibration is essential to check this stability. No independent calibration of positioning systems is totally effective unless it closely duplicates the actual operating ranges and conditions.

c. Microwave antenna considerations. Microwave propagation/refraction problems may exist in some areas during hydrographic surveys. Moving antennas a small distance (vertically or horizontally) sometimes eliminates the problem. Weather, especially humidity and temperature, affects microwave propagation through the air. Large ships, metal buildings, and even the water surface can create unwanted reflections of the microwave signals received at the antenna. Experience with microwave equipment problems and knowledge of the survey area will minimize the recurrence of these types of problems. Different antennas may be used to either boast a signal into a sector (sector antenna) or allow transmission over a full circle (omnidirectional) from the station. Circular polarization is another technique used to reduce multipath effects. Another technique used is antenna separation, which switches from one antenna to another to reduce multipath phenomena. GPS manufacturers use concentric metallic raised rings surrounding the antenna to reduce multipath effects.

d. Multipath effects. Signal multipath reflection is a major systematic error component for equipment operating in the microwave band. Errors due to this effect are difficult to detect. Most critically, they can gradually accumulate with vessel location and orientation relative to a particular remote reference station. An abrupt change due to multipath is usually readily apparent, as is total signal cancellation, termed "range holes." This gradual range increase of 1 m or more can cause what appears to be a course anomaly on a plot of the vessel's position, as if some erratic current displaced the vessel for a period of time. In addition, multipath may be present when the system is calibrated at a particular point. Consideration of multipath during antenna placement, enhanced antenna design (circular polarization, space diversity, etc.), and other internal electronic techniques and filters are required to identify and/or minimize multipath effects. None are totally effective in all cases. Antenna spacing or systems with circular polarization are recommended to minimize the possibility of these effects.

G-27. Microwave Range-Range Positioning Systems. These systems were first used by Corps districts in the early 1970's. The first systems were manufactured by Cubic Corporation, Motorola, and Del Norte Technology. They effectively replaced tag line and medium frequency

(Raydist and Decca) positioning methods that had been used by districts since the 1950's. Up until the mid 1990s, microwave positioning systems were the primary positioning system in nearly every district. After 1992 when full coverage differential GPS became available, use of microwave systems rapidly declined. In 1998 only one or two districts were still utilizing microwave positioning--all the others have gone exclusively to GPS positioning. It is unlikely such systems will be in use much after 2000. Range-range positioning by microwave systems is accomplished by determining the coordinates of the intersection of two (or more) measured ranges from known shore control points--a process termed trilateration. When two circular ranges are measured, two intersection points result, one on each side of the fixed baseline connecting the reference stations. The ambiguity is usually obvious and is controlled by either initializing the computing system with a coordinate on the desired side of the baseline or referencing the point relative to the baseline azimuth. Prior to automated data acquisition systems, microwave ranges were visually observed and steered, with data logging and plotting performed manually. As automated data acquisition systems began to be used in the early 1970s, ranges and computed positions were electronically recorded and the resultant position sent to a track plotter and helmsman guidance display unit. These microwave range-range positioning methods used by the Corps during the period from about 1970 until 1999 are described below.

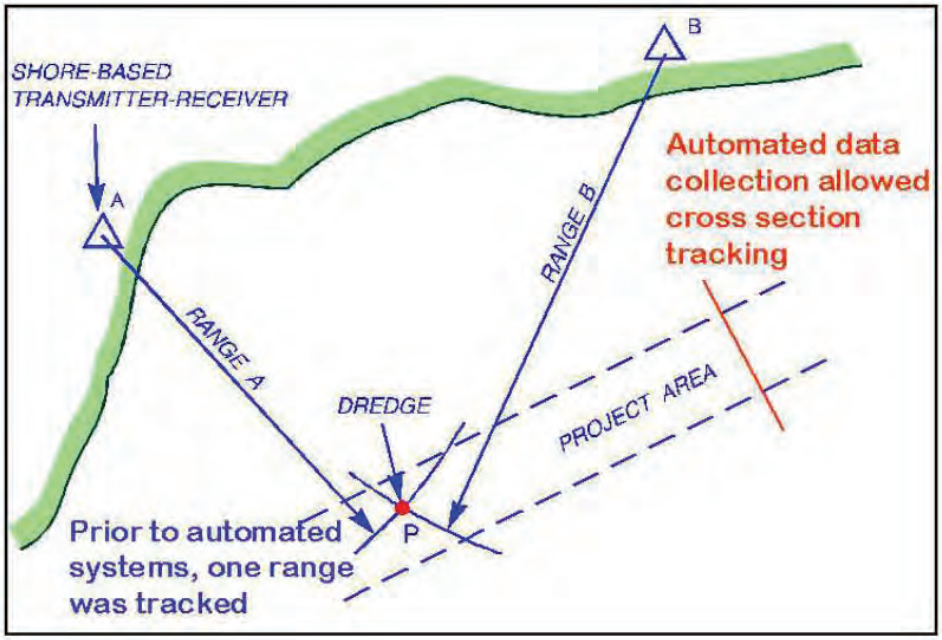


Figure G-16. Range-Range intersection.

a. Constant range tracking. Before automated data logging and processing systems were available, the survey boat was positioned by steering a constant range from one reference station and fixing at range intercepts from the other reference station (Figure G-16). At higher vessel

velocities, this is not an accurate positioning method, due to the need to estimate the intercept between range updates. In addition, the resultant survey lines are circular and are not aligned to the project coordinate system. This survey method provided a good backup capability when failures occurred in automated positioning and guidance systems. It was rarely employed, however.

b. Automated range-range tracking. When automated positioning and guidance systems were employed, the range intersection coordinates were automatically computed and transformed relative to the project alignment coordinate system (station-offset). This data was then fed to an analog or digital course indicator (or left-right track indicator), allowing any particular station/cross section or offset range to be tracked. Along-track position fixes were then taken by manually observing an along-track indicator or track plotter. The analog depth recording device is marked at each position. Normally, however, digitized depth data are correlated with positional data in an automated system at regular preset intervals by time or distance. Figure G-17 shows typical electronic ranging and positioning equipment used by the Corps during the past 30 years.

c. Range-Range accuracy. The positional accuracy of a range-range intersection position is a function of the range accuracy and the angle of intersection of the ranges. The angle of intersection varies relative to the baseline so the positional accuracy varies as the survey vessel changes location. Assuming both ranges have equal value, the positional accuracy at any offshore point can be estimated from:

$$\text{RMS (95\%)} = 2.447 \cdot \sigma \cdot \text{cosecant (A)} \qquad \text{(Eq G-5)}$$

where

σ = estimated standard error of measured range distance (1-sigma)
A = angle of intersection of ranges at vessel (or angle from vessel to baseline stations)

Since the angle of intersection (A) has a major effect on positional accuracy, quality control criteria will restrict surveys within intersection tolerances--e.g., A must be between 45 deg and 135 deg. The accuracy of microwave ranges is difficult to estimate since it is not constant with distance from a shore station. Manufacturers typically claimed accuracies of + 1 m (1-sigma), or + 2 m (95% RMS). These estimates were for ideal (calibrated) conditions. More likely microwave range accuracies were on the order of + 3 m. This would yield an average positional accuracy of about 8 m (95% RMS) at 60 deg range angle of intersection. Although an 8 to 10 m RMS error may seem excessive by today's DGPS or RTK standards, this represented a major improvement in the 20 to 50 m accuracies achieved by earlier positioning methods--especially on a project site 10 miles offshore.

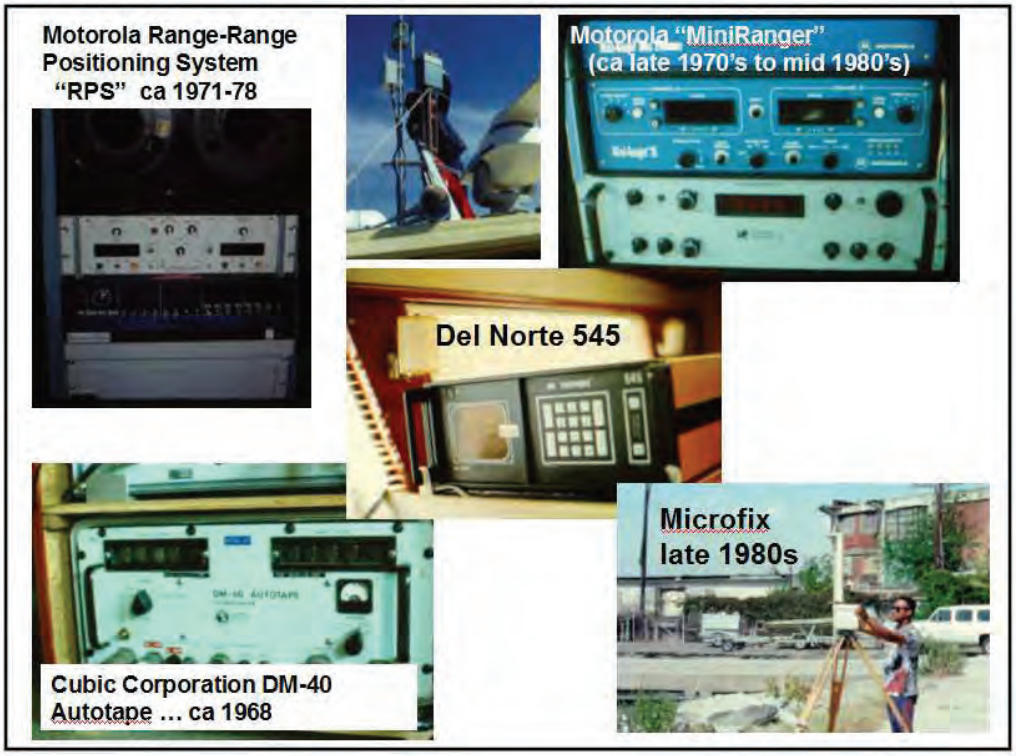


Figure G-17. Range-Range positioning systems used in Corps (1970-1995).

d. Multiple range positioning techniques. This method is simply an expansion of the range-range method described above. Jacksonville District first developed this technique in 1979. In this case, three or more ranges are simultaneously observed, and a positional redundancy results. (The Racal Micro-Fix system allowed selection of up to 8 ranges from a total of 32 interrogated.) The position is determined from the computed coordinates of the intersections of the three or more range circles. Since each range contains observational errors, all the circles will not intersect at the same point. In the case of three observed ranges, three different coordinates result. Four ranges result in six separate coordinates. The final position is derived by an adjustment of these redundant coordinates, usually by a least-squares minimization technique. Some automated microwave positioning systems simply used the strongest angle of intersection as the "adjusted" position, and others take the unweighted average of all the intersecting coordinates. All adjustment methods were typically performed on-line at each range update cycle, normally every second. The positional data are then transformed to a project-specific coordinate system in a manner similar to that described for a two-range system.

(1) Using multiple ranging can minimize positional uncertainties. The coordinated position contains redundancy and can be adjusted. Such a process reduces the geometrical constraints and provides an opportunity to evaluate the resultant positional accuracy as the survey

progresses. An on-line accuracy assessment is thus provided. This is accomplished by evaluating the positional misclosure which occurs when three or more position lines containing errors intersect, a so-called triangle of error for the simple case of three intersecting ranges, as shown in Figure G-18. The position of the vessel is obtained by adjusting the three ranges to a best fit.

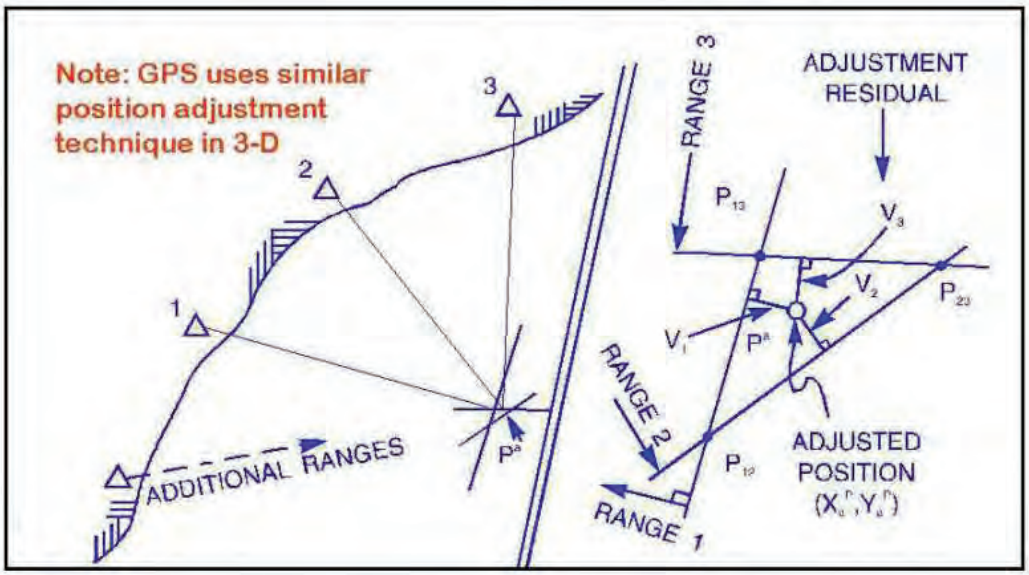


Figure G-18. Multiple range positioning.

(2) An assessment of the range measurement accuracy may be obtained by computing the residual range errors (v) for each position. These are the corrections added to each range so that all ranges intersect at the same point. When a least-squares type of adjustment is performed, the sum of the squares of the residual errors (v) is made a minimum. The magnitudes of these residual range corrections provide the statistics for an accuracy estimate of the observed distances or, more practically, an approximate quality control indicator. When a least-squares adjustment is performed, it is possible to obtain an accuracy estimate of the positional RMS error. Automated software can provide such data at each position update. If known, different weights may be assigned to individual range observations. This proved useful when different types of positioning systems were mixed during a survey (i.e., microwave and medium wave ranges).

(3) An on-line quality control indicator (e.g., 95% RMS error) can be computed. This can be directly obtained from the least squares adjustment matrix and computed from:

$$\text{RMS Error (95\%)} = 1.73 \cdot \text{sqrt}\ (\sigma_x^2 + \sigma_y^2) \qquad \text{(Eq G-6)}$$

where

σ_x and σ_y = estimated positional standard errors in x and y coordinates (from variance-covariance matrix)

Automated systems were designed to alarm when positional RMS accuracies fell outside the prescribed limits, indicating calibration problems. The initial standard error of the microwave ranges was usually assumed constant throughout the survey.

(4) Alternatively, the residual range errors (v), which result from comparing the observed distances with the inversed distances between the adjusted position and the remote shore transmitters, could be used to evaluate the accuracy of the range measurements. A variety of methods were used (on-line and/or off-line) to compute these residual errors. An approximate (unbiased) estimate of the range accuracy is obtained from the following:

$$\text{Estimated Range Accuracy } (1-\sigma) = \text{sqrt}\left[\Sigma (v^2) / (n-1) \right] \qquad \text{(Eq G-7)}$$

where

n = number of observed ranges

$\Sigma (v^2)$ = sum of the squared residuals

Adding redundant ranges will not necessarily make a significant improvement in the positional accuracy because the inherent random and systematic errors are still present. It will, however, help detect the existence of large systematic errors (and most critically, observational blunders) that might have otherwise gone undetected using a nonredundant range-range system.

(5) Figure G-19 demonstrates the use of multiple ranging in an offshore location where no independent method of calibration at the job site was available. Figure G-20 shows another project with six intersecting points, resulting from the four observed ranges. Error ellipses for each of the two-range intersections are shown. The on-line least-squares adjusted position is shown along with its (smaller) error ellipse.

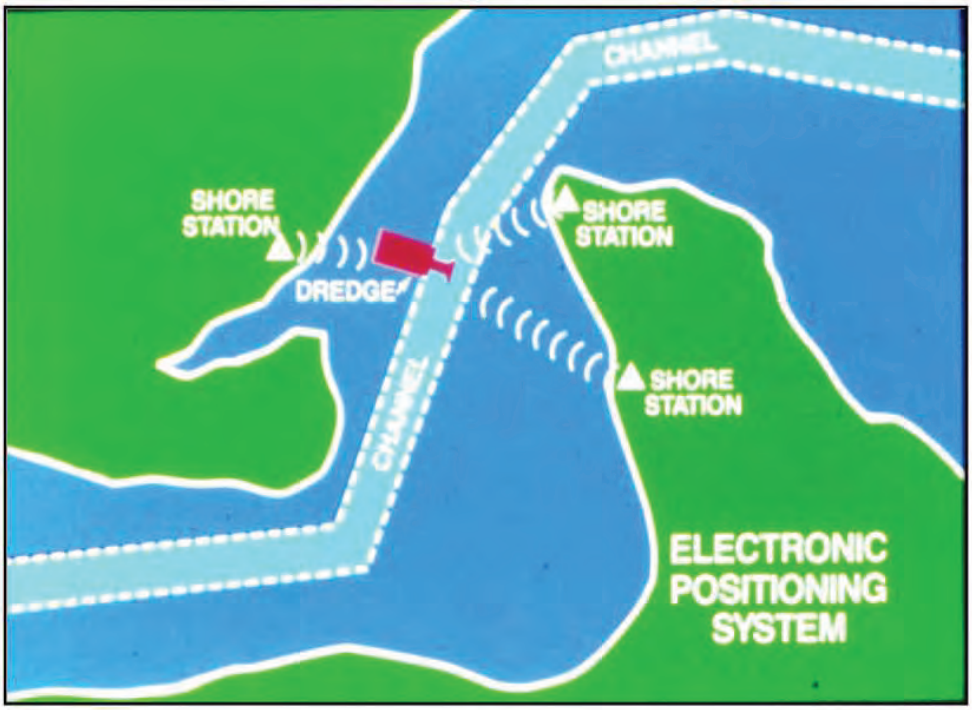


Figure G-19. Three-range microwave positioning scheme.

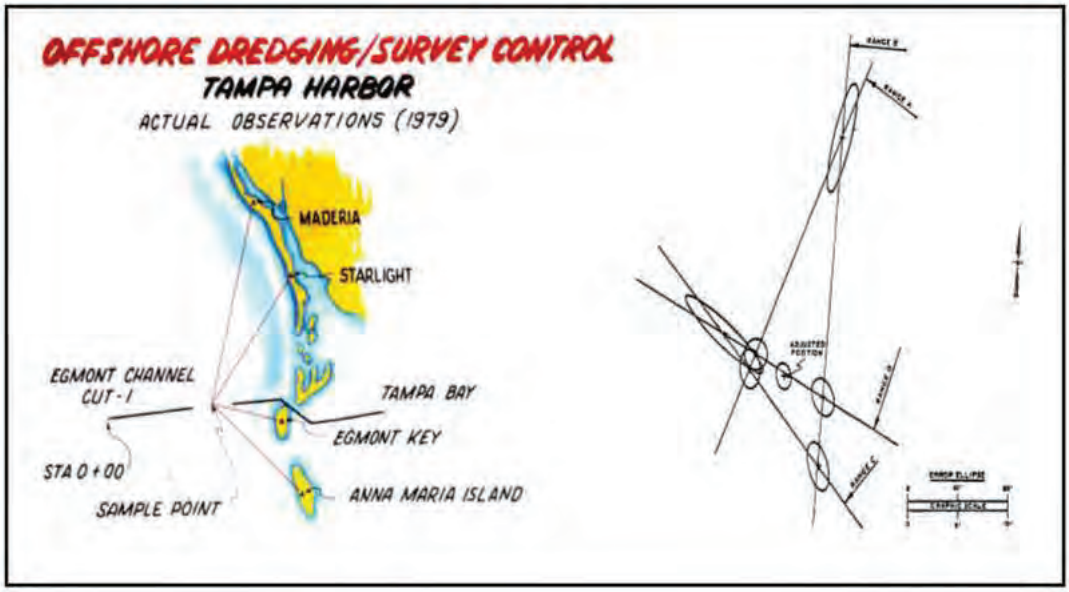


Figure G-20. Four-range intersection position solution (Tampa Harbor, Jacksonville District).

G-28. Microwave System Calibrations and Quality Control. A microwave system calibration process basically involves an independent determination of the vessel's antenna location, followed by comparison of differences between the observed microwave ranges and the distances computed from the independent calibration. An independent calibration should be at least one order of magnitude more accurate than the microwave system being calibrated. Such systems would include: theodolite triangulation, total station observations, or EDM trilateration methods. If automated coordinates are observed rather than direct ranges, inverse coordinate computations will have to be made to determine the observed ranges. If a series of independent calibrations is made, the mean range difference over this series represents a correction to be applied to the system. This range correction is dialed in the microwave system range console or is stored for software application during the position computation. Given the instability of many microwave ranging systems, coupled with inaccuracies in the calibration process itself, determining whether a range correction is statistically valid is difficult. This problem frequently occurs when baseline comparisons are made at two (or more) different calibration points offshore.

a. Repeated calibrations. An advantage of EDM, total station, sextant, or triangulation intersection calibrations is that a series of 5, 10, or more independent calibrations may be obtained at various locations in the work area. If the calibration technique is performed accurately, the mean range difference correction may be statistically valid. Its validity is best estimated by computing the standard deviation from the mean of the series of range differences. Applying a calibrated range difference may often be debatable from a statistical standpoint. For example, assume that a microwave range is calibrated by five independent distance measurements. The accuracy of the calibration process is estimated at ±0.5 m and the range is presumed stable to +0.5 m. The series of calibrations yields a (-) 0.3-m correction ±1.0 m. The ±1.0-m deviation contains the error budget of the microwave range, the calibration process, and other unknown factors (control, eccentricities, etc.). A (-) 0.3-m correction in this case would seem marginal. However, for consistency, it should be applied since no simple rule-of-thumb exists for deciding when such a correction is statistically valid.

b. EDM calibration. Direct ranges to the shore-based receiver stations may be observed using precise phase differencing laser/infrared electronic distance measurement instruments. Typically, the EDM is moved to the two or more receiver monuments, and the reflector prism is placed above or below the vessel's antenna. Depending on the type of EDM used, vessel stability is critical for maintaining lock on the reflector. A series of EDM distance readings is directly compared with the simultaneously observed microwave ranges, and corrections are assessed as described above. EDM observations are taken and corrected for slope and atmospheric refraction in accordance with standard survey methods. If control monuments other than the microwave remote receiver's are occupied, a trilaterated position of the vessel must be determined and inversed along the microwave ranges for comparison. This method is especially suitable for periodic calibration of dredges.

c. Baseline calibrations. Baseline calibrations are performed by locating the survey vessel alongside a known reference point and comparing the computed (inversed) distances with the ranges observed by the microwave system. This is the simplest and most common microwave calibration method. Any eccentricities between the vessel's antenna and the known monument must be corrected. This is usually done by observing an angle and taped distance from the reference point to the antenna and computing the grid coordinates of the actual antenna. A sextant bearing is adequate over short distances. In some instances, the vessel antenna may be removed from its mounting and placed directly over the known monument. Such a procedure may change antenna receiving characteristics and induce multipath error. Some automated systems allow input of the antenna coordinate and directly compute the distance comparisons or, alternatively, directly correct the observed ranges to agree with the fixed coordinate. (This latter method assumes only one calibration check will be employed--or the differences from different points are insignificant.) Such a process is useful on multiple ranging systems. Regardless of the method employed, a few minutes of observations should be recorded. Lengthy calibration observations at the same point serve no purpose other than measuring the system's precision (not accuracy) at that particular point. Range corrections are computed and assessed. For critical surveys, the same process should be performed at a second calibration point. Significant differences in the range corrections for each point may indicate problems with the control network, multipath errors, or both. The magnitude of the recorded range differences from each calibration point is another rough indicator of the quality of the survey. If the magnitude of these differences (or standard errors from the mean values) is significant, the source of the problem must be determined. This may require calibration at a third fixed point.

d. Total station instrument calibration. Since a typical total station EDM yields direct and accurate X-Y-Z coordinates of the remote point, it may be used to compare the coordinates of an automated positioning system. A total station may be set up at any known point with visibility to the offshore point (and within the operation ranges of both systems). With the vessel held as motionless as possible, the retro-prism is held adjacent to the microwave system antenna, and simultaneous total station and microwave system coordinates are observed at different locations. Inversed distances and microwave ranges are compared as shown in previous examples.

e. Triangulation intersection. Triangulation methods are suitable for areas where no onsite calibration points are available. This method is also particularly ideal for calibrating dredges and other large plants that cannot perform static or direct baseline calibrations. Triangulation methods are potentially the most accurate form of microwave calibration in that the process is performed in a dynamic (true working) environment. To attain this, however, excellent intersection geometry and visibility are necessary, and highly skilled theodolite tracking observers are essential. Vessel velocity must be kept at a minimum during the tracking process. For high-accuracy triangulation calibration, a third theodolite is added for redundancy. A series of 5 to 10 or more intersection fixes is made on a stable or slowly moving survey vessel or dredge at or near the work area. Microwave ranges are read at the time of each intersection fix.

Triangulated positions are computed for each position, inversed, and compared with the observed range. Care should be taken to ensure that all computations and comparisons are based on grid distances. As described previously, based on the deviations in the range differences, a judgment must be made as to whether the mean range correction is statistically valid.

f. Sextant resection. Sextant resection calibrations are valid only when resection geometry is ideal, for nearshore projects where distinct sextant targets are clearly visible and vessel velocity is near dead slow or stopped. A series of 5 to 10 simultaneous sextant resection angles and microwave range observations should be made. The sextant observers must be centered about the microwave antenna to minimize eccentricities. On a stable or spudded platform, redundant angles should be observed. Resection computations should be performed manually or with standard software. Graphical resection (three-armed protractor plots) shall not be used. Resection software should provide an estimator or indicator of the quality of the resection based on the geometry and estimated standard error of the observed angles. Without such a quality estimate, the resection solution may be less accurate than the microwave solution. Resected grid coordinates are inversed and compared with the observed microwave ranges. Range differences for each position are computed and meaned. A standard error of each mean should be computed to judge whether applying a mean correction to the range is statistically appropriate. Large variances between the resected ranges and the microwave range indicate poor resectioning, unstable microwave ranges, or both.

g. General QC criteria for electronic positioning systems. Some basic criteria for performing positioning system calibrations are described below. Some of these factors are also applicable to GPS positioning techniques.

(1) The independent calibration procedure used must have an accuracy at least equal to or better than the system being calibrated. This is not always easily accomplished when dynamic calibrations are performed.

(2) Multipath effects may not be eliminated by calibration since they can depend on the antenna location (ashore and afloat) and the orientation of the offshore vessel.

(3) A static calibration does not simulate the dynamic survey condition. Thus, any errors due to vessel motion will not be picked up (e.g., electromechanical lags or lack of system synchronization--latency errors).

(4) Calibrations must simulate, to the maximum extent possible, the actual conditions existing in the project area. This requires calibration as close to the work site as possible.

(5) Measurement systems known to be relatively stable, such as infrared electronic distance measurement devices, “self-calibrating” or phase comparison microwave systems, total

stations, and GPS, must also be independently checked, or verified, to prevent blunders. The frequency of such verification checks is more relaxed for these systems.

(6) Calibrations of pulsing microwave positioning systems are valid only for the particular range measurement system used. When antennas, receiver units, connecting cables, and the like are modified, moved, or swapped out, a full recalibration of the system must be performed. Calibration must be performed while the shore-based receivers are located at their actual sites and referenced to the permanently located vessel antenna. If not, some large systematic effects may not be properly compensated for.

(7) Calibration procedures must be consistent during the course of a project (i.e., both pre-dredge and after-dredge payment surveys). The same baselines and/or procedures should be employed.

(8) Remote points used to calibrate an established network must be adequately connected by surveys relative to the positioning network. This is especially important when calibrating from large offshore range structures which may not have been accurately positioned, or where the center point is not easily defined. This is especially applicable to long-range DGPS/RTK observations.

APPENDIX H

Kings Bay Entrance Channel Tidal Modeling for RTK Surveys (Jacksonville District)

H-1. Background. This section details the 1997 implementation of the first permanent real-time kinematic (RTK) network in USACE. This network was utilized for real-time water surface elevation measurement and to develop variations in the tidal datum in the Saint Mary's Entrance Channel. Observed RTK ellipsoid heights are reduced to a filtered water surface elevation and corrected to the local MLLW tidal datum. This single station RTK network has been continuously utilized since 1998 for all dredging and surveying operations. It is still operational as of 2013. The channel is located at the boundary between the States of Florida and Georgia and provides access to the Kings Bay FBM Submarine Base, Georgia. The Entrance Channel is maintained to a project depth of over 46 feet--out to the east channel limit eight miles offshore--Figure H-1. The project has an approximate tide range of 7 ft and has always been difficult to survey due to uncertain tidal modeling.

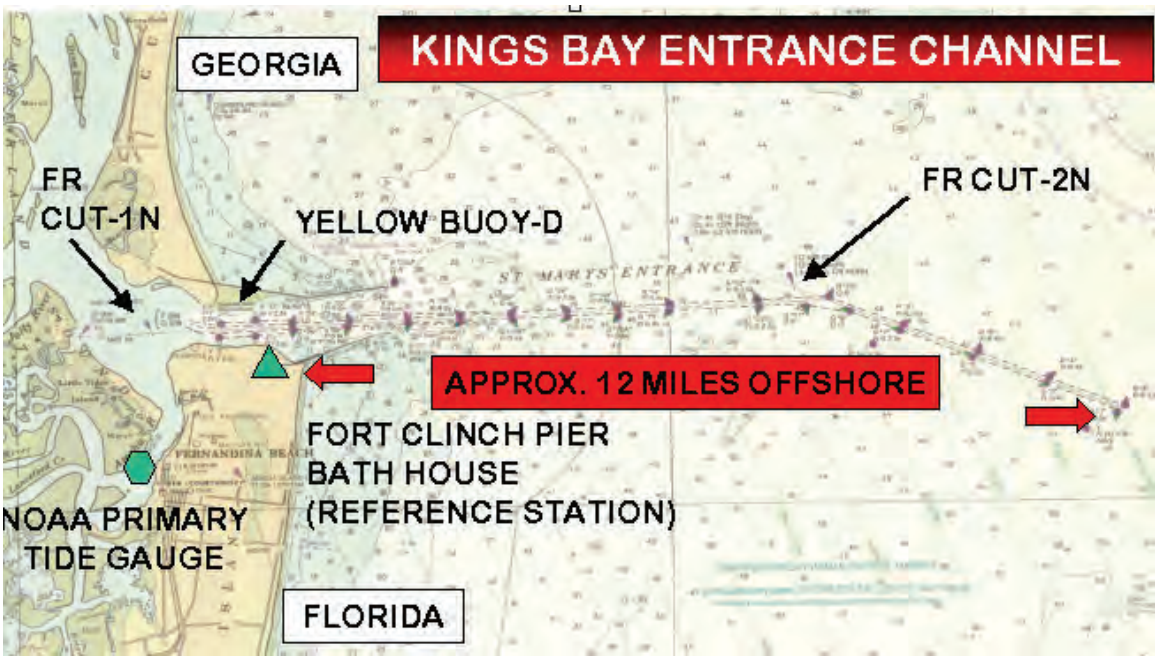


Figure H-1. Kings Bay (St. Mary's) Entrance Channel

a. In May 1997, the Jacksonville District contacted the U.S. Army Topographic Engineering Center (now Army Geospatial Center) to establish a tidal datum in the Saint Mary's Entrance Channel. The purpose was to update the entrance channel to reference the MLLW Datum. In addition, the Jacksonville District wanted to implement carrier phase RTK technology to allow hydrographic surveys to be performed without using tide gages. The Jacksonville District began the actual field work by performing wide area GPS static surveys during the Fall of 1997. Two acoustic tide gages were installed in Cut 1N between December

1997 and January 1998. The tidal datums at these two gage sites were computed by NOAA using four months of data. In order to mesh RTK water level measurements and conventional tide gage measurements, the Jacksonville District's Survey Vessel Florida performed carrier phase GPS tidal measurements between March and June 1998. The SV Florida anchored six times for 25-hour periods to provide intermediate datum points in the channel and correlate conventional tide gage methods to the GPS (RTK) tidal datum method. The vessel anchored twice at tide gage locations to check the change in ellipsoid heights received on-board from the GPS reference station (kinematic mode) against the ellipsoid heights at the tide gages (static mode) over a tide cycle. A software configuration in the hydrographic survey package developed by Coastal Oceanographics, Inc. (now HYPACK, Inc.) allows for the ellipsoid separation values to MLLW to be used to compute tide measurement from the waterline of the survey vessel.

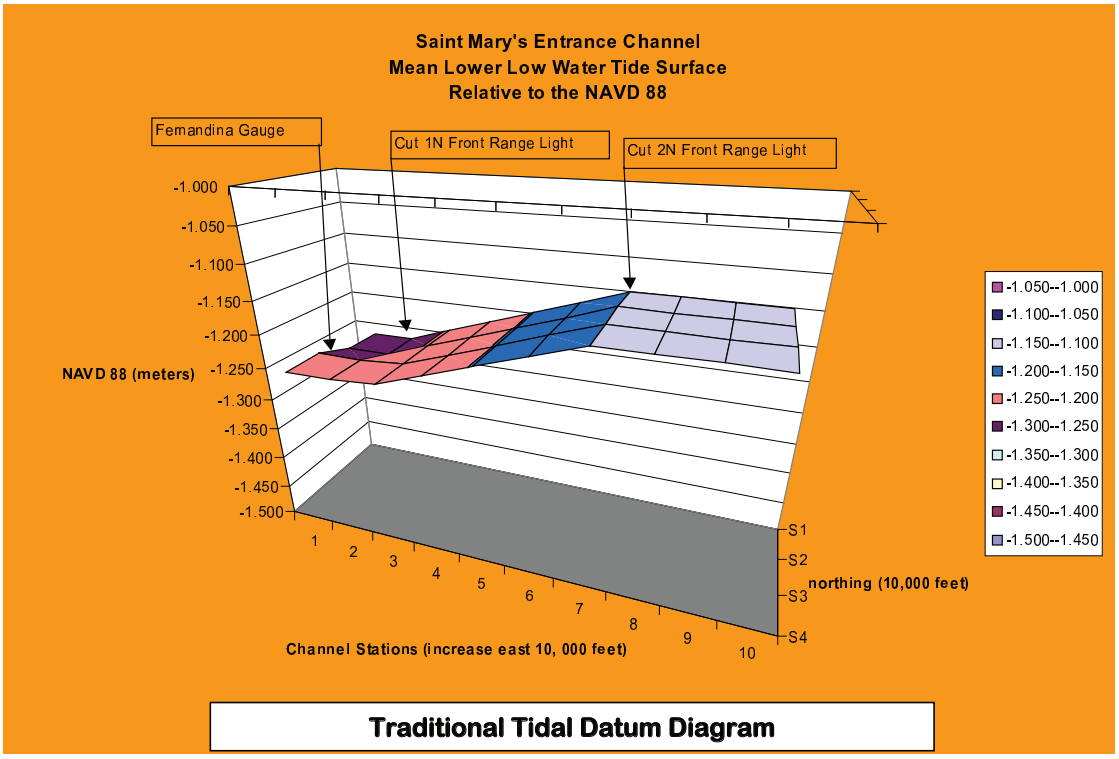


Figure H-2. Traditional tidal diagram for Kings Bay Entrance Channel

b. The entire project depended on the tidal measurements from the primary NOAA tide gage located in the Amelia River at Fernandina, Florida, two miles south of the Saint Mary's Entrance Channel. This gage was the primary tide gage used to measure the Mean Lower Low Water (MLLW) in the Saint Mary's Entrance Channel. A reference was needed to incorporate tidal datum measurements along the channel made relative to the Fernandina Gage. Two vertical references were used, the GPS ellipsoid and the North American Vertical Datum of 1988 (NAVD 88). The Jacksonville District accomplished the vertical references by performing the

GPS static survey over the entire project area. The GPS survey included two offshore front range lights used to guide submarines into port.

H-2.. Tidal Datum Diagram. A traditional tidal relationship for the Entrance Channel is shown in Figure H-2. The primary focus of modeling a project for RTK surveys is to develop the ellipsoidal tidal datum diagram shown in Figure H-3. The results shown on the tidal datum diagram provide the MLLW reference for the Saint Mary's Entrance Channel well within acceptable tolerances for dredging applications. This diagram uses the geodetic reference of NAVD 88. The mean sea level values on the diagram should theoretically be parallel to geodetic reference surface; however, the currents generated by the water moving through the inlet may help explain why the height values drop five centimeters (0.16 ft) from the ocean through the inlet to the confluence with the Amelia River. Ellipsoid height values can be plotted that map the relationship between the computed MLLW and the ellipsoid. These values and the GPS reference station used to measure the ellipsoid-MLLW separation allows kinematic GPS hydrographic surveys without tide gages.

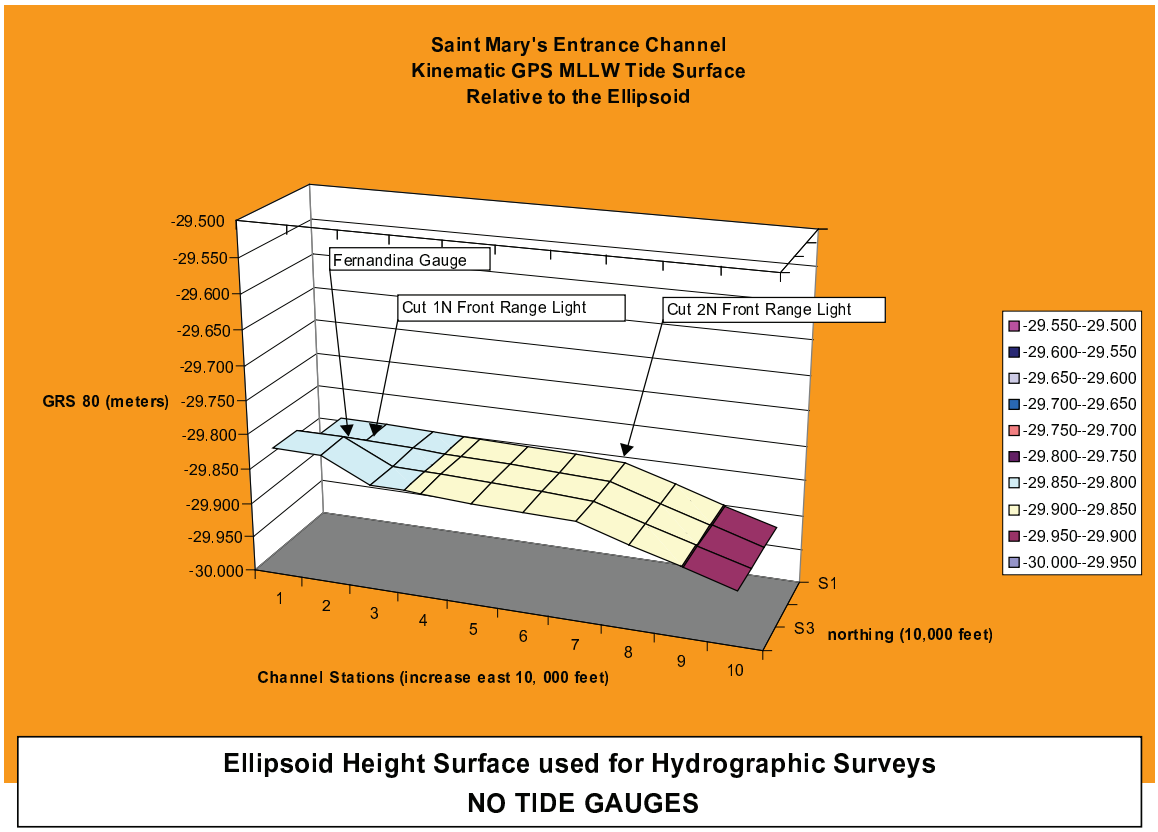


Figure H-3. Tidal model of Kings Bay Entrance Channel

H-3. GPS Reference Station. A permanent GPS reference base station (Figure H-4) was

established at Fort Clinch for future hydrographic surveys in the Saint Mary's Entrance Channel. An antenna height of (-) 20.015 m should be entered into the GPS receiver during GPS/RTK hydrographic surveys. If the RTK reference station antenna is moved, the value is invalid. If the antenna must be moved, the vertical difference between the bottom of the antenna and the reference benchmark must be remeasured-- and to confirm that the benchmark is (20.015 + 3.645 = 23.660 me below the ellipsoid. Run levels through the old antenna location and the new antenna location starting from the benchmark.

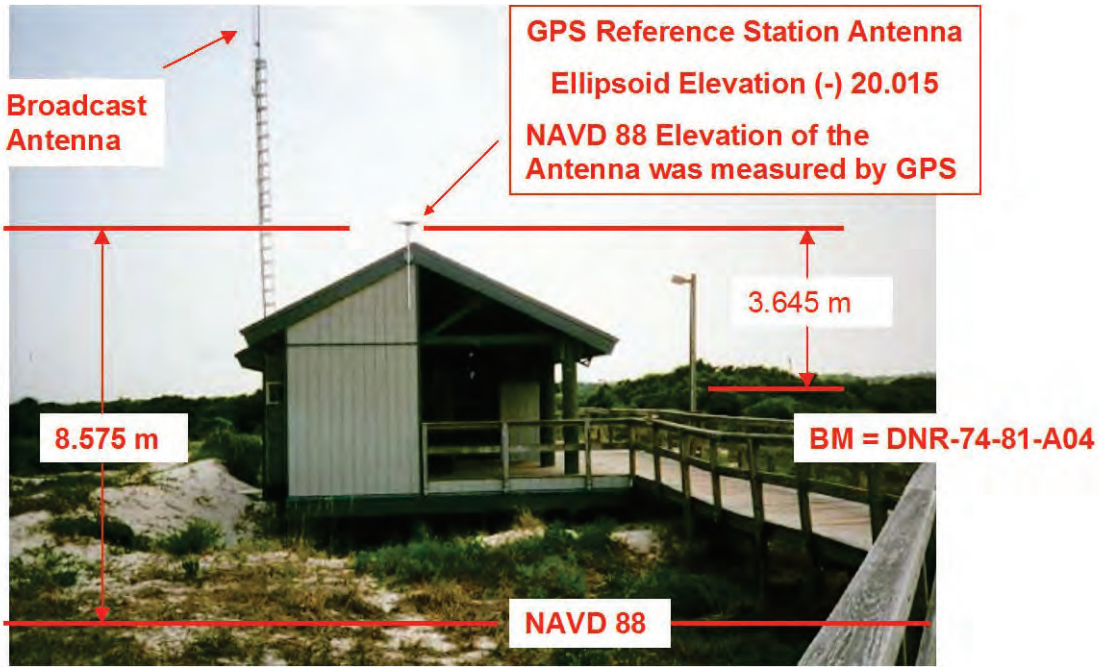


Figure H-4. RTK reference base station parameters.

H-4. Resultant RTK Elevation Accuracy. The target accuracy for real-time RTK elevations was + 0.25 feet. The resultant autonomous project accuracy is estimated to be + 0.22 feet (7 cm). The autonomous accuracy refers to the MLLW relative to the geodetic reference datum, NAVD 88. No local project modeling of the ellipsoid-geoid separation was attempted for the project. Geoid 96, a computer program written by the National Geodetic Survey, was used by entering the surveyed horizontal positions to compute the NAVD 88 /ellipsoid separations.

a. The relative accuracy of points in the channel is estimated to be + 0.13 feet (4 cm). This includes the accuracy of RTK between the boat and the reference station. The relative accuracy excludes the NAVD 88 monuments and the MLLW datum. A centimeter difference between adjusted GPS static vectors and uncertainty variations of two or three centimeters in RTK water levels observations using extremely short data series were the most difficult issues to resolve in modeling the project. The errors are insignificant for dredging. Of all the estimated vertical errors, only the GPS static survey provides a standard error of the actual measurements.

b. Hydrographic surveys for dredge payment volumes are associated with relative accuracies from the RTK reference station or relative accuracies from a tide gage. Use + 0.13 feet (4 cm) for RTK as set up for this particular channel or use + 0.2 feet (6 cm) at best by interpolating from the acoustic tide gages. Using only one tide gage, expect the accuracy to drop to at least + 0.4 feet (12 cm). Accuracy is a range not a number. This information can be used as part of the error budget associated with the accuracy of a group of soundings from a particular survey (e.g. a Mean Square Error).

H-5. Survey Vessel. The most important vertical measurement on the survey vessel is the GPS antenna phase zero measurement down to the water line of the vessel. In a static measurement condition, the measurement is as shown in Figure H-5. Underway the vessel speed through the water will change this measure. The nautical term for this phenomenon is called 'squat.' The vessel squat is not entered as a correction in the survey system in that the transducer depth is reduced by the same amount the antenna height is reduced.

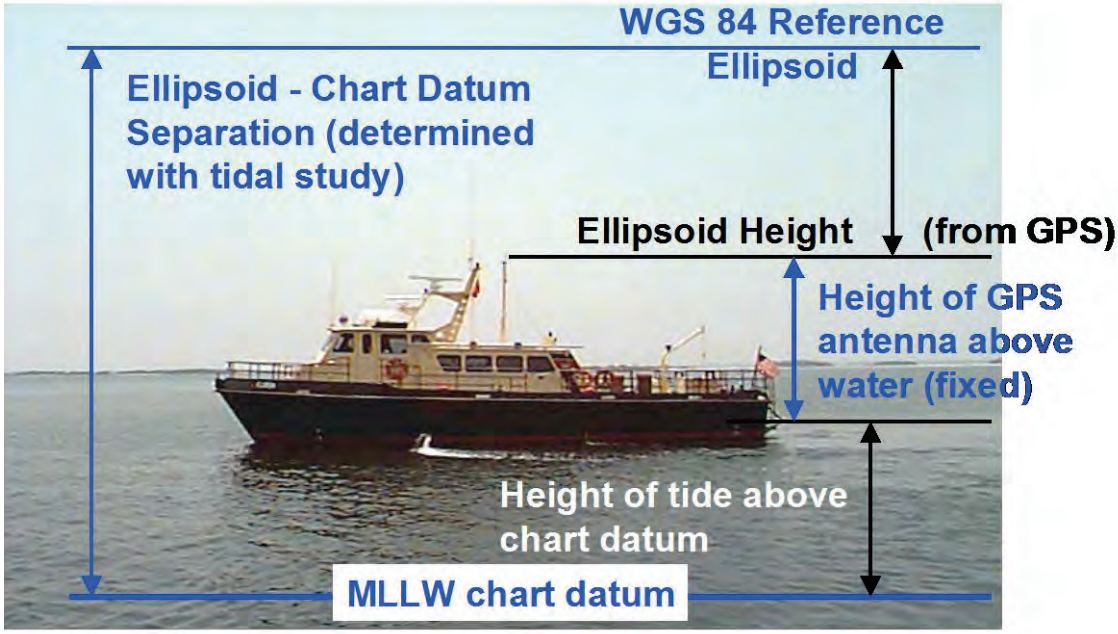


Figure H-5. RTK measurements on survey vessel

H-6. RTK Hydrographic Survey Procedures. Two survey methods are available in the Saint Mary's Entrance Channel. The traditional method will be discussed first. Two acoustic tide gages are currently running in Cut 1N on the front range light structures. The gage located on the east range light offshore has a Geostationary Operational Environmental Satellite (GOES) uplink. These data can be retrieved three hours later over the Internet as well as the Fernandina gage data. The data sets will produce a six minute time series. The inside gage is operated by the U.S. Army Corps of Engineers (USACE) and must be downloaded by USACE personnel. The data from these acoustic tide gages should be interpolated to the station numbers in the

channel where surveys are being conducted. Both gages should be used to eliminate actual time differences in the channel from average time differences between the gages. Using one gage and surveying four miles from it can result in errors to 0.4 feet (12 cm) on average. The gages are separated by 8.5 nautical miles. Using both gages, surveys conducted on different days should overlay on the outside portions of the cross-sections unless dredge material has settled on the outside areas. The second method precludes the use of a tide gage during the hydrographic survey. This tidal datum diagram was used to build a MLLW surface in the Coastal Oceanographics, Inc. program HYPACK. The HYPACK manual explains the procedure. The survey vessel must have equipment to receive specific GPS information from the USACE reference station. The Jacksonville District uses Trimble 4000 SSi RTK GPS equipment and a 25 watt (joules per second) radio transmitter that broadcasts carrier corrections every second on a frequency of 164.200 MHz. To implement this technology on a survey vessel, refer to the Survey Vessel Section. Levels must be performed on the survey vessel to obtain the vessel information.

H-7. Test Results. The first test of the RTK GPS Tides separation values (ellipsoid minus MLLW) was conducted on 29 June 1998. A matrix of the separation values was constructed in the Coastal Oceanographics hydrographic survey program called HYPACK. The SV Florida ran twenty cross-sections at 100 foot spacing in Cut 1N midway between the acoustic tide gages 8.5 miles apart. The personnel then traveled to the gages and downloaded the tides for that day. Both tide gages were interpolated to establish a tide curve time series midway between the acoustic tide gages. The interpolation method was tested and found to work in this particular channel. The survey vessel ran lines of channel cross-sections in the mid-channel area under normal survey conditions. The survey was then processed in two ways: the conventional method and the RTK method. The conventional method uses the horizontal GPS coordinates but not the vertical coordinate. The tide gage data was then used to reduce the raw soundings into reduced depths relative to the MLLW. The same survey was then processed by RTK GPS. The first depth and last depth of each line was selected for a comparison with the GPS depths differenced relative to the tide gage reduced depths.

APPENDIX I

Implementation of Inertial-Aided Post-Processed Kinematic GPS
Cape Canaveral, FL (Jacksonville District)

This Jacksonville District report describes the implementation of Applanix Post-Processed Kinematic (PPK) survey applications at a remote borrow site offshore of Cape Canaveral, FL. It also shows a comparison between PPK and RTK surveys near a reference gage.

I-1. Smart Base and Single Base Processing Using Applanix In-Fusion Technology. Traditional GNSS positioning techniques are degraded by the effects of the atmosphere, satellite clock errors, and satellite ephemeris uncertainties. In order to reduce the effects these variables, shorter baselines are utilized to maintain correlation with the base station observables. The Applanix In-Fusion Technology combines the GNSS receiver's pseudo range and phase observables with the Inertial Measurement Unit (IMU) data. This "fusion" of GNSS and IMU observables results in a more accurate analysis of positional and inertial data. The "synergy" resulting from this integration allows extended baseline lengths while still achieving higher levels of accuracy than with traditional GNSS positioning techniques. The post-processing capabilities resulting from the storage of the real-time GNSS and inertia observables also allows users to perform surveying activities without relying on radio corrections from a base station. This factor has always been a hurdle for performing surveys with high accuracy requirements outside radio range from the base station.

I-2. Inertial-Aided Post-Processed Kinematic (IAPPK) Tides. Hydrographic surveying procedures incorporate a variety of positioning techniques while collecting bathymetric data. Code phase DGPS and RTK are currently the most popular methods of determining vessel position while collecting bathymetry. While both methods have proven to be effective and somewhat reliable, their accuracy deteriorates when working outside their intended range parameters. DGPS positioning techniques provide meter- to sub-meter horizontal positioning accuracy to the survey vessel. The vertical accuracy of DGPS is not suitable for tidal reductions and thus requires a tide gauge augmented with logging capabilities or a radio transmitter to relay water level information to the surveyor. This method is somewhat limited in range and only gives accurate tidal reductions in close proximity to the gauge itself. It is incapable of accounting for variations in water surface profiles arising from tidal phase lags and extrapolated tidal readings. In regions with large tidal ranges such as those in the northeast, these effects can become quite large. In order to overcome the effects of these variations in water surface profiles, other methods must me utilized. Some surveyors set multiple gauges within their project reaches in an attempt to minimize the effects of water surface variations. An easier and more accurate solution incorporates the use of RTK (real-time kinematic) positioning.

a. Real-time kinematic tides have become the preferred method of collecting bathymetry data with high accuracy requirements. This technique achieves centimeter level accuracy both horizontally and vertically. It has the ability to accurately determine tides without the errors

associated with localized tide gauge readings. This method does, however, have its weaknesses. RTK tides depend on corrections from a base station. The base station collects carrier phase data and transmits corrections to the survey vessel. This technique assumes similar atmospheric conditions at the vessels location. This is usually accurate over short baselines (< 10 km but is not true over longer distances. Generally, the RTK corrections are incapable of reaching their intended target at ranges much greater than this anyway. Post-processing methods must then be incorporated to correct the real-time observations to an acceptable accuracy level.

b. Post-processing opens the door to a new realm of accuracy capabilities. Real-time positioning observables can be analyzed, filtered, and smoothed in an attempt to achieve higher accuracies at greater distances. When performing a survey in real-time, surveyors rely not only on their GNSS system for positioning, but also the aid of inertial measurement units. Post-processing provides surveyors the opportunity to reproduce real-time events while incorporating other sensor data such as inertial measurements into the solution. Limited satellite availability, radio communication, and extended baselines have typically hindered the ability to achieve high accuracy surveys under some circumstances. This hurdle has been overcome with the advent of IAPPK or Inertial-Aided Post-Processed Kinematic positioning. GPS outages and other anomalies incorporated within the real-time data collection are smoothed therefore producing the optimal solution. This is done by a forward, backward, and combined filtering process using the position and inertia data received from the GNSS receiver and the IMU. This is where the Applanix In-Fusion Technology got its name. The POSPAC MMS software "fuses" or integrates the GNSS and IMU data and creates a SBET or Smoothed Best Estimate of Trajectory. This software will be used to analyze several data sets using multiple processing techniques to demonstrate IAPPK and its applications.

I-3. Hydrographic Applications in IAPPK. There are a multitude of applications in which IAPPK can and should be utilized. The techniques mentioned previously outline the different methods used to collect bathymetric data as well as the errors associated with each. To demonstrate the procedure of post-processing inertially-aided kinematic positions, several scenarios are illustrated below. The following sections and screen captures describe the procedures for processing POSPAC data.

a. Offshore (10-70 km) Applications. When performing surveys within the range of 10-70 km from the shoreline, maintaining radio communications with the base station can be somewhat of a problem if not impossible. Tide gauge readings do not meet accuracy requirements at this range due to tidal phase lags. This leaves the surveyor with limited options to collect accurate bathymetry. The data must be post-processed in order to achieve the desired level of accuracy. The following illustration outlines the procedure of using POSPAC MMS Single Base In-Fusion Technology and HYPACK to process bathymetry of a borrow site located approximately 10 miles offshore.

b. Cape Canaveral Borrow Site Survey. The depiction in Figure I-1 illustrates a project in which the RTK base location is incapable of transmitting corrections to the survey site due to

range limitations. There is an active NOAA tide station located approximately 12 miles west of the survey site. This site was determined to be too far from the survey site due to phase lag issues resulting in inaccurate tidal extrapolations. IAPPK tides processed using POSPAC MMS and HYPACK were chosen to perform the survey.

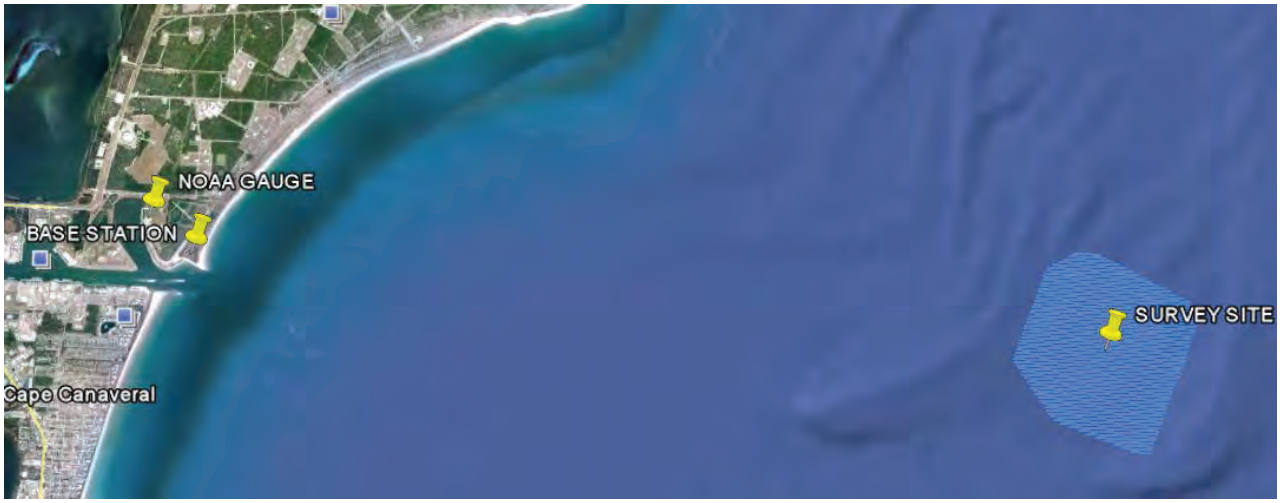


Figure I-1. Cape Canaveral Borrow Area.

c. Setting up the Hardware. Prior to surveying, setup the real-time data strings to be logged. The POS MV has an auto select option that simplifies this process, as illustrated in the following screen captures.

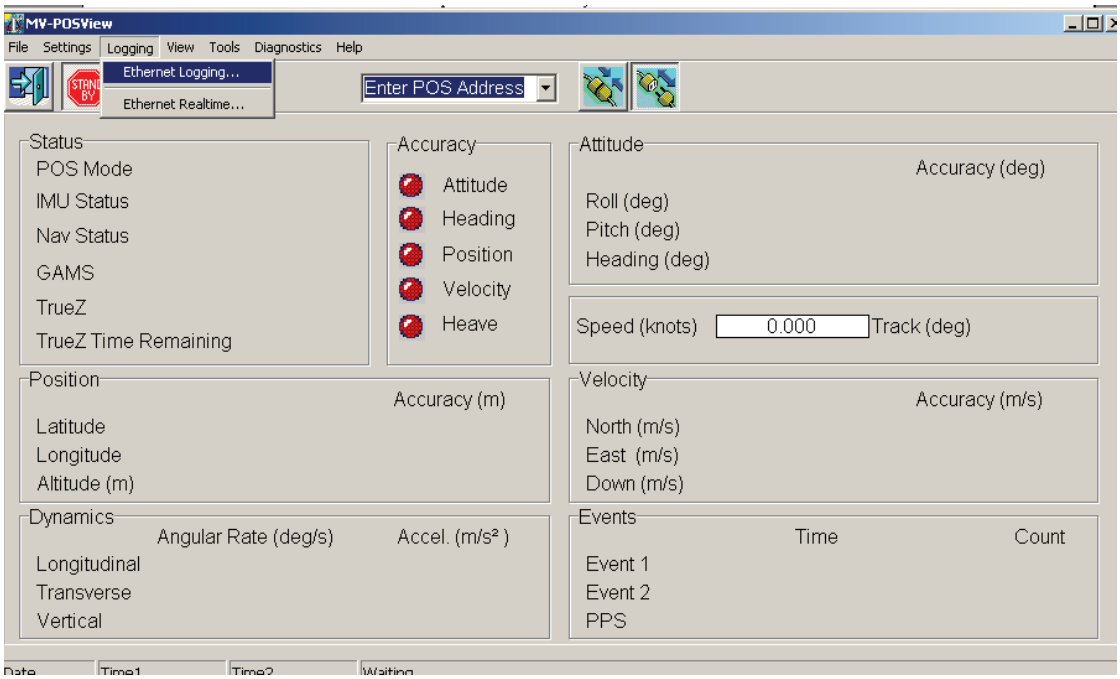


Figure I-2. MV-POSView, the startup screen on the GUI.

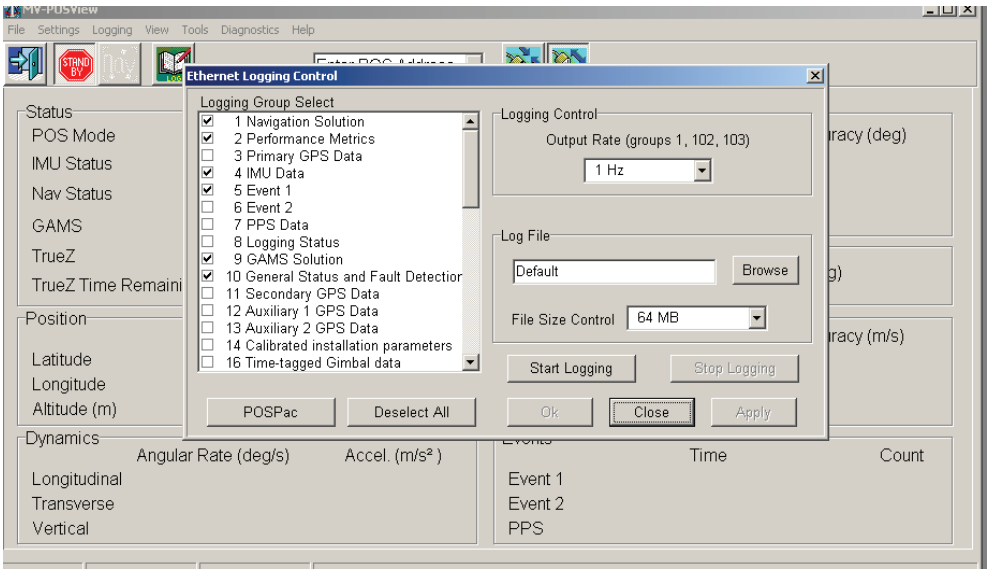


Figure I-3. Ethernet logging options window inside MV-POSView.

d. It is recommended to begin logging the POSPAC file for at least 15 minutes prior to proceeding with the data collection.

e. HYPACK Hardware Setup. Next, there are certain settings that must be addressed within the HYPACK Hardware program:

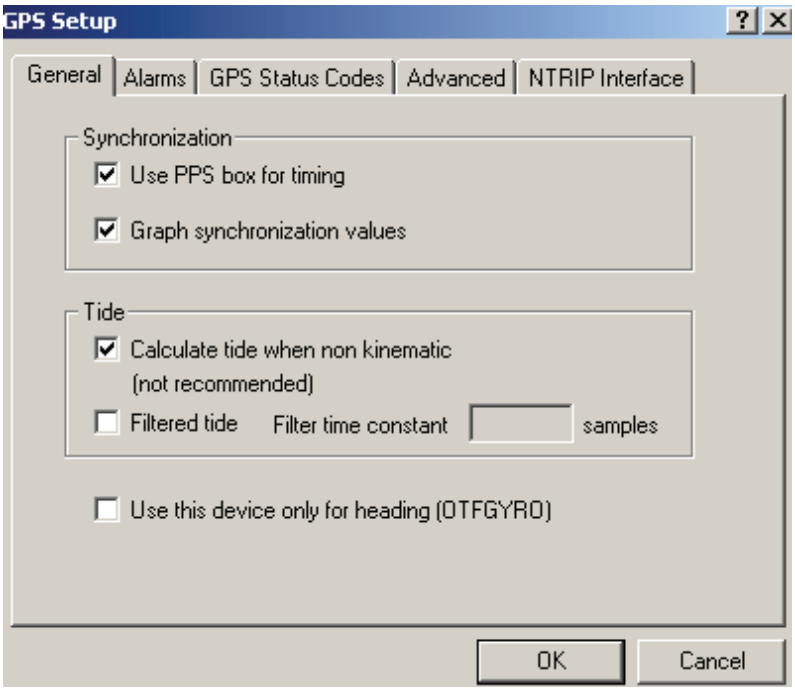


Figure I-4. HYPACK Setup window for the GPS.dll driver.

f. HYPACK must be set up to calculate tides when non-kinematic. This tells the software to look for a tidal correction from the GPS driver when proceeding into the processing mode following the data collection.

g. Processing the data. Initiate POSPAC MMS and begin a default project. Save the project with the appropriate project name and import the data files. The first step is to import the POS file (.000) logged by the Applanix. This file includes all GNSS and IMU data collected by the vessel during the real-time data collection. Another potential use of POSPAC MMS is any lever arm offsets input into POS VIEW prior to data collection can be adjusted in the Settings of the POS file once loaded. The new lever arm values will be applied in post processing. Various POSPAC MMS processing screen captures are shown below.

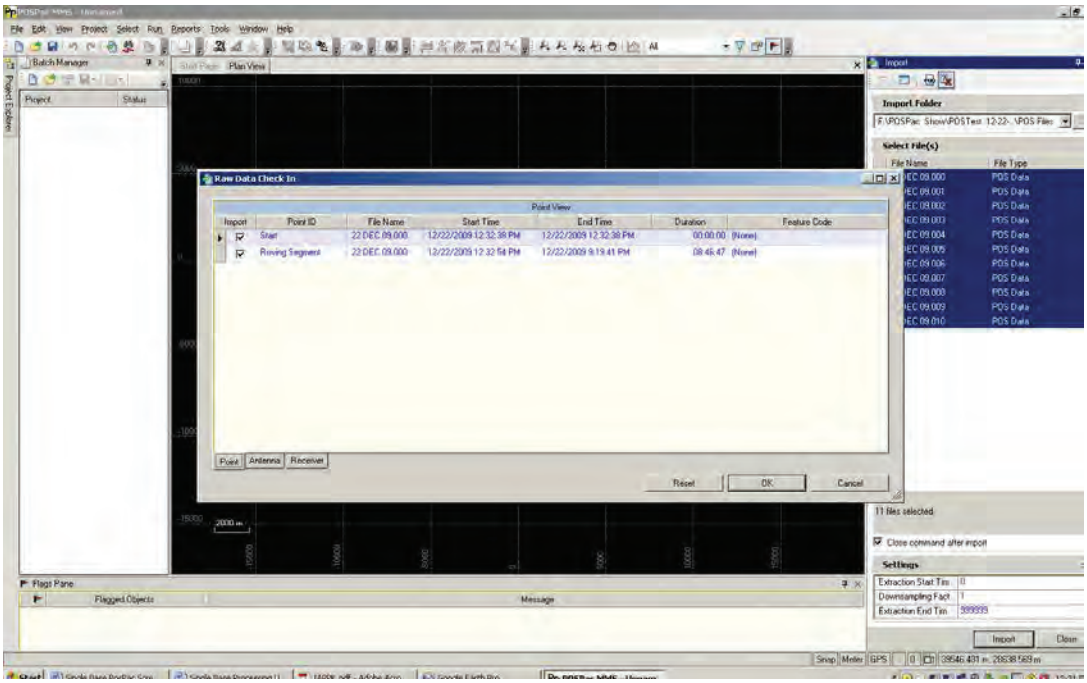


Figure I-5. Options window for importing Logged GPS and IMU data into POSView MMS.

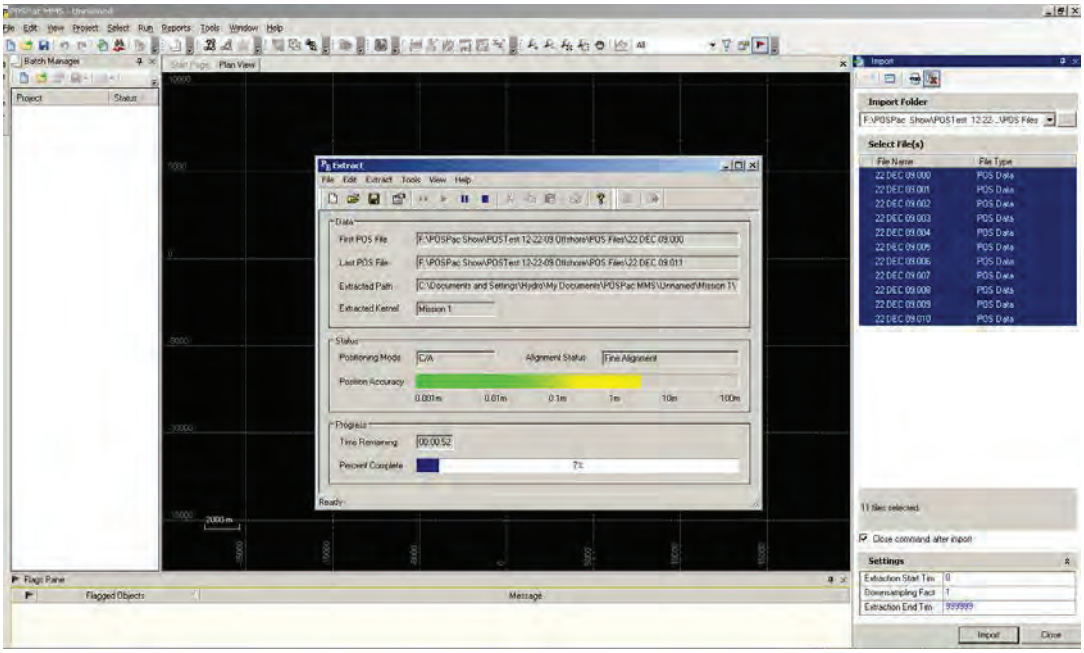


Figure I-6. Progress bar of logged GPS and IMU while being imported into POSView MMS.

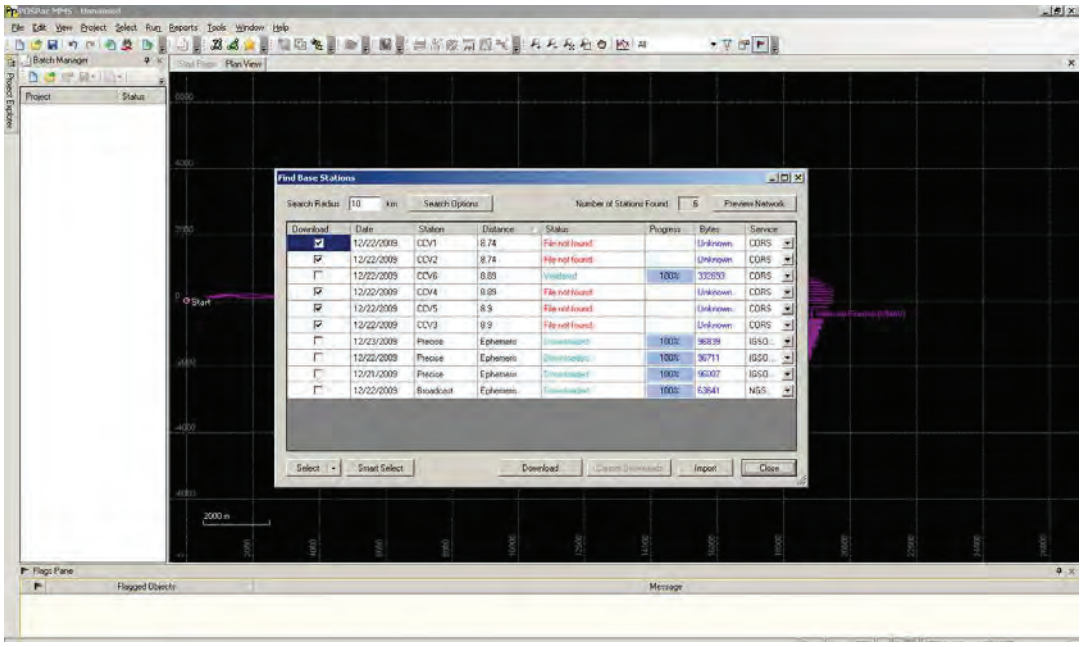


Figure I-7. Search results of available CORS data from time of survey.

h. POSPAC MMS processing. There are several ways to proceed at this point. The POSPAC MMS software allows users to choose single base or Smartbase to process the POS file. This example will utilize the single base method. First, download the ephemeris and Rinex files from the selected control station. If a local single base station is used, the ephemeris data does not need to be downloaded, which would allow the user to post process the data without an internet connection. Jacksonville District has processed multiple data sets using the single base station with and without the ephemeris and has seen no difference. This can be a control station set up by the surveyor or one of the many CORS stations near the project. The following example will demonstrate how to download the raw GPS data from a CORS station. It should be noted that there are many times that a certain CORS station does not have data available, which would force one to use a CORS station much further away which leads to less accurate results. Jacksonville District has found it best to set up a local Base station to log to and have the CORS Stations as a backup.

i. Click on the "Find Base Stations" icon and select a search radius. Start out small to determine what is available within the project vicinity. An internet connection is required to proceed with this method. The software automatically links to the appropriate websites to retrieve the raw data files needed to process the data. Optionally, download all the available data files in order to see the locations of the available control sites. The available stations can be viewed by the Preview Network button on top of the window instead of downloading them all. Once the appropriate files are downloaded, select the files to import. Import the Rinex files as

well as the ephemeris files for the appropriate time frame. POSPAC MMS will populate the appropriate ephemeris files.

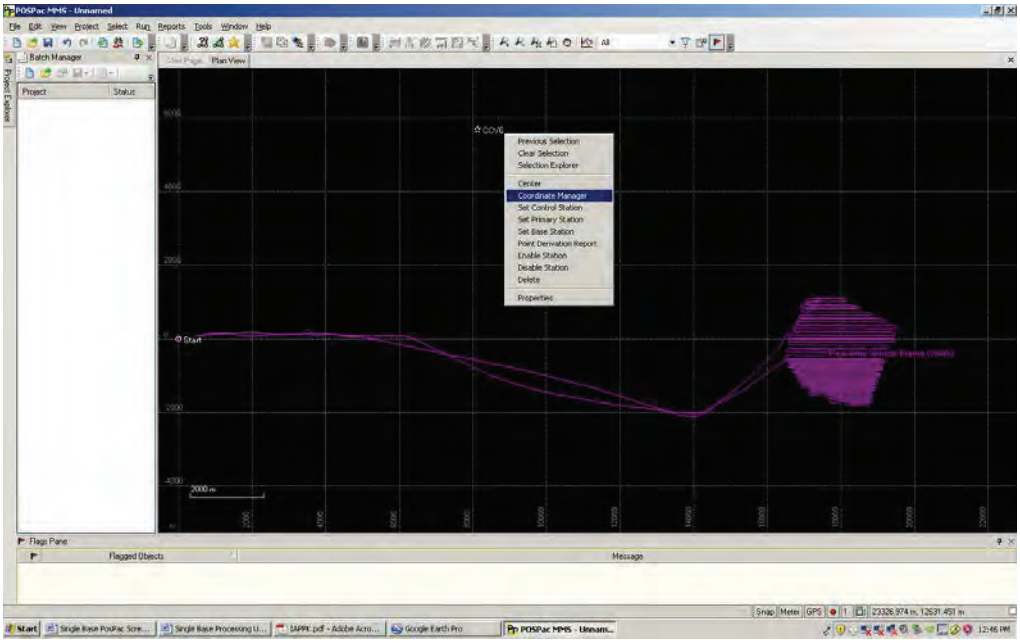


Figure I-8. Right clicking on the control point will produce the drop down menu for the selected point.

j. The control station is now populated within the project. Now evaluate the properties of the control station. This should always be done. At times the coordinates from a CORS station have been found up to three feet off. Input the coordinates of the station or change other properties such as antenna type and set-up height.

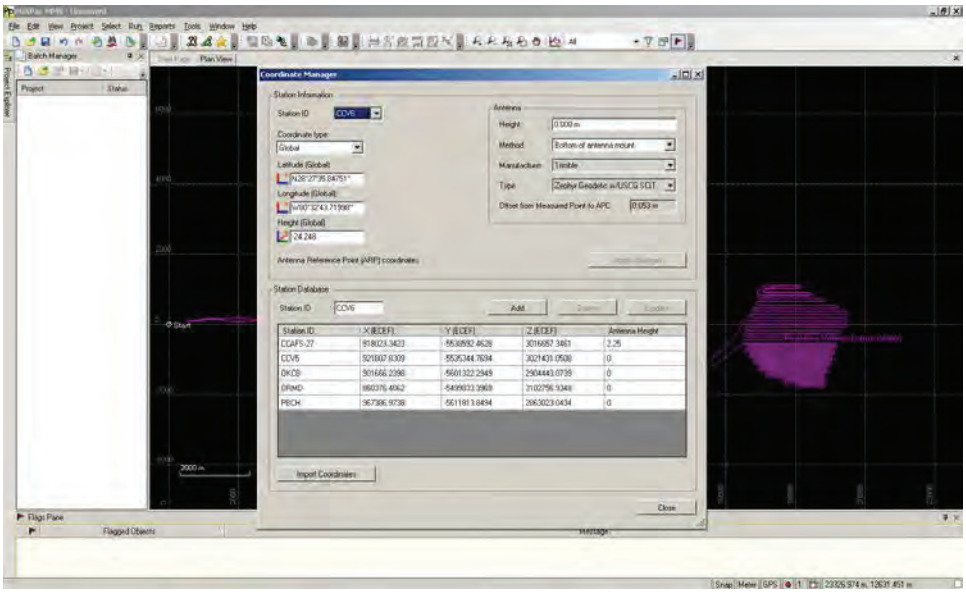


Figure I-9. POSView MMS Coordinate Manager options window.

k. Set the selected point as a base station.

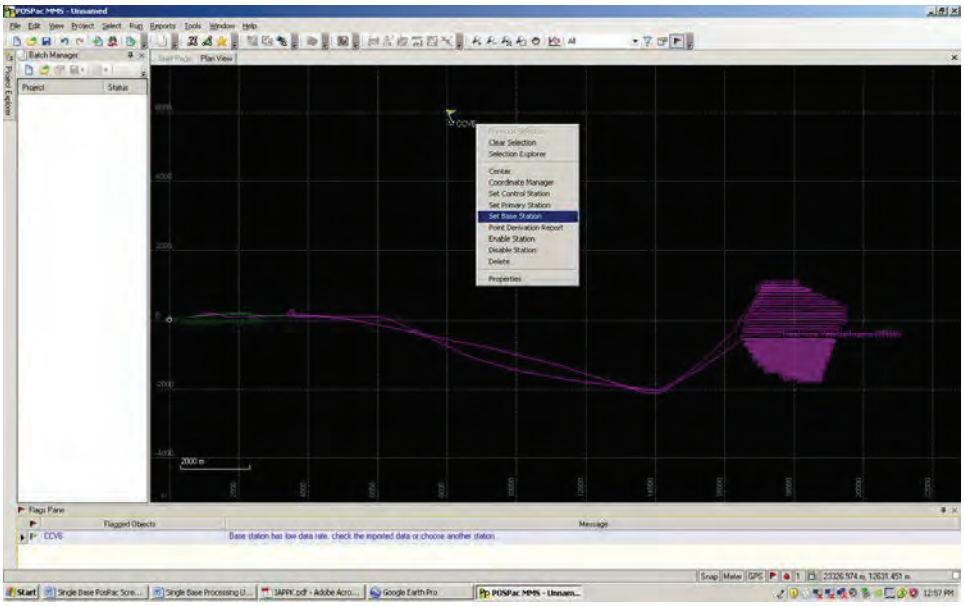


Figure I-10. Setting the selected control point as the base station for post-processing.

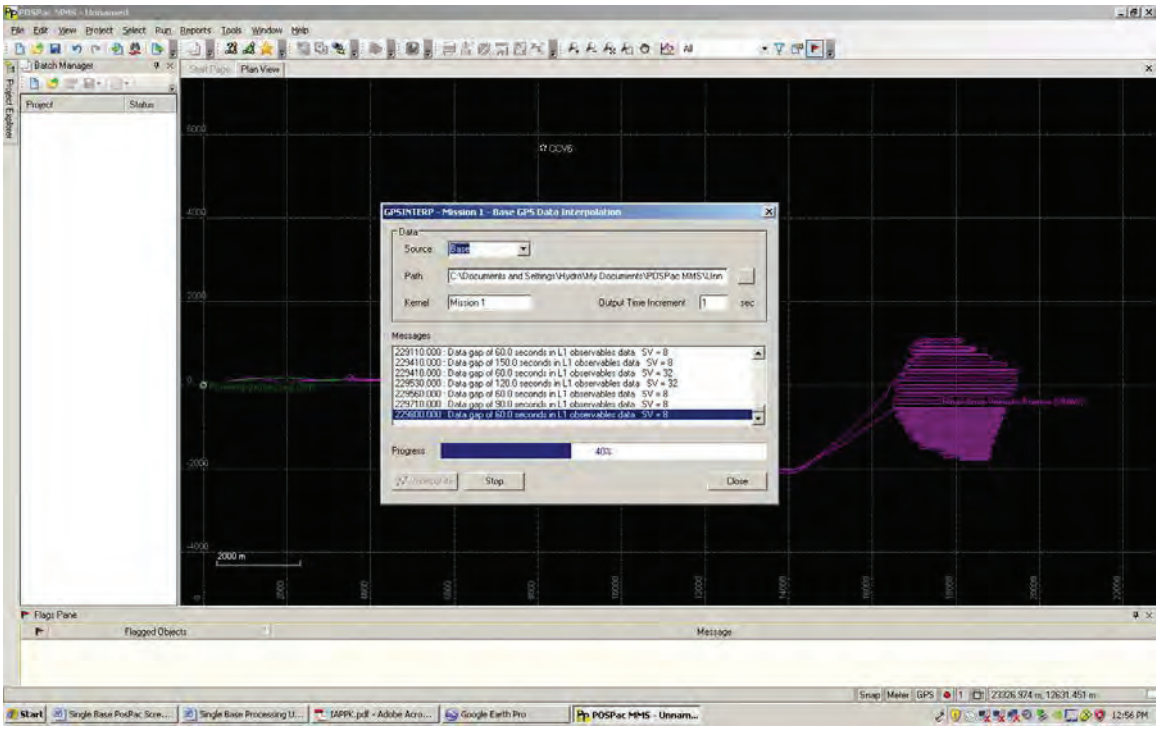


Figure I-11. Progress window of POSView MMS setting the selected base station.

l. Once these parameters are set, proceed to the GNSS-Inertial Processor.

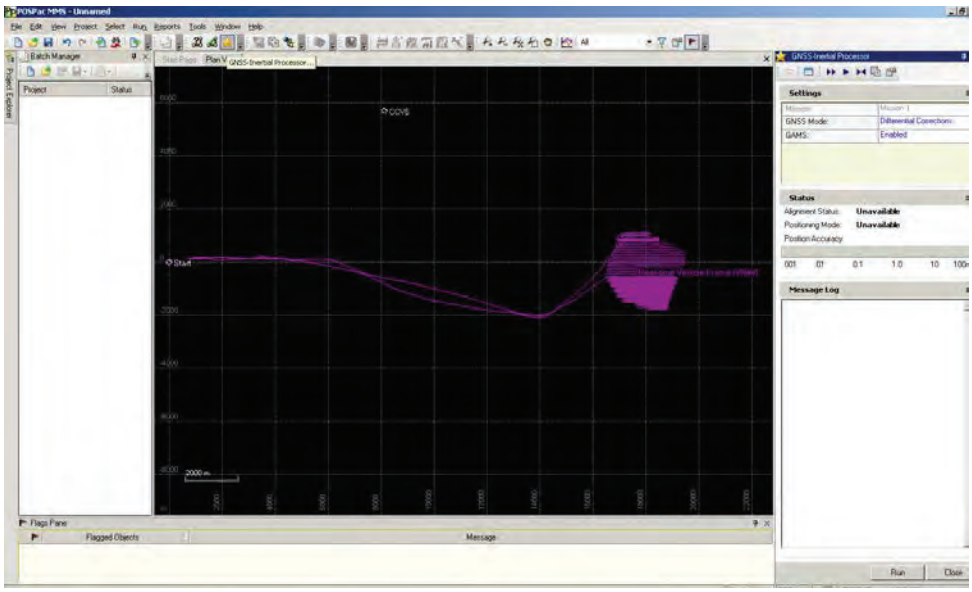


Figure I-12. Toolbar on right side screen is options window for GNSS Inertial Processor.

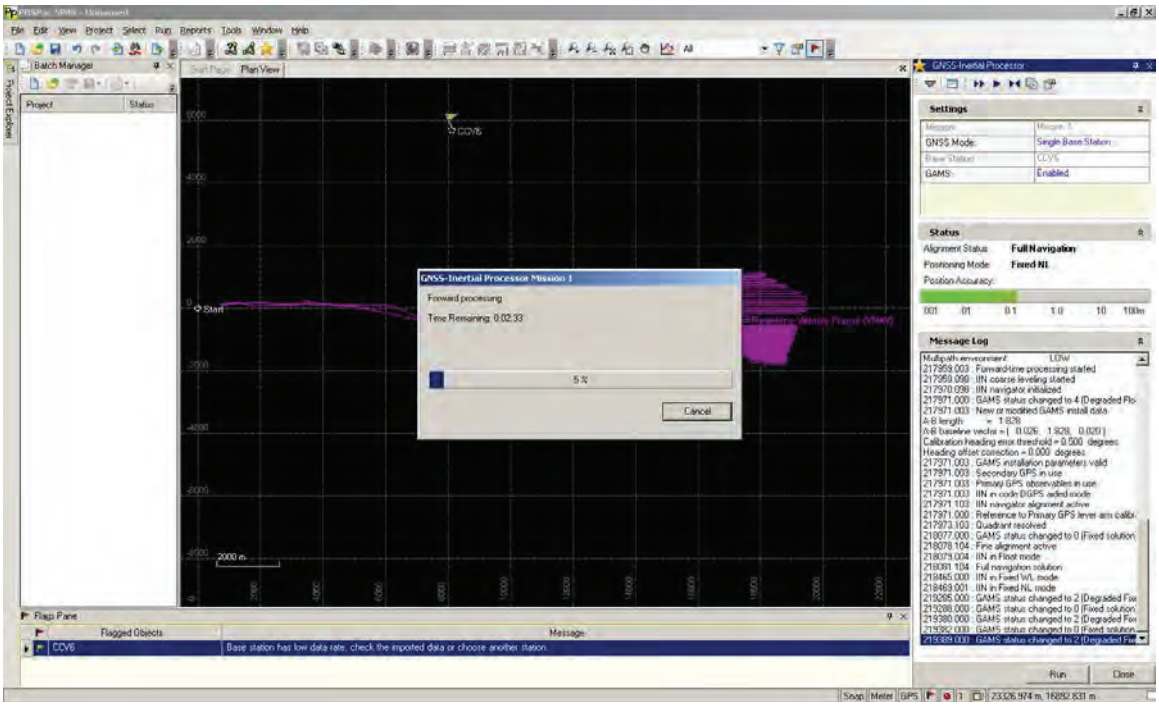


Figure I-13. Progress bar of GNSS Inertial Processer- note bar on right shows adjusted solution status.

m. The software is now performing the forward, backward, and combined integration and filtering of the GNSS and inertial data. The result will be a Smoothed Best Estimate of Trajectory (SBET) that will be used by HYPACK to reposition the sounding data. Next, analyze the results of the processing for quality control. The software creates a multitude of reports describing both real-time and post-processed data events.

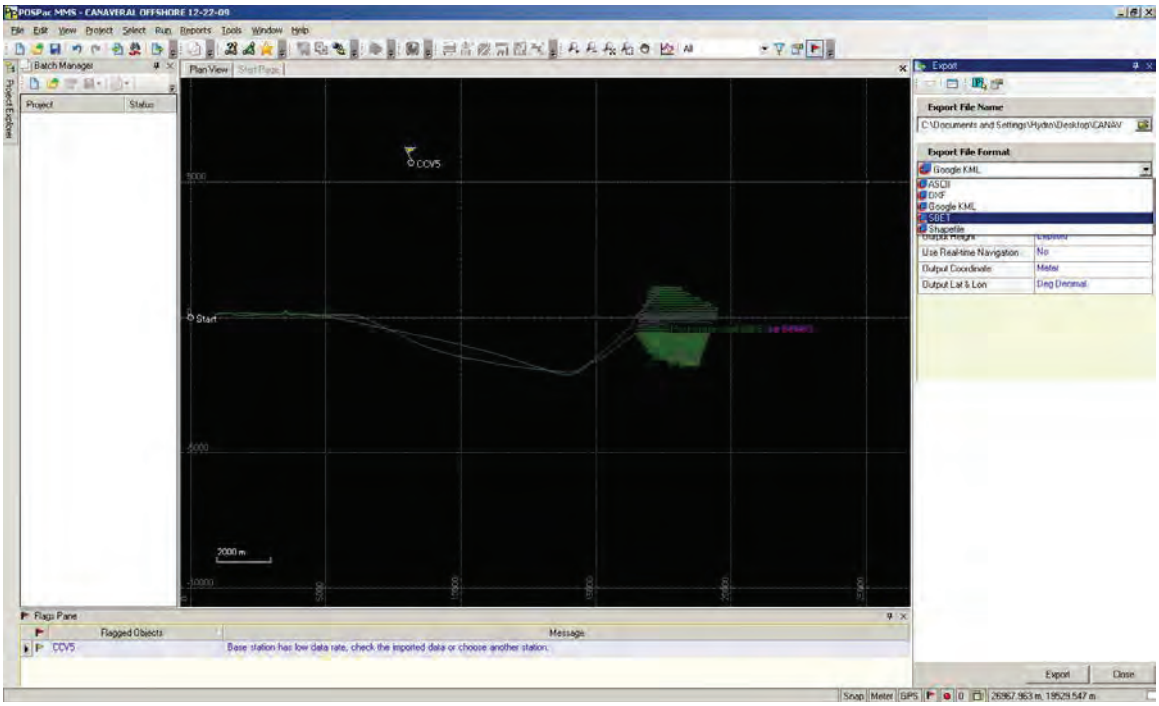


Figure I-14. The export toolbar on the right of the screen showing all the available export formats.

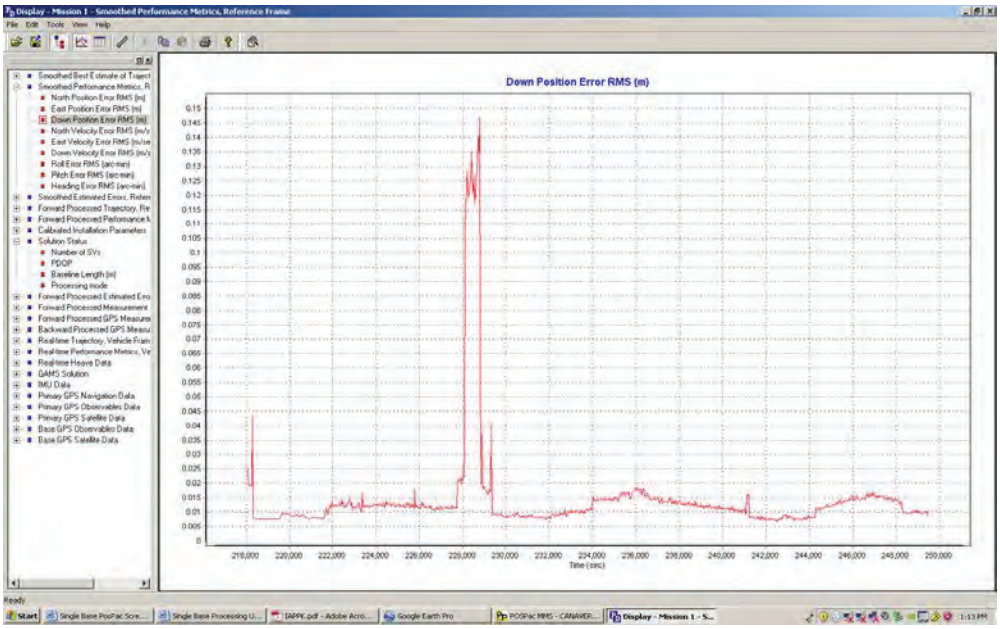


Figure I-15. Down position error RMS of the post processed solution.

n. The depiction above represents an example of one of the solution reports created by the software. This particular graph indicates the RMS of the SBET's altitude parameter. After reviewing the data and exporting the SBET file, begin processing the sounding data in HYPACK.

o. Open HYPACK'S Single Beam Editor and proceed to the read parameters. The following boxes must be checked. Make sure the project geodesy is properly configured. If there are any Orthometric height corrections, KTD files, etc., HYPACK will apply these corrections to the data in the processing phase. The KTD file will only be applied if the file is enabled in the HYPACK shell before the editor is opened. Also note that the HYPACK hardware in the processing job must match the hardware settings from the HYPACK job that was used for data collection. If this is not done the file will appear to be applied but the Tide values will "0" through all files.

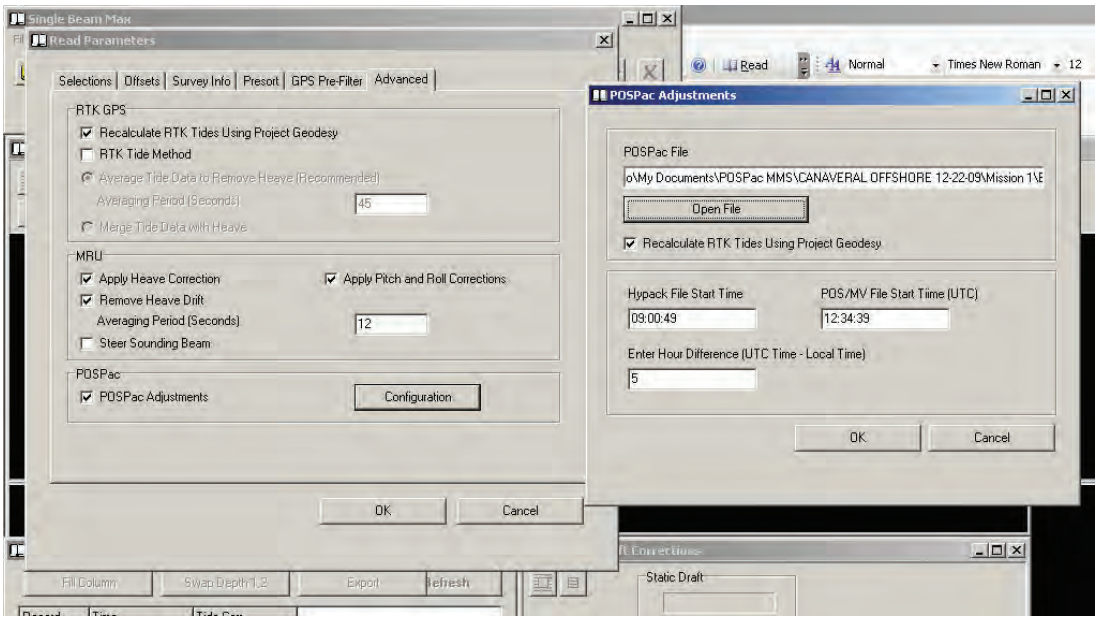


Figure I-16. Read Parameter window in HYPACK, shown importing a SBET file exported from POSView MMS.

p. Load the SBET file produced by the POSPAC MMS software. Select the Configuration icon within POSPAC Adjustments and load the file. Be sure to enter the difference between UTC Time and Local Time. Account for daylight savings time if applicable. Click OK and stand by while HYPACK loads the file and applies the corrections. This process will take several minutes and depends on the size of the SBET file.

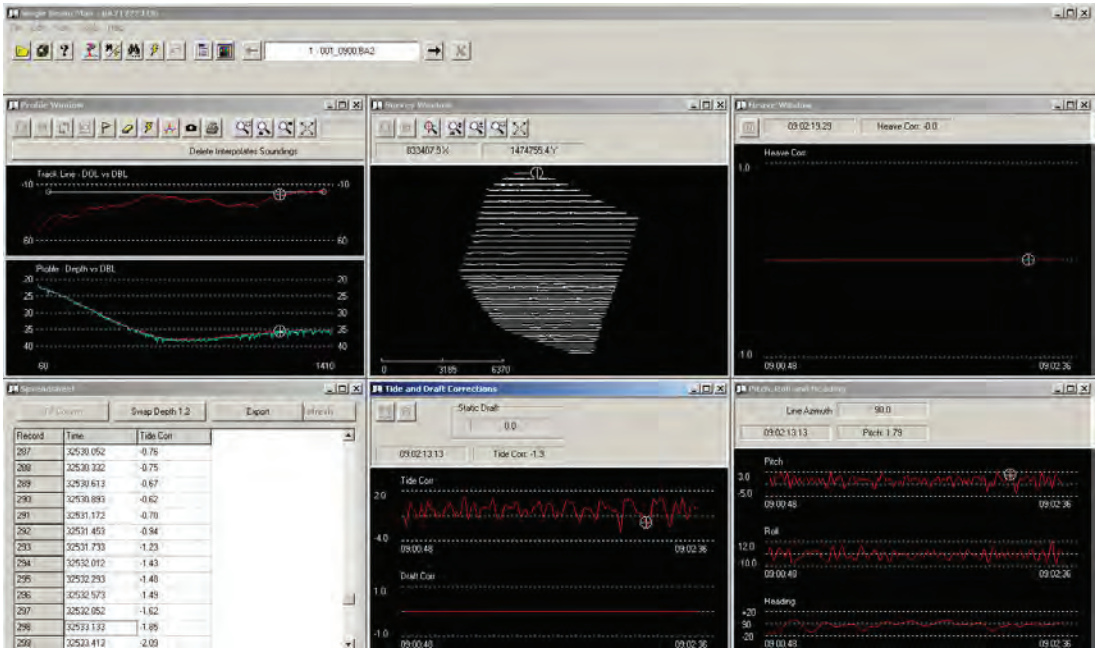


Figure I-17. Typical windows from HYPACK Single Beam Editor (SBMAX.)

q. Once the file is loaded, proceed with processing the sounding data as with any other setup.

I-4. Analysis.

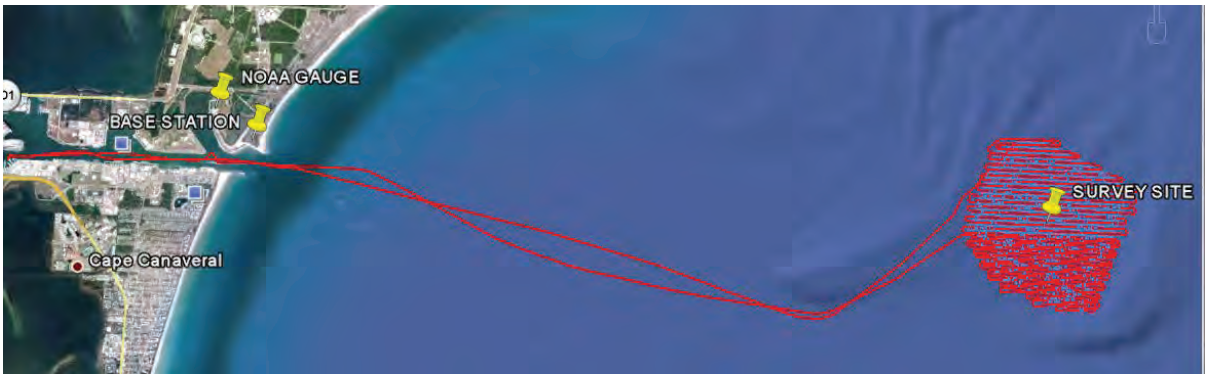


Figure I-18. An exported Google KML file from POSView MMS.

a. The SBET file is shown here as a KML file within Google Earth. The real-time data was collected using DGPS while logging a POSPAC file within the Applanix. The data was processed using the extrapolated tidal readings from the NOAA gauge as well as with the SBET

file created by the POSPAC MMS software. A sounding matrix depicting the two methods is shown below.

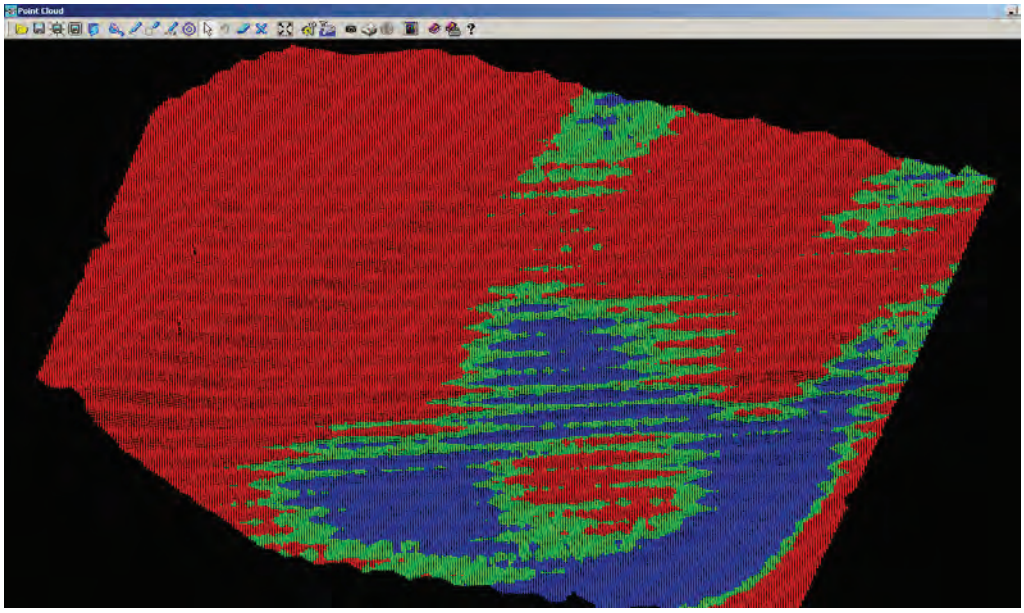


Figure I-19. Sounding Matrix showing phase lag errors caused by tides.

b. The bathymetry depicted above was collected with single beam at a 150' line interval. The data was then tinned and exported on a 25-foot grid. The data was collected on two separate days. Each day, every other line was surveyed in order to amplify any phase lag errors. Note the stair stepping of the data set. This data set was processed using observed tidal readings at the NOAA tide gauge. This gauge is approximately 12 miles from the survey site. The tidal observations at this gauge site have introduced phase lag errors into the data set.

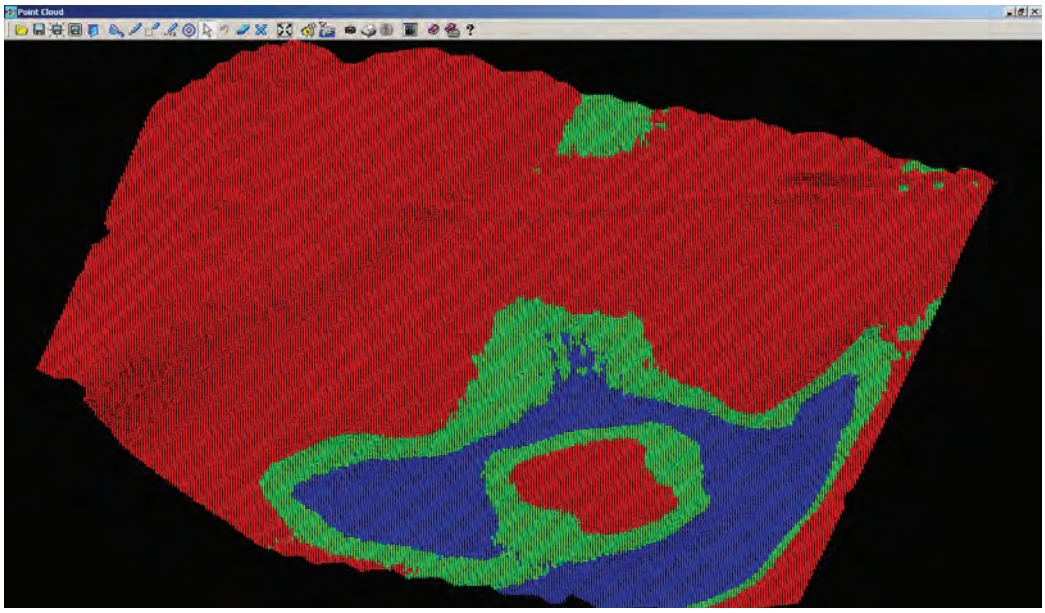


Figure I-20. Same data set, but with POSView MMS SBET file applied.

c. The bathymetry depicted above is the exact same data set processed using the Single Base Applanix In-Fusion Technology. Note the data has been smoothed and corrected for phase lag errors.

I-5. Inshore Applications. When performing surveys within a network of multiple CORS stations, a PPVRS (Post-Processed Virtual Reference Network) with the Applanix Smartbase solution is the best course of action. The POSPAC MMS software has the capability of creating a virtual reference network that completely envelops the project. This process reduces or eliminates errors associated with atmospheric biases.

a. Setting up the hardware. This method utilizes the same hardware set-up as the single base solution.

b. Processing the data. Most steps in the data processing are identical to the single base solution. The main difference is rather than downloading raw observables for a single base, we will download multiple base files in an attempt to create a network that encompasses our navigation data. Once the station data is downloaded for each site, the POSPAC MMS software will perform a network adjustment and select a single base to minimally constrain the network dependent upon the general location of the navigation data. This process creates what is known as a VRS (virtual reference station). In effect, the VRS creates a zero baseline length solution while working within the limits of the network. The figures below depict the process of creating this network.

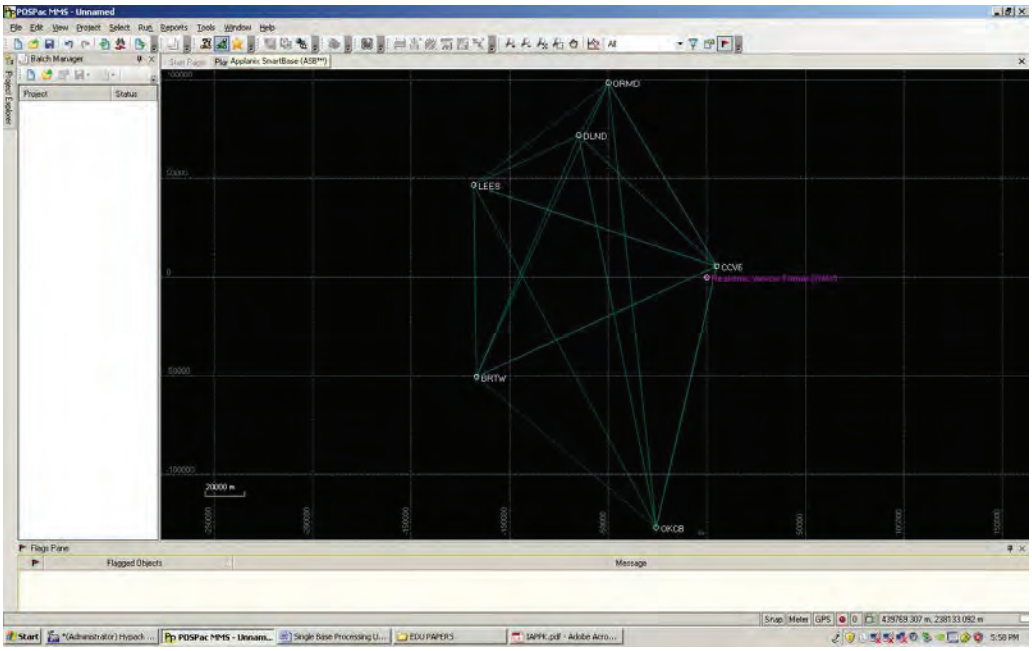


Figure I-21. GPS network created from CORS available during time of survey.

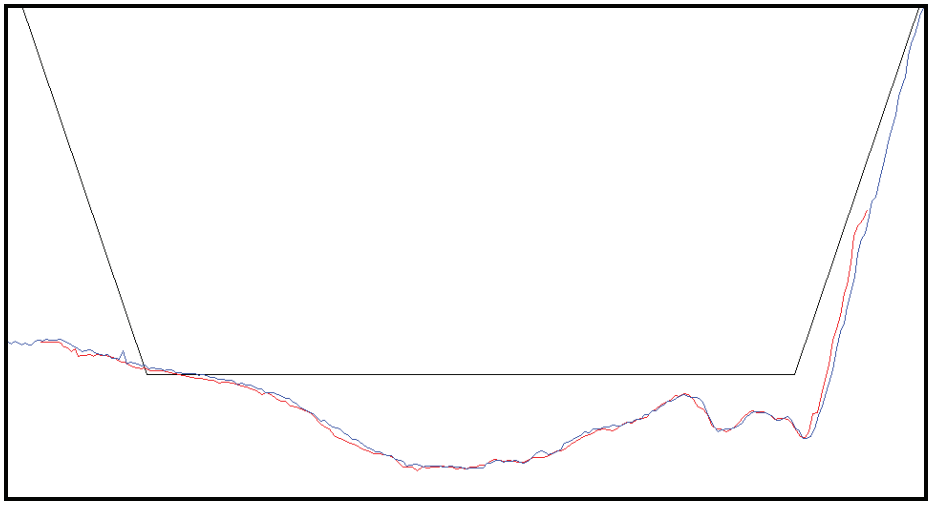
c. Download available GNSS data within the vicinity of the project. This is done be selecting a search radius around the navigation data and allowing the software to populate available sites. Once the sites are downloaded, preview the network and select the sites to utilize. The next step is to allow the POSPAC MMS software to perform the network adjustment and select a Smart Base. This is done by simply clicking the Applanix SmartBase icon.

Figure I-22. Applanix SmartBase Icon located on POSView MMS main toolbar.

d. Proceed with the GNSS-Inertial processing and export the SBET file for HYPACK. This process is performed in the same manner as previously discussed with the Single Base solution.

Figure I-23. Google KML file created by POSView MMS.

e. Analysis. The SBET file shown above is a KML file within Google Earth for Port Canaveral. The real-time data collection was performed twice. Once in stand-alone mode while logging a POSPAC file within the Applanix, and again utilizing RTK positioning from a base station approximately located one mile east. The data was processed using the RTK positioning as well as with the SBET file created by the POSPAC MMS software. This was done to demonstrate the post-processing ability of the POSPAC MMS software. There is essentially no notable difference between the two data sets. The cross section comparisons are shown below.



Red = RTK FIXED BLUE = PPVRS

Figure I-24. Cross section comparison of data using PPK vs. data using Real-time RTK

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APPENDIX J

Field Survey Report: Project Condition Survey
Tampa Harbor, Egmont Bar Channel and Mullet Key Channel (Jacksonville District)

J-1. Following is a typical field report for a project condition survey. Information from such reports is incorporated on the final drawing files and included with metadata archives. Portions of this 2011 report have been edited to conform to the revised guidance in Chapter 8 of this manual.

SURVEYOR'S REPORT
Hydrographic Survey
Pinellas County, FL
Survey Number 11-031

Project: Tampa Harbor, Egmont Bar Channel and Mullet Key Channel 43 & 45-Foot Project Examination and P & S Survey, FY11

Location: Tampa Harbor, Hillsborough County, Florida

Date: Field data was acquired from 19 Jan thru 6 Jun, 2011

Personnel: SB-Jacksonville System Operator: Gary Campbell; Boat Captain: William Turner.

Datum: The horizontal coordinates are referenced to the State Plane Coordinate System, Florida West, North American Datum of 1983 (NAD 83). Elevations are referenced to MLLW from the latest tidal epoch available from NOAA. The MLLW-NAVD88 relationship was modeled using NOAA's V-Datum and incorporated into the HYPACK Kinematic Tidal Datum Model for Tampa Harbor. The KTD file SPC-FL-West-2010-12-07.ktd was utilized for this survey.

Instruments: The following instruments were used for data collection:

Survey Vessel: SB-Jacksonville

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Data Collection Software: HYPACK version 2010
Sounders: R2 SONIC 2024 Multibeam System
[Ross Smart Sounder 835 -- 28 and 200 kHz-not used]
Positioning: Applanix PosMV 320
Trimble 5700 Base Receiver/ Trimble Trimmark3 Radio
IMU: Applanix PosMV 320

Field Procedures: A multibeam condition survey was conducted on the subject project cuts. Survey lines were run parallel with the channel at a line spacing affording 100% bottom ensonification. Side slope coverage was approximately 100 ft outward from the channel toes. This survey was controlled utilizing Real-Time Kinematic (RTK) GPS for horizontal positioning and water surface elevation determination. The base receiver was set on survey monuments "TH-89 USE" (AG0988) for all cuts. A tide staff was established from NOAA monument "6367 C" (AG7401) and read to verify RTK tide elevations. The staff set at this location depicts tide data with respect to MLLW relative to the latest tidal epoch. Tide staff v. RTK surface elevation checks were performed before and after daily survey operations. These calibrations were recorded in Tampa Harbor field survey book TH-06. Monument data can be reviewed in *APPENDIX A*.

Special Notes:

Quality Assurance: The previous surveys performed were longitudinal line surveys; an accurate comparison between the current cross-section survey and previous surveys cannot be made. Spot checks between previous and current data sets were made and found to be very close (<0.2'). A QA Performance Test was conducted. Biases between the reference and check surveys were +0.05 ft and the 95% standard deviation was ±0.5 ft within the ±45 degree beam width.

Draft & Sound Velocity Calibration: Draft & Sound velocity corrections were obtained via bar check and Odom Digibar velocity probe performed within project area. Speed of sound checks were performed daily in the project area. Complete records of bar checks and velocity calibrations are logged in Tampa Harbor field survey book TH-06.

Data Processing: The survey data was processed aboard the survey vessel upon completion of the survey. Since this entire survey was performed using Multibeam systems, quality assurance was performed during HYSWEEP processing by visually examining differences in overlapping lines as well as overlapping segments. No anomalies were found.

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Field Conditions: Sea state and weather conditions varied, but remained within survey tolerances.

Prepared and Submitted By: Matthew R. Staley, Geodesist, USACE Jacksonville District.

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MAP SHEET NOTES:

REFER TO SURVEY NO. 11-031

ELEVATIONS ARE IN FEET AND TENTHS AND REFER TO THE NOAA REPORTED MLLW TIDAL DATUM RELATIVE TO THE 1983-2001 TIDAL EPOCH.

TIDAL REDUCTIONS WERE OBTAINED USING REAL-TIME KINEMATIC GPS AND REFERENCED TO MLLW UTILIZING A HYPACK KINEMATIC TIDAL DATUM MODEL. FILE NAME: "SPC-FL-WEST-2010-12-07.KTD." THE REFERENCE GAGE WAS NOAA GAGE 8726364 AT MULLET KEY.

ALL ELEVATIONS ARE BELOW THE CHART DATUM UNLESS PRECEDED BY A (+) SIGN.

PLANE COORDINATES ARE BASED ON THE TRANSVERSE MERCATOR PROJECTION FOR THE WEST ZONE OF FLORIDA AND REFERENCED TO THE NORTH AMERICAN DATUM OF 1983 (NAD 83).

THIS SURVEY WAS PERFORMED WITH A MULTIBEAM SWEEP SYSTEM USING REAL-TIME KINEMATIC GPS POSITIONING. WITH THE FOLLOWING REFERENCE BASE LOCATION – "TH-89 USE"

VERTICAL MEASUREMENTS WERE MADE USING AN R2 SONIC 2024 MULTIBEAM SYSTEM.

SURVEY VESSEL	*DATE OF SURVEY*	*AREA*
SB JACKSONVILLE	*19, 24, 27, 28 JAN 2011*	*MULLET KEY CUT*
SB JACKSONVILLE	*16 FEB & 16 MAR 2011*	*MULLET KEY CUT*
SB JACKSONVILLE	*3 & 4 MAY 2011*	*EGMONT KEY CUT-2*
SB JACKSONVILLE	*12 MAY & 6, 9, 21, 22 JUN 2011*	*EGMONT KEY CUT-1*

THE INFORMATION DEPICTED ON THIS MAP REPRESENTS THE RESULTS OF SURVEYS MADE ON THE DATES INDICATED ABOVE AND CAN ONLY BE CONSIDERED AS INDICATING THE GENERAL CONDITIONS AT THAT TIME. THIS CHART IS SOLELY FOR THE DISTRIBUTION OF AVAILABLE DEPTHS AT THE TIME OF SURVEY.

SURVEY ACCURACY STANDARDS, QUALITY CONTROL, AND QUALITY ASSURANCE REQUIREMENTS WERE FOLLOWED DURING THIS SURVEY IN ACCORDANCE WITH USACE EM 1110-2-1003, HYDROGRAPHIC SURVEYING, 1 JAN 02. BASED ON QA PERFORMANCE TEST RESULTS IT IS ESTIMATED THAT THIS SURVEY CONFORMS TO IHO "SPECIAL ORDER" NAUTICAL CHARTING STANDARDS.

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APPENDIX A
PROJECT CONTROL

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SURVEY DATASHEET (Version 1.0)

PID: AG0988
Designation: TH 89 USE
Stamping: TH 89 1976
Stability: Monuments of questionable or unknown reliability
Setting: Light structures (other than listed below)
Mark Condition: G
Description: Station is located in St. Petersburg, Florida at Fort Desoto County Park at southeast end of Mullet Key. Mark is set flush in top of concrete sidewalk, approximately 800 feet south of the south edge of the parking area for Fort Desoto fishing pier, 84.5 feet southwest of the northeast end of concrete seawall, 62.7 feet west of the southeast corner of concrete seawall and 5.5 feet north of the concrete seawall.
Observed: 2010-12-02T13:31:00Z
Source: OPUS - page5 1009.28

Close-up View

X= 418,136.683sft
Y= 1,192,166.878sft
NAVD88 Elev= 4.032sft

REF. FRAME: NAD_83 (CORS96)	EPOCH: 2002.0000	SOURCE: NAVD88 (Computed using GEOID09)	UNITS: m	SEI PROFILE	DETAILS

LAT:	27° 36' 41.33912"	± 0.004 m
LON:	-82° 44' 6.04376"	± 0.011 m
ELL HT:	-23.079	± 0.025 m
X:	715221.618	± 0.012 m
Y:	-5610377.876	± 0.019 m
Z:	2938411.902	± 0.014 m
ORTHO HT:	1.229	± 0.044 m

	UTM 17	SPC 902(FL W)
NORTHING:	3055367.285m	363373.191m
EASTING:	328786.273m	127448.316m
CONVERGENCE:	-0.80432851°	-0.34067366°
POINT SCALE:	0.99996185	1.00000613
COMBINED FACTOR:	0.99996547	1.00000975

CONTRIBUTED BY

francis.m.woodward
US Army Corps of Engineers

Horizon View

The numerical values for this position solution have satisfied the quality control criteria of the National Geodetic Survey. The contributor has verified that the information submitted is accurate and complete.

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NOAA/NGS Control Data

[NOTE: THE FIELD REPORT CONTAINED COMPLETE NGS DATA SHEETS FOR CONTROL USED ON THIS CONDITION SURVEY. FOR BREVITY, THIS APPENDIX EXTRACTED ONLY THE FIRST FEW LINES FOR EACH CONTROL POINT]

```
DATABASE =  ,PROGRAM = datasheet, VERSION = 7.85
1        National Geodetic Survey,   Retrieval Date = JANUARY  5, 2011
 AG0988 ***********************************************************************
 AG0988  DESIGNATION -  TH 89 USE
 AG0988  PID         -  AG0988
 AG0988  STATE/COUNTY-  FL/PINELLAS
 AG0988  USGS QUAD   -  ANNA MARIA (1981)
 AG0988
 AG0988                        *CURRENT SURVEY CONTROL
 AG0988  ______________________________________________________________________
 AG0988* NAD 83(1986)-  27 36 43.     (N)    082 44 11.     (W)     SCALED
 AG0988* NAVD 88     -         1.191  (meters)       3.91   (feet)  ADJUSTED
 AG0988  ______________________________________________________________________
 AG0988  GEOID HEIGHT-         -24.31  (meters)                     GEOID09
 AG0988  DYNAMIC HT  -           1.189 (meters)       3.90  (feet)  COMP
 AG0988  MODELED GRAV-     979,158.8   (mgal)                       NAVD 88
 AG0988
 AG0988  VERT ORDER  -  SECOND    CLASS II
 AG0988

DATABASE =  ,PROGRAM = datasheet, VERSION = 7.85
1        National Geodetic Survey,   Retrieval Date = JUNE  1, 2010
 AG7401 ***********************************************************************
 AG7401  TIDAL BM    -  This is a Tidal Bench Mark.
 AG7401  DESIGNATION -  872 6367 C TIDAL
 AG7401  PID         -  AG7401
 AG7401  STATE/COUNTY-  FL/PINELLAS
 AG7401  USGS QUAD   -  ANNA MARIA (1981)
 AG7401
 AG7401                        *CURRENT SURVEY CONTROL
 AG7401  ______________________________________________________________________
 AG7401* NAD 83(1986)-  27 37 00.     (N)    082 43 35.     (W)     SCALED
 AG7401* NAVD 88     -         1.121  (meters)       3.68   (feet)  ADJUSTED
 AG7401  ______________________________________________________________________
 AG7401  GEOID HEIGHT-         -24.32  (meters)                     GEOID09
 AG7401  DYNAMIC HT  -           1.119 (meters)       3.67  (feet)  COMP
```

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AG7401 MODELED GRAV- 979,159.0 (mgal) NAVD 88
AG7401
AG7401 VERT ORDER - SECOND CLASS I
AG7401

NOAA CO-OPS Tidal Bench Mark Data

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Ocean Service

Datums Page

Station ID: 8726364 **PUBLICATION DATE: 04/21/2003**
Name: MULLET KEY, TAMPA BAY FLORIDA
NOAA Chart: 11414 **Latitude: 27° 36.9' N**
USGS Quad: ANNA MARIA **Longitude: 82° 43.6' W**

To reach the tidal bench marks from the post office at the intersection of 1st Avenue North and 4th Street in St Petersburg, proceed west on 1st Avenue North for 4.0 km (2.5 mi) to 34th Street (U.S. Highway 19), then south on U.S. Highway 19 for 5.8 km (3.6 mi) to Pinellas Bayway, then west on Pinellas Bayway for 3.7 km (2.3 mi), continue south on Pinellas Bayway for 10.6 km (6.6 mi) to Anderson Boulevard, go SW on Anderson Boulevard for 1.69 km (1.05 mi) to old Fort DeSoto, then 0.6 km (0.4 mi) south along a paved road that leads to the parking area and fishing pier at the old fort. The bench marks are in the area between the fort and the fishing pier. The tide gage and staff were on the fishing pier.

T I D A L B E N C H M A R K S

PRIMARY BENCH MARK STAMPING: 6364 A 1976
DESIGNATION: 872 6364 A TIDAL

MONUMENTATION: Tidal Station disk VM#: 11302
AGENCY: National Ocean Survey (NOS) PID#: AG0290
SETTING CLASSIFICATION: Concrete culvert

The primary bench mark is a disk set in the top of a concrete culvert in Fort

USACE, JACKSONVILLE DISTRICT
Hydrographic Surveying
OPERATIONS DIVISION

Desoto Park between pier 1 and pier 2, 70 m (231 ft) north of the shoreline, 9 m (29 ft) east of the centerline of the asphalt road, and 3.11 m (10.2 ft) NW of the SE end of the culvert.

BENCH MARK STAMPING: 10 1957
DESIGNATION: 872 6364 TIDAL 10
ALIAS: TIDAL 10 STA III 34

MONUMENTATION: Tidal Station disk VM#: 11300
AGENCY: US Coast and Geodetic Survey (USC&GS) PID#: AG5204
SETTING CLASSIFICATION: Concrete base

The bench mark is a disk set in the top of the NE corner of a 1.83 m (6.0 ft) square concrete and shell base for a partially destroyed 12 m (40 ft) high observation tower, about 0.4 km (0.3 mi) SW of Fort Desoto, 89 m (291 ft) SE of the SE corner of the fishing pier, 32.09 m (105.3 ft) NE of a sea wall, and 1 m (3 ft) above ground level.

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National Oceanic and Atmospheric Administration
National Ocean Service

Station ID: 8726364 **PUBLICATION DATE: 04/21/2003**
Name: MULLET KEY, TAMPA BAY FLORIDA
NOAA Chart: 11414 **Latitude: 27° 36.9' N**
USGS Quad: ANNA MARIA **Longitude: 82° 43.6' W**

T I D A L B E N C H M A R K S

BENCH MARK STAMPING: 12 1957
DESIGNATION: 872 6364 TIDAL 12
ALIAS: TIDAL 12 STA III 34

MONUMENTATION: Tidal Station disk VM#: 11301
AGENCY: US Coast and Geodetic Survey (USC&GS) PID#: AG5203
SETTING CLASSIFICATION: Concrete platform

USACE, JACKSONVILLE DISTRICT
Hydrographic Surveying
OPERATIONS DIVISION

The bench mark is a disk set in the top of the SE corner of a 5 x 4 x 1 m (16 x 12 x 2 ft) high concrete platform, 180 m (592 ft) east of Bench Mark 10 1957, 122 m (400 ft) north of the shoreline, 46 m (150 ft) west of the centerline of the brick pavement, and 30 m (100 ft) north of the projected centerline of the east-west brick pavement.

BENCH MARK STAMPING: 6364 B 1990
DESIGNATION: 872 6364 B TIDAL

MONUMENTATION: Flange-encased Rod VM#: 11303
AGENCY: National Ocean Service (NOS) PID#: AG9426
SETTING CLASSIFICATION: Stainless steel rod

The bench mark is a flange-encased rod located near the west end of the sign for the fishing pier, 73 m (240 ft) NE of the east edge of the south entrance to the pier parking lot, 22.10 m (72.5 ft) SE of a paved road, 19.23 m (63.1 ft) north of the north edge of the parking lot, and 1.28 m (4.2 ft) NW of the SW corner of the fishing pier sign. The datum point is the top of a stainless steel rod driven 18.3 m (60 ft) to refusal, and encased in 5-inch logo cap.

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Ocean Service

Page 3 of 5

Station ID: 8726364 **PUBLICATION DATE: 04/21/2003**
Name: MULLET KEY, TAMPA BAY FLORIDA
NOAA Chart: 11414 **Latitude: 27° 36.9' N**
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T I D A L B E N C H M A R K S

BENCH MARK STAMPING:
DESIGNATION: PINELLAS
ALIAS: 872 6364 TIDAL

USACE, JACKSONVILLE DISTRICT
Hydrographic Surveying
OPERATIONS DIVISION

MONUMENTATION: Survey disk
AGENCY: Pinellas County
SETTING CLASSIFICATION: Sea wall

VM#: 11304
PID#: AG9428

The bench mark is a disk set in the surface of the concrete sea wall on the NE side of the fishing pier, 83 m (272 ft) NW of the concession building, 57 m (186 ft) east of the rest room building, 52 m (169 ft) SE of the SE edge of the paved parking lot, 5 m (15 ft) NE of the NE side of the concrete pier, and 1 m (3 ft) below pier level.

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Ocean Service

Page 4 of 5

Station ID: 8726364 **PUBLICATION DATE: 04/21/2003**
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T I D A L D A T U M S

Tidal datums at MULLET KEY, TAMPA BAY based on:

LENGTH OF SERIES: 2 Years
TIME PERIOD: June 1990 - May 1991
TIDAL EPOCH: 1983-2001
CONTROL TIDE STATION: 8726520 ST. PETERSBURG, TAMPA BAY

Elevations of tidal datums referred to Mean Lower Low Water (MLLW), in METERS:

HIGHEST OBSERVED WATER LEVEL (12/03/1990)	=	1.041
MEAN HIGHER HIGH WATER (MHHW)	=	0.634
MEAN HIGH WATER (MHW)	=	0.556
NORTH AMERICAN VERTICAL DATUM-1988 (NAVD)	=	0.464
MEAN SEA LEVEL (MSL)	=	0.338
MEAN TIDE LEVEL (MTL)	=	0.331
MEAN LOW WATER (MLW)	=	0.106

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Hydrographic Surveying
OPERATIONS DIVISION

MEAN LOWER LOW WATER (MLLW)	=	0.000
LOWEST OBSERVED WATER LEVEL (01/19/1977)	=	-0.659

National Geodetic Vertical Datum (NGVD 29)

Bench Mark Elevation Information In METERS above:

Stamping or Designation	MLLW	MHW
6364 A 1976	1.417	0.861
10 1957	2.088	1.532
12 1957	2.742	2.186
6364 B 1990	1.276	0.720
PINELLAS	2.283	1.727

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Ocean Service

Station ID: 8726364 **PUBLICATION DATE: 04/21/2003**
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D E F I N I T I O N S

Mean Sea Level (MSL) is a tidal datum determined over a 19-year National Tidal Datum Epoch. It pertains to local mean sea level and should not be confused with the fixed datums of North American Vertical Datum of 1988 (NAVD 88).

NGVD 29 is a fixed datum adopted as a national standard geodetic reference for heights but is now considered superseded. NGVD 29 is sometimes referred to as Sea Level Datum of 1929 or as Mean Sea Level on some early issues of Geological Survey Topographic Quads. NGVD 29 was originally derived from a general adjustment of the first-order leveling networks of the U.S. and Canada after holding mean sea level observed at 26 long term tide stations as fixed. Numerous local and wide-spread adjustments have been made since establishment in 1929. Bench mark elevations relative to NGVD 29 are available from the National Geodetic Survey (NGS) data base via the World Wide Web at

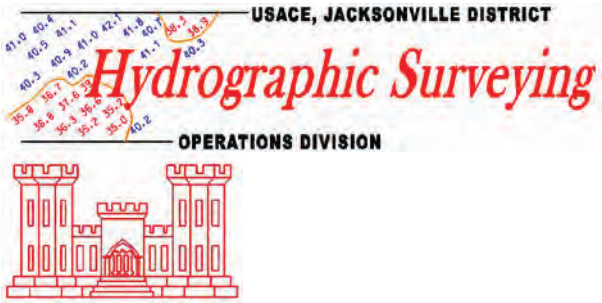
National Geodetic Survey.

NAVD 88 is a fixed datum derived from a simultaneous, least squares, minimum constraint adjustment of Canadian/Mexican/United States leveling observations. Local mean sea level observed at Father Point/Rimouski, Canada was held fixed as the single initial constraint. NAVD 88 replaces NGVD 29 as the national standard geodetic reference for heights. Bench mark elevations relative to NAVD 88 are available from NGS through the World Wide Web at National Geodetic Survey.

NGVD 29 and NAVD 88 are fixed geodetic datums whose elevation relationships to local MSL and other tidal datums may not be consistent from one location to another.

The Vertical Mark Number (VM#) and PID# shown on the bench mark sheet are unique identifiers for bench marks in the tidal and geodetic databases, respectively. Each bench mark in either database has a single, unique VM# and/or PID# assigned. Where both VM# and PID# are indicated, both tidal and geodetic elevations are available for the bench mark listed.

The NAVD 88 elevation is shown on the Elevations of Tidal Datums Table Referred to MLLW only when two or more of the bench marks listed have NAVD 88 elevations. The NAVD 88 elevation relationship shown in the table is derived from an average of several bench mark elevations relative to tide station datum. As a result of this averaging, NAVD 88 bench mark elevations computed indirectly from the tidal datums elevation table may differ slightly from NAVD 88 elevations listed for each bench mark in the NGS database.



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APPENDIX K

Channel Framework Data for Coastal Navigation Projects

K-1. Channel Framework—Overview. Coastal navigation projects should have defined channel framework parameters. A channel control framework is simply a digital 2D "plat" of a project's current (authorized) geospatial dimensions and alignments. Optionally, the framework can include vertical information (channel depths and side slope parameters), original authorization data, and subsequent alignment and depth modifications. Consistent channel framework data is essential in transferring surveys to other organizations; in particular, NOAA. It is also useful in maintaining archival geospatial data, as may be needed when comparing surveys from different eras. Channel framework data are normally maintained in a MicroStation, AutoCAD, or ESRI GIS file. The use of a single GIS framework format is recommended for Corps-wide consistency (i.e., the USACE National Channel Framework initiative). It also has use in updating the USACE Digital Project Notebook. Periodic channel condition surveys are surveyed and processed within this consistent channel framework. A channel framework may include the following data.

a. Horizontal. Georeferenced locations of a project's reference baselines (e.g., channel centerlines) and offset channel "boundary" limits (toes, basins, wideners, bulkheads, etc.). Channel coordinate locations should be referenced to the NOAA National Spatial Reference System (NSRS)—NAD83; relative to a fixed NSRS primary project control benchmark (PBM) and/or to a GNSS-based regional reference network (e.g., CORS).

b. Vertical. Project depth grades should be defined to a hydraulic tidal model that relates the varying MLLW datum (defined by the NOAA "National Water Level Observation Network"--NWLON) relative to a NOAA tidal PBM, the GNSS (GPS) ellipsoid, and the NSRS NAVD88 datum. Great Lakes projects are referenced to the NWLON IGLD85 system.

c. Authorization information. Listing of original authorization legislation and subsequent legislative modifications (realignments, widenings, deepenings, etc.).

K-2. Channel Framework Definitions.

a. Federal Navigation Channel Project. A single or multiple channels by which Congress has authorized for the USACE to build and/or maintain. It will have a defined Civil Works Information System (CWIS) project level work item number.

b. Federal Sub-Project. Within the Congressional language of a navigation project, a set section of the entire Channel. It will use its parent project’s CWIS number for its funding needs.

c. Authorized Channel. The authorized channel is defined by original, federal authorization legislation. This textual description, when manually tied to real world coordinates,

and represented by two channel toes in either an electronic or hard copy format, is known as the authorized channel.

d. Constructed Channel. The constructed channel may differ in dimension from the authorized channel due to funding shortfalls, or local geomorphic conditions that preclude or hinder the construction of the channel to authorized dimensions. Where constructed and authorized channel dimensions differ, both dimensions must be captured in the coastal channel framework. Where constructed channel and authorized channel are the same, a note stating such must be included with the data.

e. Maintained Channel. Ideally, the channel is maintained to its authorized dimensions. However, where this is not the case, a maintained channel dimension results. This maintained channel dimension should not, however, result in a new set of channel toes, centerlines, or stations. In fact, maintained channel dimensions need be reported in relation to the authorized and constructed dimensions of the channel via the channel condition report and survey. (Note that coordinates held within the National Channel Framework GIS database represent the maintained dimensions (widths, depths, lengths) rather than the authorized dimensions. Flexibility is given to the districts to highlight differences between constructed, authorized, or maintained framework within their local drawings.)

f. Channel Reach. The area within a project or sub-project traditionally used in reporting channel condition information via a channel condition report (ENG Form 4020/4021). A reach may, or may not, possess a one-to-one spatial relationship to a project or sub-project. Reaches, if used for reporting purposes, must describe the entire project length. Channel reaches are represented by individual vectors placed perpendicular to the channel centerline at the beginning/end of each reach. Channel reaches are denoted by a non-spatial table holding dimensions of each reach along with a stop/start point.

g. Channel Quarter (Report of Channel Conditions). For channels 100 to 400 ft wide use ENG Form 4021-R, Nov 90 and for channels 400 feet wide and greater use ENG Form 4020-R, Feb 2011 Channel quarters are polygons placed around quarters (or thirds for channels less than 100 ft wide). Any polygons generated should be considered an ancillary product.

h. Channel Toe. Channel toes represent external channel limits measured horizontally from and perpendicularly to the channel centerline. Channel toes form the boundaries which encompass entire federal projects and sub-projects. Toes are represented by single, continuous vectors extending from the beginning to the end of each federal project or sub project. The depth of the channel toe should be provided as an attribute attached to each channel vertex.

i. Top of Slope Line. The slope line is derived from the channel toe line depth and angle of slope values as provided with each station line. Where a line, starting from the channel toe, intersects project datum elevation zero (0), that is where the top of slope line is drawn. The channel slope angle, as well as depth of channel toe, is provided as an attribute of each channel

station. Top of Slope lines are represented by single, continuous vectors extending from the beginning to the end of each federal project or sub project. The depth of the channel toe should be provided as an attribute attached to each channel vertex.

j. Channel Stationing. A channel station is a reference line, primarily used during channel surveying and dredging operations, and meant to convey locations along a channel's length. A station is placed within a channel at consistent intervals, perpendicular to the centerline, and extends horizontally to each channel toe. Traditionally, channel stations are placed every 100 feet along a channel's length. In addition to positioning stations at regular intervals, stations also must be placed where channel toes change direction (horizontal inflection points). Channel stations are represented by individual vectors. Station names are conveyed through associated text fields. Since each district does their stationing differently, it is recommended that points be placed along the channel where there is point of intersection or a change in depth. If preferred, these points can be placed at regular intervals, but not required. The major issue with placing lines across the channel is that it is impossible to have a station that runs perpendicular to the centerline where the channel changes direction. Depending on the channel, one can end up without a single station that is actually perpendicular to the channel line; hence the stripped down component of a point along the centerline to capture location along the channel.

K-3. Channel Framework Feature Precisions and Datums. Table K-1 outlines recommended numerical precisions and datums to be used in channel framework CADD or GIS files.

a. In practical terms, the absolute geodetic location accuracy of an offshore, mathematically defined channel framework feature is dependent on (or no better than) the uncertainties in survey and dredge positioning systems. Before the mid 1990's, survey positional uncertainties were typically ±20 to ±50 ft—or worse. Current GPS dynamic survey techniques have reduced these uncertainties to a ±6 ft level (Code DGPS), and as low as ±1 to 2 ft (GPS/RTK methods). Survey precision (or repeatability) may be half these levels; however, these precision estimates would include constant positional biases.

b. Those developing channel framework parameters, or transforming datums, must consider the survey positional uncertainty relative to the mathematically defined precision of the framework. For example, 0.5 ft variations in NADCON/CORPSCON datum transforms at the same channel point are not significant given an inability to position a survey vessel to this accuracy.

c. The required CADD precision (or numerical resolution) of the mathematical channel framework coordinates is independent of their absolute datum accuracy (or survey accuracy). A fixed CADD resolution is needed for consistency in developing planned survey line files, survey data processing, and quantity computations.

Table K-1. Channel Control Feature CADD Precisions and Reference Datums

	Design File Precision	Reference Datum	Grid
Horizontal			
Channel Alignment Coordinates PIs, Toes, Basin Limits, etc.	nearest 0.1 ft	NSRS/NAD83	SPCS
Channel Alignment Orientation Bearings referenced to channel baseline PIs	nearest 1 arc-sec	NSRS/NAD83	SPCS
Channel Stationing-Offset Coordinates	nearest 0.1 ft	Local channel reach	Local
Primary Control PBMs (NSRS control)	per published NSRS	NSRS/NAD83	SPCS
[reference PID only]	per published NSRS	NSRS/NAD83	Φ-λ
Vertical			
Tidal PBMs—published NWLON/NSRS [indicate by reference to NOAA PID/ID]			
MLLW datum	per NWLON	NOAA NWLON	n/a
NAVD88 elevation	per NSRS/NWLON	NSRS/NAD83	n/a
Tidal Models	nearest 0.05 ft	NOAA NWLON	n/a

Design file precisions in no way reflect absolute geospatial accuracies

d. Channel framework files should indicate the channel coordinates are referenced to the North American Datum of 1983—"NAD83," along with the appropriate State Plane Coordinate System (SPCS) zone identification. No year date should be appended to the NAD83 datum for the channel framework—i.e., NAD83 readjustment/realization dates should not be indicated (e.g., NAD83 (CORS), NAD83 (1996), NAD83 (1999), NAD83 (2007). (Note that NAD83 is expected to be revised ca 2020—i.e., GRAV-D).

e. Coordinates/elevations of listed NOAA/NSRS PBMs or NOAA tidal station data should not be shown on the channel framework drawing, but should be referenced by NSRS PID or NWLON gage station ID to the to the appropriate NOAA database. This ensures that the NOAA database is accessed for the latest NOAA updates and readjustments, and that the framework document does not have to be continuously updated for these changes.

K-4. Recommended Requirements for Channel Framework Drawing Files. Table K-2 lists some of the basic framework data that should be documented for each coastal project. Not all of these parameters will be applicable to every project.

Table K-2. Recommended Details to be included on Framework Files.

	Plot Feature Symbol/Note/Tabulate
Horizontal:	
Reference Datum & Coordinate System	Note
Channel Alignment Centerlines	Plot and tabulate PI coordinates
Channel Azimuths between PIs	Note azimuth along centerline or baseline
Channel Limits	Plot and tabulate intersection coordinates
Channel Reaches (Cuts)	Note
Channel Widths	Dimension/note (verify w/authorizations)
Station-Offset (Range)	Plot leader notes from PIs or as required at other points
Primary Project Reference PBM (NSRS)	Plot PBM symbol and note/tabulate NSRS reference
Positioning Control Method	Note PIDs of RTK base PBM or VRN and calibration PBMs
Vertical:	
Vertical Reference Datum and Epoch	Note
Reference NOAA Tide Gauge	Plot gauge symbol and note/tabulate NWLON station ID
Tidal Model (MLLW-NAVD88)	Plot graphic MLLW-NAVD88 variations and/or reference to any digital model (e.g., KTD, VDatum). Note model date/version
Primary Project Reference Tidal PBM (NWLON)	Plot PBM and note references to NWLON & NSRS
Water Surface Measurement Method	Note PIDs of RTK base PBM or VRN and calibration PBMs (include survey procedures)

Optional Metadata:	
Shoreline topo, general outline	Plot
Authorization Data	Note and/or reference location of file
Onshore/Offshore Placement or Borrow Area Details	If included in authorization--Plot or note
Archived (Superseded) Control Drawings	Note reference location of file
Side Slope Parameters	If included in authorization—Note
Jetties, breakwaters, bulkheads, etc.	Detail if included in authorizations

K-5. Horizontal Channel Alignment Framework Data. Coordinate data for points of intersection on a project should be tabulated on design drawings as illustrated in Figure K-4. Channel stationing is indicated at each centerline PI as shown in Figure K-5. (Note that the channel centerline may not always be the station-offset system reference baseline). PIs are designated by roman numerals consecutively throughout the project. Exterior intersection points on the channel limits (e.g., toes, basins, wideners) are noted by circled numbers on the drawings, as shown in the figure. Points are numbered consecutively throughout an entire project. Station-offsets of widener or basin coordinates may be added as required to define these irregular features. It is recommended that construction station-offset coordinates on navigation projects should adhere to the following convention.

a. Start channel stationing consecutively “upstream” beginning from offshore PI.

b. Reference the channel baseline to the channel centerline.

c. Indicate channel orientation using grid bearings.

d. Reference channel baseline offsets positive clockwise.

CHANNEL CENTERLINE		
P.I.	X-EASTING	Y-NORTHING
I	976.366.11	887.563.96
II	973.866.49	887.607.83
III	970.265.60	887.671.02
IV	968.763.59	887.143.89
V	967.763.18	886.687.28

CHANNEL LIMITS		
P.I.	X-EASTING	Y-NORTHING
1	976.369.62	887.763.53
2	973.870.00	887.807.79
3	970.377.03	887.869.10
4	968.707.50	887.283.18
5	967.700.90	886.823.73
6	967.102.58	886.650.64
7	966.042.58	886.570.99
8	966.015.72	885.171.24
9	967.225.50	885.148.02
10	967.900.85	886.385.68
11	968.819.68	887.004.61
12	969.939.14	887.397.48
13	970.657.13	887.464.12
14	973.862.98	887.407.86
15	976.362.60	887.363.99

Figure K-1. Tabular block of channel centerline PIs and channel toe coordinates.

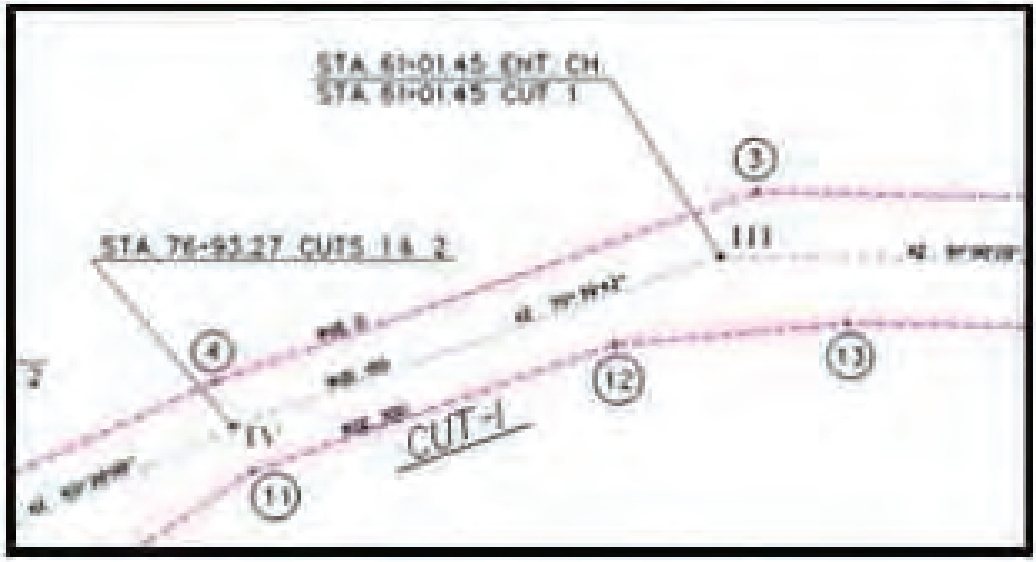

Figure K-2. Channel framework diagram of centerline and limit points.

K-6. CADD Standards for Channel Control Files. The following CADD standards are recommended for project condition survey features. These are taken from the "A/E/C CADD Standards" (currently Release 3.0—Model File Level/Layer Assignments (App A—Surveying & Mapping) and Standard Symbology (App D)). The CADD levels should be assigned in framework drawings, using the graphic defaults in A/E/C Release 3.0, Appendix A.

V-ANNO-NOTE	General notes on datums, survey PBMs, procedures
V-CHAN-CNTR	Channel centerline alignment
V-CHAN-CNTR-IDEN	Text: tabulated PI SPCS coords, station-offset coords
V-CHAN-TOE	Authorized channel limits (toes)
V-CHAN-TOE-IDEN	Text: tabulated authorized channel limits
V-CHAN-LIMT	Misc. project limits (wideners, basins, advance maint. etc.)
V-CHAN-LIMT-IDEN	Text: Misc. limits -- tabulated limits & alignment points
V-CHAN-TEXT	Cut/Reach/Basin names

Other level assignments (not necessarily used in channel framework drawings)

V-CHAN-NAID	Navigation aids & text
V-TOPO-SHOR	Shoreline topo
V-TOPO-MAJR	Major depth contours
V-TOPO-MINR	Minor depth contours
V-TOPO-SOUN	Soundings/depths
V-TOPO-COOR-STAT	SPCS coordinate grid ticks & text

A/E/C Model File naming convention should be used for dgn files, e.g. “[project]V-SPmccf.dgn.”

K-7. Authorization Data. The following example illustrates the type of authorization data that may optionally be included within a channel framework file. Maintaining and updating these data may prove difficult; thus, its application is optional. If this information is maintained in another database (e.g., Project Management), then it should not be duplicated in a framework file.

Table K-3 Additional Data in Channel Framework File

KEY WEST HARBOR, FLORIDA

Condition of Improvement, 30 September 1996

ACTS	WORK AUTHORIZED	DOCUMENTS
19 Sep 1890 (2)	The northwest entrance	H. Doc. 145/50/2 & H. Ex. Doc 39/51/1
28 May 1908	Removal of reefs in Main Ship Channel.	Specified in Act.

25 Jul 1912	The main ship channel and anchorage.	H. Doc. 706/62/2
18 Jul 1918	Removing the Middle Ground.	H. Doc. 185/65/1
14 Jul 1960 (1)	Channel into Garrison Bight.	
23 Oct 1974	Channel into Key West Bight, turning basin, and breakwater.	S. Doc. 106/87/2

(1) Approved by Chief of Engineers on 1 March 1963, for accomplishment under Section 107.
(2) 17 Nov. 1988, two not completed jetties deauthorized, Public Law 99-662.

PROJECT: Key West Harbor - Removal of coral heads and reefs from main ship channel and anchorage to provide a channel 30 feet deep and 300 feet wide; a channel 17 feet deep and a sufficient width for navigation in Northwest Channel; widening channel opposite wharves to 800 feet with a depth of 26 feet; provide a channel 8 feet deep by 100 feet wide along the north and east sides of Fleming Key and into Garrison Bight; a channel 12 feet deep by 150 feet wide extending from the 30-foot ship channel into Key West Bight, a turning basin 12 feet in the bight, and a granite-mound breakwater 800 feet long along the north side of the bight. Length of project channels is about 23 miles, including channel into Garrison Bight 3.75 miles, and channel into Key West Bight 0.6 mile.

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APPENDIX L

Almond Lake Reservoir Survey and Area Capacity Curves (Baltimore District)

L-1. The following project illustrates a typical reservoir sedimentation survey for the purpose of updating area capacity curves. The overall project involved sedimentation surveys for seven reservoir projects in Baltimore District. The report for one of these projects is illustrated in this appendix. The single-beam hydrographic surveys on the reservoir were conducted by TVGA, Inc., Elma, NY. Another contractor subsequently completed the topographic mapping portion of the work. Baltimore District then merged the two files to obtain a DTM from which they computed reservoir storage area-capacities. St. Louis District managed the hydrographic and photogrammetric mapping contracts for the Baltimore District.

a. Task order scope of work. The following Scope of Work was sent to the contractor as part of a Request for Proposal on the project. This scope succinctly describes the work to be performed and deliverables.

Figure L-1 Scope of Work

SCOPE OF WORK
TVGA ENGINEERING, SURVEYING, INC
ELMA, NY
SEVEN LAKES FOR BALTIMORE DISTRICT
HYDROGRAPHIC SURVEYS

CONTRACT NO. DACW43-96-D-0512
TASK (DELIVERY) ORDER NO. XXX

1. Description of Work:

The Contractor shall perform hydrographic surveys in the Baltimore District at seven lakes to be used to update area capacity curves to reflect the changes in storage volumes as a result of sedimentation. The seven lakes are (1) East Sidney, (2) Whitney Point, (3) Bush Dam, (4) Stillwater, (5) Aylesworth Creek Lake, (6) Jennings Randolph, and (7) Almond Lake. The lakes are located in the vicinity of northern Pennsylvania, West Virginia, and New York.

2. Information Supplied by the Government:

a. Copies of USGS Quadrangle sheet covering the five lakes with pertinent areas outlined.

b. Copies of project maps for each lake.

c. Copies of mapping specifications, for merging hydrographic surveys with the mapping being performed by others.

d. Copy of list detailing specification for individual lake. Sounding range distance interval for the lakes are listed for each lake.

e. Copy of memo from Baltimore District detailing survey requirements to be coordinated with the St. Louis District.

3. Work to be Performed by the Contractor:

The Contractor shall provide equipment, supplies, personnel, and survey boat fully equipped to perform control and standard hydrographic surveys utilizing differential global positioning system technology. Specific work shall include:

a. Take sounding along range lines spaced at 100 ft to 250 ft. intervals, but close enough so each lake bottom can be adequately defined for mapping purposes, for hydrographic surveys on the seven (7) lakes furnished in 2.b above. The surveys must be obtained during periods when each lake is below the summer conservation pool (elevation on list provided in 2.d above. The Contractor is required to maintain close coordination with CELMS-ED-HG (Bob Mesko) or CENAB-EN-GW (Bill Haines) to ensure water conditions are being met for each survey. Calibration for fathometer shall be obtained and submitted for each lake surveyed. The surveys shall meet the requirements for class I hydrographic surveys at stated in EM 110-2-1003, 30 October 1994, "HYDROGRAPHIC SURVEYING".

b. Gage readings shall be recorded twice each day for the nearest upstream and downstream gages where soundings are being taken. Also, if surveying in an area where lake gages may not accurately reflect water surface conditions, levels shall be run to water surface.

c. All surveys shall also be submitted to the St. Louis District in 3D CADD files fully operational on ARC/INFO GIS system. For hydrographic surveys, reference soundings to the National Geodetic Vertical Datum (NGVD).

d. The Contractor shall prepare a bathymetric contour map for each lake showing 1996 conditions, extending from the lowest points in each lake up to the summer conservation pool elevation. The desired contour interval is two (2) feet and the horizontal scale is 1 inch equals 200 ft, unless other scales become required to match the mapping being performed by others. Plots shall be provided for both the soundings data in NGVD and contours.

e. Paper check plots shall be provided to the Government for checking and reviewing of the finished product. The maps shall be prepared on standard engineering size drawings (30" x 42"). The standard Baltimore District title block shall be placed in the lower right corner.

f. Using the hydrographic surveys, compute elevation-area and elevation capacity relationships for each lake from the lowest point in the summer conservation pool elevation. The Contractor shall furnish data in both tabular and graphical format.

g. Visits to each project site shall be pre-coordinated (date, time, purpose) with Mr. William Haines, who will advise the dam operator. Upon arriving at a project site, St. Louis District personnel or their contractors shall check in with the dam operator before beginning work

h. Lakes at the various projects are subject to rapid and frequent changes in water levels, depending upon hydrologic conditions. Field work should be scheduled and accomplished with the understanding that the lake levels may fluctuate daily or even hourly, and there may be times when vessels are prohibited on the lakes.

i. The Contractor shall compare the DGPS positioning system to a minimum of one known survey control point in the vicinity of each lake surveyed.

4. End Results Expected:

a. Listing (coordinates) of any additional horizontal control established. Include field books showing plan view, location, references, and procedures used to establish new points. Field books shall include neat sketches showing bearings, angles, and taped distances to at least three nearby distinct permanent objects.

b. Quality reproducible mylars and five black line copies of the 1996 contour maps and soundings. Electronic data files for bathymetry maps in both contour and elevation form, for use in an ARC/INFO system as described in para. 3.d above. Maps shall be prepared on standard engineering size drawings (30"x42"). The standard Baltimore District title block shall be placed in the lower right corner.

c. Fathometer scrolls showing sounding lines cross-referenced to plan view plots in 4.b. above, complete set of survey notes, 3.5-inch diskettes, and any other medium containing raw survey data. This package is to be accompanied by documentation indicating the data type, the data format, and general instruction for its retrieval.

d. New monuments established in the field as necessary to perform hydrographic survey.

e. Corps of Engineers Form DA 1959 completed with information concerning any new control points which may have been set.

f. Diskettes containing the 3D CADD digital data files of the hydrographic surveys, fully operational on the District ARC/INFO system.

g. Original and five copies of curves and tables for the 1996 elevation-area and 1996 elevation capacity relationships. Electronic data files for curves and tables will also be submitted.

h. Bi-weekly progress reports shall be submitted to the St. Louis District and Baltimore District. This report may be made electronically (e-mail) or via fax. The POC in Baltimore is Mr. J. William Haines, CENAB-EN-GW, Phone (410) 962-6768 and FAX (410) 962-4972.

5. Schedule and Submittal:

The Contractor shall prepare and submit all pertinent data to the Corps of Engineers, ED-HG (Attn: Bob Mesko), 1222 Spruce, St. Louis, MO 63103-2833 by 31 January 1997 for every project except Jennings Randolph Lake. For Jennings Randolph Lake all information and deliverables not later than 1 June 1997 shall be submitted. Close coordination is required with ED-HG (Bob Mesko) to ensure the surveys are being obtained during period of summer conservation pool and before draw down occurs. Incremental submittals of surveys are required for the District to comment on format and content of the data. Scheduled draw downs will occur in the fall at East Sidney Lake and Whitney Point Lake. Field work must be completed at these project not later than 15 November 1996. Jennings Randolph is already being drawn down for the winter season. Refilling normally occurs in the early spring, but remains at full conservation pool for only a few weeks before whitewater, water quality, and water supply releases begin. It is anticipated that the hydrographic survey for this project will be scheduled for late March or early April 1997.

Hydrographic surveys, bathymetric maps, and area/capacity computations may be submitted to the Baltimore District and St. Louis District as projects are completed.

6. Time Extensions:

In the event these schedules are exceeded due to causes beyond the control and without fault or negligence of the contractor, as determined by the Contracting Officer, this delivery order completion date will be extended one (1) calendar day for each day of delay.

---

b. Final survey report for Almond Lake. Following is the final survey report submitted by the contractor in May of 1997 transmitting the sedimentation survey results for one of the seven reservoirs included under the task order.

Figure L-2 Survey Report

SURVEY REPORT

ALMOND LAKE, NY
CANACADEA CREEK
SUSQUEHANNA RIVER BASIN
HYDROGRAPHIC CONDITION SURVEY

CONTRACT DACW43-96-D-0512 (ST. LOUIS DISTRICT)
TASK (DELIVERY) ORDER NO. 003

TVGA Engineering, Surveying, P.C. was requested by the US Army Engineer District, Saint Louis to provide Professional Hydrographic Surveying Services to the US Army Engineer District, Baltimore under Delivery Order Number 003 of Indefinite Delivery Contract DACW43-96-D-0512. TVGA's general responsibilities related to this project consisted of the following:

1. Conduct a hydrographic condition survey to update area capacity curves that would reflect any changes in the storage volumes as a result of sedimentation. The survey operations were to be conducted at a time when the pool elevation was at/or above the recreation level. The limits of our survey were to extend to all portions of the lake which were navigable with a shallow water survey system.

2. Convey results of the field survey through preparation of deliverables that include but are not limited to: plan view mapping to present hydrographic data obtained by the survey and contours at a 2 ft interval and to provide an updated area/capacity table and curves.

RECORD RESEARCH AND SURVEY SETUP

TVGA retrieved 7.5-minute United States Geodetic Survey (USGS) quadrangle maps from in-house records to plan the survey. The contour depicting the recreation pool elevation of 1260' above the National Geodetic Vertical Datum of 1929 9 (NGVD 29) was digitized from the quadrangle maps and subsequently used to pre-plan the location of cross sections to be surveyed. Cross sections were spaced at a 250' maximum interval and generally situated perpendicular to hydraulic flow--[see Figures L-1 and L-2]. The digitized cross sections were uploaded into Coastal Oceanographics' HYPACK Software and

subsequently used during field operations as a base reference for left/right navigation information on the survey vessel.

HYDROGRAPHIC CONDITION SURVEY

The survey was conducted at a time when the top of water elevation was above the recreation pool elevation of 1260'. An automated electronic survey system was used to collect hydrographic survey data. The survey system was mounted on-board a 16' aluminum boat. The survey vessel's hull draft of approximately 0.9' and a propulsion draft of approximately 2.0' permitted safe navigation into 2.5' of water. Horizontal positioning data was supplied by an Omnistar, Inc. Model 6300A Differential Global Positioning System (DGPS). Depth data was provided by an Odom Hydrographic Inc. Model DF 3200 Mark II Echo Sounder equipped with a single 208 kHz / 3 degree transducer. Horizontal positioning data and digital depth data were logged directly onto a Toshiba 4400C laptop computer equipped with Coastal Oceanographics' HYPACK Hydrographic Survey Software. HYPACK Software was utilized to plan the survey, display real time vessel navigation information and review survey data on a daily basis.

The survey was performed in accordance with Class I accuracy specifications as described in the US Army Corps of Engineers Engineering and Design Manual EM 1110-2-1003, dated October 31, 1994 and titled Hydrographic Surveying. A generalization of specifications contained in the above EM manual that were implemented during field survey operations included but were not limited to:

1. A daily check and/or calibration of the echo sounder to verify and/or adjust for draft, squat and sound velocity. The Daily Depth Sounder Calibration Logs are included in Section H of this report.

2. A relative check of the Omnistar positioning system was made on a daily basis. This was accomplished by recovering and subsequently comparing the published geodetic coordinates of a National Geodetic Survey (NGS) survey marker with geodetic coordinates derived by the Omnistar positioning system. Xerographic copies of the field notes documenting the daily comparison are included in Section H of this report.

3. Collecting and reviewing data along cross section check lines (longitudinal sections).

4. Compensation for system latency.

Reasonable care was taken in the preparation and performance of the survey to ensure the best possible results. Copies of daily calibration reports are included Section H of this report. Weather and atmospheric conditions at the time of hydrographic survey did not in our opinion contribute any degradation in the expected survey results.

At the conclusion of the survey, the US Army Engineer District, Baltimore supplied TVGA with a Xerox copy of hourly pool elevation data recorded by an electronic gage located near the dam. As a precaution to loss of this electronic gate data, TVGA periodically interrogated the gage during survey operations and reported the data in a hard bound field book.

PREPARATION OF PROJECT DELIVERABLES

The hydrographic survey data was up-loaded onto a office based computer equipped with Coastal Oceanographics' HYPACK Hydrographic Survey software. HYPACK Software was utilized to sort, edit and apply water level corrections to digital cross section data. Digital depth data was compared against analog depth charts to correct (edit) depth spikes or false bottom returns caused by interference in the water column. Cross section data was sorted (thinned) to a 20' interval.

The edited cross section data set was read into a Bentley Systems, Inc. MicroStation 95 Version 5.05 3D CADD format. The cross section data was reviewed and a series of terrain break lines were constructed through the low point of each cross section and around the perimeter of the lake. A Triangulated Irregular Network (TIN.) was developed by Intergraph Inroads Version 5.01 software. Contours at 1' and 2' intervals were derived from the digital TIN generated from field collected hydrographic survey data and digital terrain break lines. (Figure L-3)

Plan view mapping that shows final elevations from echo soundings and contours at a 2' interval was drafted at a scale of 1"=200'. The mapping was finalized using the aforementioned MicroStation software. The mapping is in compliance with the US Army Corps of Engineers, Engineering and Design Manual EM 1110-1-1807, dated July 30, 1990 and titled Computer-Aided Design and Drafting (CADD) Systems. Copies of this mapping plotted at ½ the original size are included in Section E of this report.

The contours generated at a 1' interval were read into Eagle Point software through a Drawing Interchange Format (.DXF). This software was used to compute areas and storage volumes at a 1' interval. The digital ASCII reports produced by Eagle Point software were read into Microsoft Excel Version 7.0. to finalize the area/capacity table and curves.

A system of checks and balances were performed on data to ensure the data's integrity and completeness. A comparison between new and old area/capacity data revealed some differences. The reasons for these differences can most likely attributed to the dynamic environmental conditions (sediment transfer) inherent to this type project, dissimilarities in methodology and equipment used to conduct the original field survey and the new survey and methodology used to compute the storage capacities.

POINTS OF CONTACT (Phone 716-655-8842)

Project Manager: Clinton E. Johnson

Field Work: Aaron C. Kennerly

Processing: Scott E Waite

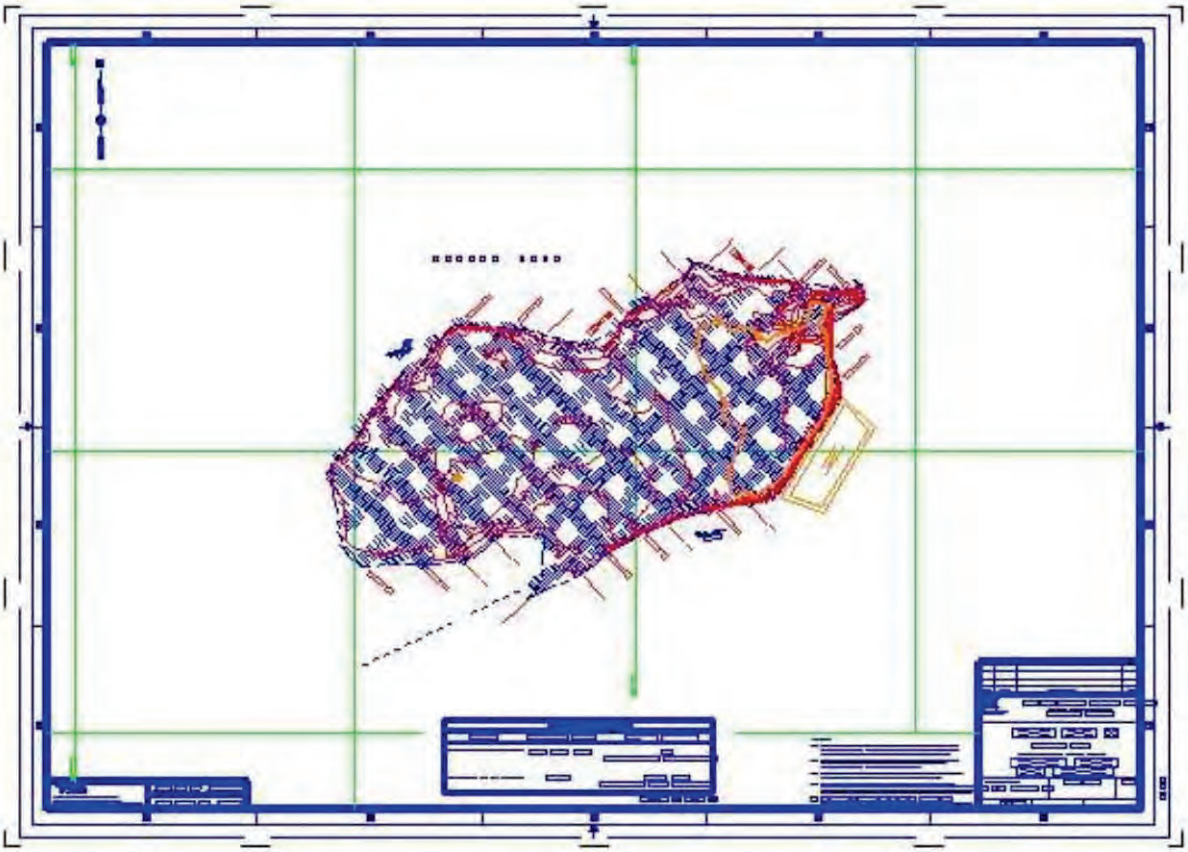

Figure L-3 Line spacing and alignment layout for hydrographic surveys of Almond reservoir. (TVGA, Inc.)

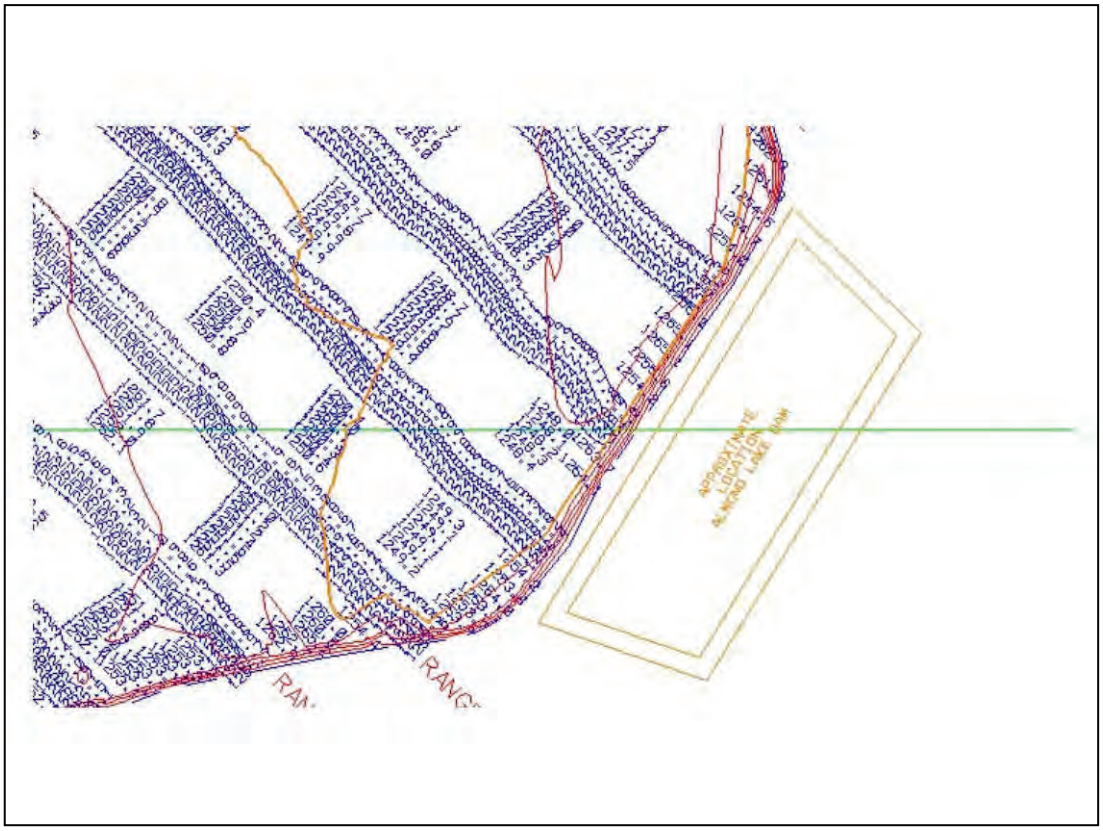

Figure L-4. Detail of survey vicinity Almond Lake Dam. 2-ft contours shown on drawings--1-ft contours used to compute storage capacities. (TVGA, Inc.)

c. Area-Capacity Computations. The contractor submitted preliminary area-capacity computations between elevations 1244 and 1260 ft, using procedures described in the above report. The elevations between 1257 and 1260 ft were estimated using digitized quad maps. Once the subsequent photogrammetric DTM was delivered by Horizons, Inc., the district computed area-capacities using the full elevation range up to the top of dam at 1320 ft.

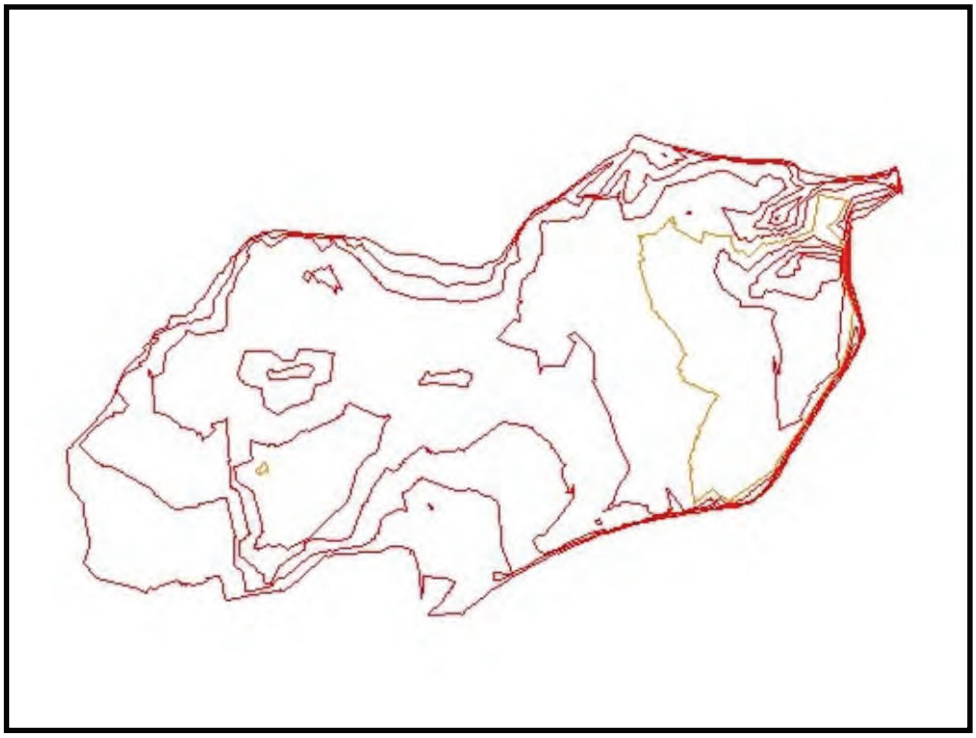

Figure L-5. Reservoir storage contours generated from Triangulated Irregular Network using MicroStation Inroads. Note that only 2-ft intervals are shown.

Table L-1 Area/Capacity Table

Area/Capacity Table -- Almond Lake, New York
Revised June 1998 by Baltimore District Water Control Management Section

Elevation NGVD 29 (ft)	Area Acres	Capacity Acre-ft	Inches of Runoff	
1229	0.0	0.0	< 0.01	Intake Sill elevation
1230	0.0	0.0	< 0.01	
……				
……				
1241	0.0	0.0	< 0.01	
1242	0.0	0.0	< 0.01	
1243	0.1	0.1	< 0.01	
1244	0.2	0.2	< 0.01	
1245	0.9	0.8	< 0.01	
1246	1.5	2.0	< 0.01	
1247	3.8	4.7	< 0.01	
1248	6.0	9.5	< 0.01	
1249	12	19	0.01	
1250	18	34	0.01	
1251	30	58	0.02	
1252	42	94	0.03	
1253	60	144	0.05	
1254	77	213	0.07	
1255	87	295	0.10	
1256	96	387	0.13	Areas below elevation 1260 ft
1257	104	487	0.16	from hydrographic surveys
1258	111	594	0.20	
1259	123	711	0.24	
1260	135	840	0.28	Conservation/Recreation Pool
1261	142	978	0.33	
1262	150	1125	0.38	Areas above elevation 1260 ft
1263	158	1278	0.43	from aerial mapping surveys
.				
.				
1300	492	13397	4.50	Spillway elevation
.				
.				
1306	540	16,277	5.47	

NOTES:

A. Drainage area = 55.8 sq miles
B. 1 in. of runoff = 55.8 mi^2 * 640 ac/mi^2 * 1 ft/12 in. = 2,976 acre-ft
C. Areas and capacities computed using TVGA, Inc. hydrographic project survey dated 20-21 November 1996 and Horizon, Inc. photogrammetric mapping surveys from June 1998
D. Spillway crest = 1,300 ft
E. Area/capacities for all elevations not shown

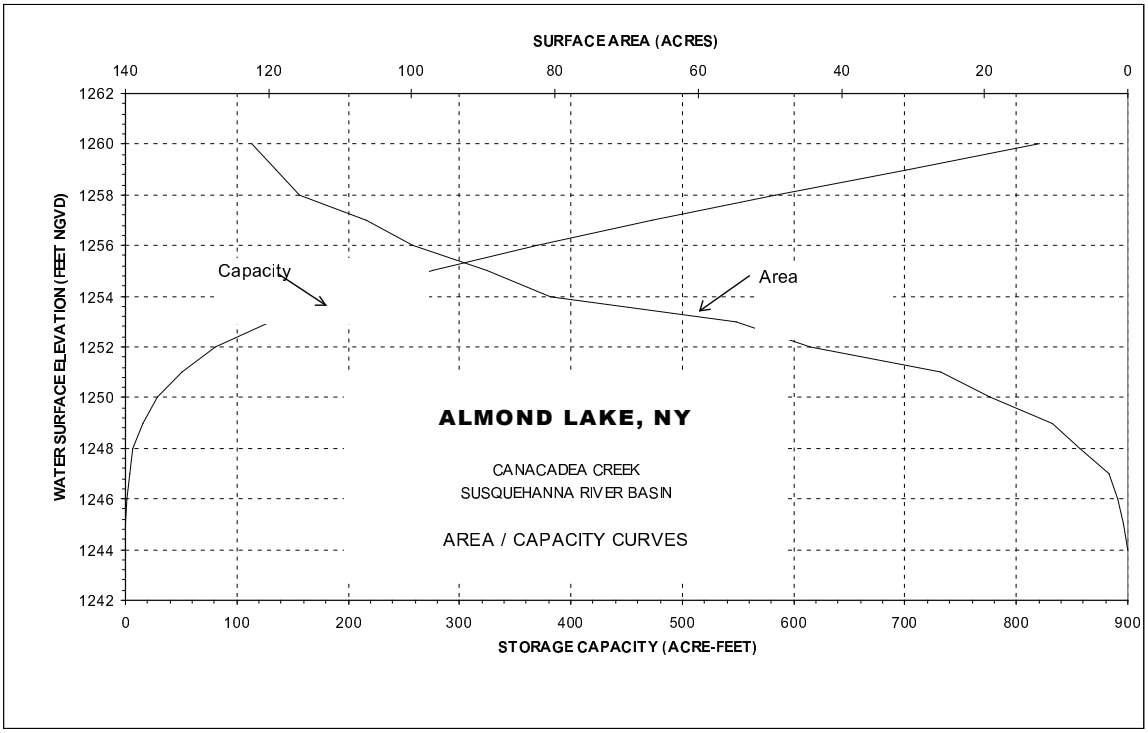

Figure L-6 Illustration of a standard Area-Capacity curve

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APPENDIX M

2010 Allegheny River Multibeam/Side Scan Sonar Scour Survey Report
(Pittsburgh District)

U.S. ARMY CORPS OF ENGINEERS
PITTSBURGH DISTRICT

Contract No. W911WN-10-D-0004
Delivery Order # 0005

2010 ALLEGHENY RIVER MULTIBEAM/SIDE SCAN SONAR SCOUR SURVEY

SURVEY REPORT

BY:

Seaside Engineering And Surveying, Inc.

SEAS

Destin, FL
Crestview, FL

INDEX

CONTRACTOR: SUBCONTRACTOR: 1

OVERVIEW OF SERVICES PROVIDED:.....1

FIELD SURVEY DATE: 1

PROJECT PERSONNEL: 1

SURVEY PREPARATION: 2

SURVEY AREA COVERAGE MAP: 2-3

DATA ACQUISITION:.....3-4
Horizontal and Vertical Positioning – Navigation System:.....3-4
Multibeam Echo Sounder (MBES): 3-4

SOUND VELOCITY PROFILER: 4

HYPACK / HYSWEEP SOFTWARE:.....5-6

SURVEY SYSTEM CALIBRATION:.....6

SURVEY CONTROL:.....7

POSITION ACCURACY CHECK:.....7-8

HYDROGRAPHIC DATA PROCESSING: 8

VERTICAL DATUM FOR SURVEY: 8-9

SURVEY VESSEL: 9

2D and 3D MICROSTATION V8 BASEMAPS: 9-10

SIDE SCAN DATA COLLECTION:.....10-13
Side Scan Data Processing: 10-11
Side Scan Mosaics and Imagery: 12-13

CROSS SECTIONS OF DAM SCOUR DATA.....14-15

SIDE SCAN SCREEN CAPTURES FROM EDGETECH DISCOVERY: 15-19

APPENDIX A - RESON SeaBat 8124 Multibeam Echo-Sounder 20-22
APPENDIX B – Applanix POSMV Wavemaster: 23-25
APPENDIX C – RESON SVP14 (Sound Velocity Profiler): 26-28
APPENDIX D – EdgeTech High Resolution Side Scan Sonar: 29-31
APPENDIX E – Topcon GR 3 GPS: 32-35
APPENDIX F – Scope of Work (SOW):.....36-41

U.S. ARMY CORPS OF ENGINEERS – PITTSBURGH DISTRICT
CONTRACT NO. W911WN-10-D-0004 DELIVERY ORDER # 0005
MULTIBEAM/SIDE SCAN SCOUR SURVEY
ALLEGHENY RIVER – VARIOUS PROJECTS
SURVEY REPORT

CONTRACTOR:
Photo Science, Inc..
104 S. Church Street
West Chester, PA 19382
Phone: (610) 344-0890
URL: www.photoscience.com

SUBCONTRACTOR:
Seaside Engineering & Surveying Inc. (SEAS)
P.O. Box 456
Destin, FL 32540
Phone: (850) 650-9563
URL: www.seas-inc.com

OVERVIEW OF SERVICES PROVIDED:
Seaside Engineering and Surveying, Inc. provided vessel and surveying support necessary to perform multibeam/side scan hydrographic surveys and data processing at AR LD-5, AR LD-6, AR LD-8 and AR LD-9 Locks and Dams on the Allegheny River. The survey was performed as per the scope of work (SOW) for D.O. 0005 (see Appendix H) to comply with the "Mandatory Minimum Performance Standards for 200% "Minimum Survey Coverage Density" for Navigation & Dredging Support Surveys, as prescribed in EM 1110-2-1003, Table 3-1. The following report details the personnel, procedures and equipment used in the performance of this task order:

FIELD SURVEY DATES:

	Bathymetry	Side Scan
AR Lock & Dam 5	9 August 2010	10 August 2010
AR Lock & Dam 6	11 August 2010	11 August 2010
AR Lock & Dam 8	14 August 2010	16 August 2010
AR Lock & Dam 9	13 August 2010	13 August 2010

PROJECT PERSONNEL:

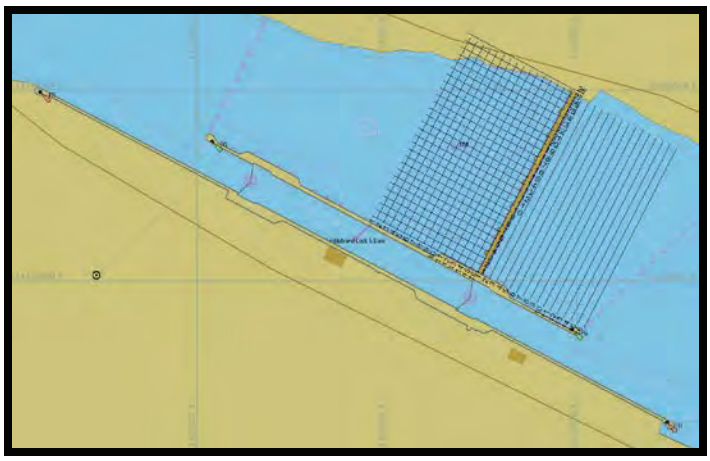
John Gustin, PSM -	Project Manager responsible for Survey planning, Field crew coordination and report preparation. QC/QA field survey and data processing.
Walt Johnson -	Survey Party Chief responsible for the collection of the field data and hydrographic sounding data daily processing and inspection.
David Shaw LSIT -	Survey vessel operator, Instrument operator and Survey Crew Member.
Kelly Komula -	MicroStation / AutoCAD technician responsible for CAD drawings; Digital Terrain Model (DTM) files; contours and ArcMap shape files

James Barton, PE - Quality Control and Side Scan data processing and hydrographic data processing.

SURVEY PREPARATION:

Prior to beginning field work the following was completed by the project manager:

- ✓ The survey area was reviewed from the navigational chart and a survey plan was made.
- ✓ Survey schedule was coordinated through Steve Leblanc. The survey required zero flow and no power generation at each dam for safety and data quality.
- ✓ Planned survey lines were computed using HYPACK software. This was accomplished by importing the Inland Electronic Navigational Chart into HYPACK and using it as a reference to draw survey navigation lines. The hydro navigation lines were laid out parallel to the lock walls and spaced at intervals sufficient to provide 200% coverage with 50% overlap above and below the dam. Lines were also laid out parallel with the dam beginning at the apron and out ***(see Survey Area Coverage Map below)*** and spaced at intervals sufficient to provide 200% coverage with 50% overlap. Lines perpendicular to the dam were laid out to begin at the dam apron and ended just beyond the end of the river wall overlapping the parallel lines at the apron.



Planned survey lines parallel to lock walls below dam

SURVEY AREA COVERAGE MAP:

AR Locks & Dam # 5
Survey Coverage Area

AR Lock & Dam # 6
Survey Coverage Area

AR Lock & Dam # 8
Survey Coverage Area

AR Lock & Dam # 9
Survey Coverage Area

DATA ACQUISITION:

Horizontal and Vertical Positioning - Navigation System:

Real-time Kinematic (RTK) corrections for GPS positioning was used for the entire survey. SEAS broadcasted RTK corrections from a local control point (listed in the table below) at each Lock and Dam. A Topcon GR3™ dual frequency GNSS GPS Receiver (see Appendix B) Base Station with an internal radio modem was used to produce and broadcast the CMR+ RTK correction message. SEAS FCC Radio Station Authorization Registration Number (FRN): 0018646646 and Call Sign WQKD252. The GPS receiver onboard the survey vessel was an Applanix POSMV Wavemaster GNSS GPS/IMU. The POSMV provides ALL motion variables and timing data at high rates for Multibeam System Surveys. Employing state-of-the-art high precision gyros which are tightly coupled to supporting GPS, the POS MV provides continuous and accurate position and orientation data logging for vessel and sensor guidance. Reliable POS MV output is produced in severe sea conditions, during periods of blocked or intermittent GPS, in areas where GPS reception is compromised by multipath effects, or at times when position drift must be reduced and faster signal reacquisition is essential.

RTK GPS base station on lock wall @ Barkley

POS MV delivers a full six degree-of-freedom position and orientation solution measuring location, velocity, attitude, and heave plus acceleration and angular rate vectors. Applanix marine solutions are able to affix position and orientation data accurately under the most

demanding conditions, regardless of vessel dynamics, 200 times each second, making direct georeferencing and motion compensation for maritime remote sensing operations a productive and practical option. The Accuracy specifications for the POSMV are listed in the table below.

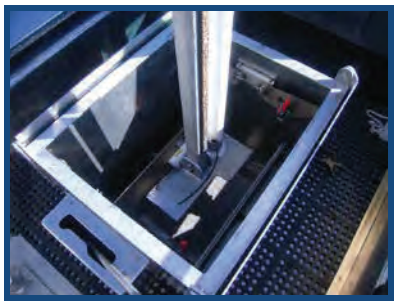
POS MV WaveMaster	DGPS	RTK	GPS Outage
Position	0.5 - 2 m1	0.02 - 0.10 m1	<3 m for 30 s outages, <10 m for 60 s outages
Roll & Pitch	0.030°	0.020°	0.040°
True Heading	0.030° with 2 m baseline	-	Drift less than 2° per hour
Heave	5 cm or 5%2	5 cm or 5%2	5 cm or 5%2

Multibeam Echo Sounder (MBES): Reson™ SeaBat 8124

All sounding data collection on the Cumberland River was performed with a RESON SeaBat 8124 Multibeam Echo Sounder (MBES) (see APPENDIX A for technical specifications). The SeaBat 8124 meets IHO and USACE Class 1 standards. The 8124 operates at 200kHz, has 120° swath coverage (3.5 x depth) and is capable of measuring up to 4,000 sounding per second.

Moon Well System

The sonar head is mounted on a 4”x4” gear driven aluminum mast and is deployed through the centerline of the survey boat hull via a 36”x24” moon well. The moon well is located just aft of the back of the cabin bulkhead. The sonar head is lowered to the survey There are hatch doors in the bottom of the moon well that are opened during the survey.



Multibeam in Moon Well

The topside (dry end) SeaBat components are the Sonar Processor and the Transceiver Unit. The sonar processor is a 19" rack unit that receives data from the transducer unit. The processor unit performs initial signal processing, beam forming, and bottom detection processing before exporting the data via Ethernet to the ship computer for storage, display, and further processing.

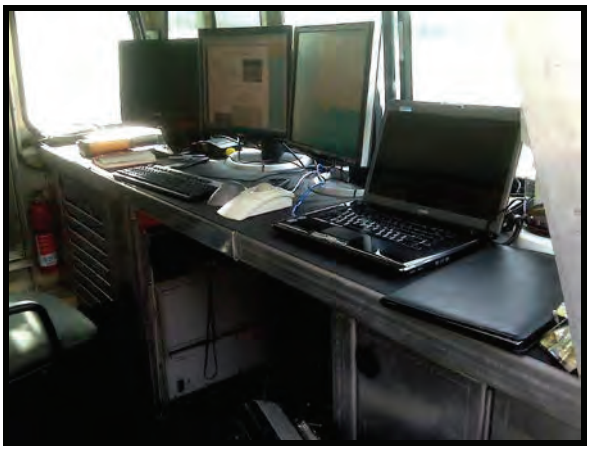
Sound Velocity Profiler:

A RESON SVP 14 to measure sound velocity profiles when performing multi-beam surveys. An accurate sound velocity profile is critical when processing multi-beam data. The use of the sound velocity profiler does not take the place of the standard bar check. The SVP 14 is lowered into the water at maximum wire speed of 3 m/s. As the SVP 14 is lowered it collects data every 0.5 meters in its internal memory. After the SVP 14 has been deployed and retrieved it is downloaded using the SVP Control software. The SVP Control software creates a Sound Velocity Profile which is used in HYPACK during data processing. (see APPENDIX C for technical specifications)

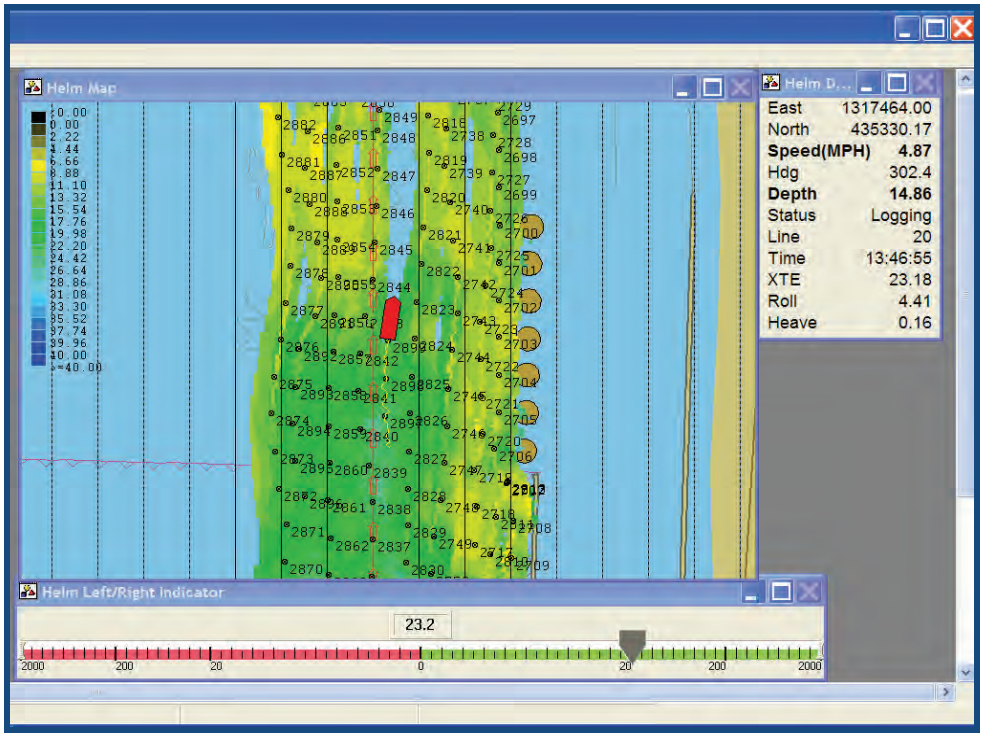
RESON SVP 14

HYPACK/HYSWEEP Software:

HYPACK and HYSWEEP™ software was utilized to display charts and collect all hydrographic data. A custom built rack mount CPU was used to run the data collection system. Data was collected parallel with the lock river walls. Data was collected parallel to the dam and the power house on the areas above and below the dam with these exceptions (could not survey above power house at Cheatham due to the debris boom and below Barkley because power generation could not be shut down completely). The lines were spaced to provide 200% coverage of the river floor. HYPACK / HYSWEEP was also used to edit the hydrographic survey data.



Ship Computer Running HYPACK



Helmsman Display is pictured below. This screen is used by the pilot to navigate the survey boat along either predetermined survey lines or the pilot can paint the screen. In the screen shot below the survey boat (red object in center of screen) is filling in an area missed due to shallower water. The width of the sweep is 3.5 times the water depth so when the water gets shallower the

sweep gets narrower. The depths are color coded as indicated by the legend on the left side of the Helm Map.

A second monitor displayed additional information about devices (GPS, sounder, heading), profile (profile view of depth data), plan view (map of survey with boat track etc...). The system also displayed Electronic Navigational Charts (ENC), Aerial photographs and other georeferenced imagery in the background during the survey. While the vessel was underway and surveying, the Crew Chief monitored the collection process. This involved watching the incoming data to be sure RTK positions and depths were consistent with the vessels location. The Crew Chief also kept notes on information that would be useful during the editing process. The system collected water depth with a location based on UTM Zone 17N coordinate system.

SURVEY SYSTEM CALIBRATION:

A **Patch Test** is a system calibration procedure for multibeam survey boats. It is nearly impossible to measure the relationships between the MBES sonar head, GPS antennas and the dynamic motion unit mounted positions and angles accurately enough for survey quality data, so the patch test is performed. In addition to pitch, roll and yaw (heading) angles, the patch test can be used to find positioning system latency. The **Latency Time** is the time delay in milliseconds (1 millisecond equals 1/1000th of a second) from when a device (instrument) takes a measurement to when it is received by the computer. Knowing the latency of each device allows the **Survey** program to correctly time tag the information from that device. Performing a patch test requires the survey boat to navigate lines over specific types of bottom terrain in a specific order.

The **Roll angle** is tested first by locating an area where the bottom is smooth and flat, and running a single line in opposite directions at normal survey speed. Over these bottom conditions, latency, pitch and yaw angles do not matter. Positioning **Latency** is tested next by running a single line twice, in the same direction across a prominent feature or up a steep slope, once at maximum survey speed then again as slowly as possible. During this test errors in pitch and yaw angles cancel out. Then **Pitch** is tested by running a single line in opposite directions across the same prominent feature or steep slope at normal survey speed.

The **Yaw offset** is an orientation offset which is added to ship's orientation. It is intended to be used with multiple transducer systems which are not oriented perpendicular to the ship's longitudinal axis. Yaw is tested last by running parallel lines in the same direction. Line separation is determined by the water depth at top of bank. After the data has been collected, the HYSWEEP Patch Test program will automatically calculate the correct roll, pitch and yaw mounting angles and positioning system latency.

Patch Test Results:

The Patch Test was performed on each day or each time the survey boat was put into water. The patch tests were processed in the field by the survey crew on-board the survey boat after the test was run. The results of the patch test were compared to previous patch test results to determine if there were any potential problems with the survey system. The results were recomputed during data processing and applied to the survey data.

SURVEY CONTROL:
Horizontal and Vertical control used for each of the Locks and Dams was provided by the Pittsburgh District Corps of Engineers and TerraSurv, Inc. The survey control stations were established by TerraSurv, Inc. at each project. The following table is a list of the control stations used for these projects

RTK GPS BASE STATION CONTROL DATA							
Project	ID	SPCS Northing FEET	SPCS Easting FEET	UTM – N FEET	UTM – E FEET	ELEV. NAVD88	ELEV. NAVD88
AR #5	M2	497,633.148	1,436,579.036	14,778,439.07	2,009,680.45	767.72ft	234.002m
AR #6	M3	509,126.921	1,460,963.512	14,790,821. 67	2,033,619.66	779.04ft	237.451m
AR #8	M3	573,370.641	1,491,221.043	14,856,126.23	2,061,479.64	807.07ft	245.995m
AR #9	M2	596,102.824	1,472,128.279	14,878,132. 83	2,041,563.77	831.54ft	253.454m

1. State Plane Coordinate System (SPCS) Pennsylvania South, NAD 1983 U.S. Survey Foot.
2. UTM Zone 17N – NAD 1983 U.S. Survey Foot.
3. Elevations are NAVD 1988 Feet and Meters.

GPS position accuracy check (disk on lock wall)

POSITION ACCURACY CHECK:
The positional accuracy of the GPS navigation system was checked prior to any data collection at each project and at the completion of data collection. The position accuracy was also checked throughout the course of the project depending on the availability of local survey control. Following is the procedure which was used in performing the Position Accuracy Checks:

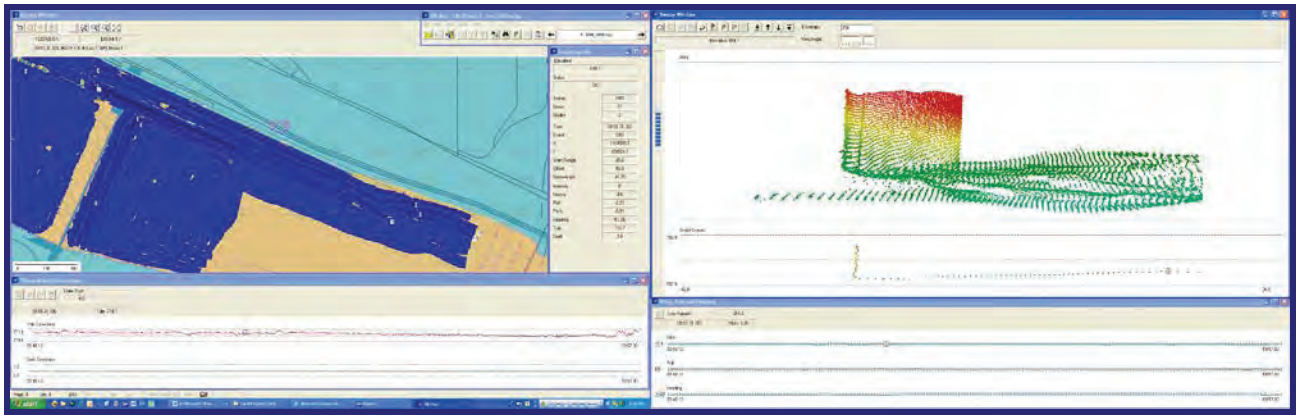
Navigation System Checks to Charted Fixed Objects:
Checks were made at lock wall and guide wall ends using the position of the end of the wall in the Electronic Navigational Chart as a reference point. Target positions were taken off of the end of the guide wall and lock wall at each lock and dam. The check was done by maneuvering the boat alongside the guide wall and measuring an offset distance from the GPS reference antenna on the boat to the side of the guide wall. The position of the GPS reference antenna was then recorded in HYPACK. The recorded position is then compared to the chart position to determine the accuracy of the navigation system. Visual checks are also made by the survey crew chief

during the survey by visually comparing the position of the survey boat as shown on the display in relation to an object in the navigation chart.

HYDROGRAPHIC DATA PROCESSING:

Multibeam Data Editing:

The Multibeam hydrographic survey data was edited with HYSWEEP™. All collected data; Positions, Heave Compensation, Heading and Soundings were displayed graphically and inspected for errors. A filter was set to remove obvious bad data (spikes). The range of depths encountered in the river was used to set a minimum and maximum allowable depth. A horizontal offset filter was also entered to filter erroneous position data that was obviously out of range, sometimes caused by bad PDOP, or loss of radio link with the GPS base unit.



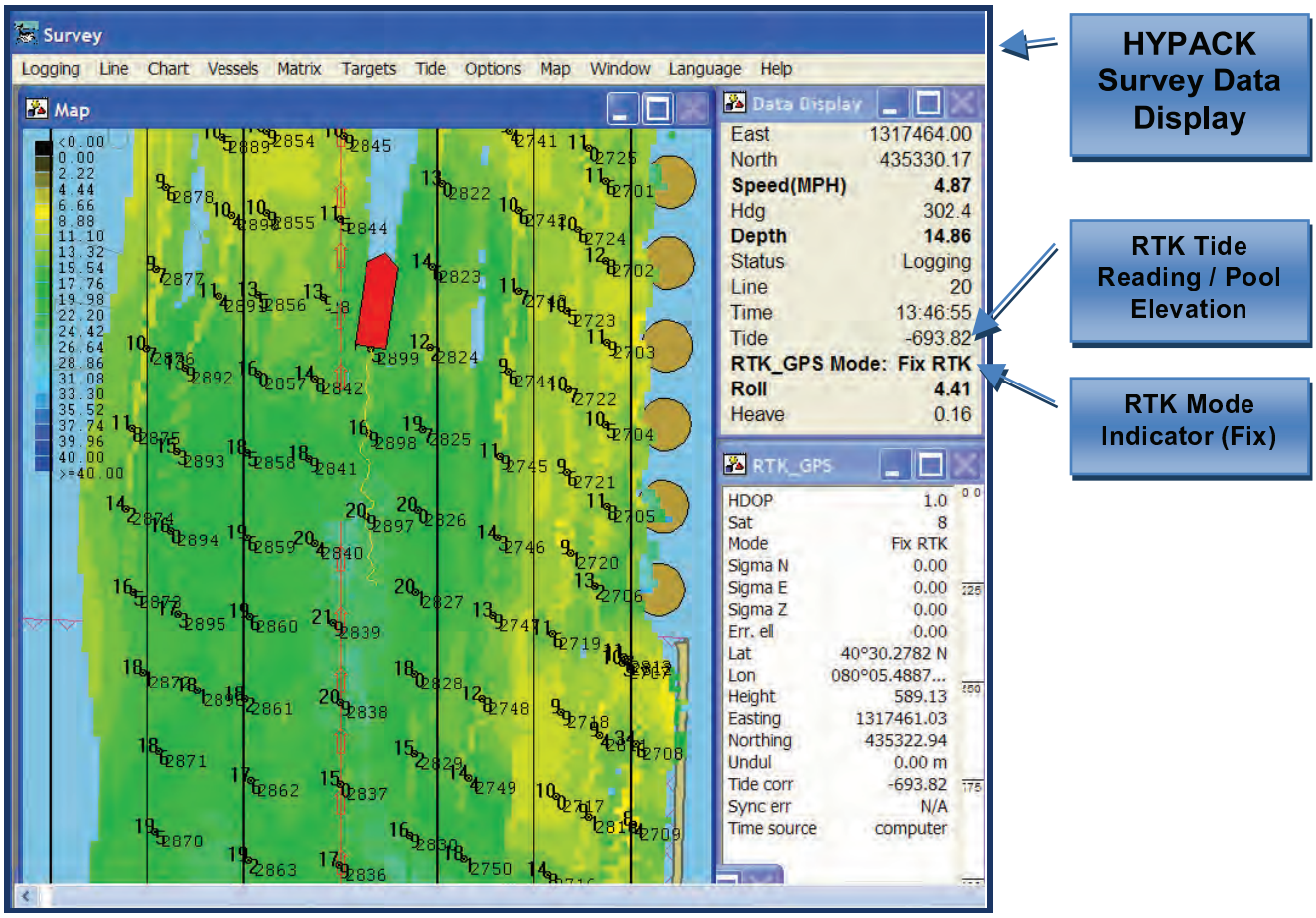
Screen capture of HYSWEEP Multibeam editing screen during data processing

RTK Tides was used for the elevation datum during processing. After the Multibeam data was edited, HYSWEEP™ Mapper was used to convert the edited data files into points (X, Y and Elevation). The multibeam system collects much more data than is needed to meet the project specifications. The Mapper program loads in all of the survey data and reduces the data to the desired density through gridding; ten and three foot grids were created in the form of a matrix (*.MTX) file, with square cells, then the soundings were loaded and reduced to one per cell. The selection process used the average depth of the cell.

The XYZ ASCII point files produced in HYSWEEP Mapper were imported into MicroStation V8 In-Roads and a DTM file was created. Contours were generated at one foot intervals from the DTM. The contours were inspected for anomalies and irregularities. The contours were then labeled. The XYZ elevation files were imported into Microsoft Excel and the depths were subtracted from the Project Pool elevation to produce ASCII depth files one for the upper pool and one for the lower pool. The XYZ depths files were imported into HYPACK and exported as dxf files. The dxf files were imported into Microstation V8.

Vertical Datum for Survey:

The Vertical Datum for the survey is North American Vertical Datum 1988 (NAVD88). RTK GPS was used to provide the vertical datum reference during the survey. The Latitude, Longitude and Ellipsoid Height of the survey control station was entered into the reference GPS receiver which was set up on one of the control station on a lock wall listed in the table above. The Geoid03 Region 7 geoid model was selected in HYPACK and the Height of the GPS antenna above the water surface was entered into HYPACK Survey. The Tide reading from HYPACK was then compared to the gage reading (reduced to pool elevation) provided by Lock personnel during the survey. This data was recorded in the field book during each survey. During data processing in HYPACK the electronic stored data is compared to the survey field notes for accuracy.



SURVEY VESSEL:

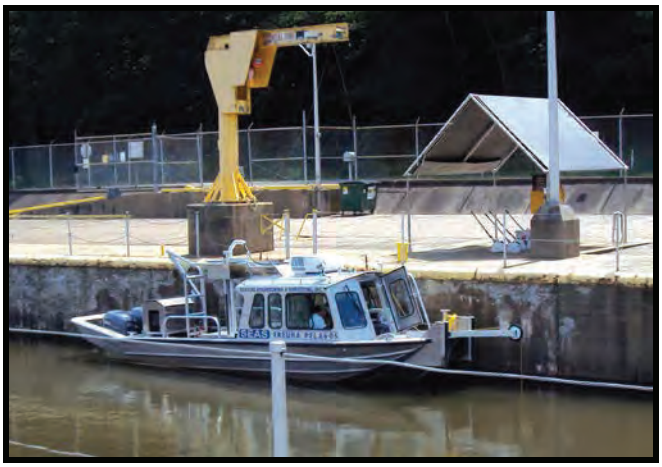
SEAS survey vessel used for this project is a 2009 Scully's aluminum survey boat with an overall length of 28 feet and an 8.5 foot beam. The hull is a shallow V type and drafts about 20" loaded. The boat has an 8 foot cabin. The rear deck is self bailing with a moon well for the deployment of singlebeam, multibeam transducers, or a fixed

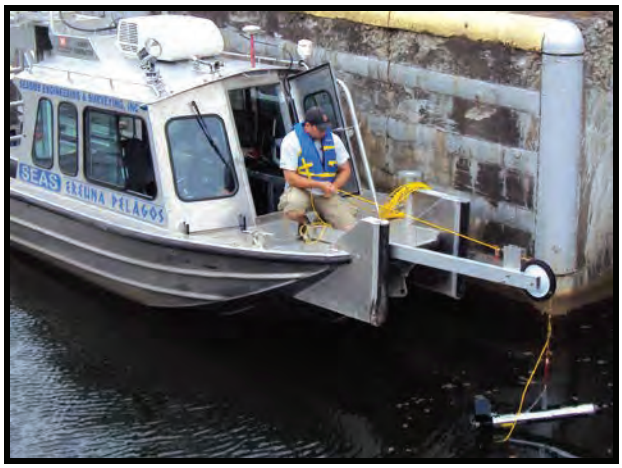
Survey Boat - SEAS Surveyor II

mount side scan. The vessel is powered by twin Yamaha 200 hp engines. Power on the vessel is provided by a Honda 6500 kW generator. The electrical system on the survey boat is equipped with GFCI Safety Protected AC outlets.

2D and 3D MICROSTATION V8 BASEMAPS:
SEAS Microstation technicians created 3D Contour Planviews and Color Planviews of each lock and dam structure. The 3D model files contain the lock and dam and powerhouse (if applicable), the survey control marks, survey control data, grid ticks, survey notes, river mile, shoreline, pool information, north arrow, graphic scale, project information and Pittsburgh District border sheet. The Color Planviews contain the colored terrain, and the Cross Section layout one above and one below the dam structure. The 3D model files are in the Universal Transverse Mercator (UTM) Zone 17N Coordinate System and the units are U.S. Survey Foot.

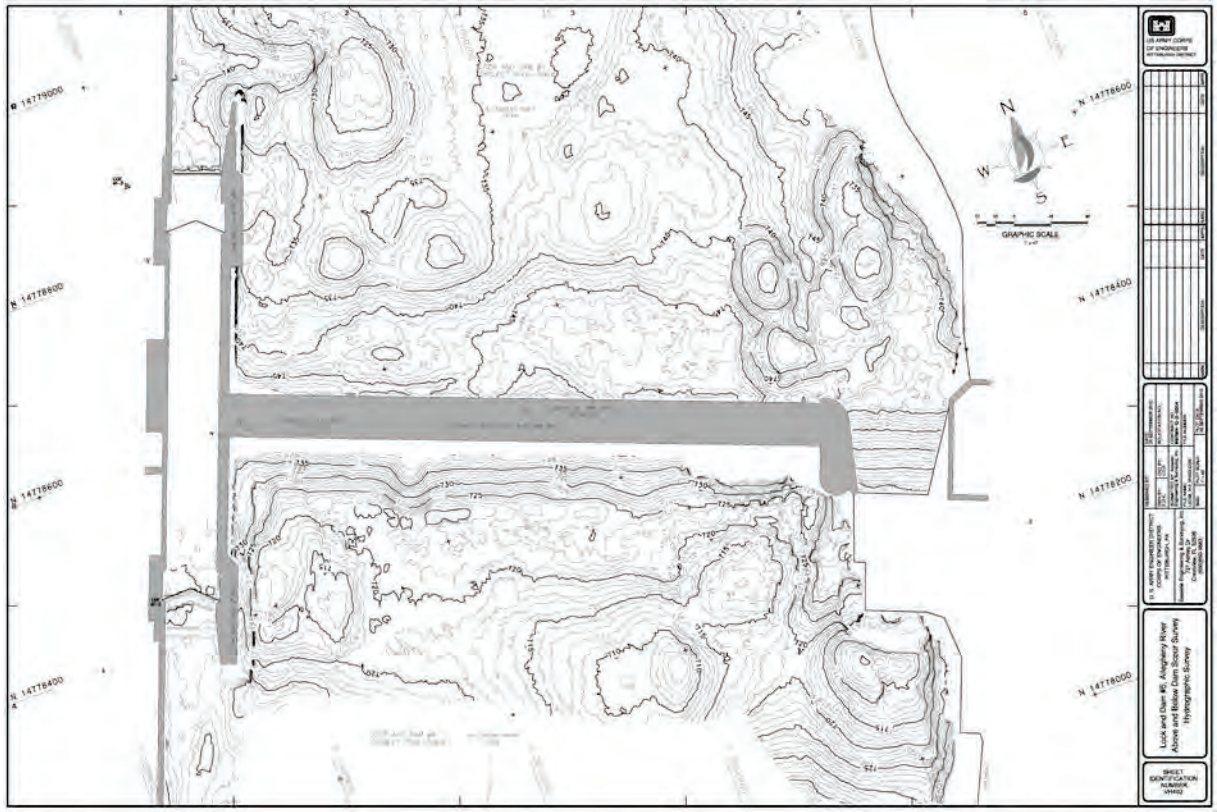
SIDE SCAN DATA COLLECTION
The side scan data was collected with an EdgeTech 4125-P dual High frequency sonar system (see Appendix D). This system is a 400/900 kHz dual frequency stainless steel towfish,

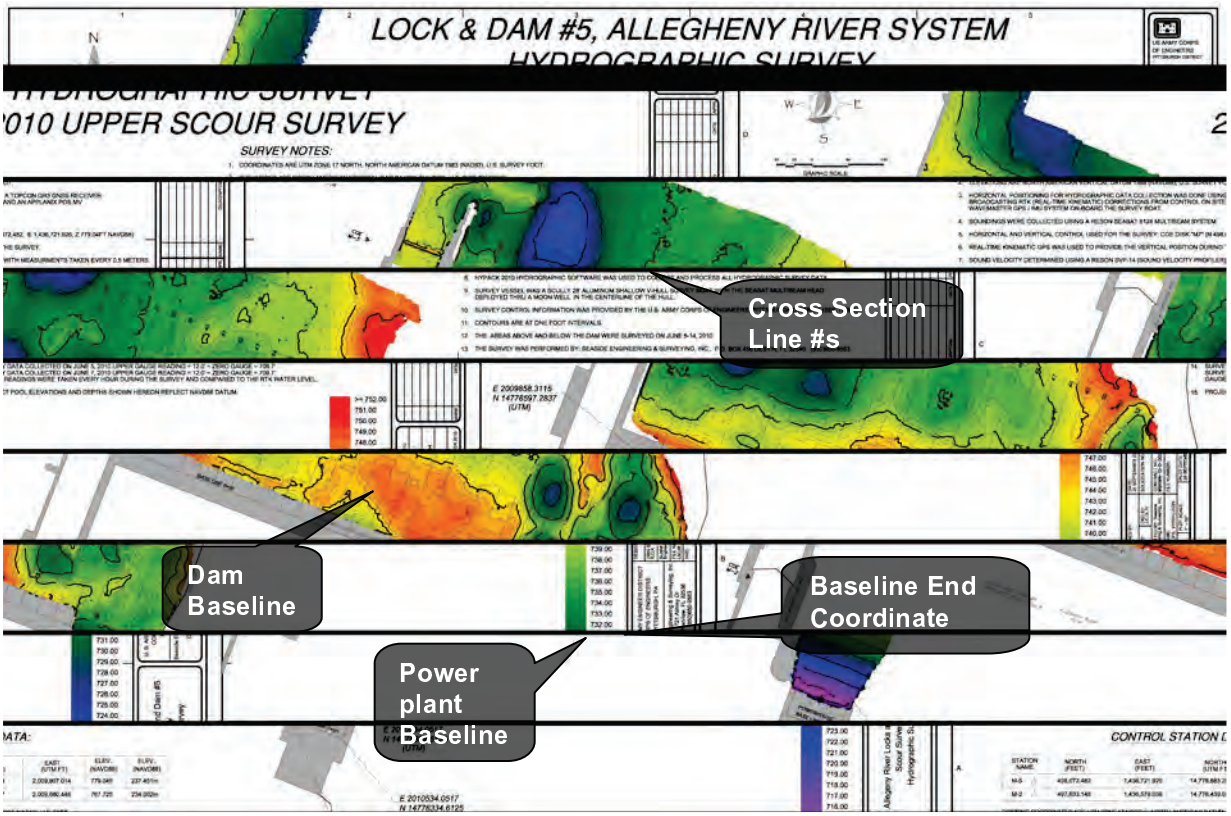

SEAS survey boat in lock chamber with side scan



EdgeTech Towfish mounted off the bow

combined with a small portable water resistant topside processor. The towfish has internal sensors which measure the roll, pitch, heading and depth and a 50 meter tow cable. The towfish was deployed over the bow of the survey boat. The side scan data was collected with EdgeTech's DISCOVER software. The horizontal and vertical offsets of the location of the tow point in relation to the survey boats navigation system reference frame and the cable layback are entered into the EdgeTech DISCOVER software.




LOCK & DAM #5, ALLEGHENY RIVER SYSTEM
2010 UPPER SCOUR SURVEY
SURVEY NOTES:
Cross Section Line #s
Dam Baseline
Baseline End Coordinate
Power plant Baseline

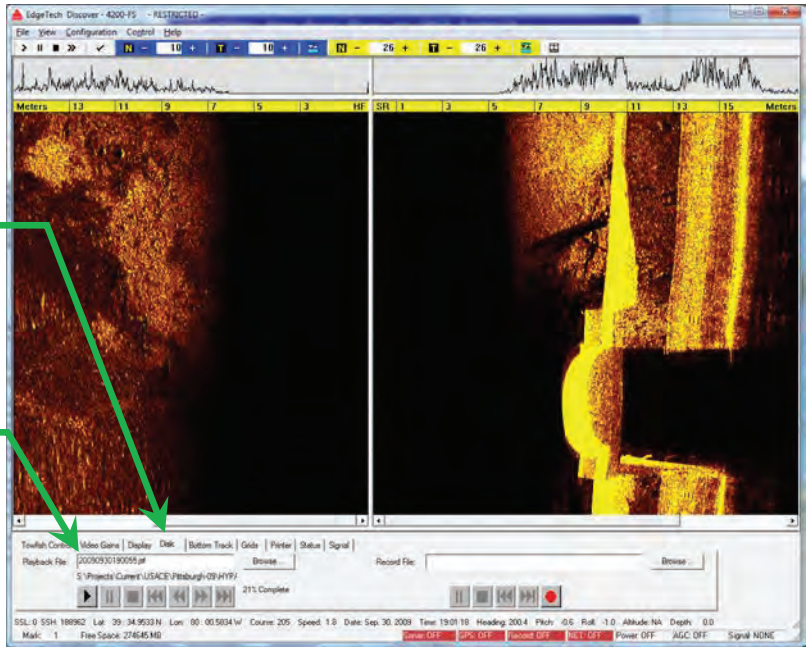
Side scan data processing:

EdgeTech 4125 Towfish and Topside Processor

The side scan data was processed with Chesapeake Technology, Inc. SonarWiz Map software. The side scan data was collected in the native EdgeTech JSF file format and in XTF file format. The native JSF format files are imported into the SonarWiz Map software. The individual lines or passes are corrected for cable out and layback. The bottom track of the towfish is also corrected for each line. A mosaic of all of the lines is created and exported as a Geotiff as well as the individual lines. The EdgeTech DISCOVER software is the best way to view the side scan imagery. The raw side scan JSF files can be loaded into the DISCOVER program and played back.

The DISCOVER program has been provided on the submittal disk.

DISCOVER Software

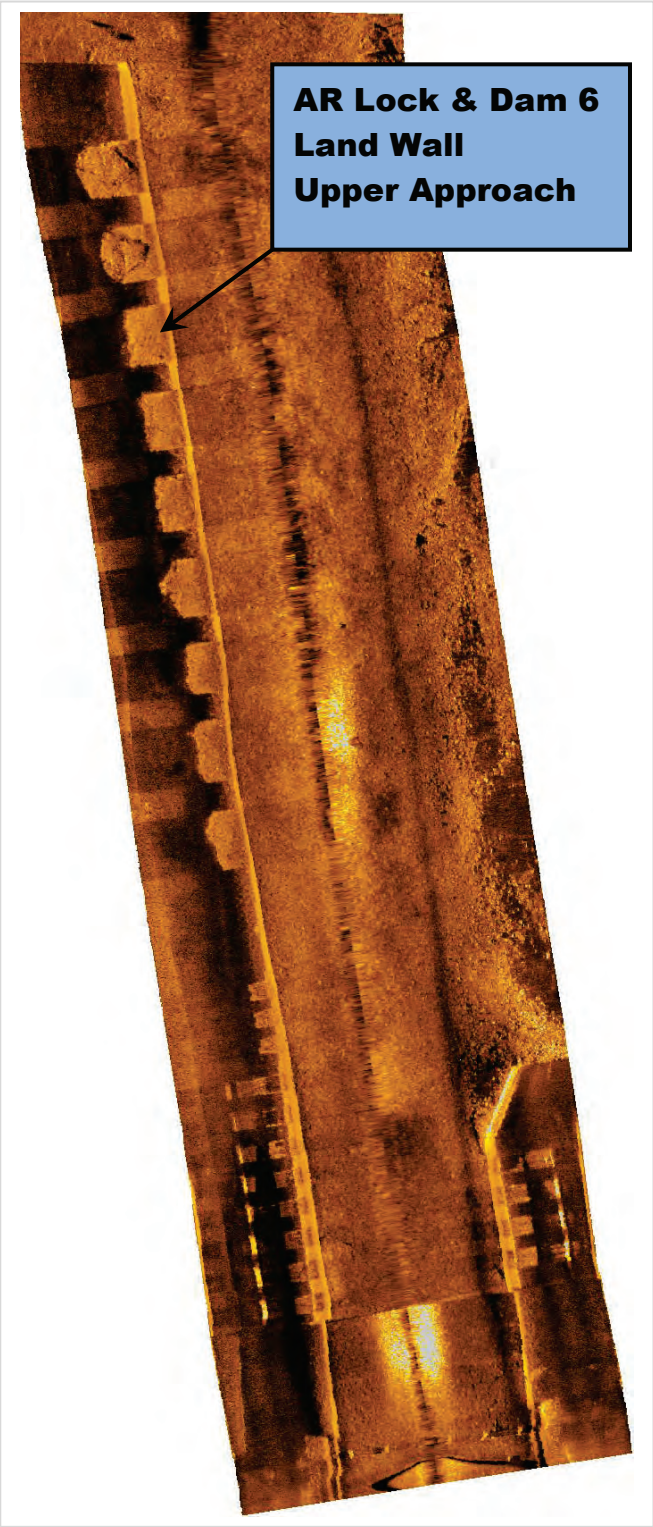


Select the Disk tab of the control panel to load and playback side scan imagery

Browse to the desired JSF file and press the play button.

The side scan data was processed to create mosaics at each project. The mosaics are georeferenced TIFF images. The mosaics are created from a compilation of the single passes/lines of the High (900kHz) and Low (400 kHz) side scan data. Georeferenced TIFF images have also been created for each individual pass/line of the high resolution side scan data. An example mosaic in Google Earth and single pass image is shown below.

SIDE SCAN IMAGE SINGLE PASS ABOVE AR - 6 LOCK & DAM

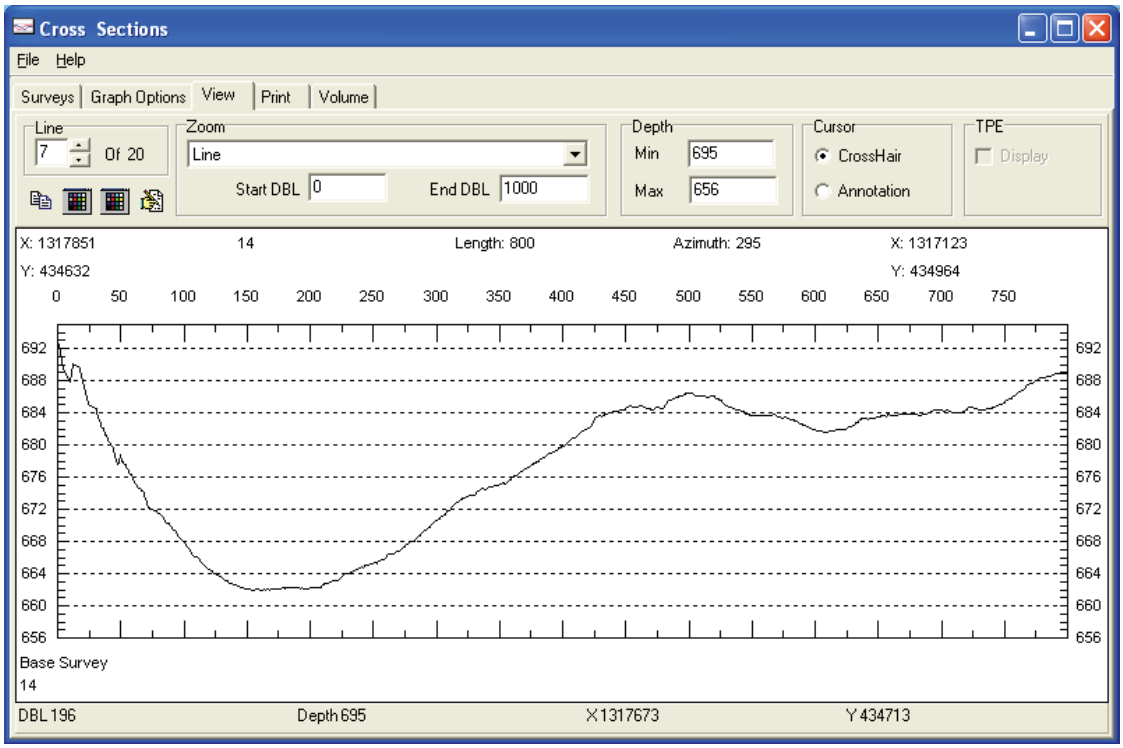


SIDE SCAN IMAGE MOSAIC ABOVE CHARLEROI DAM

(GOOGLE EARTH KMZ FILE)

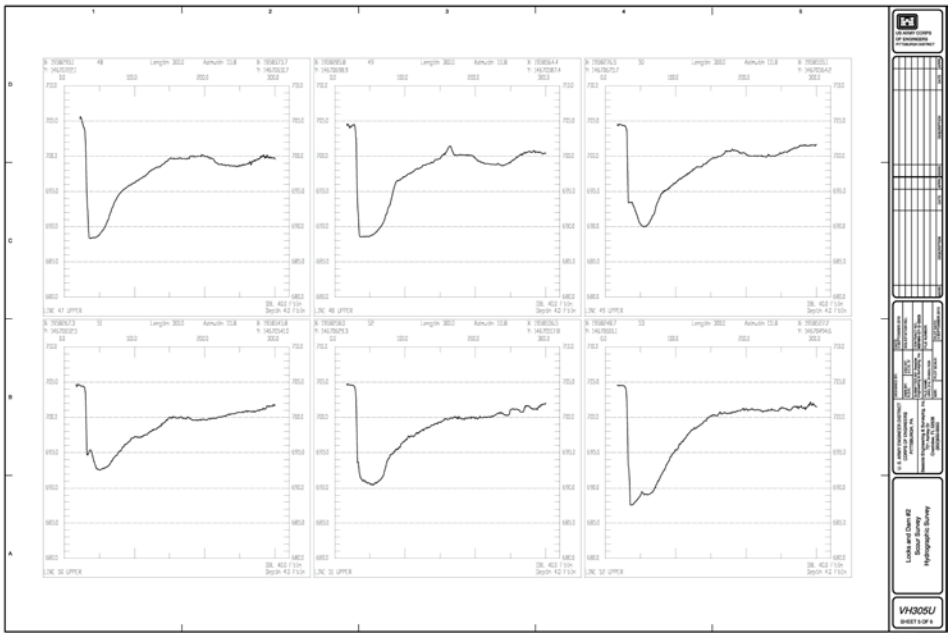
CROSS SECTIONS OF DAM SCOUR DATA:

For each dam surveyed scour, SEAS technicians created cross sections of areas above and below the dam. A baseline was created in MicroStation along the center of each dam. The baseline is not monumented in the field but the UTM Coordinates of the beginning and end points are listed in each of the drawings. The sections were created perpendicular to the baseline at 25' spacing. The cross section alignment was then created in HYPACK using the line editor. The coordinates



View of cross section station in HYPACK

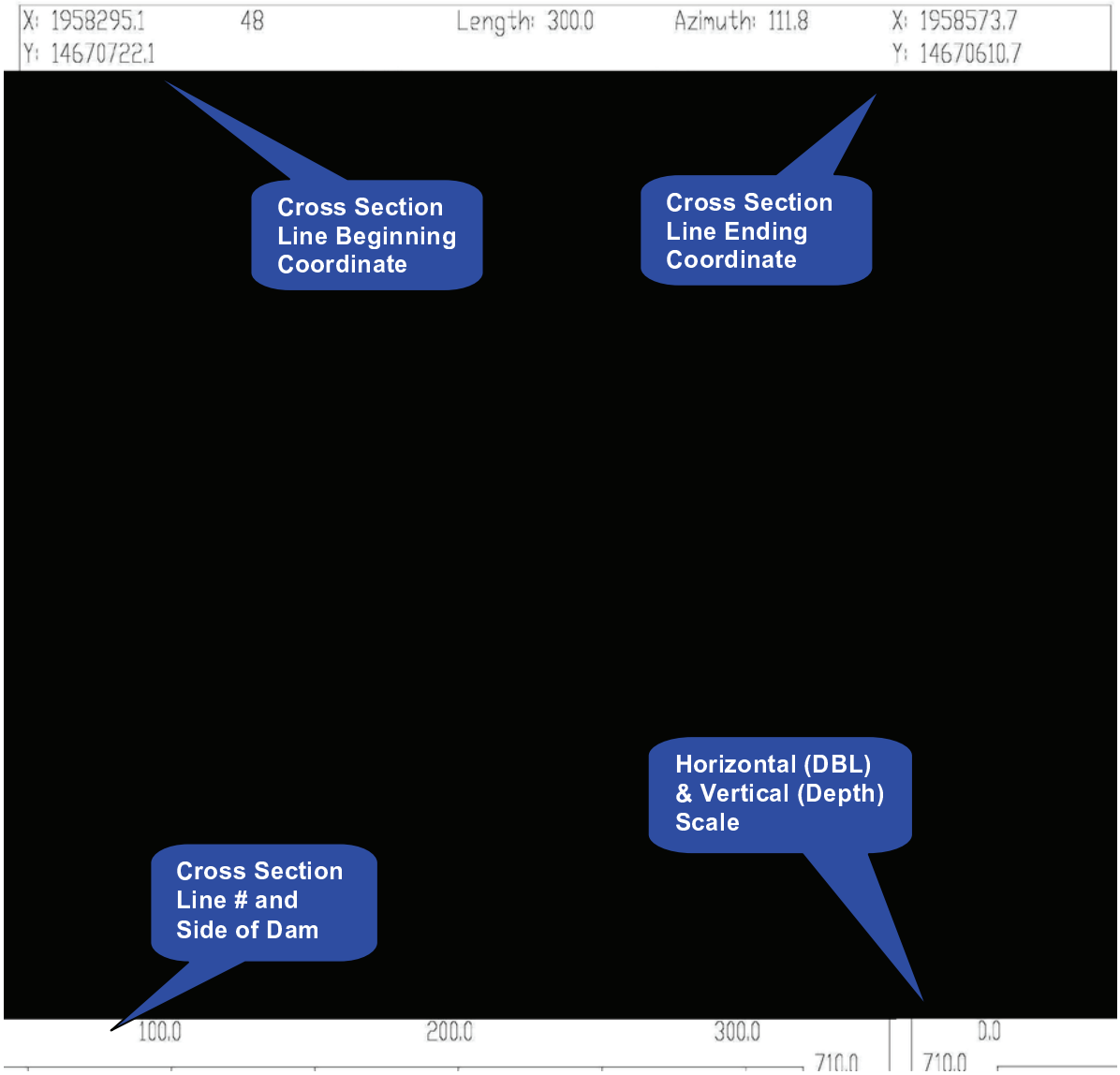
for each cross station was and offset at



end of section 0+00 entered then 25 foot

MicroStation Cross Section sheet above Braddock Dam

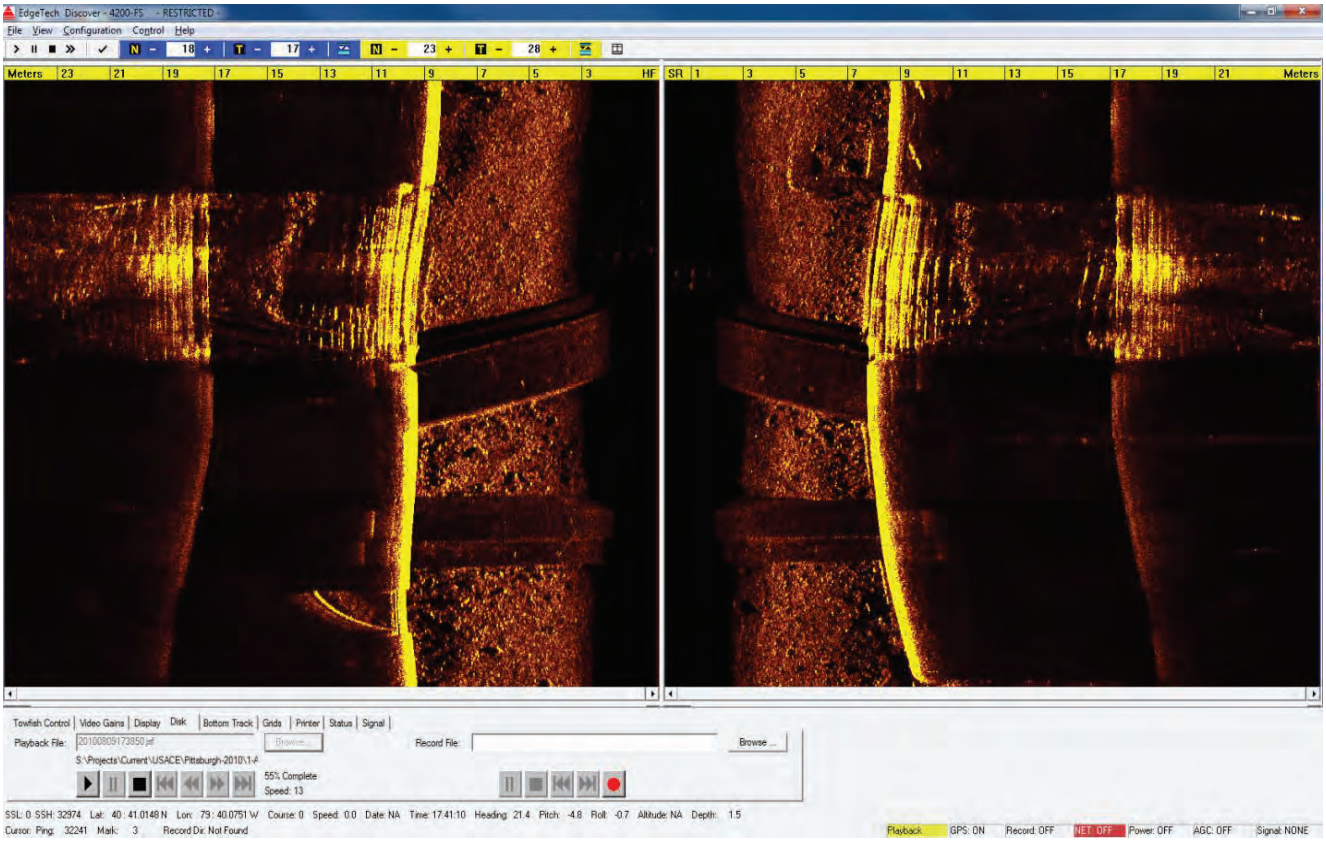
intervals to the end station. A TIN was created in HYPACK from the edited multibeam data. The cross sections were pulled through the TIN data. The cross sections were then exported out of HYPACK into a DXF file and imported into MicroStation. A sample Cross Section is shown below with the pertinent information pointed out.



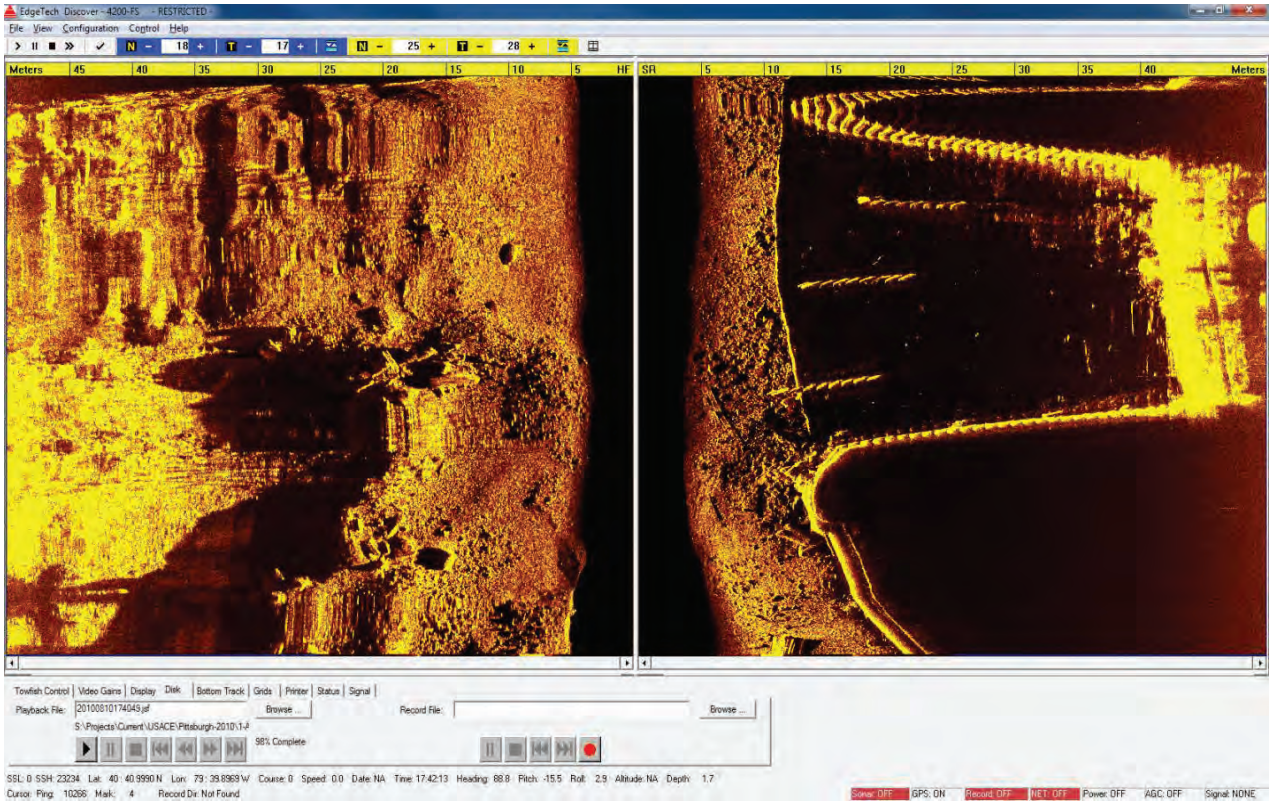
SIDE SCAN SCREEN CAPTURES FROM EDGETECH DISCOVERY:

The raw side scan JSF files can be loaded into the DISCOVER program and played back. The screen shots on the following pages were captured from the playback of the side scan data.

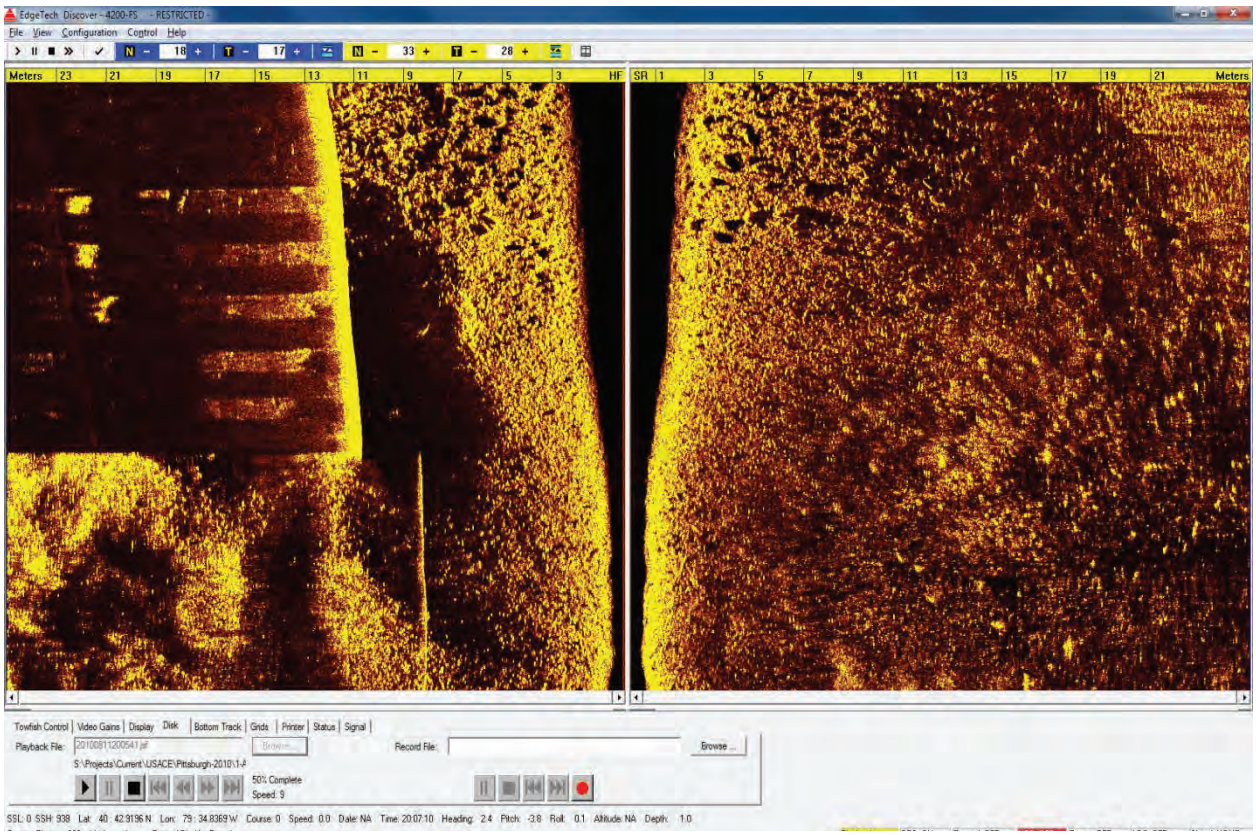
AR LD-5 Lower Guard Seal and Gate Seal



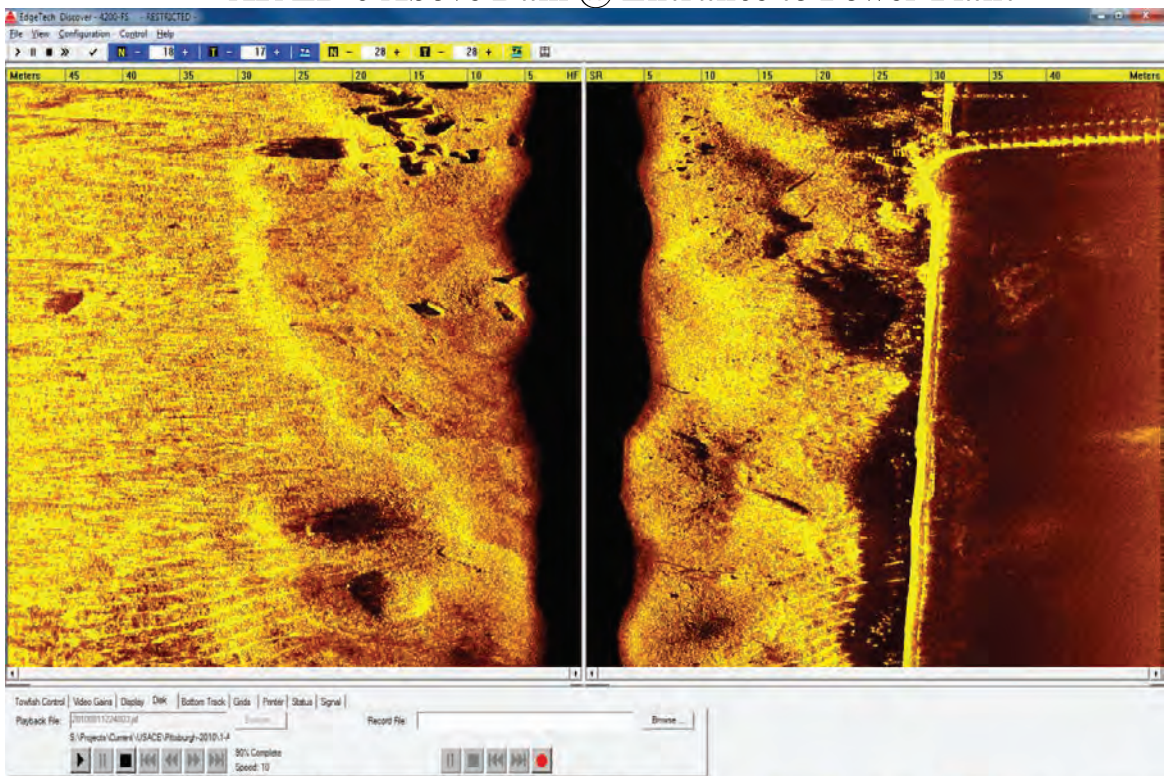
AR LD-5 Power Plant Intake Area



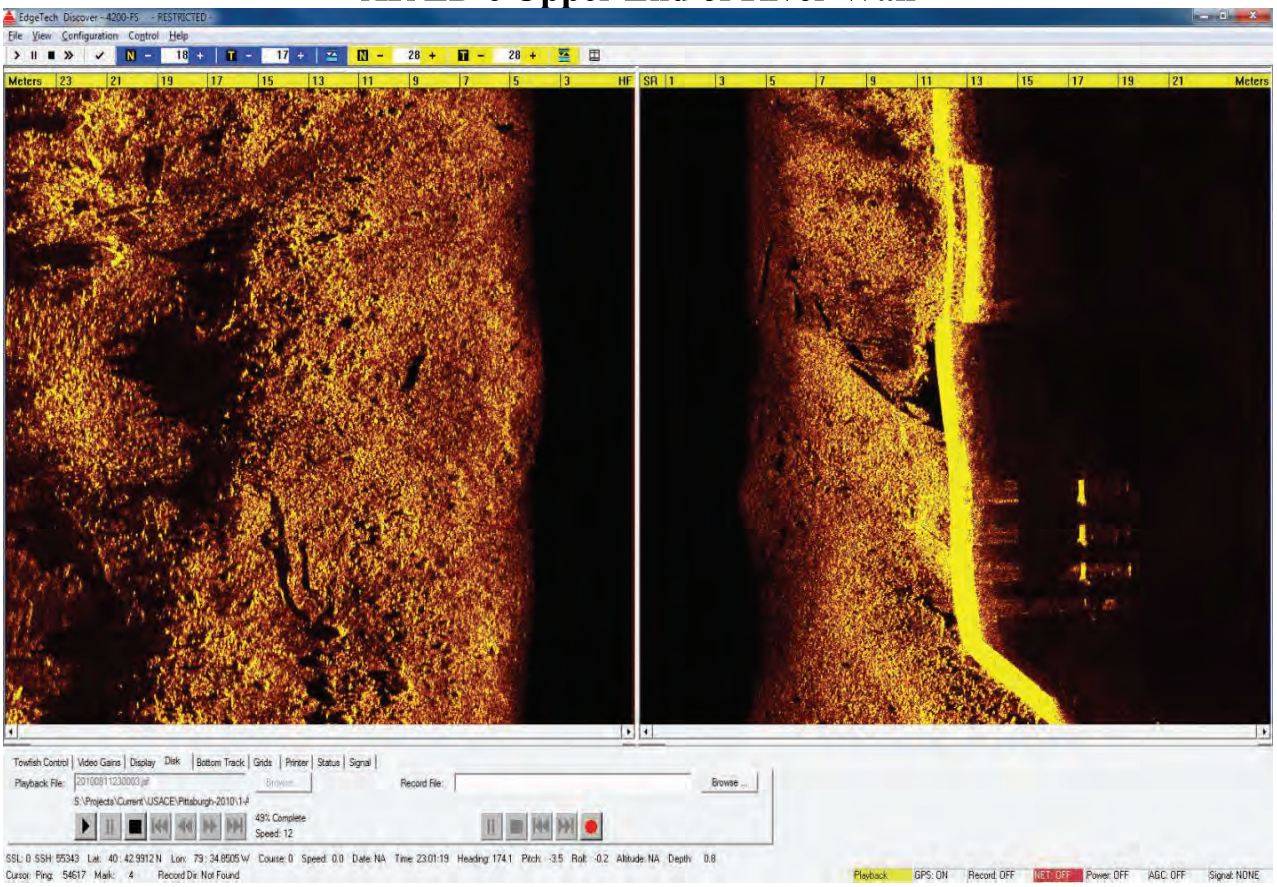
AR LD 6 Lower end of River Wall



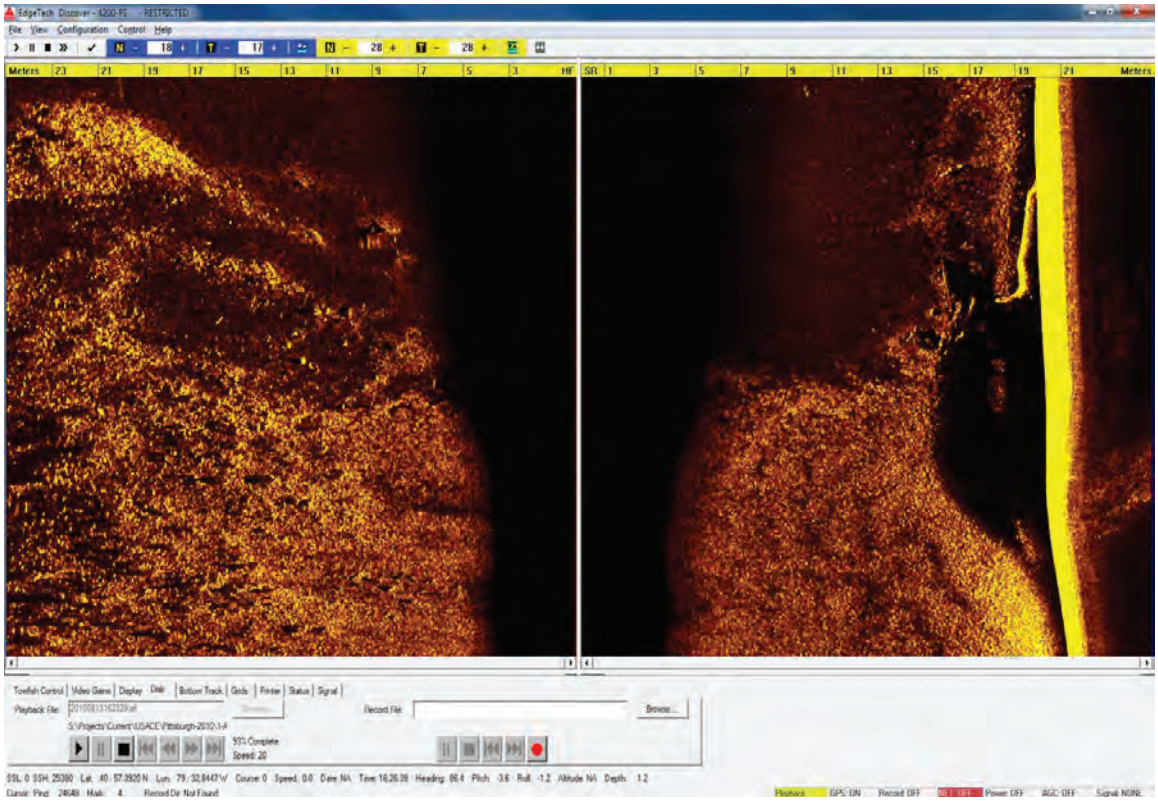
AR LD 6 Above Dam @ Entrance to Power Plant



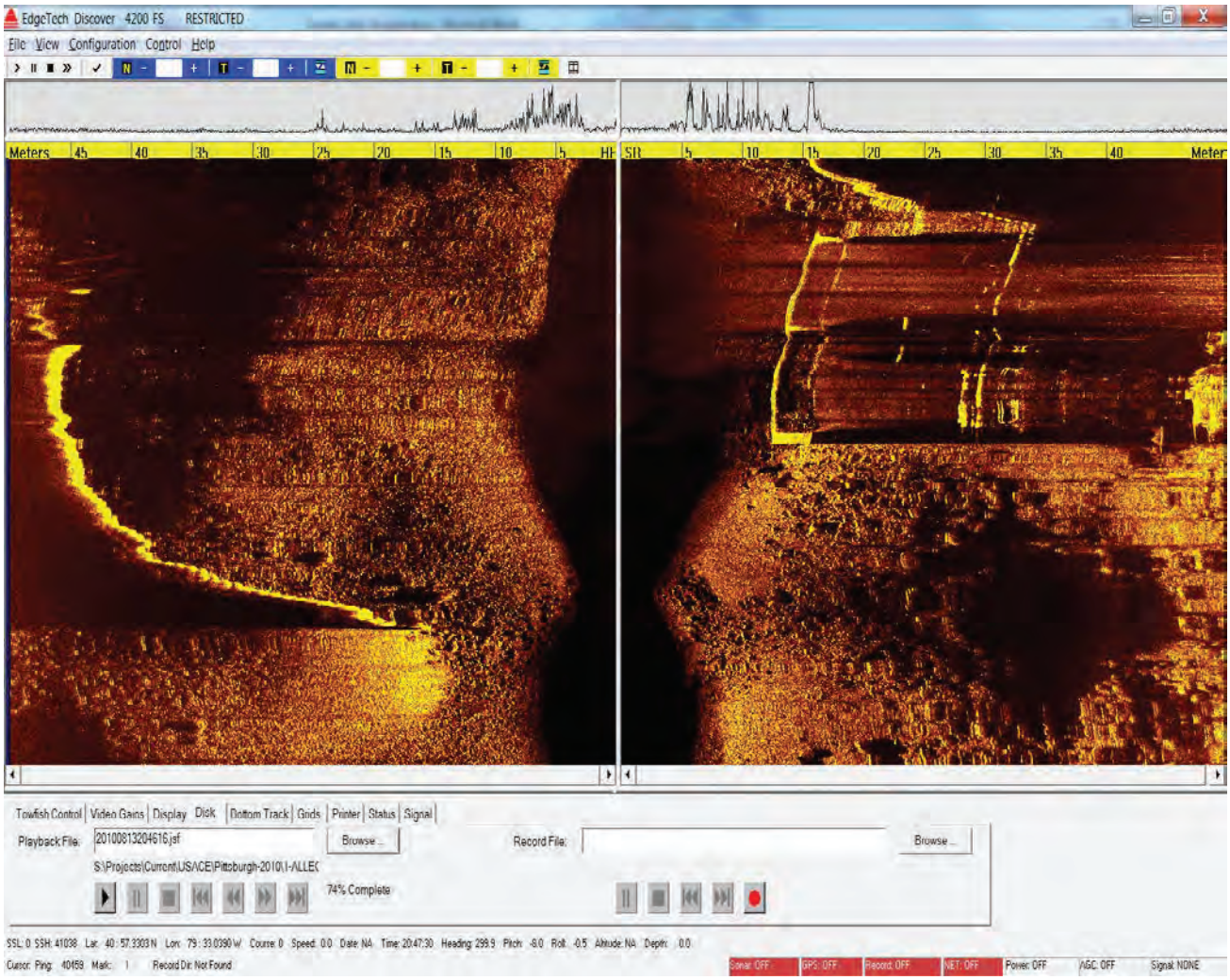
AR LD 6 Upper End of River Wall



AR LD 9 Below Dam



AR LD 9 Below Power Plant



APPENDIX A

RESON SeaBat 8124 multibeam echo-sounder

APPENDIX B

Applanix POSMV Wavemaster
GPS GNSS IMU

APPENDIX C

RESON SVP14 (Sound Velocity Profiler)

APPENDIX D

EDGETECH 4125-P (High Resolution - Side Scan Sonar)

APPENDIX E

Topcon GR3

APPENDIX F

Scope of Work (SOW)

[NOTE: ALL APPENDICES TO THE SURVEY REPORT WERE WITHDRAWN FROM THIS APPENDIX]

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APPENDIX N

Application Examples of Underwater Structural Investigation Surveys

N-1. This appendix contains examples of application projects provided by various inland districts. It is intended to illustrate the capabilities of these USACE districts in applying multibeam systems and related sensors to obtain detailed underwater (and above water) topography of locks, dams, bulkheads, and other structures. The indicated districts should be contacted for additional information on these applications.

N-2. Lock and Dam Multibeam Surveys. The following figures are examples of the resolution details available from multibeam surveys navigation lock approaches, approach wall pilings, gates, baffle blocks, and scour areas.

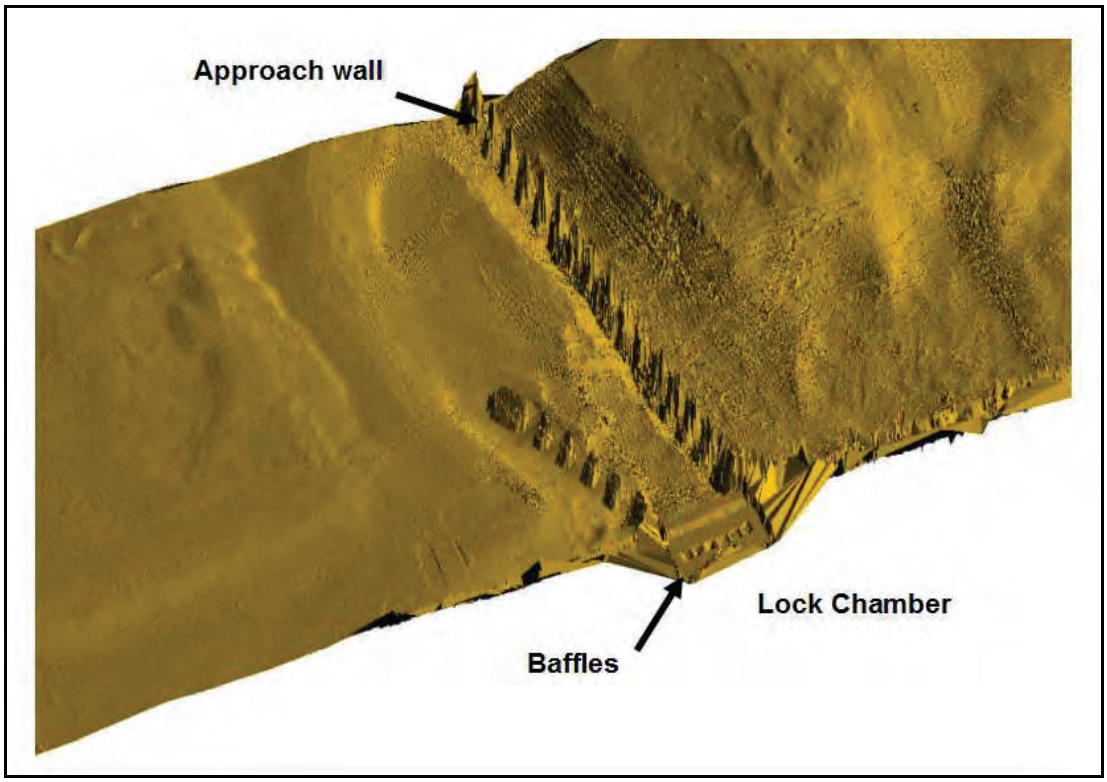

Figure N-1. Model from multibeam survey of approaches to Woodruff Lock and Dam, Apalachicola River, FL. (Mobile District--EMC, Inc)

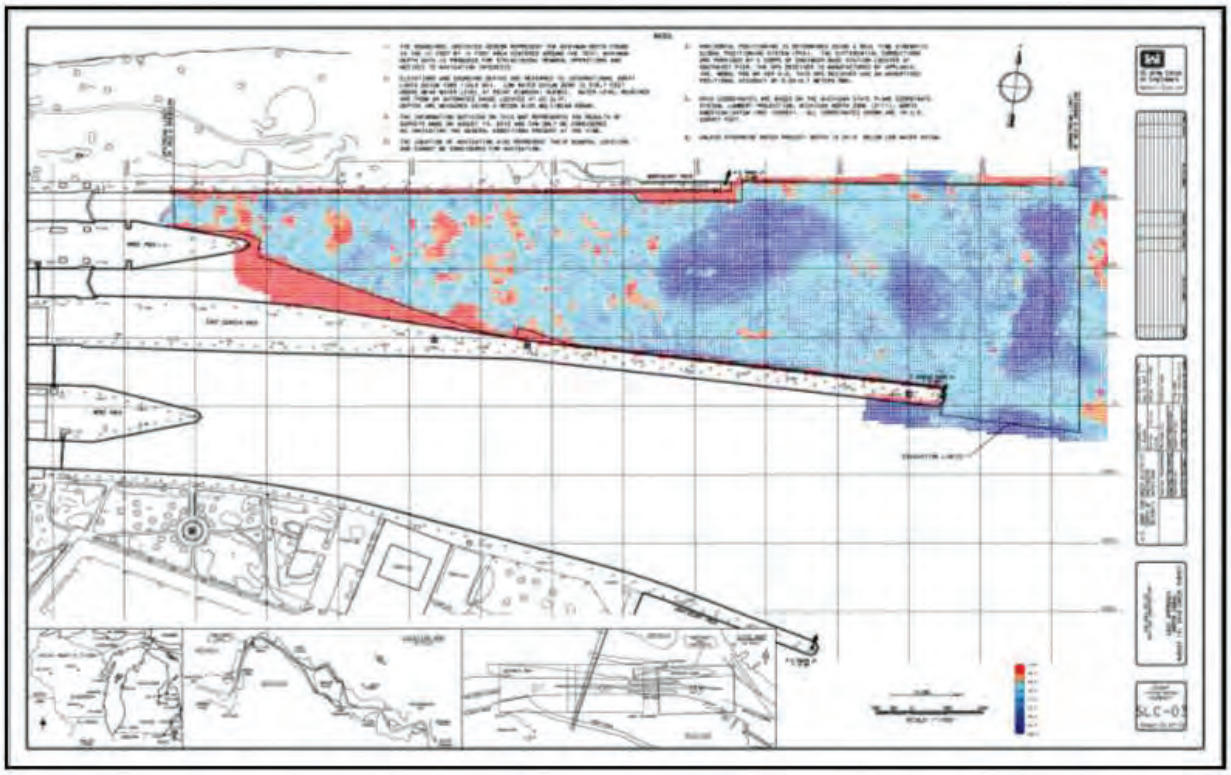

Figure N-2. Soo Locks East Approach Deepening Contract. Detailed multibeam survey by S/V Bufe, Soo Area Office. (Detroit District)

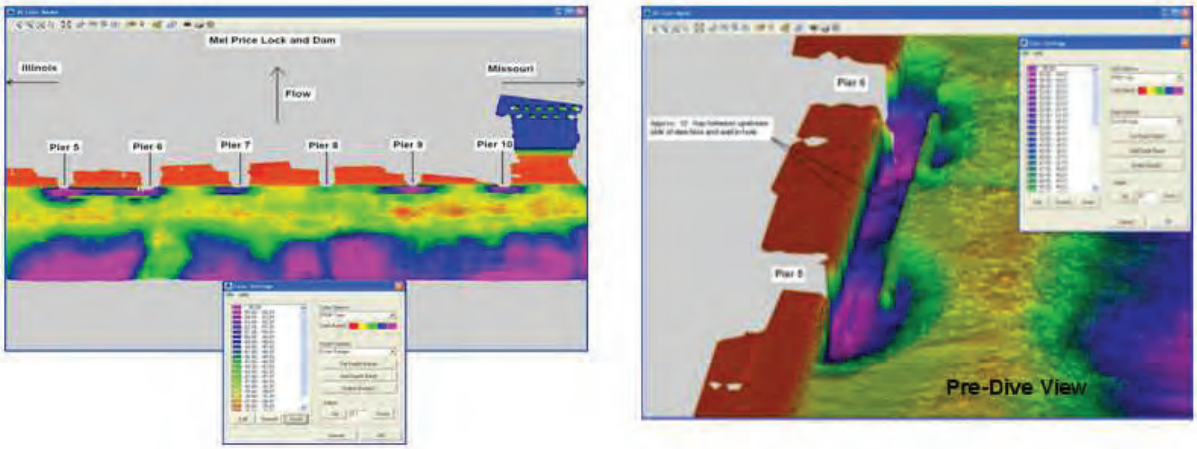

Figure N-3. On left, initial plan of multibeam survey at Mel Price Lock & Dam (Mississippi River). Significant scour (15 to 20 ft below normal grade) was indicated at piers 5, 6, 9, and 10). On right, 3D detail model of Pier 5 and 6 scour area furnished to divers. (St. Louis District)

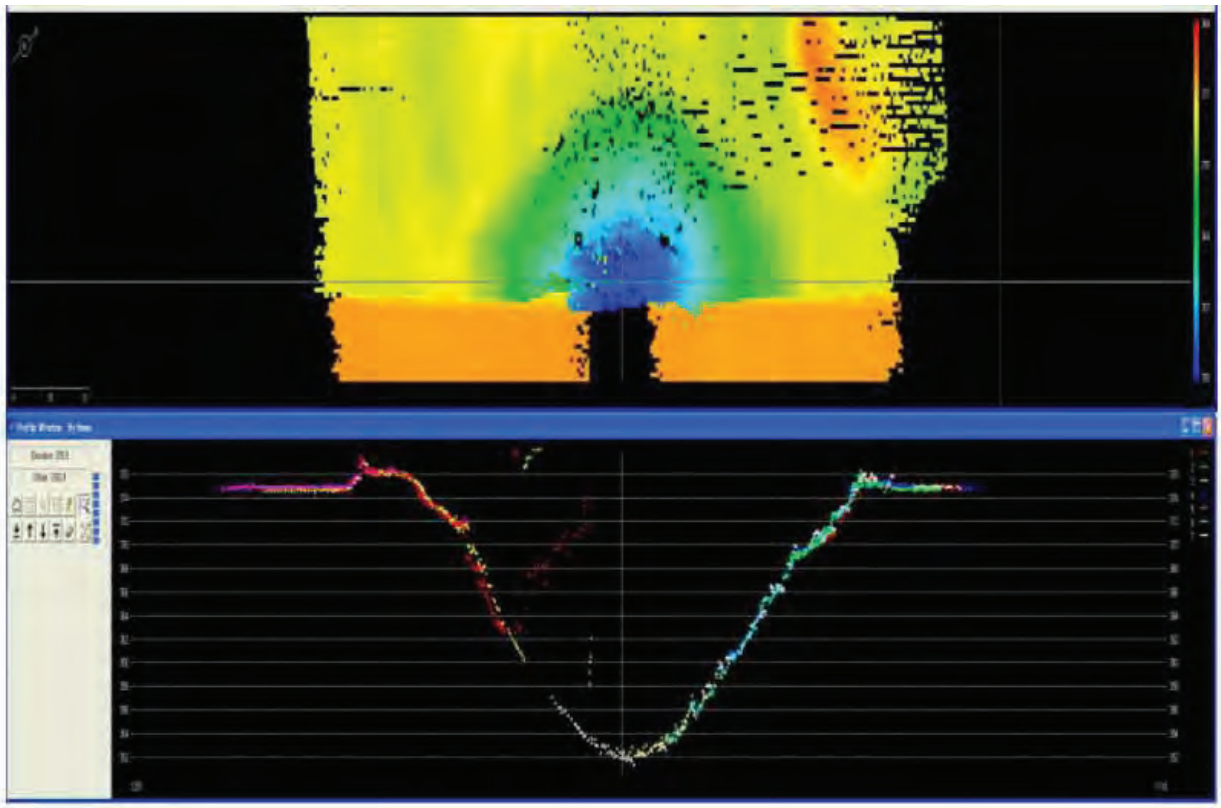

Figure N-4. Selected cross-section of the scour area in Figure N-3 used to estimate rock fill quantities. Mel Price Lock & Dam. (St. Louis District)

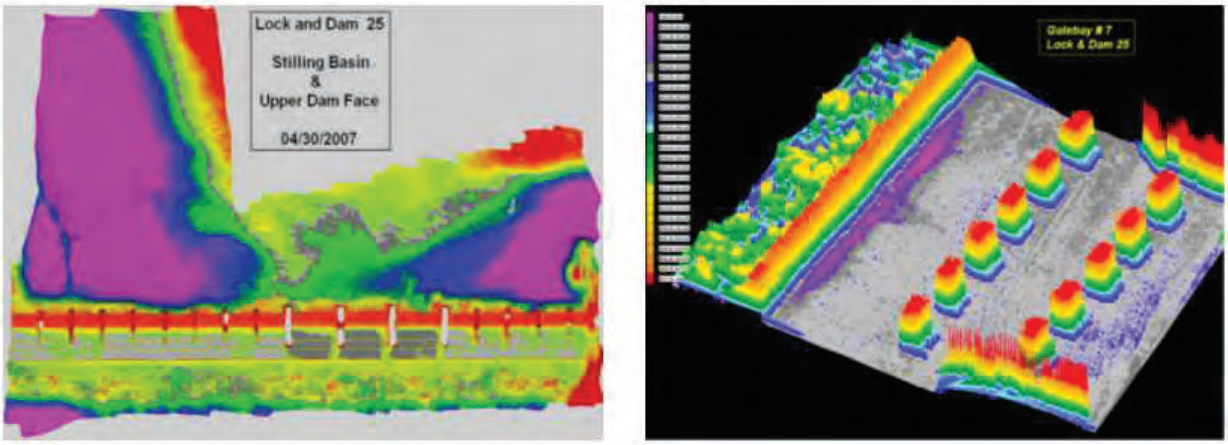

Figure N-5. Multibeam survey of Lock and Dam 25 (Mississippi River). Expanded 3D details showing a scour area and baffle blocks below gate 7. (St. Louis District)

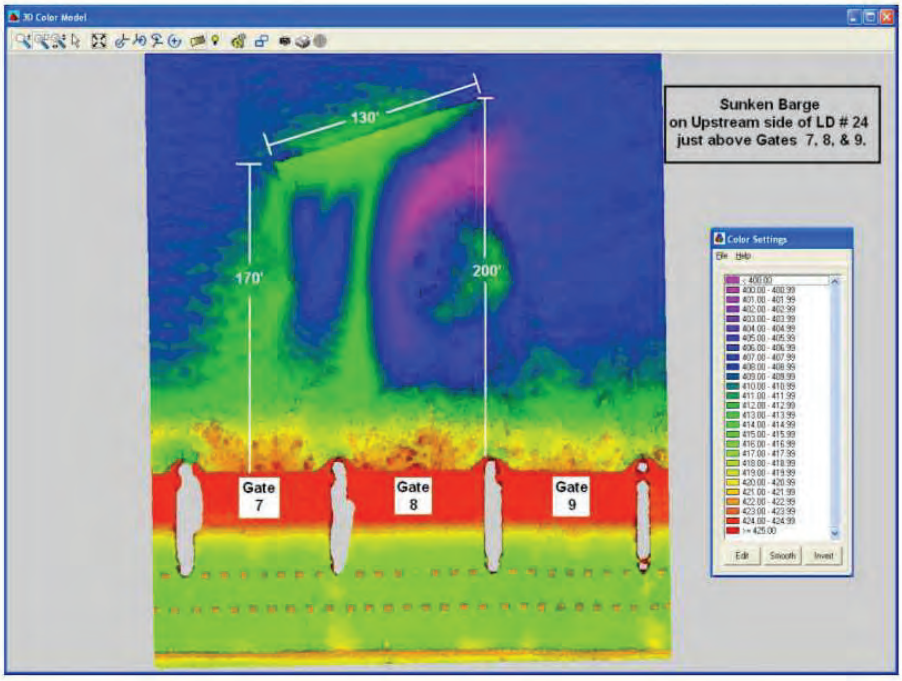

Figure N-6. Multibeam survey of sunken barge on upstream side of Lock & Dam 24, Mississippi River. (St. Louis District)

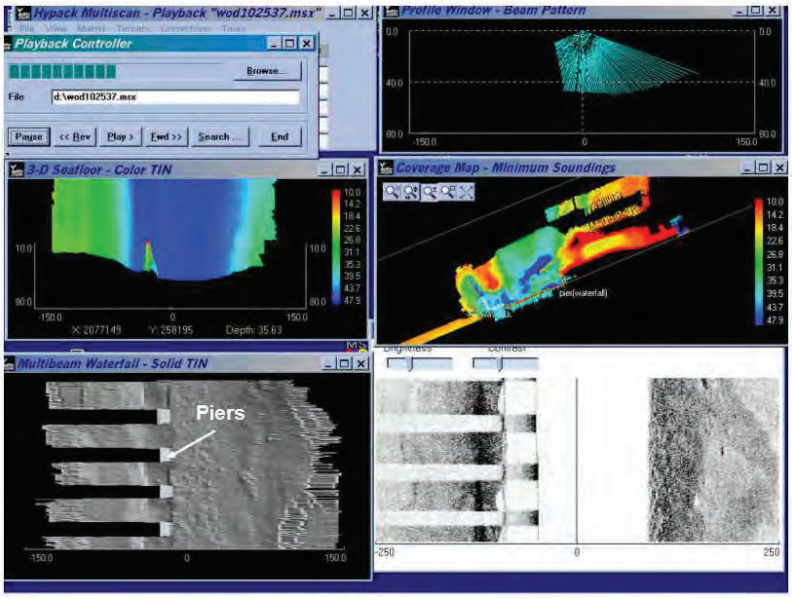

Figure N-7. Real-time multibeam screen displays of lock approach wall piers. Topographic model (lower left) and side scan sonar (lower right) depicts imagery between pilings. Woodruff Lock and Dam (Mobile District--EMC, Inc.)

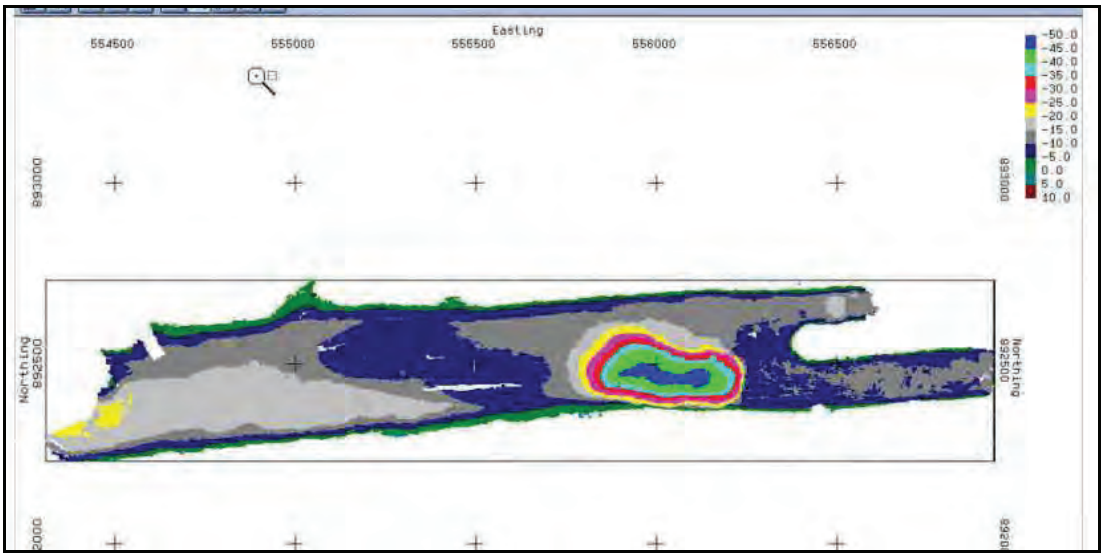

Figure N-8. Deep scour hole in vicinity of approaches to Ortona Lock, Okeechobee Waterway, Jacksonville District. (EMC, Inc.)

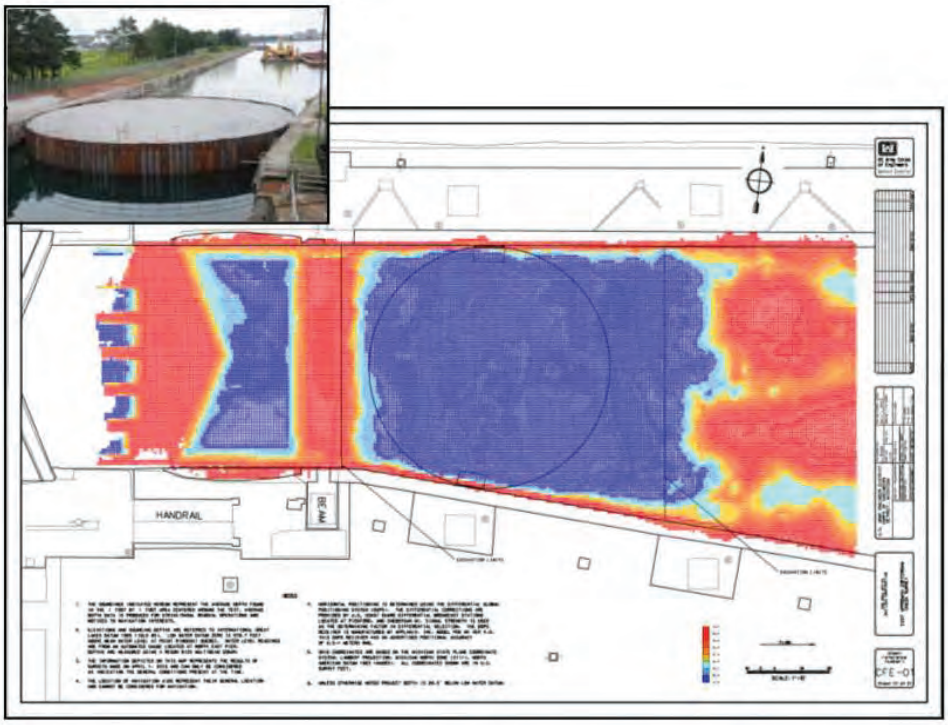

Figure N-9. New Soo Lock—Multibeam survey of cofferdam excavation. Soo Area Office. (Detroit District)

N-2. Louisville District Surveys of Ohio River Lock and Dam 52. The following figures illustrate a Louisville District survey of Lock and Dam 52. The wicket gates at the lock generate extreme noise in the water, necessitating winter high waters to conduct scour investigation surveys, typically when the entire lock and dam complex is submerged under 8 ft of water.

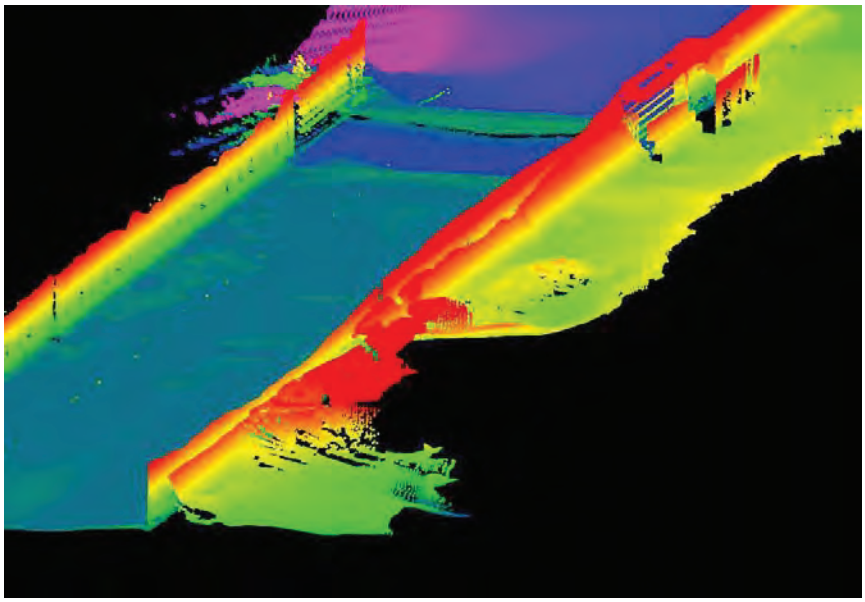

Figure N-10. Composite Reson 8125 multibeam survey of Ohio River Lock 52. (Louisville District)

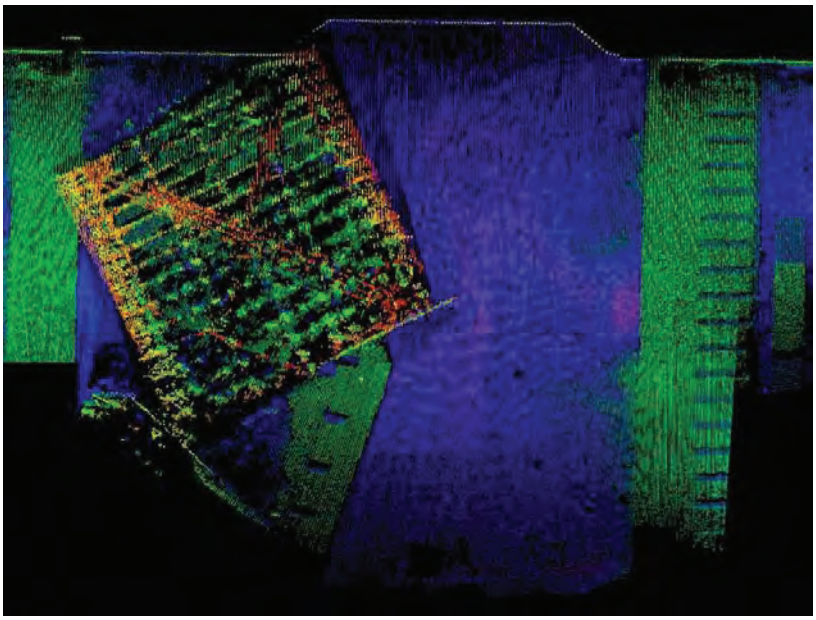

Figure N-11. Multibeam survey of Markland Lock Gate that broke free and fell into the lock sill. Detailed surveys allowed the district to determine the damage to the gate and if it could be safely removed without dewatering the chamber. (Louisville District)

Figure N-12. Louisville District 30-ft multibeam survey boat. This vessel is typical of those used for investigation surveys around Ohio River locks and dams. The Reson 8125 transducer is deployed through a moon pool in the hull.

N-3. Examples of a Navigation Chart Survey on the Ohio River. Figure N-13 is an example of typical navigation charting surveys by Louisville District. Depths are gridded by 250-x-250-ft bins. Color coded channel clearance levels clearly depict clear channel depths.

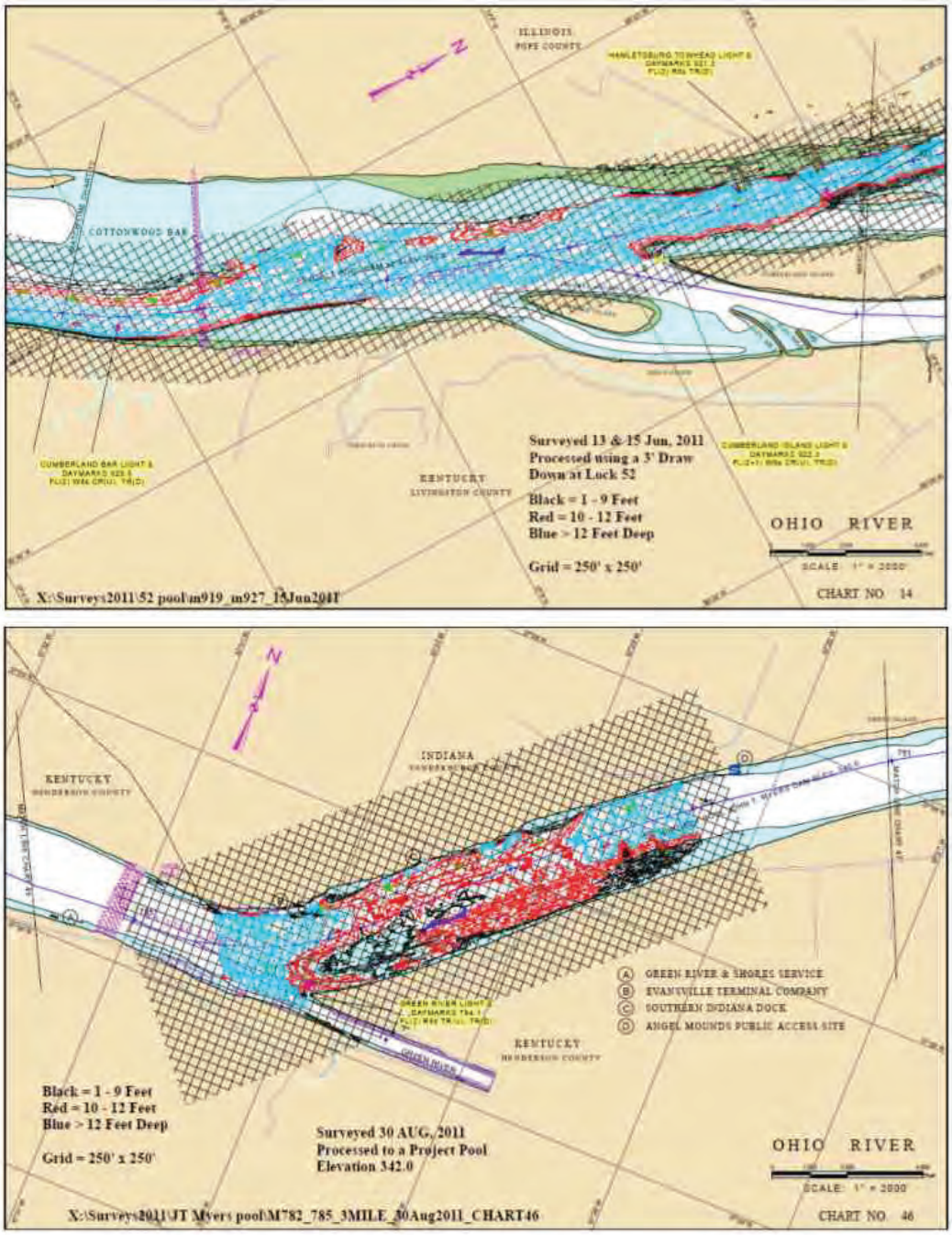

Figure N-13. Louisville District surveys of pools on the Ohio River. Depths below 12 ft are color-coded in red and black.

N-4. Additional Examples of Underwater Structure Investigation Surveys.

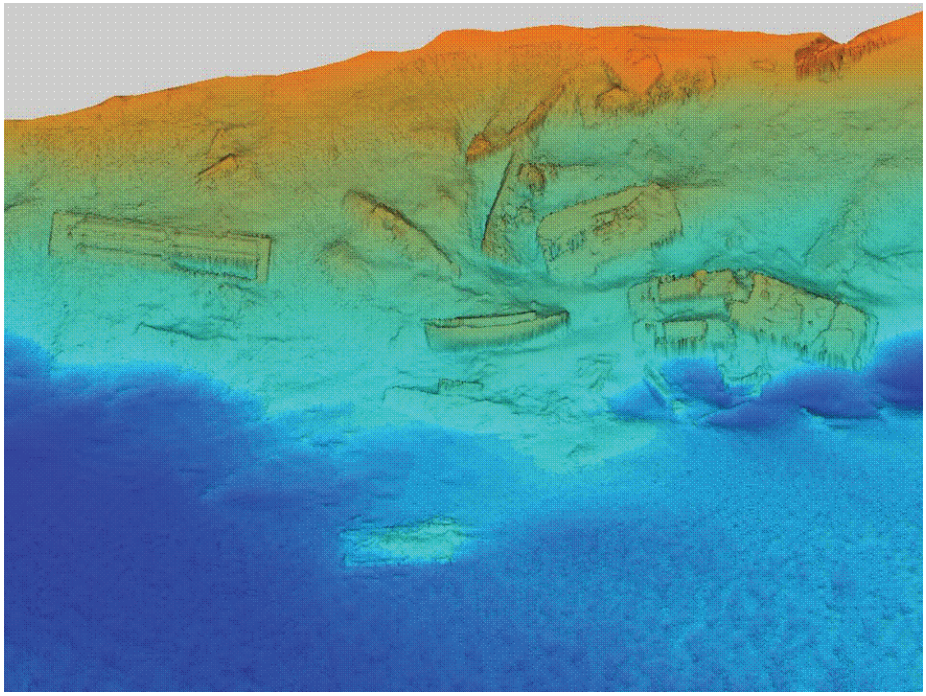

Figure N-14. Multibeam survey depicting sunken barges and other ship wrecks along a revetment bank on the lower Mississippi River. (New Orleans District)

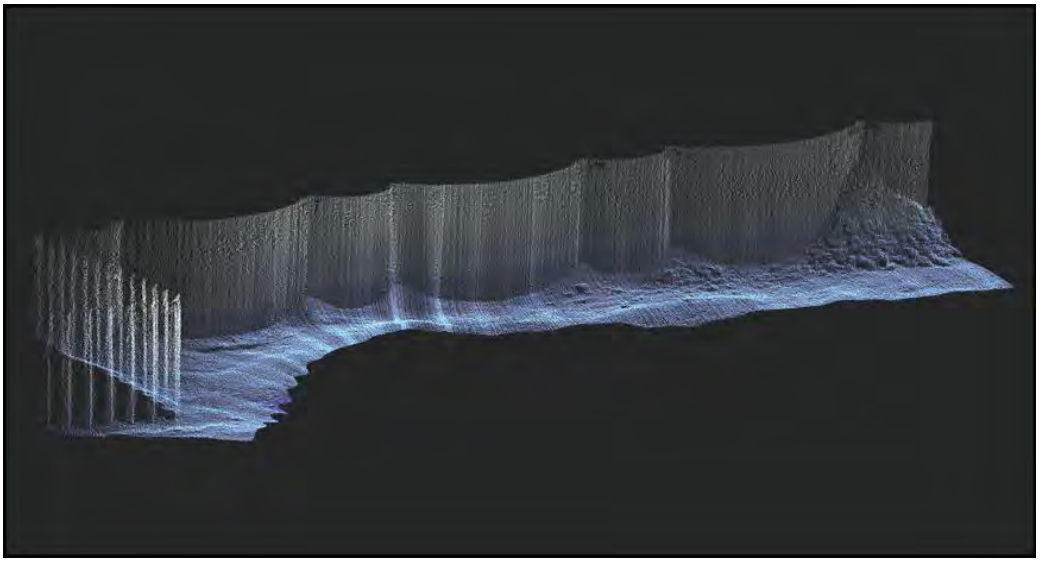

Figure N-15. Multibeam steel sheet pile inspection at Milwaukee Harbor CDF. (Detroit District, Soo Area Office)

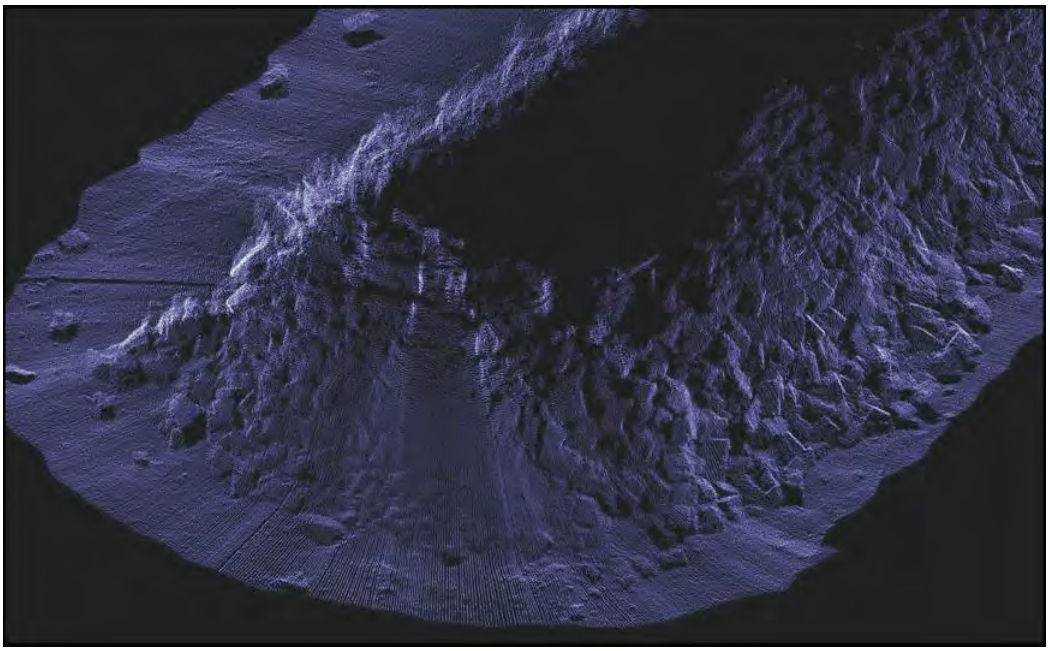

Figure N-16. Chicago Harbor multibeam breakwater inspection.
(Detroit District, Soo Area Office)

N-5. Multibeam Surveys at the Mississippi River Old River Control Structure. The New Orleans District developed a unique multibeam survey technique for assessing scour around the highly turbulent discharge areas around the Old River Control structure. The structure regulates the flow of water leaving the Mississippi into the Atchafalaya River. This system utilized a crane to deploy a heavily weighted multibeam transducer in the turbulent water at the Low Sill Structure.

Figure N-17. Old River Control Structures—surveys were performed at the Low Sill Structure. (New Orleans District)

Figure N-18. Weighted multibeam transducer with DGPS positioning (POS/MV).

Figure N-19. Multibeam transducer deployed from crane on Low Sill Structure.

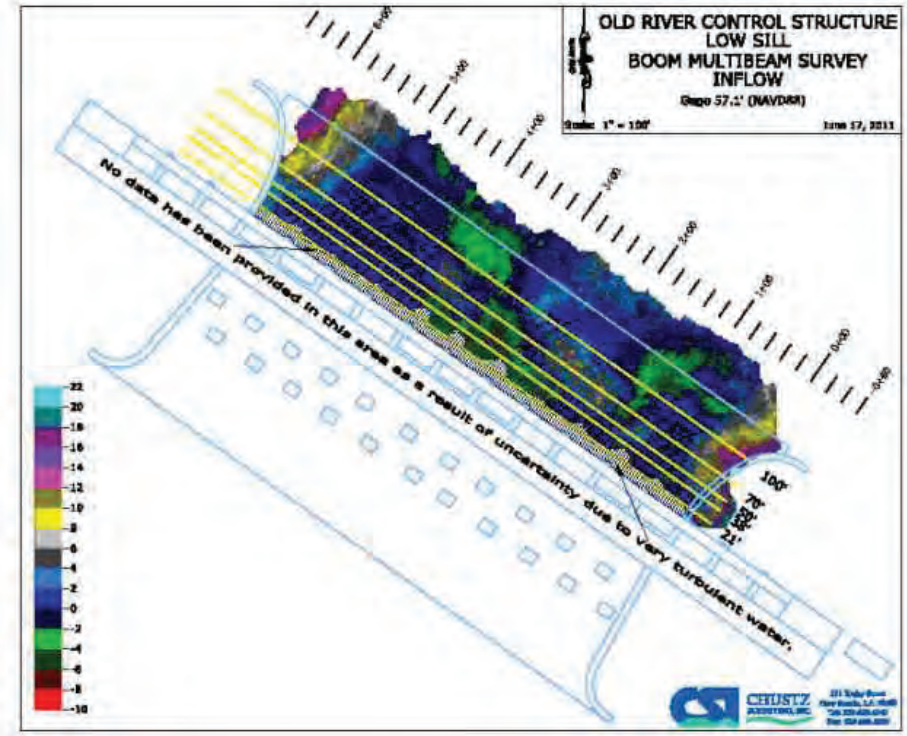

Figure N-20. Final plot of data along Low Sill Structure.

N-6. Marine-mounted Terrestrial LASER Scanning Systems. The following figure shows the resolution obtained from a terrestrial LIDAR scanning system on a lock and dam. This particular system (OPTECH LYNX) utilizes up to four LIDAR sensor heads. It fuses the LIDAR data with an on-board passive imaging system, a Trimble/Applanix POS/MV system, and an operational software platform to produce survey grade 3D data from a mobile vehicular platform.

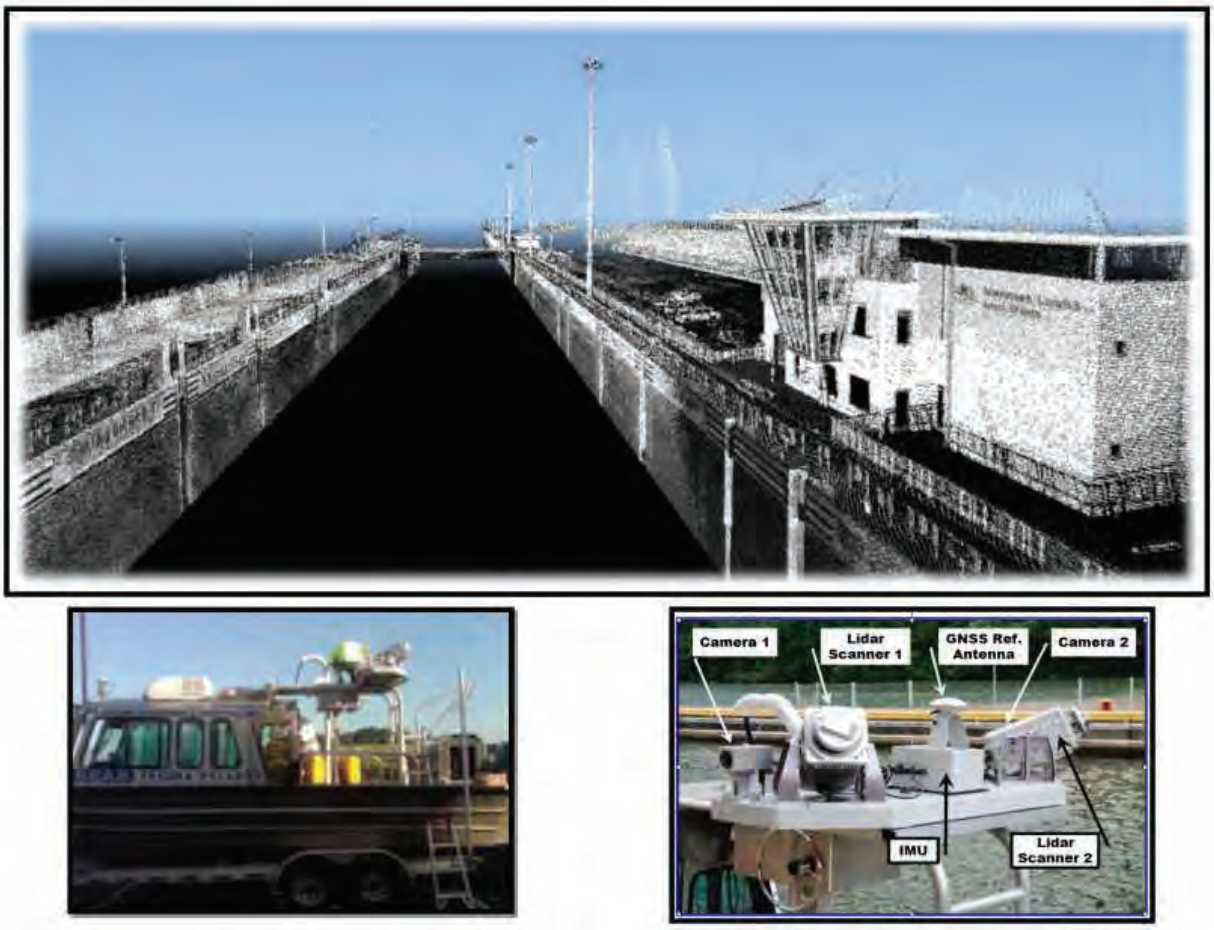

Figure N-21. OPTECH LYNX marine mounted laser scan of Marmet Lock & Dam, Kanawha River, Huntington District. (Seaside Engineering and Surveying, Inc.)

N-7. Merged Hydrography and Airborne LIDAR Data. Figures N-22 and N-23 are screen captures from projects done in 2009 by the Mobile District. They are a merge of hydro and overbank LIDAR, collected for sedimentation analysis and pool capacity calculations. The Alabama River LIDAR was collected by Tuck Mapping with their EagleEye sensor mounted aboard their helicopter. The hydro surveys were collected in-house by the Tuscaloosa Site Office using their multiple transducer sweep system.

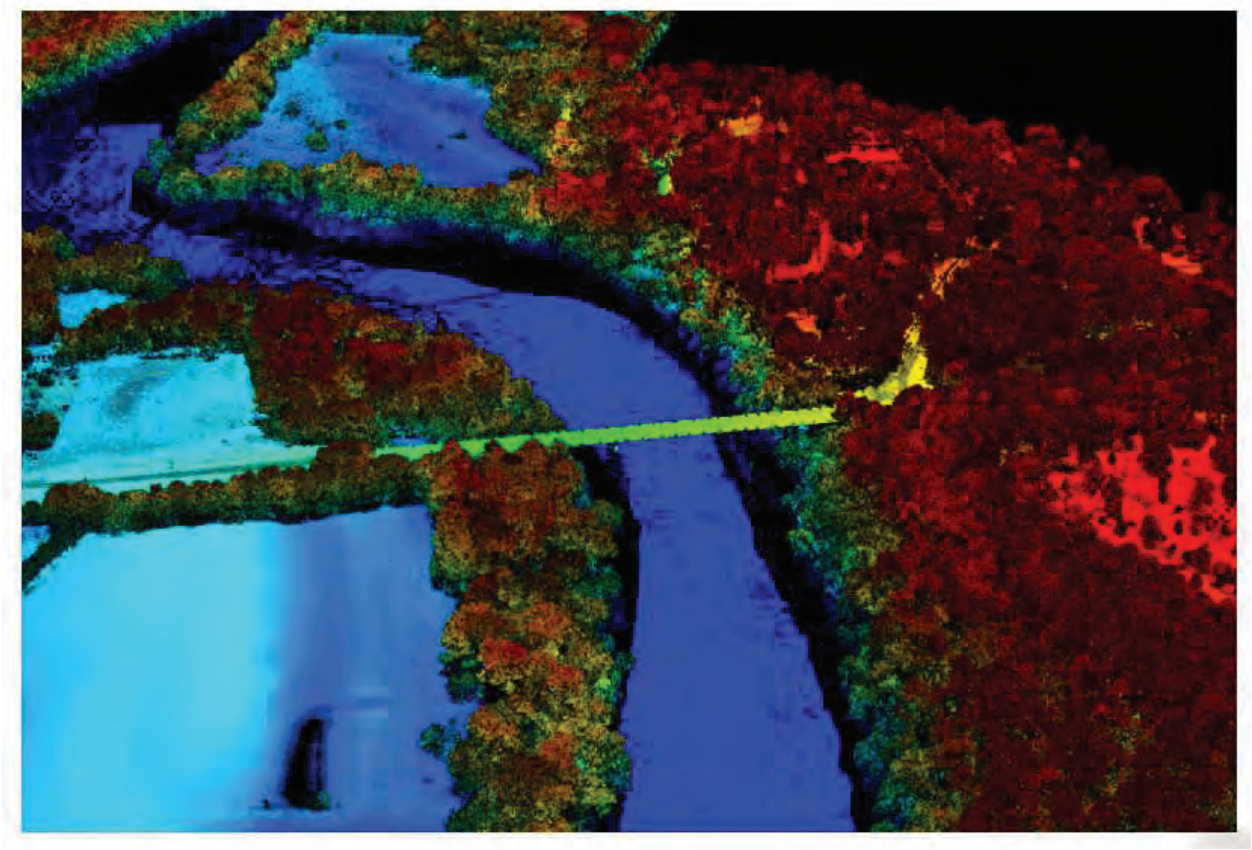

Figure N-22. George W. Andrews pool, Chattahoochee river, LIDAR and hydro point classes merged. LIDAR in LAS format, hydro in XYZ. Bridge is south of Walter F. George Lock and Dam, looking north. (Mobile District)

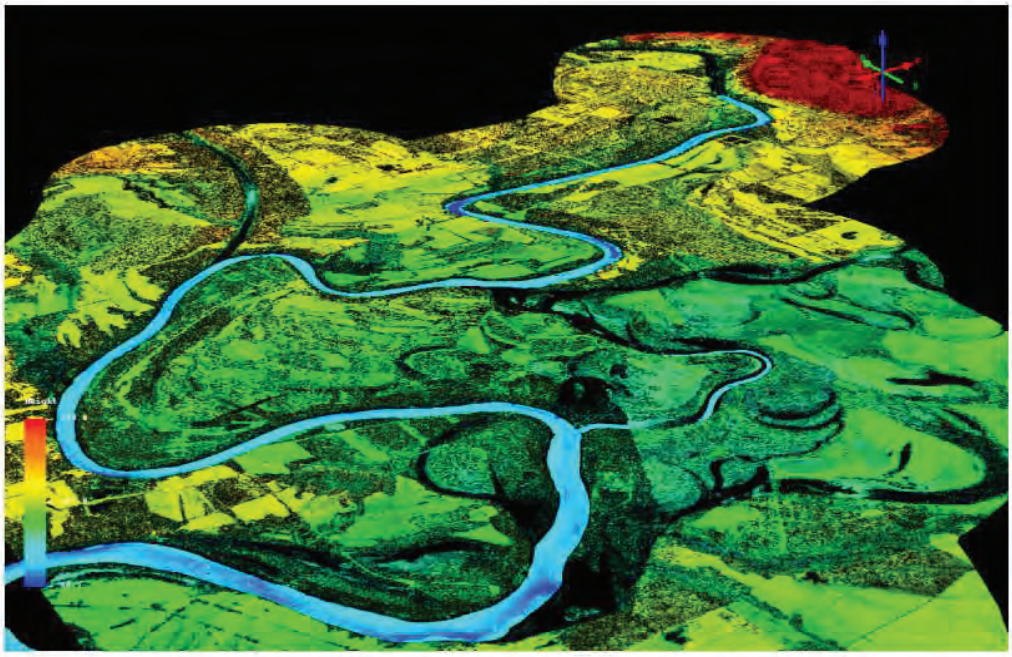

Figure N-23. R.F. Henry Pool, Alabama River. LIDAR and hydro merged datasets. Looking northeast, upstream. (Mobile District)

N-8. Biological and Bottom Classification Survey Applications. The figures below are examples of bottom classification and biological data collected in the Mississippi River by the St. Louis District Survey Vessel Boyer. Sensing systems included the DT 5000 120 kHz Dual Beam System for Locating Fish or Biomass (BioSonics), the DT 4000 200 kHz Dual Beam System for Identifying Bottom Classification (BioSonics), and the RoxAnn Seabed Identification Sonar to Identify Bed Material Types (Stenmar Sonavision).

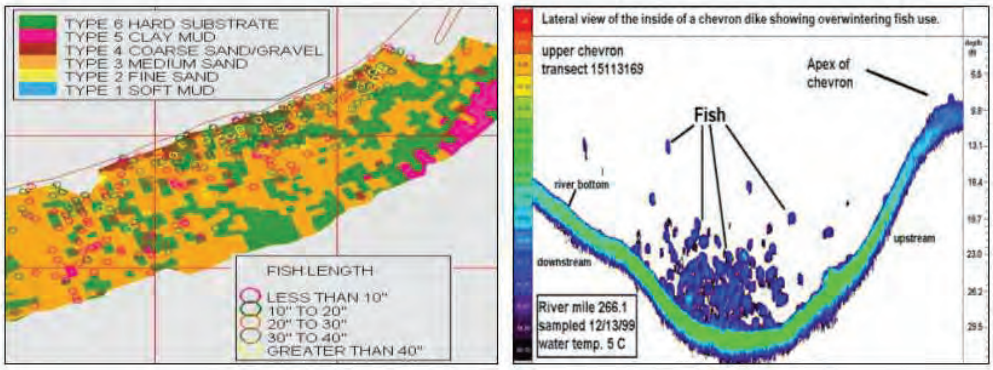

Figure N-24. Fish length and bottom material classifications. Chevron Dike, Mile 266, Mississippi River. (S/V Boyer, St. Louis District)

N-9. Carr Creek Dam, Kentucky (Louisville District). Figure N-25 depicts a multibeam survey of the pool above Carr Creek Dam.

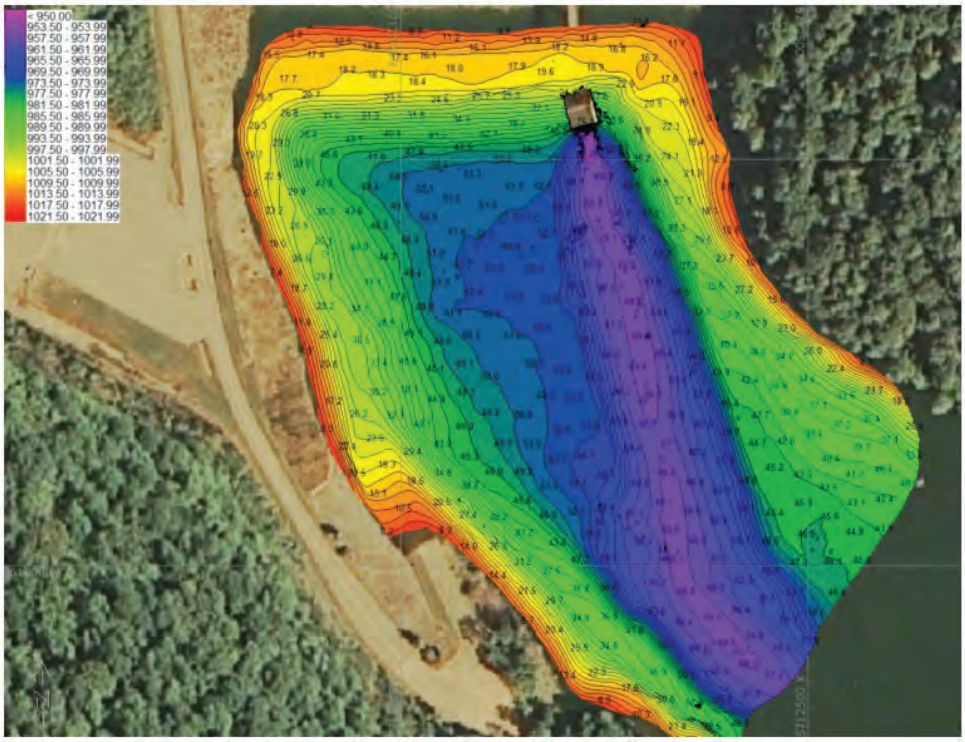

Figure N-25. Carr Creek Dam survey – 28 Aug 12. (Louisville District).

N-10. Example Bridge Clearance Surveys (Louisville District).

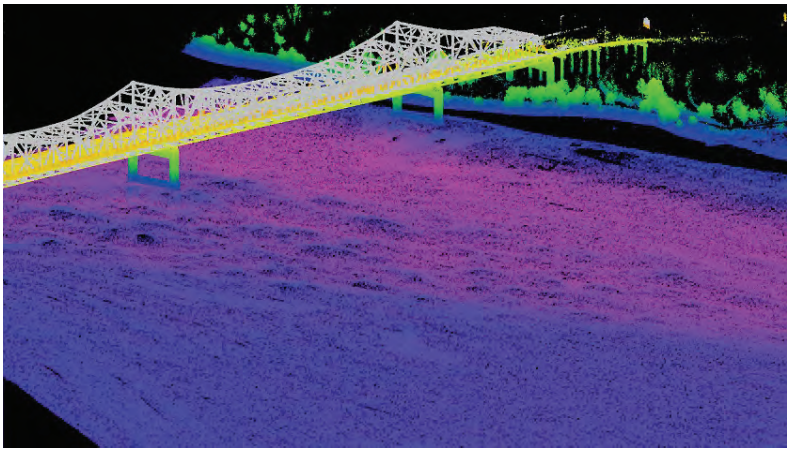

Figure N-26. Merged Multibeam and LIDAR data – Ohio River. (Louisville District)

John F. Kennedy Memorial Highway Bridge

RIVER MILE 603.1

DOWNSTREAM VIEW

PROJECT POOL STAGE	
DATUM	ELEV.
OHIO RIVER DATUM	420.00
NGVD 29	419.15
NAVD 88	418.66

CHANNEL SPAN									
VERTICAL DATUM	OHIO RIVER DATUM (ORD)			NGVD 29			NAVD 88		
LOCATION	LEFT PIER	CENTER	RIGHT PIER	LEFT PIER	CENTER	RIGHT PIER	LEFT PIER	CENTER	RIGHT PIER
ELEVATION OF LOW STEEL	492.1	495.4	498.7	491.3	494.6	497.9	490.8	494.1	497.4
VERT. CLEARANCE AT PROJECT POOL STAGE	72.1	75.4	78.7	72.1	75.4	78.7	72.1	75.4	78.7
ALTERNATE SPAN									
VERTICAL DATUM	OHIO RIVER DATUM (ORD)			NGVD 29			NAVD 88		
LOCATION	LEFT PIER	CENTER	RIGHT PIER	LEFT PIER	CENTER	RIGHT PIER	LEFT PIER	CENTER	RIGHT PIER
ELEVATION OF LOW STEEL	498.9	495.3	492.1	498.1	494.5	491.3	497.6	494.0	490.8
VERT. CLEARANCE AT PROJECT POOL STAGE	78.9	75.3	72.1	78.9	75.3	72.1	78.9	75.3	72.1

NOTE: ALL UNITS ARE IN FEET

Figure N-27. LIDAR Scan used to Produce Bridge Clearances.
(John F. Kennedy Memorial Bridge, Ohio River Mile 603.1 at Louisville, KY)

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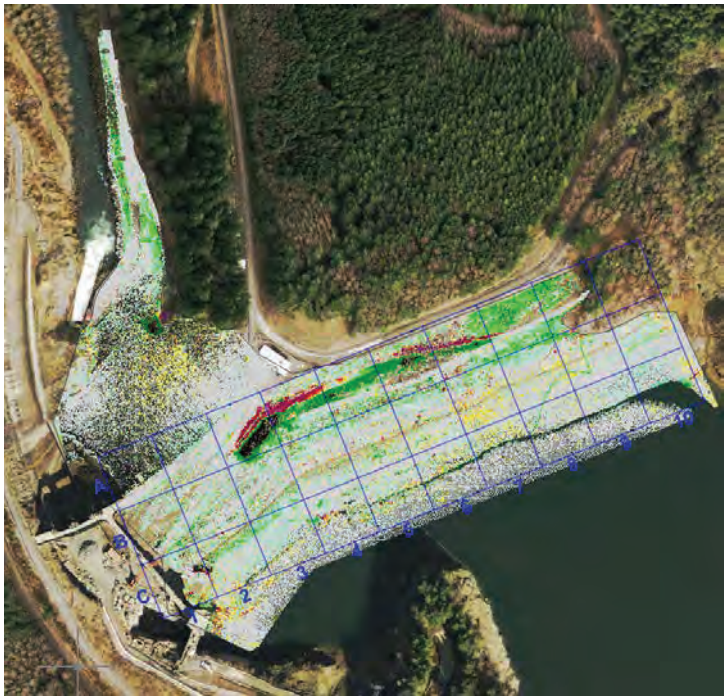
APPENDIX O

Howard Hanson Dam Monitoring

December 2009 Survey – Approximate Pool Elevation 1074'
Hydrographic and Terrestrial Survey Report
Contract No. W912DW-09-D-1015, Task Order No. 0009

December 2009



Color Coded Elevation Difference Image (Dec 09 to March 09 Baseline)

Owner:

U.S. Army Corps of Engineers
Seattle District

Prepared by:

David Evans and Associates, Inc.
2801 SE Columbia Way, Suite 130
Vancouver, WA 98661
(360) 314-3200

Howard Hanson Dam Monitoring

December 2009 Survey – Approximate Pool Elevation 1074'
Hydrographic and Terrestrial Survey Report
Contract No. W912DW-09-D-1015, Task Order No. 0009

December 2009

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TABLE OF CONTENTS

Page

1.0 INTRODUCTION 5

2.0 DATUMS AND PROJECT CONTROL 5

2.1 POSITIONING ACCURACY VERIFICATION 6

3.0 BATHYMETRIC SURVEY METHODOLOGY 6

3.1 SURVEY COVERAGE 6
3.2 SURVEY VESSEL AND CREW 7
3.3 POSITIONING AND NAVIGATION 7
3.4 WATER SURFACE OBSERVATIONS 7
3.5 MULTIBEAM DATA ACQUISITION 8
3.6 MOBILE LASER SCAN DATA ACQUISITION 9

4.0 MARINE EQUIPMENT CALIBRATION 9

4.1 CALIBRATION TESTS 9
4.2 MULTIBEAM SONAR BAR CHECK 10
4.3 SOUND VELOCITY 10

5.0 MARINE DATA PROCESSING 10

5.1 MARINE SURVEY ACCURACY 11

6.0 UPLAND SURVEY METHODOLOGY 11

6.1 SURVEY COVERAGE 11
6.2 SURVEY CREW AND EQUIPMENT 12
6.3 SURVEY CONTROL 12
6.4 HIGH-DEFINITION LASER SCANNING 12
6.5 CONVENTIONAL CROSS-SECTIONS 13
6.6 UPLAND SURVEY ACCURACY 14

7.0 DATA EXPORT AND MERGING WITH UPLAND DATA 14

7.1 DATA INTERPRETATION 15
7.2 DELIVERABLES 15

List of Tables

Table 1: Control Coordinates 5
Table 2: RTK GNSS Observation vs. Provided Position - Point 2202 6
Table 3: Water Elevation Checks 8
Table 4: Correctors Applied to Sensor Data 9

Table 5: Marine Laser Scan Data vs. Control Point Targets 11
Table 6: Cross-Section Observations Results 13

List of Figures

Figure 1: Conventional cross-sections 13

Appendices

Appendix 1: List of Survey Control
Appendix 2: Survey Notes and Logs

Acronyms and Abbreviations

ACSM	American Congress on Surveying and Mapping
ASCII	American Standard Code for Information Interchange
DEA	David Evans and Associates, Inc.
DGN	MicroStation drawing file
DTM	Digital Terrain Model
DXF	Data eXchange Format
GLONASS	Russia's Global Orbiting Navigation Satellite System
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GRS-80	Geodetic Reference System of 1980
HIPS	Hydrographic Information Processing System
Hz	Hertz
IAKAR	Inertial-Aided Kinematic Ambiguity Resolution
IMU	Inertial Measurement Unit
kHz	kilo Hertz
LN	Line Number
M	Meter
NAD 27	North American Datum of 1927
NAD 83	North American Datum of 1983
NAVD 88	North American Vertical Datum of 1988
NGVD 29	National Geodetic Vertical Datum of 1929
OTF	On-the-fly
PDF	Portable Document Format
POS/MV	Position and Orientation System for Marine Vessels
RTK	Real-Time Kinematic
SPCS	State Plane Coordinate System
TIFF	Tagged Image File Format
USACE	United States Army Corps of Engineers

INTRODUCTION

In December, March and April of 2009, David Evans and Associates, Inc. (DEA) conducted precision upland control and laser scanning surveys in conjunction with multibeam bathymetric surveys of the Howard Hanson Dam near Enumclaw, Washington. The primary goal of the surveys was to develop accurate elevation data of the dam and surrounding areas as part of a periodic monitoring program. For this monitoring survey, hydrographic survey operations were conducted on December 3rd while upland survey work was conducted between March 24th and April 16th, 2009. This report describes the control used for the surveys, data acquisition methodology, and data processing procedures. In addition to this report, deliverables include a project CD-ROM containing ASCII (American Standard Code for Information Interchange) XYZ gridded point data and an updated "post-construction" contour map in DGN format.

1.0 DATUMS AND PROJECT CONTROL

Conducting a survey on an established coordinate system, referenced by monuments, enables the survey to be reproduced at a later date with repeatable results. For this survey, hydrographic field operations were conducted on NAD83 (CORS96 Epoch2002)/NAVD88 datums, and final data sets generated, using the North American Datum of 1927 (NAD27) horizontal datum projected to the State Plane Coordinate System (SPCS), Washington North Zone with units in U.S. Survey Feet. Vertical datum for this survey is the National Geodetic Vertical Datum of 1929 (NGVD29).

Positioning and vertical control for the marine based survey were provided by a combined inertial and real-time kinematic (RTK) global navigation satellite system (GNSS) with vertical observations based on NAVD88 elevations. GNSS receivers were used during this survey to track not only the global positioning system (GPS) satellites, but also the GLONASS satellites to provide better accuracy in the heavily obstructed areas around the dam structures due to the low pool level. An RTK GNSS base station was deployed on monument 2200 which had been established by DEA for the USACE (United States Army Corps of Engineers) under an earlier contract. Table 1 presents coordinates and elevations for monuments used during the hydrographic survey. A complete listing of project control is located in Appendix 1.

Table 1: Control Coordinates

Monument Designation	NAD83 WA North		NAD27 WA North		NGVD29	WGS84
	North M	East M	North US Ft.	East US Ft.	Elev. Ft.	Ellipsoid Ht. M
2200	31085.118	427889.874	102044.617	1763714.473	1229.962	354.844
2202	31188.069	427774.936	102382.384	1763337.380	1201.535	346.172
69001	31289.759	427926.337	102716.01	1763834.098	1106.606	317.244
69002	31326.877	427997.029	102837.788	1764066.027	1094.848	313.662
69003	31355.508	428070.295	102931.722	1764306.399	1089.915	312.161

Performance of the RTK GNSS was improved by using Geodetic Reference System of 1980 (GRS-80) values as the reference for the RTK GNSS base station. Coordinates of the control monuments used for the RTK GNSS base station were converted to GRS-80 geographic coordinates and GRS-80 ellipsoid heights. CorpsCon version 6.0.1 software, using NADCON lookup tables, was used for the horizontal position conversion. An ellipsoid separation model, based on GEOID03, was utilized for on-the-fly conversion from the GRS-80 ellipsoid heights (ellipsoid from which GNSS heights are derived for NAD83) to NAVD88 elevations.

2.1 Positioning Accuracy Verification

The survey included a horizontal and vertical position check using RTK GNSS techniques on "2202" before the survey on December 3rd, 2009. Table 2 presents the differences obtained from RTK GNSS observations to the converted provided position for "2202". All hydrographic data was recorded in meters during survey operations and adjusted to project datum and units during post-processing.

Table 2: RTK GNSS Observation vs. Provided Position - Point 2202

Direction	*Diff. Meters*	*Diff. Feet*
Northing	0.028 m	0.09 ft
Easting	-0.005 m	-0.02 ft
Elevation	0.002 m	0.01 ft

2.0 BATHYMETRIC SURVEY METHODOLOGY

3.1 Survey Coverage

Complete multibeam and laser scan data coverage was attained within the area defined by the project specifications across the 1,500-foot wide forebay of the dam. During this monitoring survey, the pool elevation was very low (approximately 1074' NGVD29), leading to very shallow depths for the vessel to navigate. This also increased the blockage of the satellite signals in the areas close to the intake structure and dam face. Care was taken in these areas to ensure they were surveyed at the best possible time using the predicted constellation and Trimble's planning software. Multibeam coverage was limited to areas safely navigable by the vessel, and was not significantly impacted in any areas apart from the northeast corner of the dam near the creek run-off. Here, a small gap exists between the multibeam and laser scan data as the vessel could not get as close to the shoreline.

The mobile laser scan data was acquired along the lower exposed section of the dam from the water level at the time of the survey up to a distance of approximately 150 feet up slope from the

edge of water (approx 1150' NGVD29). This provided considerable overlap with the terrestrial laser scan data for comparison.

3.2 Survey Vessel and Crew

The vessel for this survey was the *Motion Marine*, a 21-foot custom survey boat operated by DEA. The vessel is equipped with an integrated navigation and data acquisition system, a custom mount for the SeaBat 8101 sonar head and Riegl z390i laser scanner, and is ideal for shallow water survey operations in tight quarters. The hydrographic survey crew consisted of a senior hydrographer and vessel operator/hydrographer from DEA. The crew has conducted numerous multibeam and side scan sonar surveys and has had extensive training in hydrographic surveys.

3.3 Positioning and Navigation

Horizontal positions were acquired with an Applanix POS/MV combined inertial and RTK GPS navigation system. The POS/MV system integrates two GNSS receivers with an inertial measurement unit (IMU), although only GPS measurements are used in the real-time solution. This system not only provides motion information (heading, roll, pitch, and heave) to compute X, Y, Z data from the multibeam sonar measurements; it also provides accurate inertial navigation through GPS outages for up to 30 seconds. The GPS/inertial positioning system enabled the survey vessel to run near the intake structure without jeopardizing positioning integrity from satellite signal loss or multipath.

Position data was used in real-time to provide navigation information to the vessel operator and was time tagged and logged with multibeam and other ancillary data. The actual survey tracks are displayed with multibeam swath coverage in real-time on a monitor located at the helm to aid in a systematic survey of the area.

The POS/MV system was configured to not only output real time positions and attitude, but also log raw GNSS and IMU data to a separate file for post processing.

3.4 Water Surface Observations

As all bathymetric data is time tagged and recorded relative to the water surface, accurate water surface observations in the vicinity of the survey are required to account for water level changes. Water surface measurements were obtained in real-time by RTK GNSS with on-the-fly (OTF) ambiguity resolution using a Trimble SPS881 RTK GNSS receiver. An RTK GNSS base station was deployed to provide RTK GNSS correctors to the rover GNSS receiver aboard the survey vessel. RTK correctors were applied to the shipboard GNSS for logging of water surface elevations at a rate of one hertz (Hz). The GEOID03 ellipsoid separation model (g2003u01) was used in Hypack MAX software for OTF conversion from the GRS-80 ellipsoid (ellipsoid from

which GNSS heights are derived) to NAVD88 vertical datum. RTK GNSS water level observations were used as a real time quality check during survey operations and enabled comparison with Howard Hanson Dam tide board readings and digital data provided by the USACE. A summary of these comparisons is shown in Table 3 along with the difference between USACE digital water level readings and RTK GNSS water level values.

Table 3: Water Elevation Checks

Date & Time (Local)	*12/03/09 11:40*	*12/03/09 15:00*
USACE Readings	1074.06*	1073.82
RTK GNSS	1073.88	1073.68
Tide Board Reading	1074.0	1073.8
Difference (USACE – RTK GNSS)	0.18 ft	0.14 ft

** elevation interpolated from 11:00 1074.15' and 12:00 1074.01'.*

3.5 Multibeam Data Acquisition

Soundings were acquired with a Reson SeaBat 8101 multibeam bathymetric sonar using a frequency of 240 kilo-hertz (kHz). The system records 101 soundings in a single sonar ping. Additionally, DEA's 8101 includes options such as a stick projector for enhanced shallow water performance and the ability to output side scan sonar imagery. The stick projector option on the Reson SeaBat 8101 improves the system performance in shallow water (depths less than 150 feet).

Multibeam data was conducted in the forebay by running lines parallel with the back of the dam for the length of the project. For this survey, the sonar head was mounted with a 15º starboard angle offset to allow for maximum coverage of the dam structure and shoreline. This enabled coverage from nadir (straight down) 90º to starboard (horizontal) and from nadir out to 60º to port with a recorded depth every 1.5º. Sonar swaths were recorded at a rate of 15 Hz as the vessel transited along the survey track lines. Running with a 110º swath (55º to port and starboard), the system provided nearly three times the water depth coverage in a single pass. The total swath width of full coverage mapping in a single pass varied with the water depth. Survey lines closest to shore were run with the starboard side facing the shore and the starboard swath was opened to 90º to maximize sonar coverage up the abutment.

The most vital measurements in a multibeam survey are heading and attitude angles. To account for vessel heading, heave (vertical movement), pitch and roll, an Applanix POS/MV motion reference sensor was utilized. By utilizing vessel speed over ground and heading data provided by GPS, the POS/MV can isolate horizontal accelerations from vessel turns and provide highly accurate motion data. The POS/MV system was also used to record vessel heading (yaw) from

which the sonar beam orientation was derived. The POS/MV provides a higher degree of accuracy for heading measurements than a conventional gyrocompass.

The navigation and survey control system was a personal computer running Hypack MAX version 2008 software. Both Hypack's Hysweep software and Triton Imaging's ISIS software were used for multibeam and sensor data acquisition. Hypack software allowed the swath bathymetric data to be displayed as a painted color image on the navigation screen. This real-time display gave the hydrographers immediate indications of data quality and coverage. Data collected in ISIS was used for processing and final deliverables.

3.6 Mobile Laser Scan Data Acquisition

Mobile laser scan data was acquired with a Riegl z390i. In the vessel mounted configuration, it is set-up as a 2-dimensional scanner. It measures range and angle to determine points in a linear swath that is 80º (40º each side of horizontal). The instrument uses an electro-optical pulsed time-of-flight measurement of short infrared laser pulses to determine range, coupled with a rotating multi faceted mirror to provide fully linear, unidirectional scan lines. During this survey, the system was configured to collect approximately 10 scans per second with 801 points in a single scan.

The same principles of position and attitude measurement used with the multibeam bathymetry apply to the laser data. All data was collected in Hypack's Hysweep software for both navigation and final processing.

4.0 MARINE EQUIPMENT CALIBRATION

4.1 Calibration Tests

Calibration tests were conducted to confirm alignment of the survey sensors with the POS/MV and verify delay times applied to the time-tagged sensor data. This consisted of a series of lines run in a specific pattern, which were used in pairs to analyze roll, pitch, and heading alignment angles for the multibeam echosounder and for the vessel mounted laser, as well as latency (time delays) in the time tagging of the sensor data. Table 4 lists the applied correctors for sensor bias determined through analysis of the patch test data.

Table 4: Correctors Applied to Sensor Data

Point	*Position Timing (seconds)*	*Pitch (degrees)*	*Roll (degrees)*	*Yaw (degrees)*
Reson 8101 Multibeam Sonar	0.00	0.00	-0.75	0.00
Riegl LMS Z360i Mobile Laser	0.00	-0.30	0.55	0.52

4.2 Multibeam Sonar Bar Check

To confirm the draft of the sonar head, a bar check was performed by lowering a flat plate to a known distance from the water surface and placing it under the sonar head. The recorded sound velocity corrected sonar depth is then compared to the known depth of the bar check device. The bar check performed at Howard Hanson Dam showed agreement within 0.03 feet of measured values to the known depth.

4.3 Sound Velocity

Detailed measurements of the sound velocity profile through the water column are crucial in multibeam surveys. Changes in the velocity profile will not only affect acoustic distance measurements, but can also cause refraction or bending of the sonar path as it passes through layers in the water column with different velocities. An Applied Microsystems AML SV Plus V2 was used to measure the speed of sound of the water column and the depth at which the sound velocity was measured.

5.0 MARINE DATA PROCESSING

Processing of multibeam sonar and vessel mounted laser data was conducted utilizing Caris HIPS hydrographic information processing system software. Patch test data were analyzed and alignment corrections for both survey sensors were calculated and applied during processing. In addition, the real time navigation solution was overwritten with a post processed Inertial-Aided Kinematic Ambiguity Resolution (IAKAR) solution which included updated heading, attitude and navigation measurements.

The IAKAR solution was computed using Applanix POSPac MMS 5.2 software to post processes the raw navigation solution using a single base station as a reference. In addition to broadcasting RTK correctors the GNSS base station also logged 1 second epoch GNSS observables which were incorporated in the IAKAR post processing of the POS MV navigation solution.

Final GNSS water levels were computed by editing the real-time data for flyers and averaging the results to remove the effects of short-period vessel heave. A 30-second moving average was applied in Hypack MAX software and the averaged water level values were exported with a time stamp every second for import into Caris HIPS. The GNSS water levels were relative to NAVD88 and account for the distance between the GNSS antenna phase center and the measured location of the waterline along the vessel's hull. All measurements for this survey were reduced to NGVD29 elevations in the delivered data set.

Velocity profiles measured in the field were converted to Caris format then used to correct multibeam sonar slant range measurements and compensate for any ray path bending.

Data cleaning began with review of each survey line using the Caris HIPS swath editor. Verified water surface correctors were applied to the data set at this time. Position and sensor data were examined and any data not meeting survey requirements were flagged as rejected. Sounding and laser data were reviewed and edited for data flyers. In each case, data was not eliminated and can be re-accepted in the future if required.

After swath editing, all data was reviewed through the Caris HIPS subset editing program to ensure no flyers remained in the data set, or to re-accept data previously flagged in the swath editor. In the Caris subset editor, a set of lines was reviewed together for line to line comparison to ensure agreement to one another in a Caris session.

5.1 Marine Survey Accuracy

Hydrographic data was acquired at the USACE specification for hard bottom dredge surveys which states an accuracy of +/- 0.5 feet vertically (in water depth less than 15 feet) and 6 feet horizontally for 95% of all data points. Quality assurance/control checks indicate better accuracies were achieved. Marine laser data comparison with upland data indicate achieved accuracies on the order of +/- 0.3 feet in both horizontal and vertical components in the majority of data points.

During the marine survey, several tripods with targets were setup over known control points on the dam. These targets were then scanned with the vessel mounted laser for accuracy assessment. Table 5 lists the results.

Table 5: Marine Laser Scan Data vs. Control Point Targets

Monument Designation	Northing Difference (ft)	Easting Difference (ft)	Elevation Difference (ft)
69001	0.10	-0.09	-0.10
69002	0.08	-0.16	-0.14
69003	0.10	-0.18	-0.14

6.0 UPLAND SURVEY METHODOLOGY

6.1 Survey Coverage

The upland portion of the survey included the front and back sides of the dam, and the right abutment. On the back of the dam, the survey extended from the easterly tree line on the right abutment to the spillway control tower. The survey included the face of the dam and the initial 1,000 feet of the right bank of the Green River.

Laser scanning was performed on the dam, along the right abutment, and along the Green River. Scan position and registration points, consisting of a 2-foot long rebar with plastic cap, were set throughout the face, back, and right abutment of the dam. Four cross sections were surveyed along the slope between the access roads on the right bank of the river. Also surveyed were 18-inch wooden hubs with a tack which were previously set along the cross sections.

Prior to the time of this survey, the right abutment of the dam was heavily modified by the construction of a new access road and concrete pad for the construction of the grout curtain. This construction destroyed many previously set scan control points. This area of construction is noted as "General Area of Construction" on the maps associated with the phase 3 post-construction December 2009 survey.

6.2 Survey Crew and Equipment

Prior to beginning the survey, field personnel met with the project manager to discuss the scope of work, detailed field procedures and site safety. Equipment (tripods, tribrachs, and survey instruments) used for the survey was checked and adjusted per the manufactures specifications prior to beginning the survey, with the check and adjustment noted in the survey field books.

A Leica TCRP1201, 1 second electronic total station, was utilized for horizontal and vertical control. Differential leveling was performed with a Leica DNA 03 digital level. A Leica ScanStation II was used for the laser scanning.

6.3 Survey Control

Existing control points 2200 and 2203 were used as the primary control points for the survey (see section 2.0 for primary control point values). Control point numbers 2202 and 10 were utilized to check the locations of the primary control points and to detect any movement in the primary control. From the primary control points the scan locations along the face and back of the dam were established. Four sets of angles and distance measurements were taken to all of the scan points and traverse points. Closed loop differential leveling was run from the site bench mark, control point 2203, through all of the laser scan control points.

6.4 High-Definition Laser Scanning

Thirty-one high-definition laser scans were taken throughout the surveyed area with a full 360° field of view. The laser scanner was set up over the rebar and cap scan position points. Targets were set over adjacent scan points to facilitate orienting the scans onto the NAD27 coordinates, and to verify the relative accuracy of the scan points. The scanner set up heights and scanning density were noted and will be duplicated for future monitoring to ensure consistency.

6.5 Conventional Cross-Sections

Four cross-sections were established on the slope between the upper access road and the right river bank (Figure 1). Each cross-section is a series of 18-inch wooden hubs with tacks set at approximately 25' intervals. In December 2009, a traverse and differential levels were run through the control points along the upper road. Each cross-section hub was then measured from the traverse point at the top of the hill. The results of these cross-section observations are shown in Table 6.

Figure 1: Conventional cross-sections

Table 6: Cross-Section Observations Results

Point Number	March 2009 Elevation (ft.)	December 2009 Elevation (ft.)	Difference (ft.)
68100	1198.95	1198.99	0.04
68101	1175.38	1175.42	0.04
68102	1149.84	1149.89	0.05
68103	1127.88	1127.88	0.00
68104	1196.59	1196.64	0.05
68105	1168.30	1168.34	0.04
68106	1140.43	1140.47	0.04
68107	1117.11	1117.12	0.01
68108	1096.58	1096.62	0.04
68109	1187.83	1187.85	0.02
68110	1164.41	UNABLE TO LOCATE	N/A
68111	1136.47	1136.48	0.01
68112	1115.71	1115.79	0.08
68113	1097.65	1097.72	0.07
68114	1189.86	1189.99	0.13

68115	1160.75	1160.81	0.06
68116	1128.20	1128.26	0.06
68117	1098.27	1098.34	0.07
68118	1094.03	1094.09	0.06

6.6 Upland Survey Accuracy

Control point and scan control point accuracy is 0.03 feet-horizontal and 0.01 feet-vertical, relative to the primary control. Cross section monitor point accuracy is 0.05 feet horizontally and vertically, relative to the traverse control point at the top of the section line. Laser scan accuracy is 0.04 feet relative to the scan control.

7.0 DATA EXPORT AND MERGING WITH UPLAND DATA

To take advantage of the level of detail the multibeam bathymetric survey provided for the dam monitoring, full resolution soundings were created by the HIPS processing software and exported to an ASCII XYZ file. The XYZ file was exported in NAD83/NAVD88 coordinates in meters and converted to the project coordinates (NAD27/NGVD29 US Feet) using CorpsCon version 6.0.1 The soundings from the full resolution multibeam data were loaded in to CARIS Bathy Database V 2.1 points from the mobile laser data and over 500 million raw topographic data points from the terrestrial laser system. The marine mobile laser data junctioned well with the terrestrial data. The merged datasets were processed into a 1 foot matrix using Bathy Database with the "Shoal Depth True Position" algorithm which also calculates a mean value based on all raw data within the 1 foot cell along with statistics on density (i.e., number of raw elevations) and standard deviation. The mean values, calculated at the center X,Y location of each cell, were used for differencing analysis in comparing with the March 2009 baseline data (which was reprocessed using the same gridding method).

The mean values from the combined December 2009 survey datasets, was used for differencing against the baseline survey conducted in March 2009, as well as, for producing an updated topographic map of the dam. The topographic map is displayed at 1" = 80' scale drawing in sheet 1. The difference image is displayed as a color map at a 1" = 80' scale in sheet 2. To enhance the interpretation of these data sets, a grid system has been overlaid on the maps of the front of the dam to allow focused view of detailed areas. The grid system consists of thirty, 150' x 150' areas which are referenced by rows (A, B and C) and columns (1 through 10). Areas within the reference grid where significant features occur (i.e., areas showing negative change in elevation over a horizontal area of approximately 10 square feet or more) are included in this report at a larger scale (1" = 20') for better clarity. Detail areas B5 through B10 are included. Detail areas C4 and C10 are also included because they depict features of interest, possible grout build up and creek changes, respectively. The significant changes depicted along row A are attributed to extensive construction and grading and no details in that general area are include. Each anomaly

detail includes geographic coordinates to assist engineers in the field for inspection activities. General profiles across each feature are shown to help characterize the anomaly.

7.1 Data Interpretation

The December 2009 vs. baseline (March 2009) difference image (sheet 2) is predominantly comprised of grey shaded grid cells indicating no change greater than +/- 0.25 feet. This is also a very good indication of the general repeatability of the measuring systems utilized. Areas of no data (white) occur where either one or both of the survey grids had no elevations and therefore no difference could be calculated. Due to the significant shadowing which occurred because of large equipment operating during the baseline survey and lower data density due to submerged scan locations during the December 2009 survey, there are some significant areas which were shadowed and not covered. Most areas depicting change appear to have reasonable explanations, such as: increase in vegetation, road grading, extensive construction activity, wood debris which floated off, etc. A few significant areas (i.e., showing negative change in elevation over a horizontal area of approximately 10 square feet or more) were relayed to the USACE on 12/2209 for quick field investigation.

This interpretation is DEA's general assessment of the more significant features of the data to help assist the engineers that will use it in understanding what the difference image depicts. The intent of the difference map is to make a graphical representation of elevation changes between the December 2009 survey and the baseline survey of March 2009 which can be used as a visual tool to help indicate to engineers and investigators possible areas which may need further inspection. It may be useful for those reviewing the maps to also reference the digital versions, both Microstation and PDF formats, which may produce sharper colors, magnification and better detail than can be produced on paper copies.

7.2 Deliverables

Deliverables consisted of the following:

- Color plan view maps of scan locations and 2-foot interval elevation contours
- Report documenting survey methodology, calibration procedures, data processing, quality assurance procedures, and statement of survey accuracy
- XYZ comma-delimited ASCII data at 1 foot grid spacing
- Two copies of CD containing ASCII data and electronic copies of report, drawings, and field notes.

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APPENDIX P

Depth Measurement and Construction Payment in Unconsolidated Material

P-1. General Scope. Determining the clearance or payment grade is difficult when irregular rock fragments, soft strata, vegetation, or suspended sediments are present. Various mechanical and acoustic survey systems have been developed in attempts to assess and define clearance grades in these adverse conditions. Mechanical sweep methods were described in Chapter 10. This appendix focuses on depth measurement in projects with unconsolidated bottom material such as fluid mud or suspended sediments.

a. Suspended sediments in the water column will commonly occur during dredging activities when the excavation process has resuspended the bottom material, resulting in clouds of suspended sediment material, often termed "fluff." In some cases, relatively low-density saturated sediment (fluid mud) is naturally present, and a finite reference grade is difficult to define (especially for contract payment purposes). Other difficult depth measurement conditions include gassy sediments, moving bottoms, and vegetated bottoms. Also, small rock fragments may not reflect sufficient acoustic energy to be detected on standard echo sounders. Industrial waste can also create problem areas where there are large discharges of organic material, such as downstream of paper or pulp mills where the suspended organic material can be acoustically very reflective but have very low shear strength.

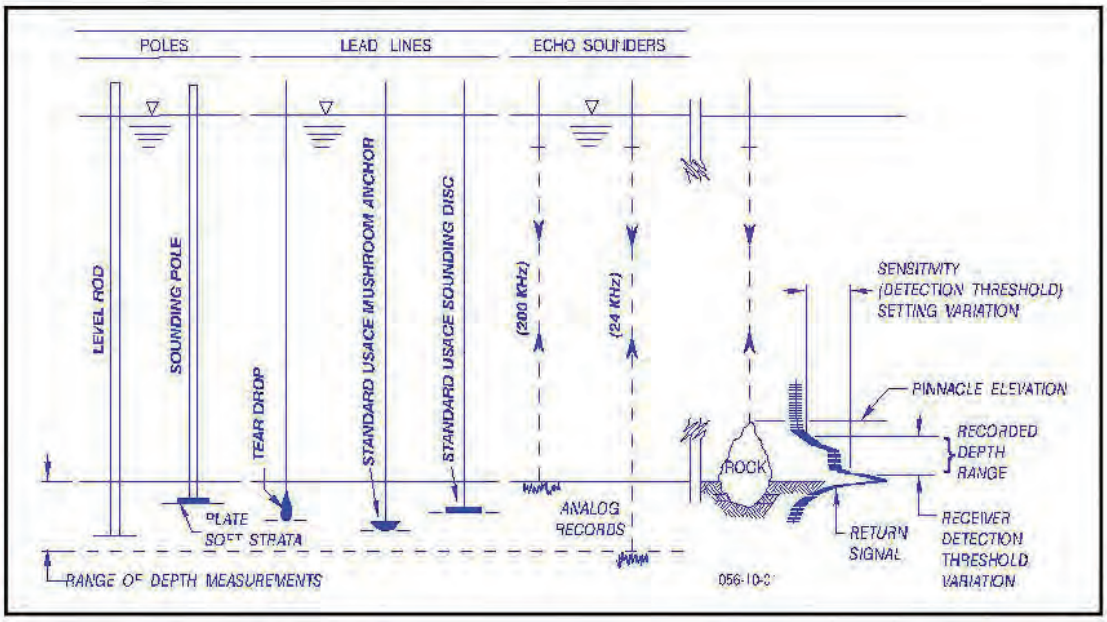

Figure P-1. Depth measurement variations in soft bottoms, illustrating variations between mechanical lead lines and acoustic methods. Acoustic returns on rock pinnacles also have uncertainties due to echo sounder threshold variations.

b. When the upper sediment layer is not well consolidated, the three major depth measurement methods used in USACE (echo sounding, leadline, and sounding pole) will generally not correlate with one another, or perhaps not even give consistent readings from one time to the next when the same type of instrument or technique is used. These potential variations in depth are illustrated in Figure P-1. This appendix presents information about the effects that difficult bottom conditions can have on hydrographic surveying methods and describes some optional methods of estimating depth data in unconsolidated bottom material. Although the primary focus is on measurement in suspended sediment conditions, it applies equally to other bottom conditions that present problems for acoustic measurements.

P-2. Causes of Suspended Acoustically Reflective Material. Causes of fluff layers, fluid mud, and other soft bottom conditions are not understood very well. A significant amount of research has been conducted to improve an understanding of these processes and to develop improved methods of determining and defining the nautical bottom. Fluid mud conditions are reported most frequently from districts that maintain waterways in the warm-weather sections of the country and are most prevalent in estuaries where mineral-laden fresh water mixes with salt water. Freshwater mineralogical sediment flocculation is accelerated when the sediment reaches saltwater. These flocculants are very loose aggregates that are 95% or greater water content and can hang in suspension for a long time. Several layers of progressively denser material can occur.

a. Dredging impacts. Conditions downstream from a dredge will probably also be quite different from those described in the preceding paragraph. The suspended material will not become stratified for some time after being resuspended by the dredge, and a return signal can result from reflection and dispersion of the signal from a wide vertical portion of the water column. While not applicable to depth measurements, acoustic reflection techniques have been used in research studies to survey spatial and temporal characteristics of plumes generated by dredging operations.

b. Currents. Swift natural currents also can cause turbulence that resuspends sediment material in clouds (fluff). This condition, like dredge plumes, can cause acoustic reflection that will obscure normal reflection from the more consolidated sediments of the waterway bottom. Acoustic reflection analysis of layer reflections does not apply to this condition.

c. Fluid mud and nautical bottom. Fluid mud is a high concentration aqueous suspension of fine grained sediment in which settling is substantially hindered by the proximity of sediment grains and flocculants, but which has not formed an interconnected matrix of bonds strong enough to eliminate the potential for mobility, leading to a persistent suspension (McAnally 2007). It can be characterized as suspensions with density gradations that range from slightly greater than that of the overlying water in its upper layers, to that of stiff, dense lower layers with mud densities ranging from 1050 to 1350 g/l, with concentrations ranging from 50 to 500 g/l or 2-13 percent solids by volume, and consist of silt and clay-sized material with clay minerals and organic material (Teeter, 1997).

d. In navigation channels with more consistent bottoms, e.g., sand, an underkeel clearance (distance between the central fore-aft structural member in the bottom of the hull and channel bottom) is used to account for parameters such as ship motion from waves, squat, safety clearance, water density etc., to avoid contact between ship and bottom. In channels with fluid mud, as per PIANC 1997,

> "Although the upper part of the mud layer has a somewhat higher density than water, its rheological properties are comparable with those of water, so that a ship's hull suffers no damage when it penetrates this interface. Even navigation with an under keel clearance which is negative referred to the interface can be considered, which implies that the ship's keel is permanently in contact with the mud. On the other hand, safety of navigation requires that the pilot must always be able to compensate for the effects of mud on ship behavior by means of its own control systems or external assistance (e.g., tugs).
>
> An acceptable compromise between the safety of navigation and the cost of channel maintenance can only be reached by introduction of non-conventional definitions and survey methods, and requires additional knowledge about the navigational response of ships in muddy water."

e. To implement this alternative approach, the terms bottom and depth can be modified to nautical bottom and nautical depth where nautical bottom is defined (PIANC 1997) as

> "the level where physical characteristics of the bottom reach a critical limit beyond which contact with a ship's keel causes either damage or unacceptable effects on controllability and maneuverability,"

and nautical depth as

> "the instantaneous and local vertical distance between the nautical bottom and undisturbed free water surface."

f. To complete the definition of nautical bottom, the physical characteristic(s) on which the "critical limit" criterion is based and the criteria for "acceptable" ship behavior must be provided. Consequently from a practical and operational perspective (as per PIANC 1997), implementation of a nautical bottom concept requires:

- " a practical criterion, i.e., selection of the physical mud characteristic acting as a parameter for the nautical bottom approach and its critical value;
- a practical survey method for continuous determination of the accepted level;

- a minimum value for the required underkeel clearance with reference to this nautical bottom, ensuring a minimal risk for contact with the latter and acceptable ship behavior;

- knowledge about ship behavior in these situation; if necessary, measures to compensate adverse effects on controllability and maneuverability."

g. At the present time, density (with a critical value of 1.2 g/cm^3) is predominantly used throughout the world as the nautical bottom criterion.

h. For additional discussions on nautical bottoms see "Evaluation of Nautical Bottom Detection Techniques" (Sea Technology 2008). Vessel movement through fluid mud involves complex parameters such as the mud/water interface, stickiness or adhesion, bearing capacity, and deformation—for details on this research see "Rheology as a Survey Tool" (HYDRO International 2011).

P-3. Acoustic Depth Measurement in Suspended Sediments. Figure P-2 illustrates the kind of depth records that can occur when surveying with conventional single beam echo sounders over waterway bottoms with soft material surfaces or suspended material above the consolidated sediment surface. These analog records cannot be interpreted reliably unless other correlating information is developed. Automated depth digitizers may be even less reliable in providing a depth reading because such equipment cannot use any objective judgment in deciding whether to accept or reject the incoming information. Thus, the use of conventional survey systems does not help in this type of surveying environment, as far as getting good, reliable data is concerned. Records such as those depicted in this figure result from the fundamental principle on which acoustic depth sounding is based. When there is a sufficient difference in density (i.e., gradient) of the underwater material, some of the incident acoustic energy will be reflected. When using high-frequency transducers (i.e., 200 kHz), even very small density differentials will cause sufficient energy to be reflected, causing the depth sounder to display one or more returns. For this reason, lower or variable frequency transducers may be required to depict the bottom—Figure P-3. The following sections provide an overview on the principles whereby these density variations result in multiple returns in fluid mud.

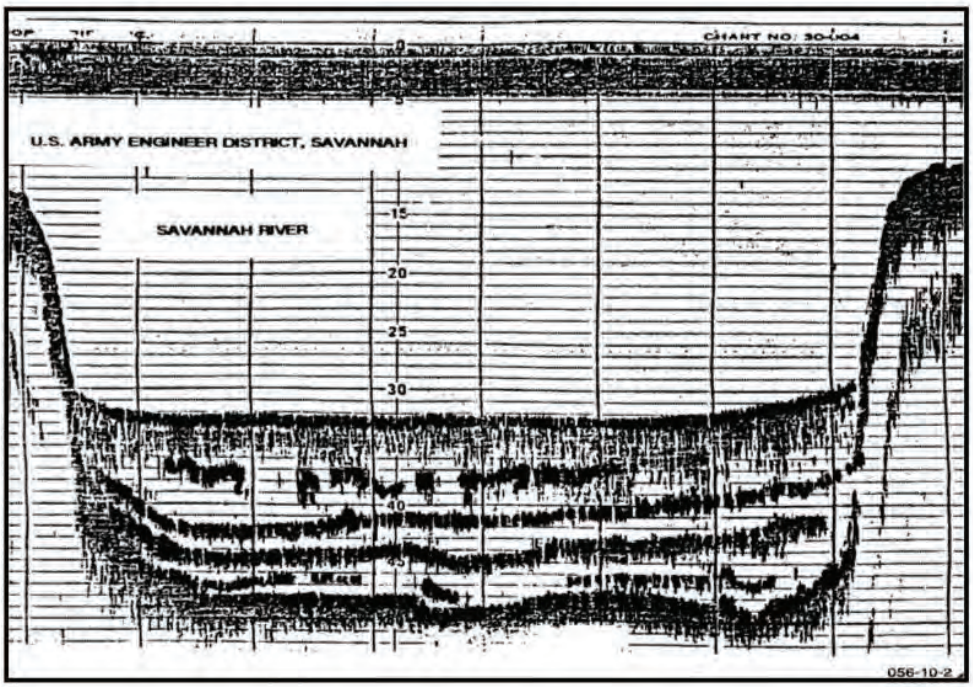

Figure P-2. Suspended sediment record in a section of the Savannah River ca 1970s. Upwards of 15 ft of low-density sediment layers are present. Frequency uncertain—probably a lower frequency given amount of penetration. (Savannah District)

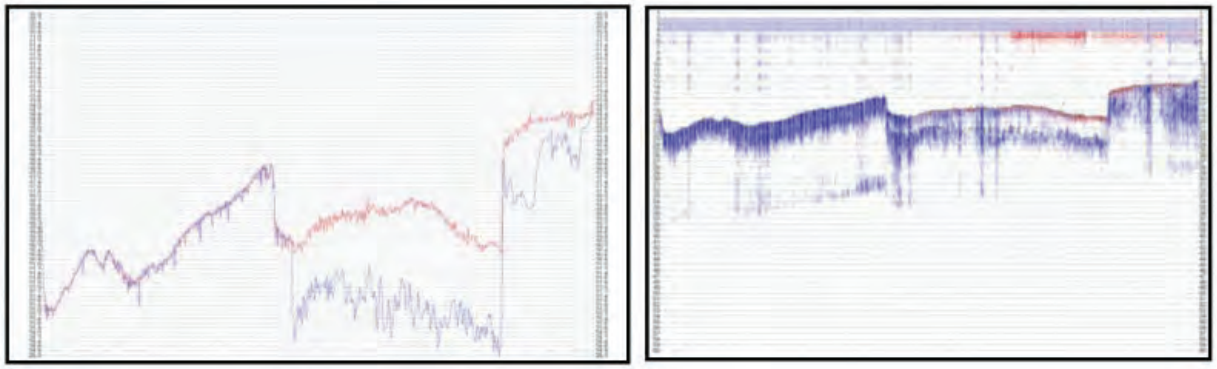

Figure P-3. 4 to 5 ft differences between high (200 kHz) and low (24 kHz) frequency Returns in fluid mud areas on the Atchafalaya River, LA (2011). (New Orleans District)

a. Velocity of sound in water. The velocity of sound in water is a function of the density and compressibility of the medium through which the sound is traveling. Compressibility is

technically related to the "bulk modulus elasticity" which is a function of temperature, salinity, or other dissolved materials.

b. Acoustic impedance. Acoustic impedance corresponds to the resistance of the medium to the wave propagating through it, i.e., a proportionality factor between the particle velocity and the acoustic pressure—see IHO 2005. In underwater acoustics, a related term ("specific acoustic impedance") is used. The specific acoustic impedance "Z" is a function of the density of the medium "ρ" and the velocity "c."

Specific Acoustic Impedance: $Z = \rho \cdot c$ (Eq. P-1)

where,

Z is in $Kg/(m^2\text{–sec})$ or Rayls
ρ (density) is in Kg / m^3
c (velocity) is in m/sec

(1) Changes in the densities between the water and the bottom (or layered sediments) will change the acoustic impedance, resulting in reflected signals back to the sounder. Reflections at these density interfaces are also measured by "acoustic reflectivity" or "E."

Acoustic Reflectivity $E = (Z_2 - Z_1) / (Z_2 + Z_1)$ (Eq. P-2)

where
Z_1 = acoustic impedance at layer 1
Z_2 = acoustic impedance at layer 2

(2) Figure P-4 illustrates the reflection of acoustic energy from multiple stratified layers of underwater material. The acoustic reflectivity at each layer is also shown. As energy generated from an acoustic source arrives at a boundary between two layers of differing material properties, part of the energy will be reflected back towards the surface and part transmitted downward. Portions of the transmitted energy will undergo absorption or attenuation in the layer while the remainder propagates through to the next stratigraphic boundary. Ratios between transmitted and reflected energy (reflection coefficients) are dependent on the density and velocity of the materials through which the energy is propagating. Systems have been developed to measure the density of bottom surface material and subbottom stratified sediment layers at different depths using these acoustic impedance techniques.

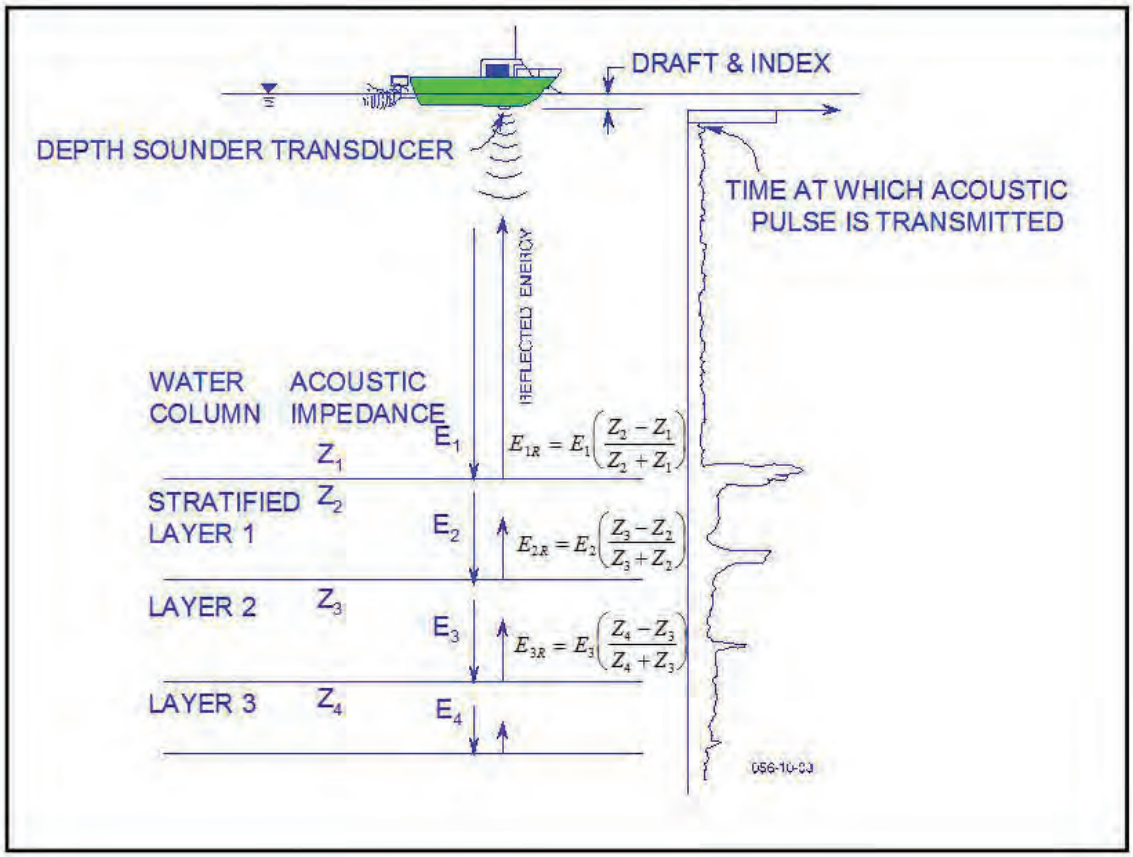

Figure P-4. Acoustic impedance (Z) and acoustic reflectivity (E) changes in differing sediment densities.

(3) Table P-1 lists impedances for water and various materials. Very small changes in impedance between two mediums will result in an acoustic reflection. The large change between water and hard materials results in solid, sharp returns, such as those received from a bar check. Air bubbles in the water also provide strong returns given the large difference in impedance between air and water.

Table P-1. Acoustic Impedance Values for Different Materials

Substance	Acoustic Impedance
Air	4.1×10^{2}
Fresh water	1.46×10^{6}
Salt water	1.54×10^{6}
Suspended sediments	(varies)

Fish skin	1.6×10^{6}
Rubber	1.8×10^{6}
Silty Clay	2.3×10^{6}
Clayey Silt	2.5×10^{6}
Silty Sand	2.9×10^{6}
Very Fine Sand	3.1×10^{6}
Fine Sand	3.2×10^{6}
Medium Sand	3.3×10^{6}
Coarse Sand	3.5×10^{6}
Gravelly Sand	3.7×10^{6}
Sandy Gravel	3.9×10^{6}
Clay (hard)	7.7×10^{6}
Rock	1.5×10^{7}
Steel	4.7×10^{7}

c. Reverberation and scattering (R2Sonic 2010). The sea is not homogenous in nature. Everything from suspended sediment particles to fish, from the sea surface to the sea floor will scatter, that is reradiate, the acoustic energy. All of the effects of individual scattering can be termed reverberation. The effect of reverberation is to lessen the acoustic energy and this leads to transmission losses. Reverberation is divided into three main areas: sea surface reverberation, bottom reverberation, and volume reverberation (the body of water that the energy is passing through). Both the sea surface and the sea bottom will reflect and scatter sound, thus affecting the propagation of sound. Sea surface scattering is influenced by how rough the sea is (which is related to wind velocity) and also the trapped air bubbles in the near surface region. The sea surface is also a good reflector of acoustic energy; this can lead to second and even tertiary bottom returns as the bottom return acoustic energy is reflected by the sea surface and is then reflected once more by the sea bottom. In the case of the sea floor, the strength of the scattering depends on the type of bottom (composition and roughness), the grazing angle of the acoustic pulse and the operating frequency of the sonar.

(1) There is also bottom absorption based on the sea floor terrain and composition. Bottom absorption is also dependent on the operating frequency of the sonar and the angle of incidence. Bottom absorption will be greater for a higher frequency and large angle of incidence. It is more or less intuitive that a mud bottom will absorb more of the acoustic energy than a rocky bottom. When the acoustic energy is absorbed it means there is less that will be reflected back to the receivers. The surveyor must be aware of the bottom composition as adjustments can be made to the receiving system's operating parameters to help compensate for the bottom absorption.

(2) In waters with a large sediment load, the suspended particles will scatter the sound wave, thus leading to transmission loss. In the scattering process, there is also a degree of energy that it is reflected (backscatter); this can be a cause for ‘noise’ in the sonar data. Again, the

surveyor should be aware of this condition and, if need be, change the operating parameters of the recording system. When discussing the changing of the operating parameters, it is generally a matter of increasing transmit power or pulse length to get more total power into the water. In some circumstances, increasing the absorption value will allow the system to rapidly increase gain to capture the reflected energy that has been dissipated by seafloor absorption or scattering in the water column.

(3) As noted above many of the effects of absorption, scattering, and bottom absorption are frequency dependent. On variable frequency echo-sounder systems, such as the R2Sonic 2024, the operator can adjust the sonar frequency to optimize the system for the survey conditions. This will take some trial and error; however, lower frequencies tend to do best in areas of absorbent bottom and high sediment load (scatter).

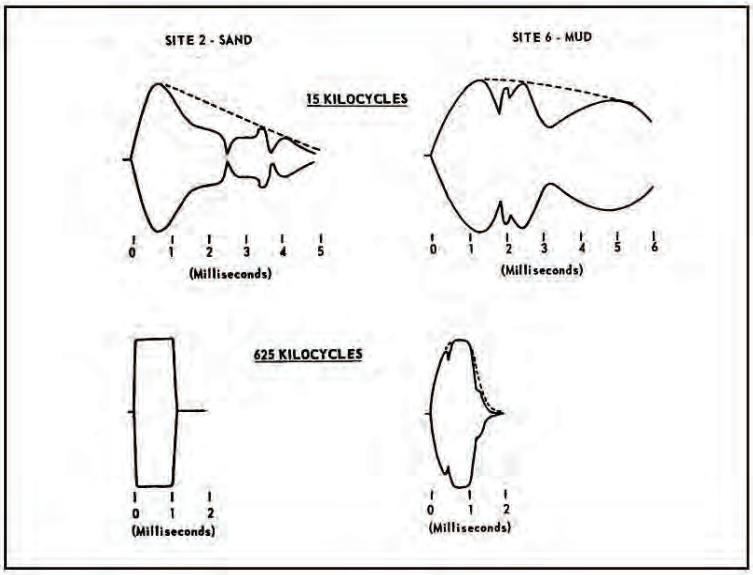

Figure P-5. Signal return variations at different frequencies from sand and mud.

d. Echo sounder gain or sensitivity control. An important point to remember is that the amplitude of the first signal return is proportional to the density of the upper layer. Thus, a hard sand surface layer will give a much stronger signal return than a low-density fluff surface layer, no matter what frequency is used (see Figure P-5). Keeping this fact in mind can be helpful in making a rational setting of the transmit power and sensitivity controls on a depth sounder. Consider the situation in which a survey is under way and the depth recorder (analog chart or digital display) begins to print (display) irregularly in a particular area. The natural tendency is to adjust the depth recorder sensitivity control until the depth recorder prints (displays) a solid line again. Increasing the sensitivity of the recorder permits the display of a signal return from a softer bottom. The potential problem with this type of adjustment is that the higher sensitivity

may cause the depth recorder to register a "fluff" layer and not a true bottom. Thus, one should not "crank up" the sensitivity control to keep a solid line on the recorder and do nothing else. If a sensitivity adjustment is necessary, it is also necessary to make a correlating depth check using one of the alternate depth measurement techniques described in this appendix. If the alternate method agrees with the depth recorder, the sensitivity adjustment is probably warranted. If there is no correlation, use of the alternate depth measurement method is indicated.

d. Acoustic signal return in multiple sediment layers. When acoustic energy hits the upper surface of an underwater layer of material, some of the incident energy is reflected and some continues downward through that layer and hits the next layer. At the next interface, some of the energy is reflected and some continues downward. At each interface between layers, this process continues, with the incident energy becoming smaller with each transition due to reflection, attenuation, and scattering. Energy is reflected principally at the interface surfaces between layers and not in the interior of the layers, except where particles within a layer cause a local density gradient. Figure P-6 depicts a 24 kHz signal return from multiple layers of material.

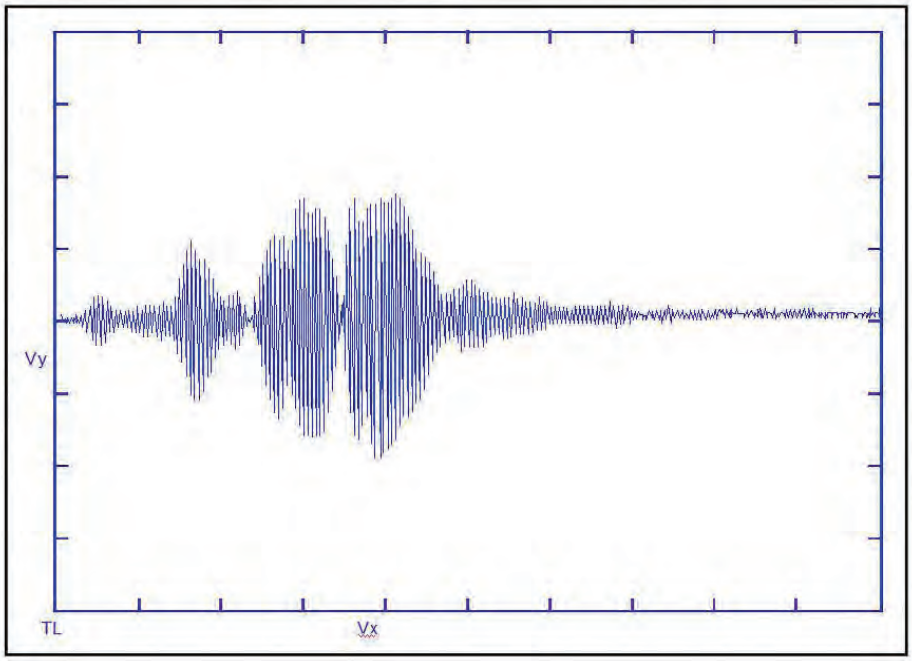

Figure P-6. 24 kHz signal return in multiple sediment layers.

P-4. Attenuation of Acoustic Energy in Suspended Sediments. Attenuation is the loss in energy of a propagating wave due to absorption, spherical spreading, and scattering by particles in the water column—see IHO 2005. As acoustic energy passes though a material such as water, underwater sediments, or suspended material, some of the energy is absorbed and the signal becomes weaker with the distance traversed. Energy absorption is referred to as “attenuation”

and is usually given in decibels (dB). Different types of underwater materials will have different attenuation effects, and signal calculations must take this factor into account. At each interface surface, the downward-going acoustic energy will be reduced by both the preceding reflection reduction and the attenuation loss. The upward-going acoustic energy suffers the same reduction in amplitude ratio as does the downward-going energy (from attenuation and reflection redirection at each layer interface). These effects are doubled on the upward-going energy through the soil layers because it has twice the path length to traverse and must lose a proportion of reflected energy at each interface surface. Thus, because of the attenuation and reflection, a progressively smaller portion of the reflected energy comes from the lower layers of sediment, and the reduction in signal amplitude is drastic. The signal strength returning to the depth sounder transducer is an extremely small percentage of the transmitted energy. Only by electronic amplification is it possible to detect such minute signals.

a. Effect of frequency on attenuation. Attenuation of acoustic energy is proportional to the frequency, as illustrated in Figure P-7. Thus, 200 kHz energy is attenuated much more rapidly than 24 kHz energy when passing through the same material. Since high-frequency energy is attenuated more than low-frequency energy, a much smaller proportion of the high-frequency energy comes back to the depth sounder transducer from the lower layers of sediments than is the case with the low-frequency energy.

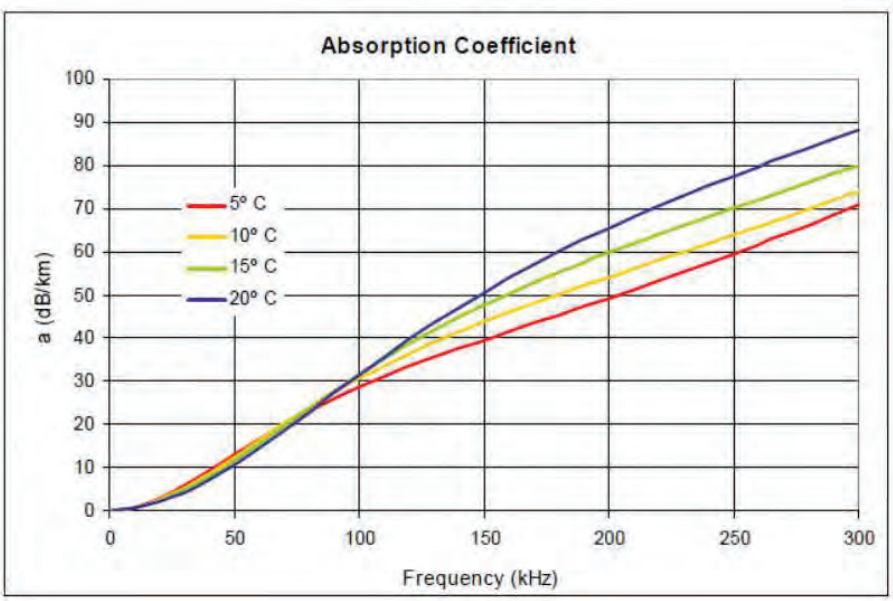

Figure P-7. Acoustic signal attenuation versus frequency. The rate of absorption is also dependent on the physical and chemical (primarily magnesium sulphate) properties of seawater. (IHO 2005)

b. Attenuation of different frequencies in suspended sediment layers. An example showing the effect of attenuation as a function of frequency is given in Figure P-8. This is a graph of the amplitude of the output from a 200-kHz transducer (upper curve) and the output from a 24 kHz transducer (lower curve). The two transducers were mounted side-by-side and aligned so that the response pattern of both transducers was vertical. Both transducers transmitted simultaneously, and the time scale is the same for both transducers. The 200 kHz channel was adjusted to have a higher gain than the 24-kHz channel so that the maximum amplitude of both channels, as viewed on the graph, was comparable. Due to the high attenuation of the 200 kHz signal, there is no detectable energy received from the lower sediment layers even though they had a higher density. The 24-kHz signal shows a maximum amplitude at one of the lower sediment layers because the attenuation of the 24-kHz signal in the upper layer is relatively low and the reflectivity of the upper layer is quite low. In this example, both transducers show the reception of first reflected energy at the same time. The 24-kHz energy reflected by the upper layer (the primary reflector of 200 kHz energy) appears to be very low in amplitude. The amplitude of the first layer reflection is, however, just as large at 24 kHz as it is at 200 kHz. However, the ratio of this reflectivity to the lower reflectivity gives the higher amplitude at the lower layer. The main point is that the reflectivity is about the same at both frequencies, but the attenuation is much higher for the higher frequency. The net result is that the high-frequency depth channel normally registers the upper layer of reflective material, even a very low-density one, and the lower frequency depth channel will register a lower layer if that lower layer has a higher acoustic reflectivity than the upper layer. Low-frequency depth sounders will always penetrate to a lower depth than will higher frequency energy at the same transmitting power level and receiver sensitivity. From a hard upper surface such as sand or rock, the surface reflection will be the maximum reflection amplitude for either a high- or a low-frequency signal.

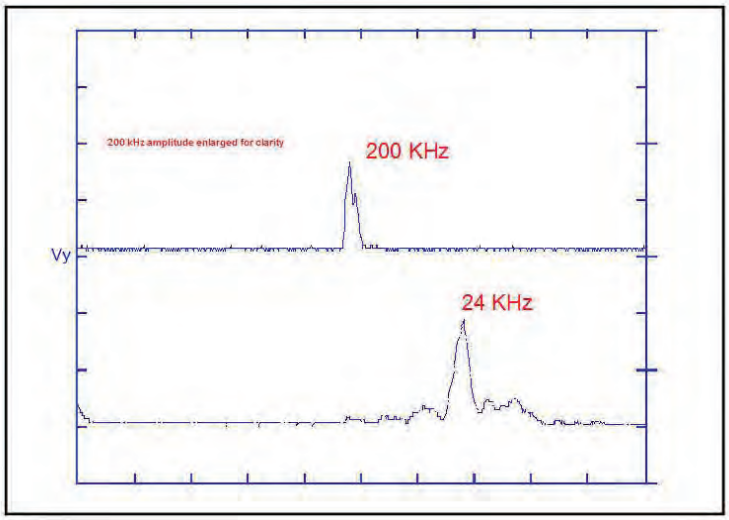

Figure P-8. Comparison of 24- and 200-kHz signal attenuations

P-5. Effects of Surface Roughness and Incident Angle. Amplitude of the reflected signal will be affected by both the surface roughness and the incident angle. For depth sounding over level bottoms, the acoustic path will be close to vertical when using narrow-beam transducers or vertically aligned transducers. This simplified assumption is not valid for multibeam systems and when working with single-beam systems over sloping surfaces, when the survey boat is pitching and rolling, or when the transducer is not narrow-beam.

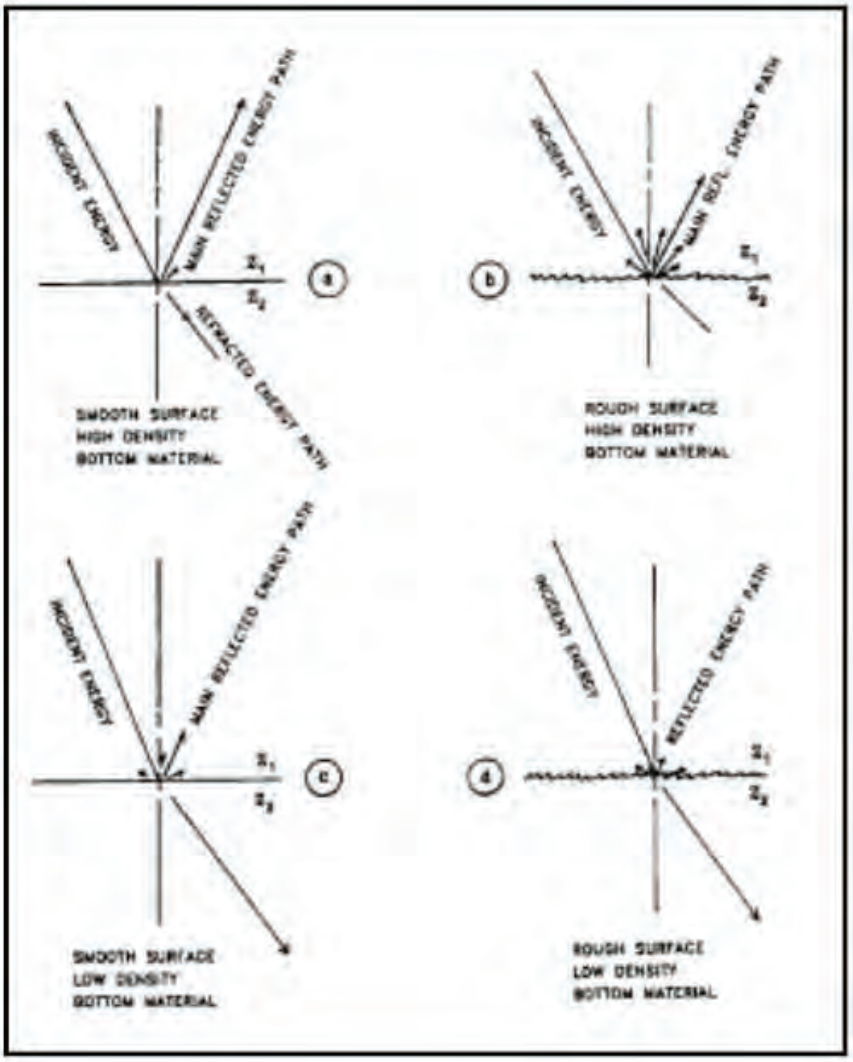

Figure P-9. Effect of surface roughness on reflected acoustic energy.

a. The four quadrants of Figure P-9 illustrate some effects of surface roughness and bottom surface density. Quadrant P-9a illustrates the reflection, refraction, and dispersion effects on a smooth hard bottom surface. Under these conditions, a high percentage of the incident energy is reflected and the dispersion of the reflected signal is low. Low dispersion results in a stronger

signal along the reflection path. A vertical signal path and level bottom give the strongest possible signal return to the depth transducer. If the bottom surface is a sloping rock surface, a very low signal return may result because the energy would be directed away from the transducer in much the way a mirror reflects light. For this reason, small irregularly shaped rock fragments with smooth surfaces may go undetected by conventional echo sounders.

b. Quadrant P-9b illustrates the reflection, refraction, and dispersion effects on a rough high-density bottom surface. In this instance, a much higher percentage of the incident energy is dispersed at angles different from the main reflection path. High dispersion results in a lower signal along the main reflection path. When the signal path is vertical and the bottom is level, there is a weaker signal return to the depth sounder transducer than under the conditions shown in quadrant P-9a. When the bottom surface is not level, the rough surface illustrated in quadrant P-9b may give a higher signal return than the smooth surface. As an example, a rough-surfaced boulder would be much easier to detect than a smooth-surfaced boulder.

c. Quadrant P-9c illustrates the reflection, refraction, and dispersion effects from a smooth low-density bottom surface. A fluff layer in a channel without wind or currents to disturb the surface would approximate this condition. In this instance, low dispersion results in a stronger signal path along the reflection path. If the signal path is vertical and the bottom is level, most of the reflected energy is directed back at the transducer. The reflected energy would still be relatively low due to the low density. It is improbable that a low-density material will have other than a small surface angle because it will migrate down the slope.

d. Quadrant P-9d illustrates the reflection, refraction, and dispersion effects from a rough low-density bottom surface. A fluff layer in a channel with wind or current to disturb the surface would approximate this condition. In this instance, the high dispersion in the surface reflection results in a weaker signal along the reflection path than the conditions illustrated in quadrant P-9c.

e. The IHO Manual on Hydrography (IHO 2005) presents a more detailed treatment on acoustic dispersion, reflection, and backscattering. In this manual, these effects are expressed in a 'Sonar Equation' which is used to "study and express the detection capability and performance of echo sounders as a function of operating conditions ... and to understand the processes involved in acoustic signal propagation and echo detection." The sonar equation for echo sounders defines the signal or echo detection as the Echo Excess (EE),

$$EE = SL - 2\,TL - (NL-DI) + BS - DT \qquad \text{(Eq P-3)}$$

where SL = source level, TL = transmission loss, NL = noise level, DI = directivity index, BS = bottom backscattering strength, and DT = detection threshold. Refer to Chapter 3 of the IHO Manual on Hydrography for a detailed explanation of the terms in the Sonar Equation. Of particular interest in evaluating suspended sediments is the seabed Backscattering Strength (BS),

which is dependent on the reflective properties of the seafloor and the effective signal scattering area.

P-6. Dual-Frequency Acoustic Depth Measurements in Suspended Sediment Conditions. Dual-frequency echo sounders are commonly employed by the Corps in areas where fluff or fluid mud is present. In order to assess the data quality between the high and low frequency returns, it is helpful to be aware of some of the characteristics of each frequency, as listed in Table P-2 below. Figures P-10 and P-11 illustrate dual frequency records from typical echo sounders.

Table P-2. High- and Low Frequency Characteristics.

High-frequency echo sounders – 200 kHz typical
- Narrow beam—small transducer size/weight
- More accurate depth measurement & resolution
- Picks up small density changes
- Will pick up multiple fluff layers ... Grass, kelp
- Will record vegetation above hard bottom
- Lower power requirements
- Side echos minimized
- Digital depths easier to obtain
- Must be directly over object to detect (obtain return)
- Limited in depth range... few hundred feet
- More difficult to obtain bar check

Low frequency echo sounders – 24 kHz typical
- Wider beam …large transducer size/weight
- Less accurate depth measurement & resolution ... side echos smooth out features
- Bar check calibration easy
- May detect “truer” bottom
- May penetrate through bottom grass
- Will not detect small density changes
- Higher power requirements
- Increased depth range.

General features of high and low frequencies
- Acoustic energy is absorbed at each density layer
- Reflected energy also absorbed on return path
- Returning signal strength is very small (amplifying signal becomes problem)
- 200 kHz energy attenuated 10 times more than 20 kHz
- Low frequency may not pick up initial density change if small
- Low frequency may penetrate to sub-surface rock
- Signal return amplitude proportional to density of return surface

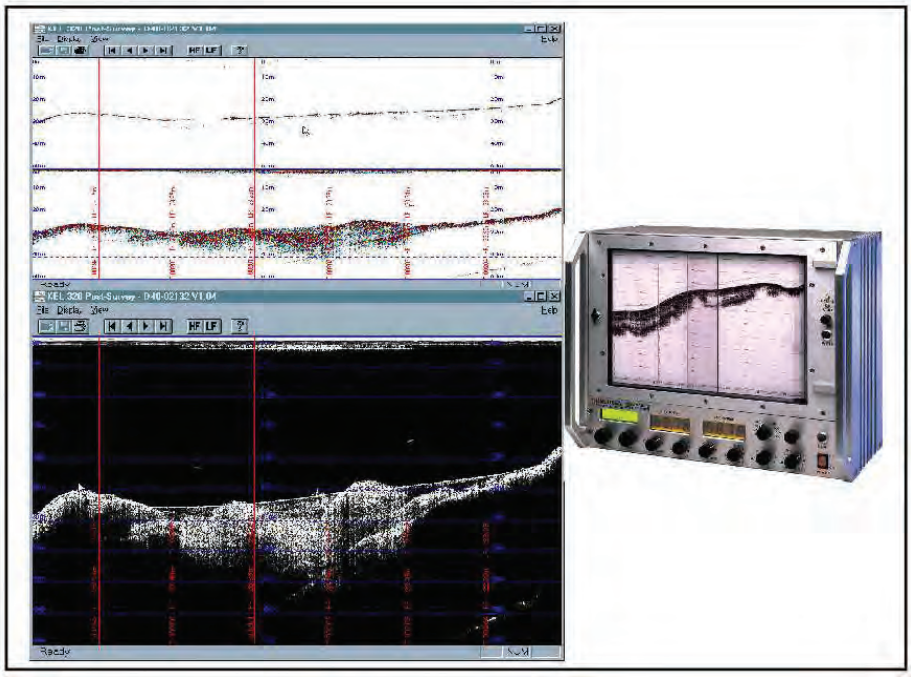

Figure P-10. Knudsen 320M dual frequency recorder (24 kHz and 210 kHz). The upper part of the figure shows the profiles recorded by the two separate frequencies. The bottom part shows the merged records in color-reverse grayscale.

P-7. Dual Frequency Parametric Subbottom Profiling. The Innomar SES-2000 parametric profiling echo sounder (Figure P-12) uses the combination of two or more frequencies to measure subsurface layers and objects, such as pipelines. It can operate in water depths down to 400 m with penetration up to 50 meters, and can resolve embedded objects or sediment layers as small as 5 cm. The term "parametric" refers to the mixing of frequencies to form sum and difference frequencies. Returns from the two high and low frequencies are added and subtracted, with the frequency difference being used to evaluate and measure penetrated sub-surface layers. Both frequencies have the same beam width. For small object detection, the survey vessel speed is kept to less than 2 kts during surveys. Applications of parametric frequency measurements are listed in Table P-3.

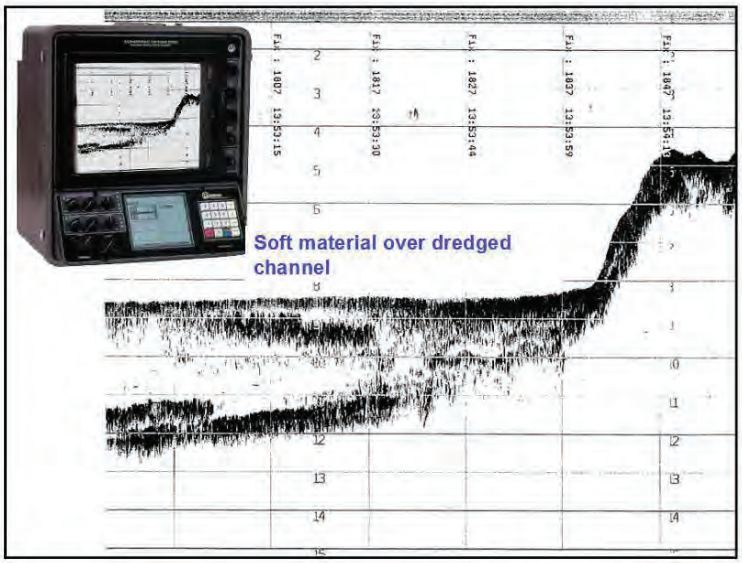

Figure P-11. Teledyne Odom Hydrographic ECHOTRAC MKIII dual frequency thermal echo sounder (24 kHz and 200 kHz), depicting soft sediment material over dredged channel.

Table P-3. Dual Frequency Parametric Profiling Applications.

Geological and geophysical explorations
Soil investigation campaigns for dredging projects
Route Surveys for pipeline and cable laying projects
Detection of fluid mud and sediment structures for dredging tasks
Search for mineral resources
Surveys of small and shallow waters, gravel pits, harbor basins, flood gates, shore zones
Search for objects, wrecks, pipelines, sea cables, navigation obstacles, stones, toxic wastes
Archaeological investigations for wrecks, historical buildings, and settlements

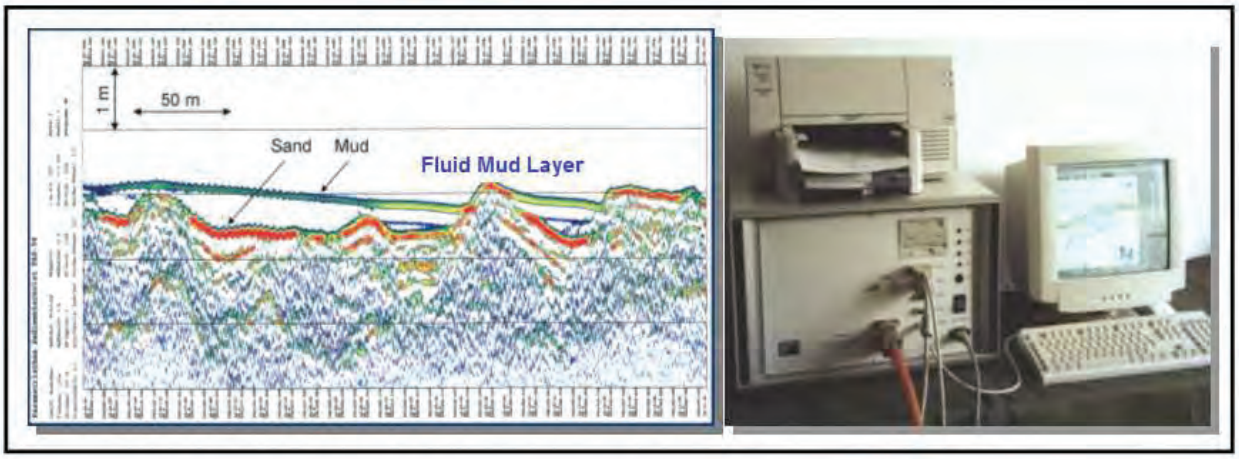

Figure P-12. SES-96 (SES-2000) Dual frequency profiling system. Enhanced processing of signals can identify different material layers in a channel, including fluid mud. (Innomar Technologie GmbH)

P-8. Alternative Depth Measurement Techniques in Suspended Sediments. The preceding paragraphs described the principles underlying the operation of acoustic depth sounders and limitations of this measurement technique in complex bottom conditions. All depth measuring techniques in fluid mud layers, including mechanical lead lines, have their limitations and constraints. The following paragraphs describe the uses and limitations of other depth measurement methods in suspended sediments or fluid mud layers. Not all of the following methods have practical application in that they were limited to research projects by the US Army Engineer Research and Development Center's (ERDC) Coastal and Hydraulics Laboratory.

a. Lead lines or sounding disks. Mechanical depth measurement using a lead line or sounding disk is usually considered a slow but very reliable method of determining depth. With hard bottom material, this assumption is valid. However, with soft bottom materials, it may not be. A variety of lead weights are used, such as mushroom anchors and round flat plates 4 to 12 inches in diameter. A lead weight will fall until the shear strength of the sediment is sufficient to stop the vertical movement of the weight. The high density of the lead weight is such that it will never come to an equilibrium depth on the basis of density. The shear strength of sediments can be affected by the velocity of the lead weight, stirring action, and the amount of time that the weight is allowed to rest on the soft sediment.

(1) As a result, two different people using the same lead line can get different results, depending on the length of time the weight is allowed to rest on the bottom and whether or not the weight is jiggled a bit to feel the bottom. With soft bottoms, it is difficult to feel when the weight actually touches bottom—i.e., hits "refusal." Moving the weight while it is on the bottom tends to break down the internal structure of the soft sediment and convert it from a semi-solid to a viscous liquid, causing the lead line to sink deeper than if handled otherwise.

(2) In addition to not stopping at a consistent level, a lead line may not stop at a level that is an acceptable nautical bottom. For instance, a lead line may pass through a sediment layer with a consistency of mayonnaise, but this kind of mud layer would probably so disrupt a ship's steerage that it would be unacceptable to shipping interests. A sediment with a mayonnaise-like consistency would, however, probably give a good response on an acoustic depth sounder. This also would be the correct surface to call bottom for dredge clearance and payment evaluation. This example is given to show that when acoustic depth sounders and lead lines disagree, the assumption should not be made that the lead line is the correct depth. Other correlating information may need to be developed.

(3) The accuracy of lead line depth measurements degrades considerably when currents are present, causing excessive slope in the line. In such conditions, and in depths greater than 20 ft, lead line accuracy exceeds ±0.5 ft. In depths exceeding 40 ft, lead line observations are, at best, around the ±1 ft range.

(4) Even with the above deficiencies in lead line measurements, it is still the most common method used by the Corps to correlate echo sounder readings when suspended sediments are present. Lead line observations are compared with high- and low-frequency recordings to assess channel clearance and to arrive at an equitable payment for material removed.

(5) Sounding poles or expandable (25-ft) level rods have been used on some projects to measure refusal depths in soft bottoms. A fixed plate should be attached to the bottom of the pole/rod to provide resistance. As with lead lines, determining the depth refusal point is extremely subjective and operator dependent. Depth measurements are generally limited to about 15 ft.

b. Nuclear density probes. Nuclear density probes can be used to measure the density of bottom sediments. Most nuclear density probes work on the principle that a more dense material will absorb a higher percentage of the radiation passing from the source to the detector than will a less dense material.

(1) A typical probe is configured so that the sediment material passes between the source and detector as the probe is lowered. Nuclear density probes can give an accurate graph of sediment density as a function of depth if properly calibrated and used.

(2) Nuclear density probes are used as a nautical bottom depth measuring technique in The Netherlands and Belgium, where fluid mud is a widespread condition.

(3) Nuclear density probes will not work in areas where there has been a discharge of radioactive material into the waterway. Calibration of nuclear density probes depends on having a uniform natural background radiation level in the area when the probe is to be used. Water discharged from industrial and government facilities has sometimes in the past contaminated the

sediments with low-level radioactive wastes. These wastes distort the background radiation level and will cause measurement error of the sediments apparent density.

(4) Another limitation to the use of nuclear density probes is the increased regulations governing their use, including the extensive paperwork involved. Nuclear density probes can be used only by licensed personnel, and the probes must be stored under special conditions that are expensive to implement and maintain. As a result, nuclear density measurements are not practical for most Corps dredging applications.

c. Mechanical towed sled method. A 260-lb towed sled system was developed at the USACE Waterways Experiment Station (now ERDC) in the 1970's to measure fluid mud shear strength and density measurements. This system modeled the ability of a vessel to navigate, given a resistance developed by the fluid mud. The sled (a direct contact method) depicted the boundary between suspended and consolidated silt. Sled sensors measured hydrostatic pressure, sled velocity, sled attitude, nuclear density, and cable tension. A crane winch assembly was required to operate the sled system. The depth of the sled was determined by the hydrostatic pressure (head) gages on the sled. For hard-bottom channels the head gage was inferior, but for unconsolidated channel bottoms the sled was used to measure the material density which can impede a ship's navigation in the channel. In tests conducted at Gulfport Channel (MS), the 200 kHz transducer was more consistent than the sled after repeated runs along the channel centerline. The sled was more consistent than the 24 kHz system. Weight was added to the sled in order to follow a density of 1.2 $g/cm^3 \pm 0.1$ g/cm^3. The 200 kHz transducer was estimated to reflect off material at 1.05 specific gravity. This tool was not intended to replace acoustic depth measurement, but to augment soundings in areas of fluid mud.

d. High Resolution Density Profiler (HRDP). An Interagency Agreement (IAG) was signed between the ERDC and USEPA's Environmental Sciences Division (ESD) of the Office of Research and Development's National Exposure Research Laboratory, the objective of which is to have ERDC modify the ADMODUS probe (an acoustic impedance-based navigation fluid mud survey prototype system successfully demonstrated in the Gulfport, MS navigation channel and in the laboratory) for use in characterizing dredge residuals for environmental dredge projects. Dredging residuals refer to contaminated sediment found at the post-dredging surface of the sediment profile, either within or adjacent to the dredging footprint. After the initial consolidation period (i.e., within a period of several days to a few weeks, depending on sediment characteristics and site conditions), generated residuals (excluding sloughed materials) typically occur as a thin veneer (1 to 10 cm thick) of fine-grained suspended material.

(1) One of the goals in developing this new sensor system (this is a current--2013--R&D project under the Dredging Operations and Environmental Research (DOER) program) is to produce an instrument that uses easy-to-obtain, and well supported, acoustic-signal processing hardware and non-proprietary signal processing techniques. The new sensor system is named the High Resolution Density Profiler (HRDP). The HRDP operational methodology to calculate density is based on the measurement of three ultrasound parameters:

- Acoustic impedance of the medium (Z_{med})
- Sound speed within the medium (c_{med})
- Ultrasound transmission characteristics (attenuation) of the medium

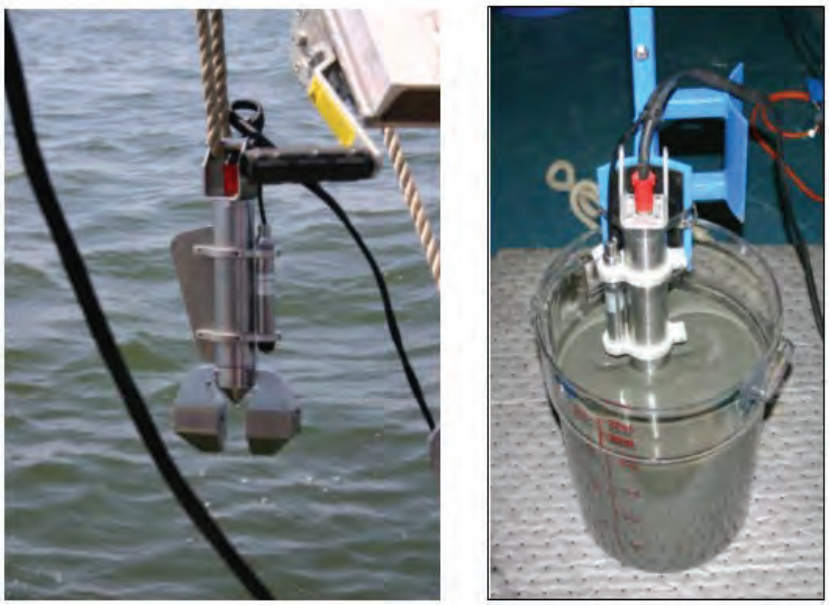

Figure P-13 High Resolution Density Profiler (HRDP) and its immersion in a static (fluid mud) bucket test.

(2) The prototype probe (shown in figure P-13) was tested in "static" buckets of various (bulk) density suspensions of fluid mud collected from the Gulfport (MS) Ship Channel, and compared to laboratory pycnometer measured densities. The results from these comparisons are shown in Table P-4. Based on these promising results, the HRDP is currently (2013) being modified for subsequent laboratory and field testing.

Table P-4. HRDP measured densities compared with pycnometer measured densities.

Pycnometer Density	Average HRDP Density	HRDP Standard Deviation	Difference HRDP-Pycnometer
0.997*	0.995	0.002	-0.002
1.082	1.092	0.029	0.010
1.127	1.125	0.005	-0.002
1.141	1.133	0.007	-0.008
1.170	1.166	0.006	-0.004
1.193	1.228	0.005	-0.035

Values are in g/cm^3

e. GraviProbe. The GraviProbe is a rheological and density profiling system designed to; (1) determine the depth and thickness of underwater sediment layers, (2) provide additional information on the sediment structure and build up in relation with multibeam echo sounder and seismic data, and (3) measure nautical depth. It's a free fall impact instrument that analyzes the underwater sediment layers by intrusion. Under its own weight it accelerates and penetrates fluid and consolidated mud layers (the intrusion depth can go up to several meters). It has a weight of 7 to 10 kg and a terminal free fall velocity of about 6.5 m/s. The dimensions of the mud version are 1 m length and 0.05 m diameter (see Figure P-14).

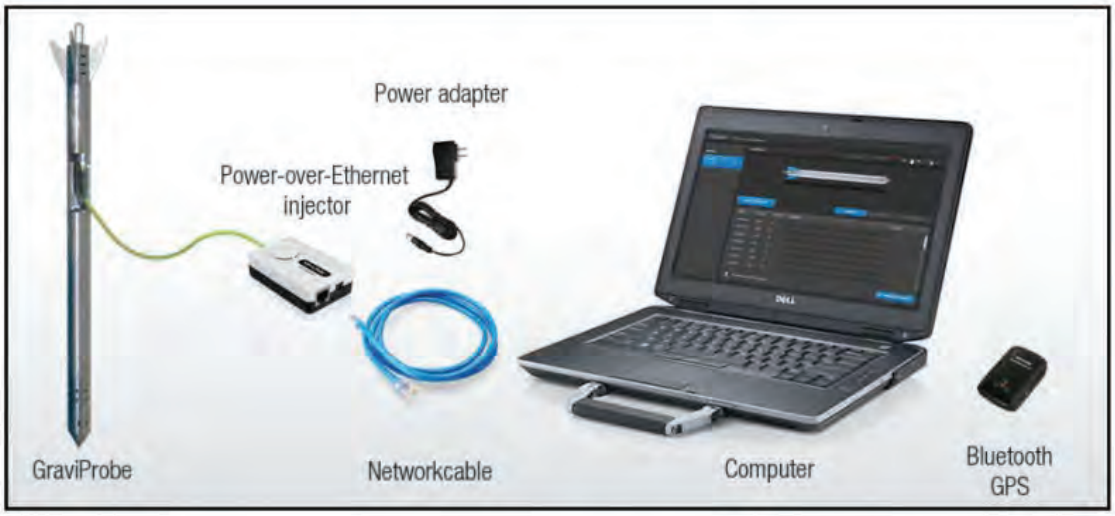

Figure P-14. GraviProbe Kit.

Density and shear strength of the sediment layers are measured by an independent set of sensors and a pressure sensor is used to determine the pore pressure in the soft sediment layers and derive the density. The density is (reportedly) determined every 0.005 m with a resolution of 2%. The data from on board accelerometers feed a dynamic model and resistance model of the intruded medium. Figure P-15 shows a GraviProbe profile of density and shear strength vs. depth.

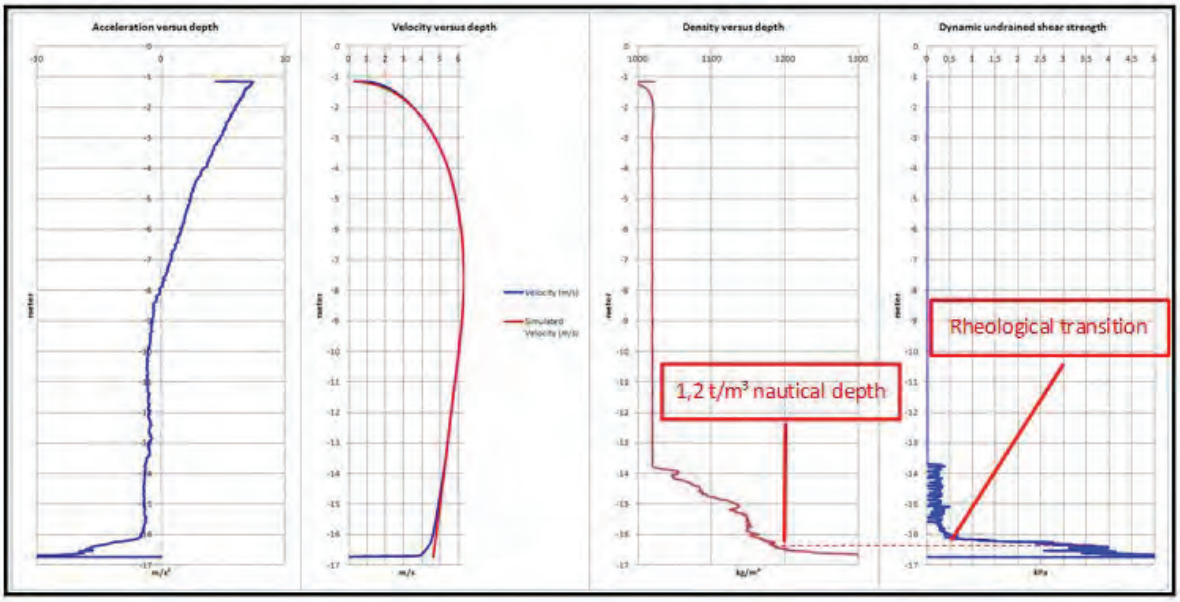

Figure P-15 GraviProbe profile of density and shear strength vs. depth.

f. The Rheocable Method. The Rheocable is designed to determine the nautical depth as defined by the rheological transition level based upon the rheological properties (viscosity) of the mud rather than density. The Rheocable Method is designed to detect the interface between fluid and solid mud. A towed object, when kept in a velocity window, is (reportedly) always positioned at this interface between fluid and solid mud, thereby making it possible to develop a new maintenance dredging strategy - leave/ignore the fluid mud and remove only the solid mud. The Rheocable Method utilizes a weighted pressure sensor package connected to a data display deck unit (see Figure P-16) dragged along the seabed as illustrated in Figure P-17). The pressure sensor is placed in a sealed pressure pod with two circulation tubes reaching above the liquid mud layer to ensure the correct translation of pressure measurements into water depths based on the known density of seawater. The water density is continuously measured at several levels along the umbilical cable using CTD (Conductivity-Temperature-Depth) probes. During post processing, pressure/depth is further compensated for atmospheric pressure. Following the sensor package is a short resistivity cable. The resistivity cable is used to verify that the sensor package is traveling on the liquid/solid mud interface and not floating above the interface. For routine applications the Rheocable method requires a constant tow speed ranging from normal survey speeds of 3 to 5 knots. More detailed information regarding the Rheocable Method is available in Druyts and Brabers (2012). Figure P-18 shows the difference plot between the Rheocable depth measurement and a 33-kHz survey system depth measurement from a demonstration survey in the Wilmington Harbor, DE, on the Christiana River in 2012.

Figure P-16. Rheocable Method towed array and deck unit.

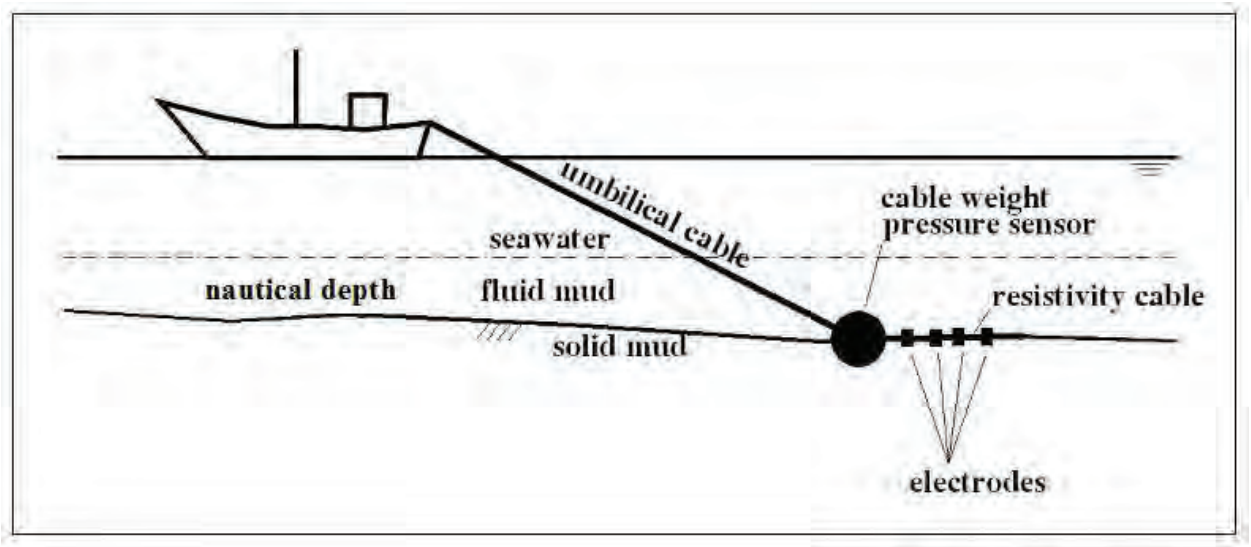

Figure P-17. Rheocable deployment operational methodology.

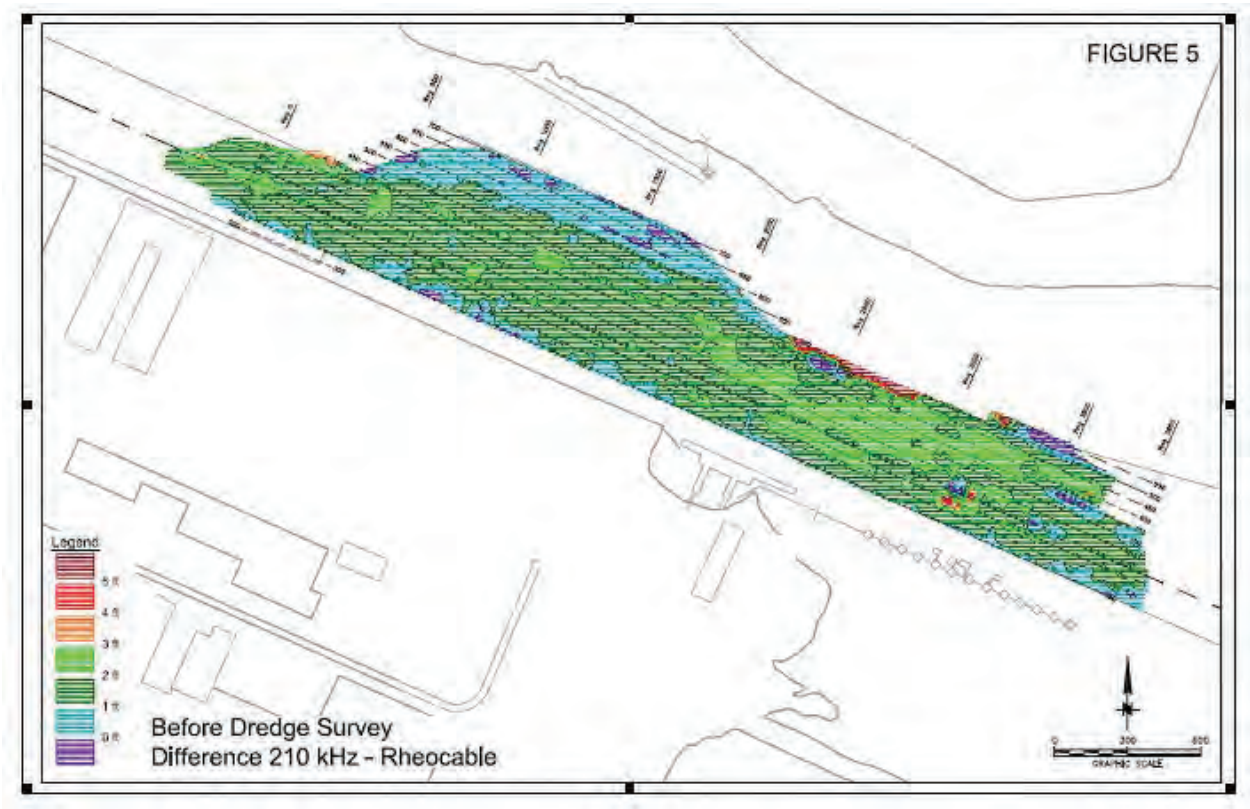

Figure P-18. Difference plot between Rheocable and 33-kHz depth measurements demonstrated in Wilmington Harbor, DE.

g. The STEMA System. The STEMA system consists of two primary components, a DensiTune (or RheoTune, see Figure P-19) probe and the SILAS software. The system is designed to estimate the nautical depth in navigation channels, the density of silt layers in dredge and disposal areas, and to monitor siltation in ports and marine traffic areas. The DensiTune (and RheoTune) are fluid mud profiling probes that operate on the "tuning fork" principle, with one of the legs of the tuning fork vibrating at a specific frequency, and the other leg vibrating at a frequency that depends on the density and rheological properties of the medium in which the probe is inserted. The DensiTune probe measures in situ density vs. depth, and the RheoTune system measures in situ density, shear strength, and viscosity vs. depth. The SILAS software was developed for the acquisition and processing of acoustic subbottom reflection signals in the low frequency range of 3.5 to 33 kHz. The low frequency acoustic returns are processed to determine signal attenuation and calibrated for density with the density profiles collected with the DensiTune or RheoTune.

(1) Under the USACE Dredging Operations and Environmental Research (DOER) program, The DensiTune and RheoTune density probes and SILAS software have been tested and evaluated on some USACE coastal navigation projects by the ERDC Coastal and Hydraulics

Laboratory (CHL), in conjunction with surveying conducted by the New Orleans District and the Mobile District. These tests indicate that these systems have potential for reliably measuring nautical bottom as previously described.

(2) The New Orleans District deploys Rheotunes from the S/V Teche by a semi automated winch down into the channel (see Figure P-20), to measure and record water and fluid mud densities and yield stresses as a function of depth. Figure P-21 presents an example of a DensiTune's density vs. depth profile from the Calcasieu Bar Channel (New Orleans District). Figure P-22 shows a SILAS-generated cross-section from the Gulfport Ship Channel (Mobile District), illustrating the concept of select density horizons generated from total acoustic reflection signals. Figure P-23 illustrates three different density horizons (1.20 g/cm^3, 1.16 g/cm^3, and 1.03 g/cm^3) relative to the Gulfport channel template.

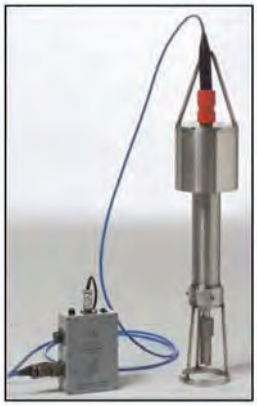

Figure P-19. Stema RheoTune tuning fork shear strength, viscosity, and density probe.

Figure P-20. Rheotune probe being deployed off the New Orleans District S/V Teche via a semi-automated winch.

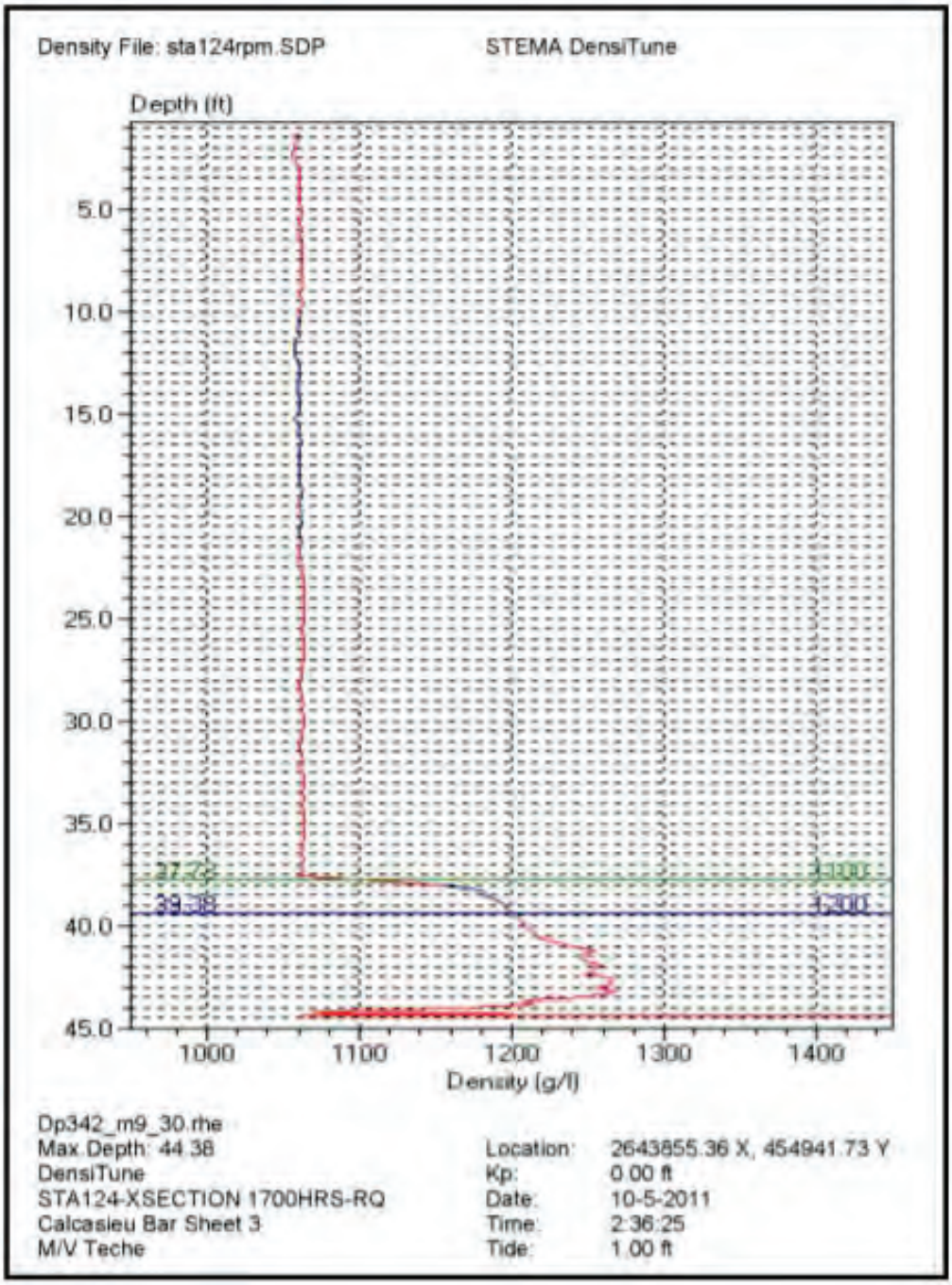

Figure P-21. STEMA DensiTune measurements taken in 42 ft Calcasieu Bar Channel on 05 Oct 11 at right quarterline one week following Wheeler Dredging Exercise. A density of 1100 g/l (green) was recorded at -37.0 ft depth and 1200 g/l (blue) at -39.0 ft. (New Orleans District)

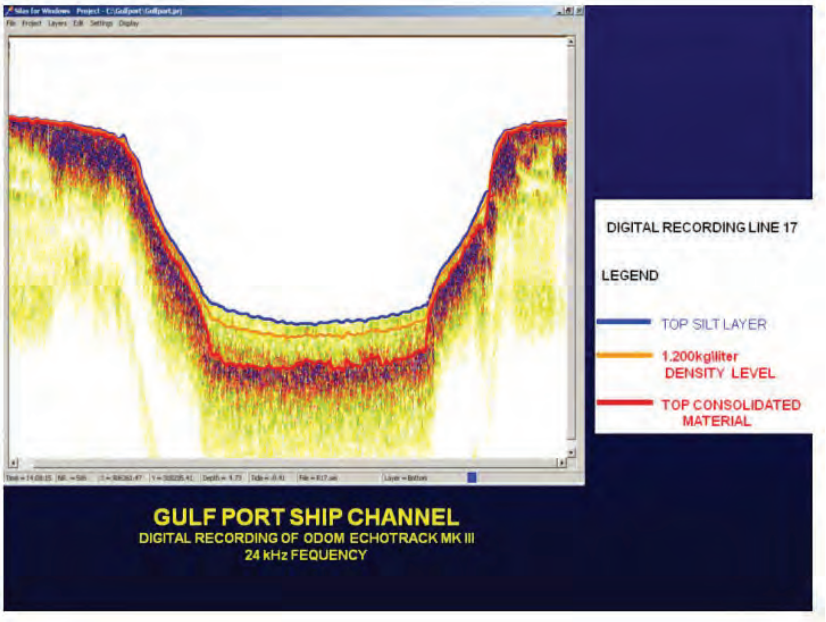

Figure P-22. SILAS-generated cross-section of Gulfport Ship Channel illustrating concept of measuring top of fluid mud, 1.2 g/cm3 density horizon, and top of consolidated material. (Mobile District)

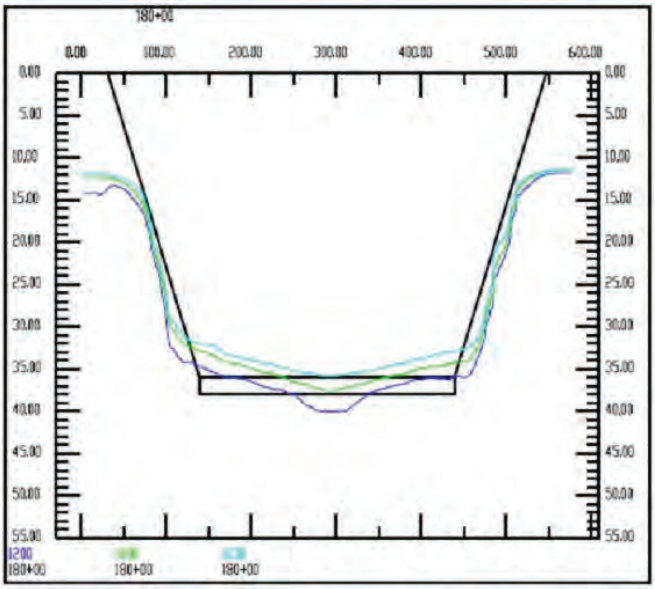

Figure P-23. SILAS-analyzed density horizons (1.20 g/cm3, 1.16 g/cm3, and 1.03 g/cm3) of STA 180+00 Gulfport Ship Channel 9 April 2012 relative to channel template. (Mobile District)

P-10. Recommended Procedures to Use in Unconsolidated Sediment Areas. When a survey is to be performed in a dredging area where fluid mud or fluff may exist, the following considerations should be observed if contract payment will be based on in-place measurements, or if payment is based on a daily rental basis. In areas where resolution of in-place payment quantities is extremely difficult with acoustic measurements, then a rental basis might be considered. In either case, determination of final project clearance and release of the dredge will require use of some of the techniques described below.

a. Determining frequency to use in a given project. Prior to any dredging it is necessary to establish what acoustic frequency best fits a project with existing fluid mud conditions. Or, in some cases, which frequency to use when fluff conditions exist only after dredging has been completed. If the depth measured by the independent check method (lead line, density probe, etc.) agrees with the high-frequency depth measurement, use the high-frequency depth measurement. If the depth measured by the independent check method does not agree with the high-frequency depth measurement but does agree with the low-frequency depth measurement, use the low-frequency depth measurement. Do not use the low-frequency depth reading on (or near) steeply sloped bottoms, pilings, or other structures.

b. Contract specifications. In areas of known fluid mud conditions, dredge contract specifications should detail the equipment and measurement techniques to be used during the project, such that an acceptable and equitable contract payment is achieved. Failure to identify known adverse site conditions results in unnecessary contract changes and modifications.

c. Acoustic frequency. Selection of this frequency should be based on its correlation with a practical criterion, i.e., selection of the physical fluid mud characteristic acting as a parameter for the nautical bottom approach and its critical value (e.g., 1.2 g/cm^3). Both the high- and low-frequency channels on the depth chart or digital record may be recorded, but in no case should frequencies be arbitrarily swapped, e.g., 24 kHz on a pre-dredge survey and 200 kHz on the after-dredge survey. The same frequency should be used for measurement and payment, and clearance assessment. Any variation in frequencies in the same area should be thoroughly justified. The construction contract specifications must indicate the frequency (or frequencies) to be used for channel clearance and payment. As an example, the Jacksonville District adds the following note on contract plans for known suspended sediment conditions in selected reaches (Ranges E thru I) of the Kings Bay (Navy) Entrance Channel in Florida/Georgia. This statement in the bid documents implies payment in the defined reaches will be made using the low frequency data.

VERTICAL MEASUREMENTS WERE MADE USING A ROSS SMART SOUNDER MODEL 835 DUAL FREQUENCY SOUNDER WITH A 28/200 KHZ SINGLE BEAM TRANSDUCER AND A RESON 8101 MULTIBEAM SYSTEM. SOUNDINGS SHOWN FROM RANGE A THRU RANGE D ARE IN HIGH FREQUENCY (200 KHZ) AND FROM RANGE E THRU RANGE I ARE IN LOW FREQUENCY (28 KHZ).

d. Single-beam vs. multibeam systems. Vertical single-beam systems are usually preferred in areas where fluff and/or fluid mud is a problem. Multibeam systems have bottom detection methods (amplitude, phase, interferometric) that vary with signal strength, automatic signal processing, angle of incidence, manufacturers, etc. As a result, in these areas, depth measurements may not be consistent from survey to survey, by different survey systems, and even on the same survey system at different beam angles.

e. Same survey vessel, depth measurement system, and crew. The same survey system should be employed throughout a dredging project. This will better ensure repeatability and consistency given the high variables that can occur between different depth measurement systems (e.g., echo sounders, etc.).

f. Establish, set, and monitor power and gain settings. The transmit/receive power and gain (sensitivity) settings should be established prior to dredging and not varied throughout the project unless changing site conditions (sea conditions or suspended sediment in water column possibly identified while doing a bar check) require a re-evaluation of the setting(s). These settings should be recorded in a field book. Periodically, the echo-sounder operator should evaluate the sensitivity of the gain on the recorded bottom and/or sediment layers—i.e., does a small change in gain significantly vary the depth measurement levels. Use of AGC and other automated signal processing filters is not recommended. (Maintaining consistent settings and related depth measurements can be a difficult process in fluid mud areas.)

g. Inconsistent cases. If the depth measured by an independent check method does not agree with either the high- or low-frequency depth measurements, then an alternate measurement system may be needed to determine clearance and/or payment. Under the Corps Monitoring Completed Navigation Program (MCNP) and Dredging Operations and Environmental Research (DOER) program, the ERDC is currently working with the Mobile District to develop and apply the operational requirements to implement nautical depth (as previously defined in this Appendix) in the Gulfport Ship Channel in Gulfport, MS. This implementation of nautical depth consists of the following activities:

- Form project delivery team to guide project execution including members from other Districts that have channels with fluid mud.

- Upgrade Mobile District surveyors with RheoTune and SILAS fluid mud surveying equipment (previously described in this appendix) and train personnel on its use to survey channel.

- Characterize channel's fluid mud physical characteristics (density, rheometry, etc.).
- Develop hydrodynamic model for ERDC ship simulator to calculate ship response to the variety of forces (Gulfport-specific environmental and mariner controlled) being exerted upon the vessel (without fluid mud) and have Gulfport pilots do runs to validate model.
- Modify ship simulator with fluid mud/ship maneuverability hydraulic coefficients.

- Have Gulfport Pilots operate simulator with different fluid mud densities and underkeel clearances to rate the difficulty of these respective maneuvers and define nautical bottom criterion and its respective critical value.
- Survey dredging operations to optimize maintenance dredging contract management.

a. All these data will be analyzed and activities synthesized to define criteria for implementing nautical bottom in the Gulfport Ship Channel, and a paradigm will be developed (including procedures, tools, guidance, etc.) for implementing nautical depth on a Corps-wide basis for applicable projects.

b. Savannah District has used the following contract measurement and payment clauses in practical attempts to address measurements in fluff.

"Soundings for all dredging surveys under this contract will be obtained by the use of a marine depth recorder operating at a frequency of [24 kHz]. Sensitivity setting will be adjusted to reflect the type of bottom material in the area being surveyed. In areas where double bottom (fluff) conditions are encountered, soundings with an 8-lb lead with a 6-in. perforated disc will be taken in conjunction with sounding data secured by the depth recorder. Adjust the data thus secured to the depths equivalent to those obtained by lead line soundings.

If soundings obtained as stated in the above paragraph (adjusted by lead line soundings) indicate a fluff or double bottom condition that exceeds 5 feet above the adjusted firm bottom, the firm bottom line will be adjusted to 5 feet below the fluff line. This adjusted firm bottom line will be used for yardage (volume) calculations."

P-10. Checklist for Depth Measurement in Irregular or Unconsolidated Bottoms. Table P-5 below is a general checklist for surveys that will be performed in irregular or unconsolidated materials. It is intended for use in developing measurement and payment provisions in dredging contracts during Preconstruction Engineering & Design (PED). It is not inclusive of all conditions encountered on Corps navigation projects.

Table P-5. Checklist for Depth Measurement in Unconsolidated Sediments--Dredging Contract Specifications (PED)

Identify potential existence of fluid mud or fluff in project--by reach/stationing if available
Contract by in-place measurement or rental?

Describe measurement and payment or clearance measurement system
- specify acoustic measurement system ... vessel, brand, etc.
- specify pre & post dredge frequency used for payment

Describe alternate depth correlation method
- lead line or sounding pole, including measurement refusal times
- other nautical depth measurement methods
- detail procedure for correlating acoustic & mechanical depths

(If applicable) specify nautical depth criterion (and respective critical value) and suitable depth measurement systems.

Describe volume computation procedure (if in-place payment method used)
- data processing method
- data thinning method
- data set binning methods

Clearance procedures for rock fragments, underwater hazards, pipelines, etc.:
- acoustic sweep methods (bar, acoustic, side scan, etc.)
- specific sweep system employed
- sweep overlap criteria (single or double coverage)
- required number of acoustic hits
- tolerances designed for hazards in required depth and overdepth prisms
- other clearance assessment methods

APPENDIX Q

Navigation Project Object Detection--Side Scan Sonar

Q-1. General Scope. This appendix provides a general overview on the use of side scan sonar techniques to search for objects lying above project grade in USACE navigation channels. Additional guidance is contained in the "NOS Hydrographic Surveys Specifications and Deliverables" manual (NOS 2011) and the NOAA "Field Procedures Manual,"(OCS 2011).

Q-2. Side Scan Sonar. Side scan sonar offers a high-resolution tool that provides a general depictive map on both sides of a survey vessel's path. Side scan sonar will not provide absolute elevations of objects. It will, however, provide relative elevations off the surrounding sea floor from which an approximate top elevation may be estimated. Side scan is a practical method for obtaining detailed acoustical pictures of the sea floor called sonographs, which are displayed on a computer screen with appropriate software, and can provide digital side scan records that can be permanently recorded. Digital side scan systems, when coupled with multibeam survey systems, have application in performing strike detection surveys or final acceptance clearance surveys in critical navigation channels.

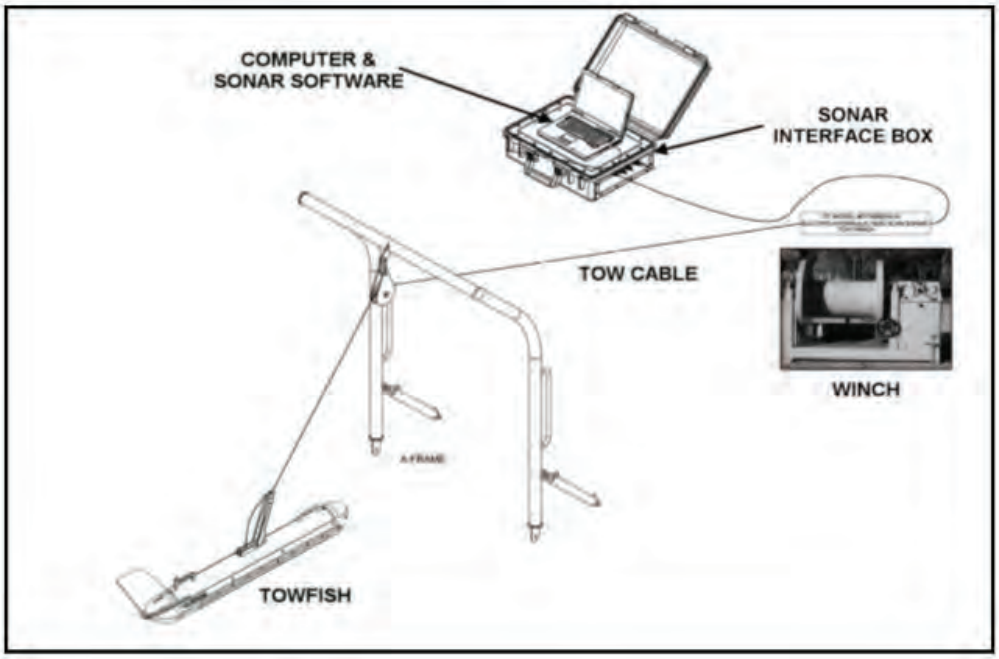

Figure Q-1. Block diagram of side scan sonar components.

a. Operating principles. A side scan sonar consists of a topside sonar interface box connected to a computer, an underwater sensor called a towfish, and a towing electro mechanical

cable to connect the two shown in Figures Q-2. In basic operation, the side scan sonar has high voltage transmitter circuitry in the towfish that provides a short high intensity electrical pulse on command from the embedded computer in the towfish to the transducers, which then emit the acoustic pulse that propagates out through the water. Then over a very short period of time, the returning echoes from the sea floor are received by the transducers, amplified on a time varied gain curve, and transmitted up the tow cable to the topside sonar interface box and computer. The software in the computer further processes the signals, calculates the proper position for them in the final record, pixel by pixel, and then displays these echoes on data viewer window one scan or line, at a time. The horizontal beam width of side scan sonar is typically between 0.2 and 1 deg. The vertical beam width is typically 40 deg to the -3 db points of the beam pattern.

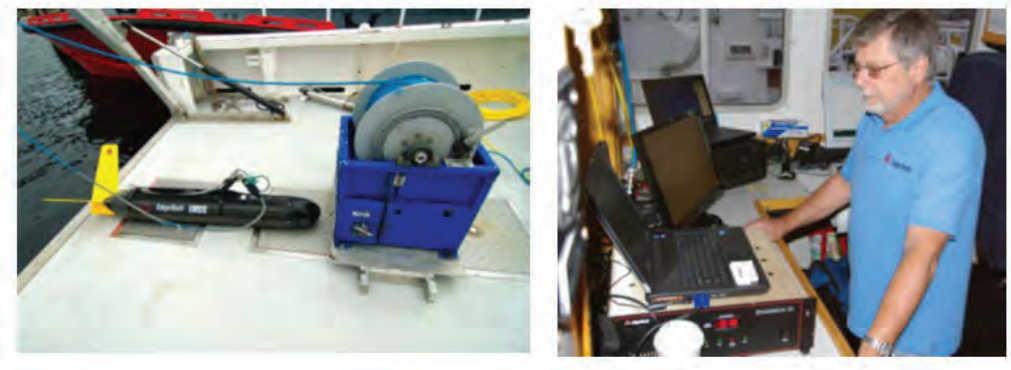

Figure Q-2. Basic components of a side scan sonar system. (left) Towfish and tow cable on winch. (Right) Sonar interface box and computer. (EdgeTech)

(1) The sonar data is logged digitally to the hard drive of the computer system and each ping is tagged with all pertinent data such as towfish position, heading speed, time, date, altitude, depth etc. Digital data collection will permit the application of slant range corrections in order to produce approximate planimetric images, which may be assembled into mosaics to depict large areas of sea floor. An example geo-referenced mosaic processed with SonarWiz 5 software (Chesapeake Technology, Inc.) is shown in Figure Q-3.

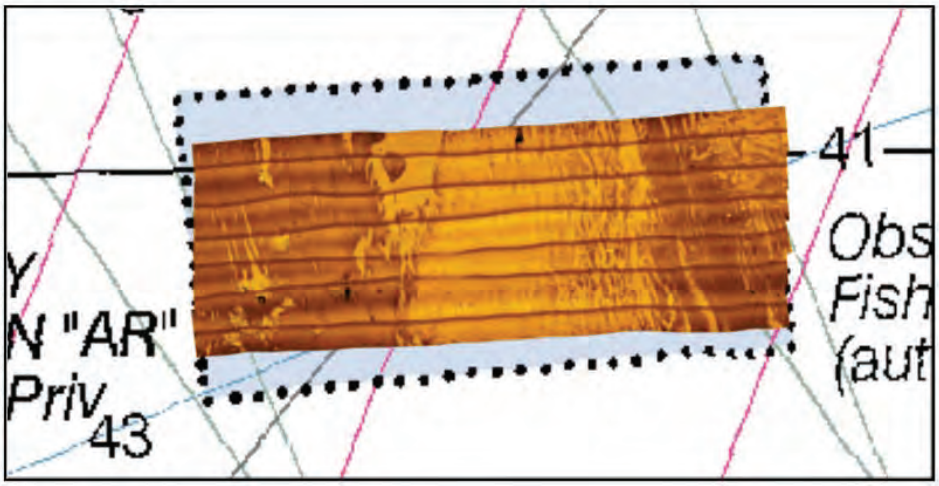

Figure Q-3. Sonar data processed with SonarWiz 5 software into a geo-referenced mosaic.

(2) A complete sidescan system deployed from a small vessel is depicted in Figure Q-4. Digital side scan data files can also be merged with concurrently recorded swath data from a multibeam system.

Figure Q-4. Digital side scan display system (Sea Systems Corporation)

b. Tow height and speed. The quality of the sonar data is often a function of the height of the towfish above the bottom, or bottom targets during a survey or target imaging. In general, with standard sonar configurations, surveys are performed with the towfish positioned a distance above the bottom approximately equivalent to between 8 percent and 20 %of the range setting of the sonar. If the transducer array is towed high off the seafloor, shadowing will be lessened and target recognition may be reduced. If towed too low, the reflectivity at outer edges will be reduced limiting the effective range of the system. When the towfish is towed at less than 8 %above the bottom, the swath width that is considered achieved is reduced. NOAA's "Rule of Thumb" is: Below 8%, the achieved range = 12.5 x towfish height (m). The towing speed is adjusted such that 3 acoustical hits (pings) are received on an object.

c. Object imagery. The accuracy or ability of the system to detect a given size object is dependent on a number of factors, including the material type, size, and shape of the object, refraction, noise, biological interference, boat wakes, surface reflections, and towfish stability. On a homogeneous bottom type, shadow zones or lighter areas (or darker areas for digital reverse image display) on the sonar record are typically a function of the amount of ensonification an area receives. A shadow zone in front (towards the towfish) of a strong reflector indicates a depression in the sea floor. A shadow zone behind (away from the towfish) of a strong reflector indicates a rise in the sea floor.

d. Object height computation. Approximate heights of an object can be estimated from these shadows--see Figure Q-5. Acoustic reflectivity is a function of the size of the object (surface area presented), the shape of the object, its orientation relative to the towfish, and its composition. Steel or rock are good reflectors. Fiberglass, soft pine, plastics, and rubber are poor reflectors. Usually 200% scanning coverage is required with a side scan range scale set at 100 m. Confidence checks should be conducted daily to ensure the specified size object is being detected.

e. Object position determination. In order to accurately determine the position of a side scan sonar contact, we need to first determine the position of the vessel, and then translate that position to the towfish. The software provided today with side scan sonar systems have a layback algorithm that, when the correct inputs are applied, will estimate and calculate with good accuracy the geographic position of the towfish. The typical inputs for the layback calculation to work are x, y, & z offsets between the reference point (usually GPS antenna) on the survey vessel and the tow point, the amount of tow cable paid out (instrument pulley cable counters are very useful), and towfish depth (usually from a pressure sensor in the towfish). A typical example of layback setup is shown in Figure Q-6 for EdgeTech Discover software. The positioning of a target or feature now only requires the sonar operator to put the cursor over the target and click. The computer program will then automatically calculate a geographic position of the target as in Figure Q-7.

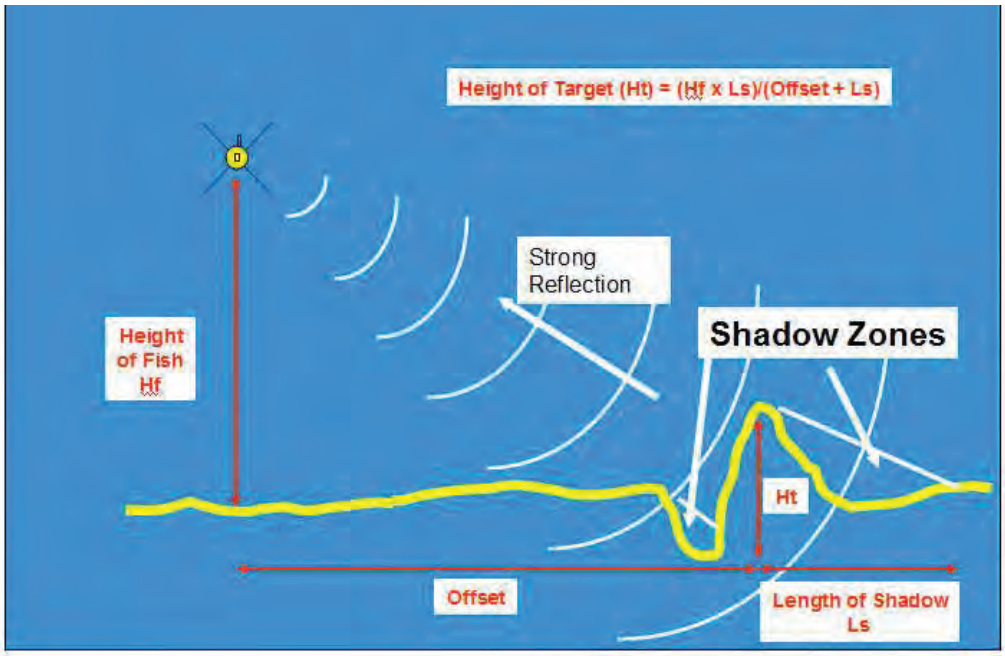

Figure Q-5. Side scan height and contact height computations (NOAA)

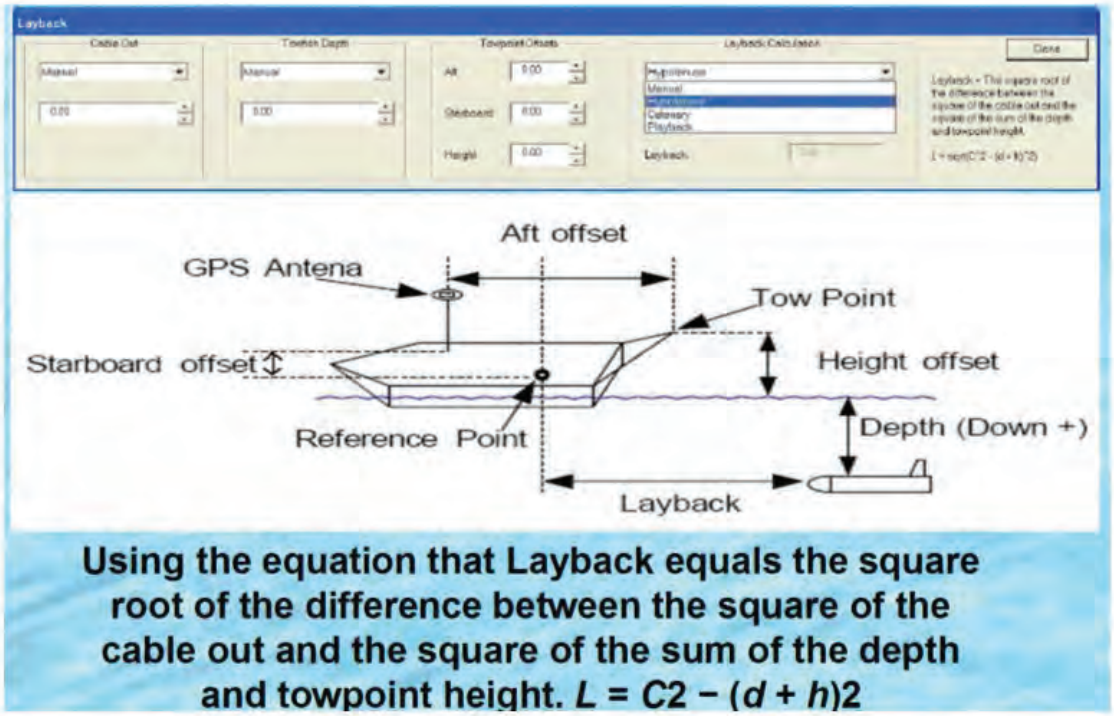

Figure Q-6. Layback setup parameters to allow target position calculations.

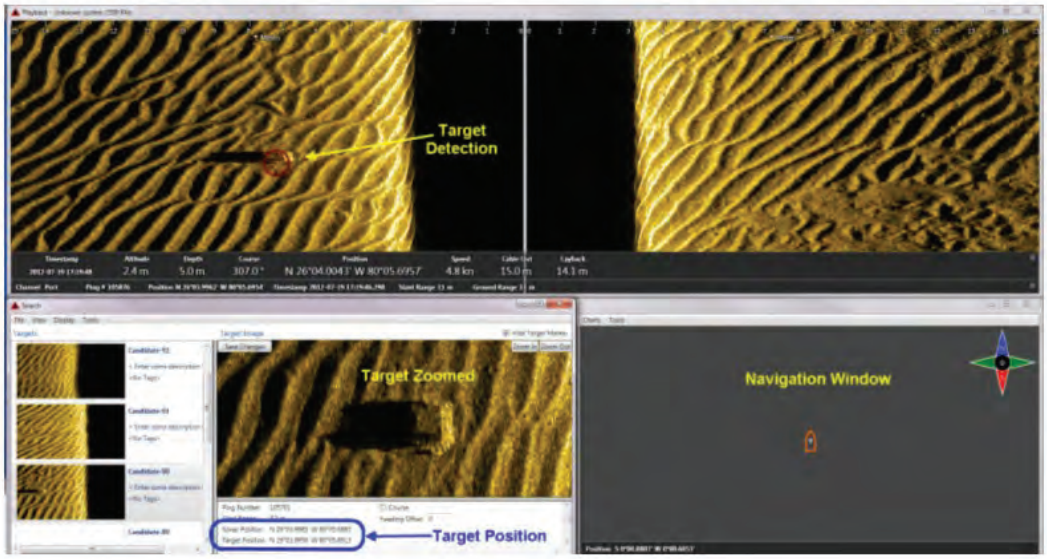

Figure Q-7. Target position calculated by software layback algorithm. (EdgeTech Discover II software)

f. Side scan sonar images. In general, there are two ways to view sonar data. Slant range corrected data shows distances as if the bottom were flat as if taken by an aerial photograph. By knowing the fish height above the bottom, the slant range from the fish to the bottom can be rectified. In addition, speed correction based on the speed of the survey vessel is applied along track such to keep the scales the same in both axes. Therefore, for example, on the sonar display, 70 meters in the along-track direction will equal 70 meters in the across-track direction. Uncorrected records show the fish height as the first return and scales are different in across track and along track axis. True horizontal distances cannot be scaled directly from the uncorrected sonar display. The image shown in Figure Q-8 depicts uncorrected versus corrected data display. The sonar image shows fine sediment with a rock outcropping. A rock is shown with a bright mark, signifying a strong return. The black behind the rock is an acoustic shadow. The position of the rock is calculated by placing the cursor over the rock and clicking. The shadow height is scaled in the target zoom window to determine the height of the object off the bottom. Figure Q-9 depicts computer-generated side scan imagery enhancements that will provide significant detail of bottom objects or sediments.

g. Accuracy. Movement of the fish can cause a degradation of the side scan record. In particular, on a short tow in shallow water, the surface waves affecting the ship can have a coupling effect with the towfish. As it pitches fore and aft, the towfish experiences a similar dampened motion. The rapid accelerations and decelerations of the towfish degrade the sonar record.

(1) Roll - The rhythmic movement of a ship or tow body along its longitudinal axis.

(2) Yaw - An instability characterized by the side-to-side movement of a ship or towed body about its vertical axis.

(3) Heave - The rise and fall of a surface vessel or towfish in a rhythmic movement.

(4) Pitch - An instability in the towfish expressed by the alternate rise and fall of the nose and tail about a horizontal axis.

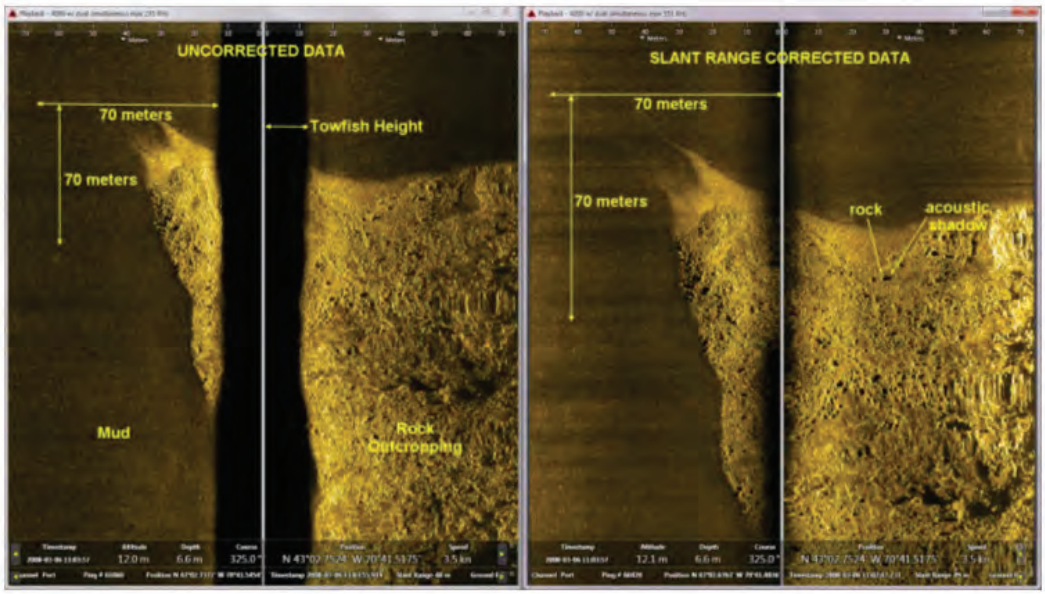

Figure Q-8. Side scan sonar record comparison of uncorrected versus corrected data display.

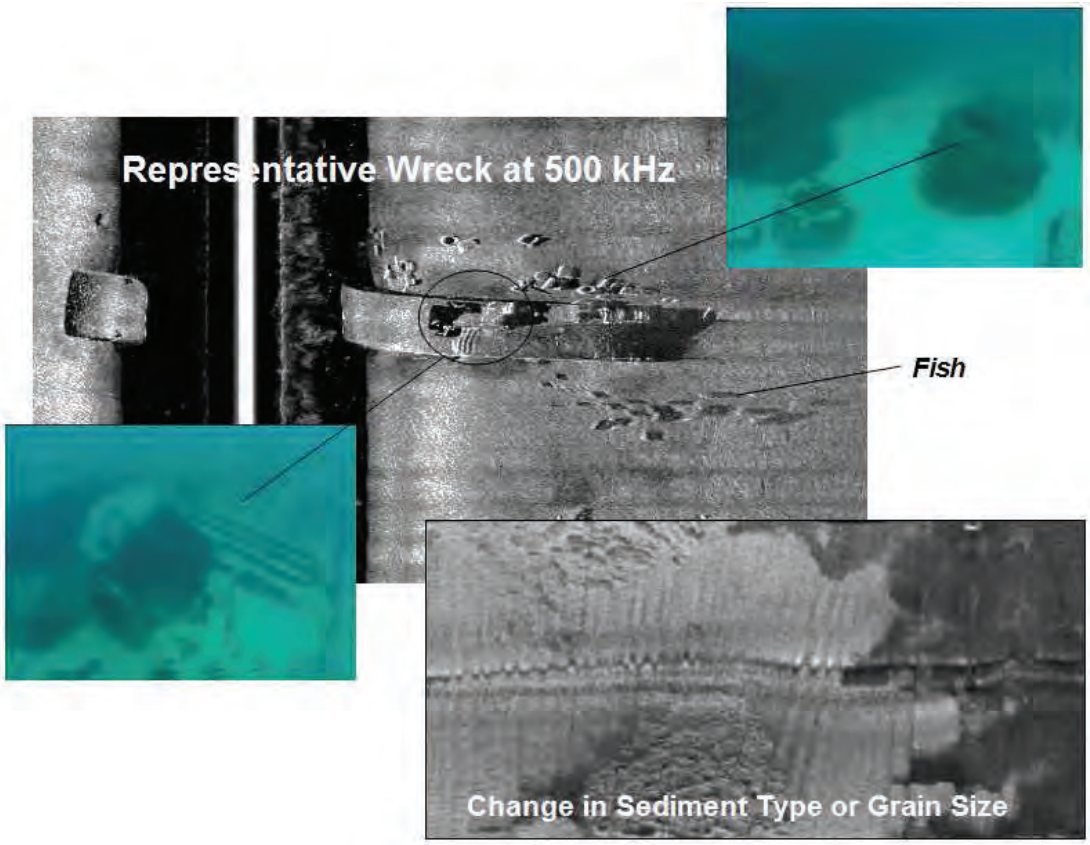

Figure Q-9. Enhanced side scan imagery depicting detailed underwater features. (Sea Systems Corporation and OIC GeoDas)

Q-3. Example Side Scan Sonar Survey Specifications (NOAA). The following paragraphs under this section contain excerpts from side scan specifications developed by NOAA ca 2000 for both internal survey forces and contracted forces. Although they were developed for nautical charting applications, these specifications and standards may be applicable to side scan survey operations performed by Corps in-house or contract crews on USACE navigation and dredging projects. Bracketed areas relate to project-specific information.

a. General Requirements. Side scan sonar shall be used to locate obstructions and a shallow water multibeam sonar system shall be used to determine the least depth over the obstructions. Side scan sonar data shall be collected over the channel areas indicated on the drawing in Figure Q-12, which is identical to that required for multibeam coverage. The Contractor shall acquire digital side scan sonar data using a towed system. The side scan sonar system shall be operated with a maximum range scale of 100 meters and with a towfish height

above the bottom of 8% to 20% of the range scale in use--see Figure Q-10. The side scan sonar data shall be horizontally referenced to [NAD 83].

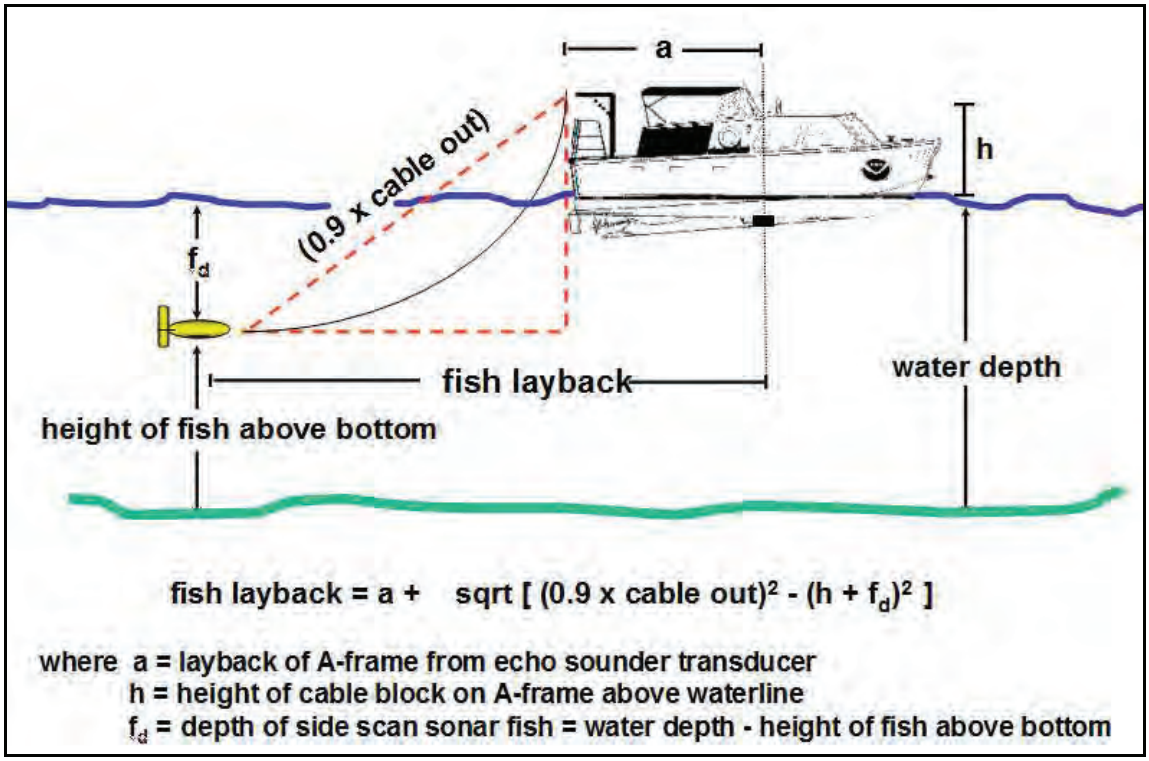

Figure Q-10. Height and position determination of towfish. (NOAA)

b. Accuracy. The side scan sonar system shall be operated in such a manner that it is capable of detecting an object that measures [0.5] [1.0] meter cube from shadow length measurements.

c. Towing Speed. Since the sonar is pulsing at a fixed rate based on its range scale, the speed that the towfish is being towed will have an affect on the ability to resolve items. In general, the slower the fish is towed the more definition is obtained. The side scan sonar shall be towed at a speed such that a detected object in the channel would receive a minimum of three pings per pass. The required towing speed may be computed as shown in Figure Q-11.

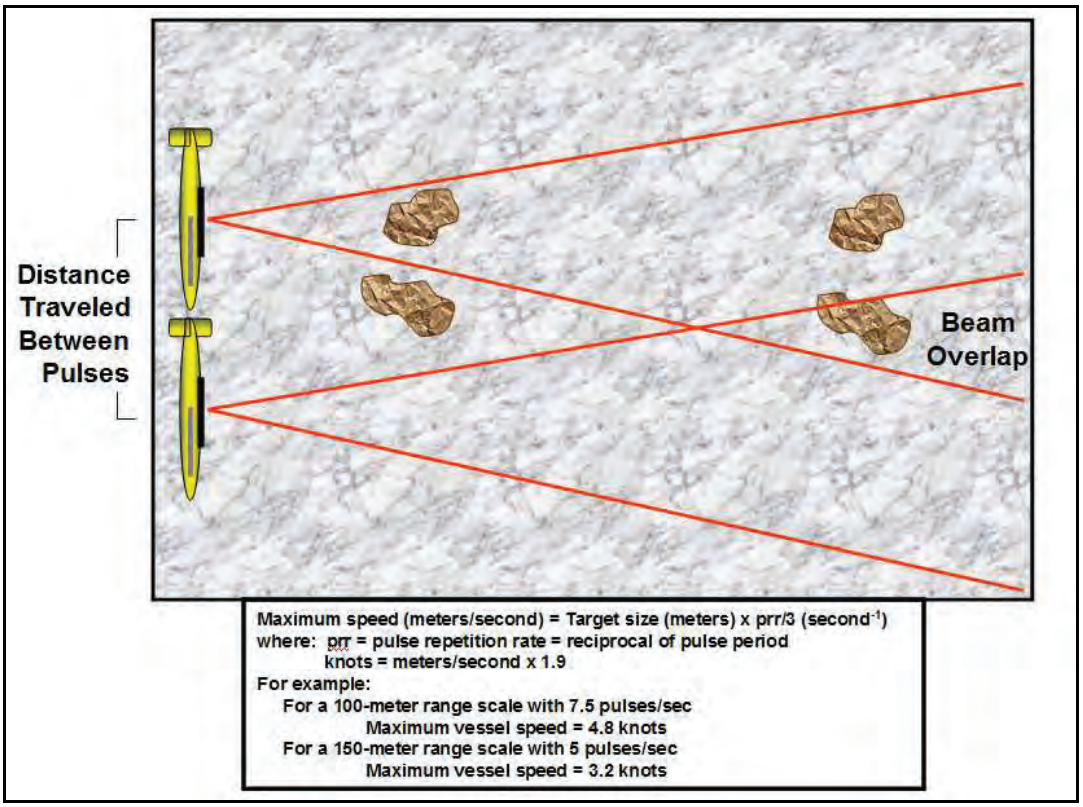

Figure Q-11. Determining towing speed for side scan sonar (NOAA)

d. Coverage. (Figure Q-12). The scanning coverage shall be 200%. "Scanning coverage" is the concept used to describe the extent to which the bottom has been covered by side scan sonar swaths, that is, the band of sea bottom which is ensonified and recorded on the side scan sonar record along a single vessel track line. Track line spacing shall be reduced from the maximum if the quality of the side scan sonar records deteriorate, i.e., record does not show features in the outer edges of the swath. For hydrographic purposes, scanning coverage of an area is expressed as multiples of 100%, and is cumulative. One-hundred percent coverage causes an area to be ensonified once, with a small overlapping area between adjacent swaths that is ensonified twice. For example, if a region of the bottom is ensonified twice, coverage of that region is said to be 200%. Approved 200% coverage techniques are as follows:

(1) Technique 1. Conduct a single survey wherein the vessel track lines are separated by one-half the distance required for 100% coverage.

(2) Technique 2. Conduct two separate 100% coverages wherein the vessel track lines during the second coverage split the distance between the track lines of the first coverage. Final track line spacing using this technique is essentially the same as Technique 1. The advantage of this method is that areas are viewed at different parts of the range scale for each run. (The ability

to distinguish targets directly under the fish and at short ranges is difficult. This method ensures an area is covered other than directly under the fish.) The disadvantage is that an obstruction with a narrow east/west aspect could be undetected.

(3) Technique 3. Conduct two separate 100% coverages in orthogonal directions. This method allows contacts to be ensonified from two different aspects. Also, depending on weather conditions, a vessel course can be selected to obtain the best return from the sonar. The disadvantage is that some areas have only been ensonified with the fish directly overhead.

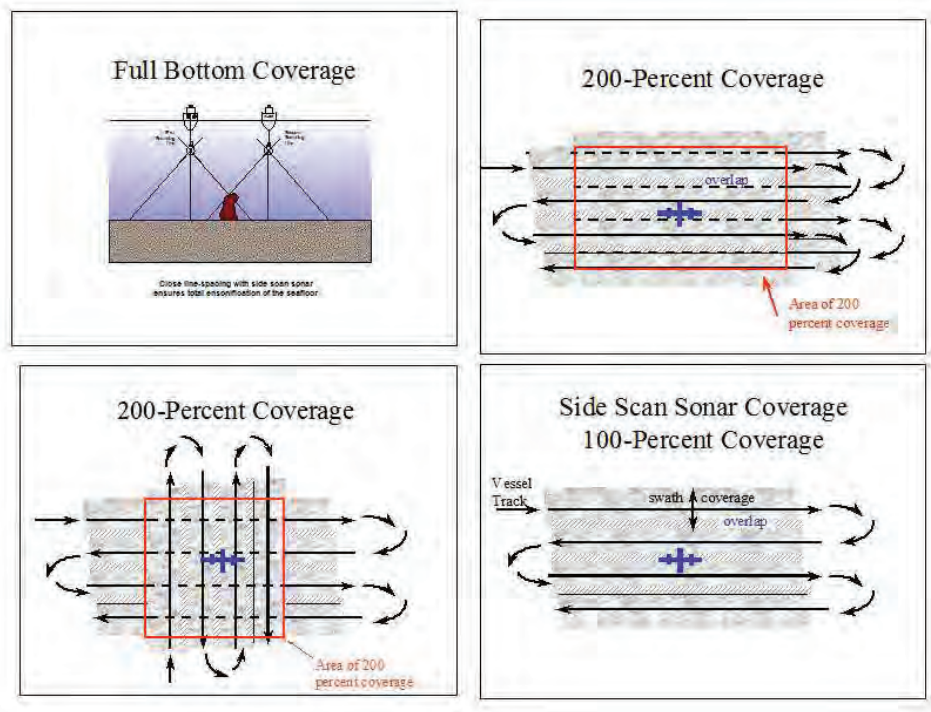

Figure Q-12. Side scan coverage. (NOAA)

Figure Q-12 shows a plan view of a side scan sonar search area. The object in the middle is a cartographic symbol signifying the submerged wreck that is being searched for. The dark lines with arrows represent the vessel trackline. On the 100% coverage sketch, the search was conducted by running east-west lines. The side scan sonar ensonifies an area to the north and south of the vessel trackline. The line spacing may be computed as follows:

Image-correcting:
Recommended Line Spacing = (2 x RS) - 40 meters
Non-correcting:
Recommended Line Spacing = (2 x RS) - 40 meters - (0.05 x RS)
where RS = range scale (i.e., 100 or 150 m)

e. Quality Control.

(1) Confidence Checks. Confidence checks of the side scan sonar system shall be conducted at least once daily. These checks should be accomplished at the outer limits of the range scales being used based on a target near or on the bottom. Each sonar channel (i.e. port and starboard channels) shall be checked to verify proper system tuning and operation. Confidence checks can be made on any discrete object, offshore structure, or bottom feature that is convenient or incidental to the survey area. Targets can include wrecks, offshore structures, navigation buoy moorings, distinct trawl scours or sand ripples. Confidence checks can be made during the course of survey operations by noting the check feature on the sonargram. If a convenient or incidental target is not available, a known target may be placed on or near the bottom and used for confidence checks. Confidence checks shall be an integral part of the daily side scan sonar operation and shall be noted in the daily log book.

(2) Significant Contacts. Contacts with computed target heights (based on side scan sonar shadow lengths) of at least [0.5] [1.0] meter should be considered "significant." Other contacts without shadows may also be considered "significant" if the sonogram signature (e.g., size, shape, or pattern qualities) is notable.

(3) Correlate with Multibeam Data. The Contractor shall examine the multibeam data and correlate anomalous features or soundings with the side scan sonar data. The contractor shall examine and correlate targets between successive side scan sonar coverages (i.e., compare the first 100% with the second 100% sonar coverage). Anomalous features or targets which appear consistently and correlate in each type of data record provide increased confidence that acquisition systems are working correctly and help to confirm the existence of these features or targets. The Contractor shall cross reference and remark on each target correlation in the Remarks column of the Side Scan Sonar Contact List.

(4) Identification of Potential Field Examinations. The Contractor shall use the sonar contact list, in conjunction with an analysis of multibeam least depths, to identify hydrographic features which may require further examination. The contractor shall make recommendations for additional field examinations that are deemed necessary to establish survey completion.

f. Side Scan Sonar Contact List and Coverage Plot. The contractor shall produce a separate sonar coverage plot for each 100% side scan coverage. This provides a graphic means for documenting that the effective scanning swath from each search track sufficiently overlaps the effective scanning swath from adjacent tracks.

(1) Contact List. The Sonar Contact List is compiled manually using a form or as the output of an automated listing device. An acceptable method is described below. The column entries required on the Sonar Contact List are the specific elements of information which the Hydrographer needs to prepare the preliminary Sonar Contact Plot. The various column entries are described below, along with a brief discussion of how each is to be derived.

Column 1. Search Track Number - identifies the particular search track from which the contact was observed.

Column 2. Contact Number - uniquely identifies the contact. An example of a contact number is a number based on the date/time the contact was observed, followed by a letter indicating the port or starboard (P or S) channel; i.e., if a port-side contact is observed on day 181 at 150125, the contact number will be 181/150125P. Using signed (+ or -) contact range in column 4 eliminates the need for the P or S indicator.

Column 3. Towfish Layback - the approximate distance in meters from the positioning system antenna to the towfish. Unless computed by an automated system, the towfish may be assumed to be directly astern of the towing vessel and on the search track.

Column 4. Contact Range - the horizontal distance from the towfish track to the contact, expressed in meters. All ranges scaled from the sonogram are slant ranges for standard sonars, true ranges for image-correcting sonars. True ranges are obtained from slant-range information by geometric corrections using the Pythagorean Theorem.

Column 5. Contact Position - the preliminary position as determined by reconstruction of the vessel position, towfish layback, towfish position, port or starboard channel, and contact range at the time the contact was observed. The Contact Position shall be stated as a latitude/longitude.

Column 6. Estimate of contact height computed from range and shadow length.

Column 7. Remarks - used to denote first impressions of the contact's identity (wreck, rock, etc.), or to make any comments deemed appropriate. If after examining the records and correlating targets from overlapping coverage the Hydrographer determines that a contact does not warrant further investigation, it shall be noted as such. A brief statement of the reasons must be made. This determination should not be made until all numbered contacts are plotted on a preliminary Sonar Contact Plot. Any abbreviations should be defined on the list.

Column 8. Comparison with shallow water multibeam data - used to note the corresponding shallow water multibeam data (day/time, line number, etc.), the results of comparing the side scan sonar data with the multibeam data (e.g., contact did not appear in the multibeam data, SWMB least depth = x.x - SSS least depth = y.y), and the type of multibeam coverage (i.e., center beams or reconnaissance beams).

Column 9. Contact is depicted on a drawing [file] - yes/no.

Once added to the list, a contact should never be removed. If after further processing a contact is deemed not significant by the hydrographer, it shall be labeled as such in column 7. The

contact list, and any subsequent field examination lists and records developed from the contact list, shall be included with the data submission in both hard copy and digital forms.

(2) Contact Plot. The Contact Plot will show the position of all significant contacts entered on the Sonar Contact List. Only "significant" contacts, along with the views from adjacent lines, need to be plotted on the Sonar Contact Plot. In some areas, "significant" contacts may be clustered (e.g., debris, boulder fields). Such an area may lend itself to being depicted as a single feature with least depth(s). Only the most significant contact(s) in the group needs least depth(s) and position(s) determined.

g. Sonar Record Keeping. A daily log will be kept noting where applicable the following information and referenced to the digital data by time & date. . Time references shall be made in Coordinated Universal Time (UTC). Additional annotations will be added during contractor processing.

(1) Header Annotations. Header annotations are required to identify the sonar work and for ease of later reference. Header annotations are:

(a) Registry number

(b) Item number (AWOIS, if applicable)

(c) Day of year and calendar date

(d) Towing vessel

(e) Tow Point

Header annotations shall be made:

(f) at the beginning of a each survey line,

(g) at the beginning of each day's work (for 24-hour operations, these annotations shall be made at the beginning of the first complete track of the new day),

(h) when there is a change in the towing configuration during a day's operation.

(2) System-Status Annotations. System-status annotations are required to describe the sonar settings and the towing situation. System-status annotations are:

(a) mode of tuning (manual or auto)

(b) range-scale setting

(c) left and right channel recorder settings

d) operator's initials

(e) length of tow-cable deployed (tow point to towfish)

(f) depressor in use (yes or no)

(g) weather and sea conditions

System-status annotations shall be made:

(h) prior to obtaining the first position of the day,

(i) prior to obtaining the first position at the start of a new survey line,

(j) at any time the sonar has been switched off and then back on,

(k) while on-line, approximately every hour, regardless of any changes made.

(3) First Position/Last Position Annotations. The following annotations shall be made at the first position on each search track:

(a) Line begins (LB) or Line Resumes (LR)

(b) tow-vessel heading (degrees true or magnetic)

(c) towing speed (engine rpm, and pitch if applicable)

(d) index number and time (at event mark)

The following annotations shall be made at the last position on each search track:

(e) Line turns (LTRA, LTLA), Line breaks (LBKS), or Line ends (LE)

(f) index number and time of event

(4) Special Annotations. The occurrence of any of the following events shall be annotated in the daily log, or as soon after as possible, the time the event occurs:

(a) new index number (at event mark)

(b) change in operator (new initials)
(c) change in range-scale setting

(d) confidence checks

(e) individual changes to sonar channel settings

(f) change in tow-cable length (tow point to towfish)

(g) change in towing speed (engine rpm and pitch) or vessel heading

(h) change in tow point

(i) significant contact observed (flag using an arrow)

(j) surface phenomenon observed (wakes, passing vessels, etc.)

(k) passes by buoys or other known features within sonar range

(l) interference (state source if known)

(m) time corresponding to the index marker.

The Hydrographer shall make any other annotations necessary to note any occurrence that may later serve to reconstruct the operation. Too much information is always better than not enough.

(5) Annotation Methods.

(a) freehand in the daily log,

(b) by use of a stamp,

(c) by use of an automatic annotator or manual input to the sonar software program, if available.

The method is left to the Hydrographer's discretion, but should be used consistently throughout the operation.

h. Side Scan Sonar Data Format and Media. [The Government] will review the side scan with CARIS SIPS or Chesapeake Technologies SonarWiz 5 processing software . Therefore, all side scan data shall be submitted as a digital file stored in the industry standard XTF format, such that, the data can be loaded directly onto the workstation and viewed using CARIS SIPS or SonarWiz 5. The contractor shall include a file listing and describe the archiving method used,

and shall work with the Government to ensure no compatibility problems exist after data submission.

i. Final report of contacts. If a final survey report is required then side scan sonar operations should be included. Identify the manufacturer, model, and serial number of all side scan sonar equipment used. State the vertical beam width used and depression angle, if adjustable. State the frequency used (for example, 100 or 500 kHz). Briefly describe the operations. Include range scales, depths of water, standard line spacing, and point of deployment (bow, stern, or beam). Describe the methods and frequency of confidence checks. The percentage of area coverage (normally 100 or 200) obtained by the swaths should be noted. Where necessary, factors affecting data quality, such as towfish stability, signal interference, degraded returns due to thermoclines, and clutter, should be addressed. A discussion of side scan sonar work devoted exclusively to item investigation is not necessary in this section if the information is included in the Item Investigation Report, or an equivalent form, filed with the survey data. Methods and standards used to examine sonar records should be noted and a brief description of processing procedures should be provided. Two examples of topics include the methods for establishing proof of coverage and the criteria for selecting contacts.

Q-4. Channel Obstructions. Once an obstruction is detected from routine hydrographic surveys or other reports, a special survey is performed to determine its precise horizontal and vertical extent. The horizontal detection and mapping can be done by a variety of methods, but perhaps the best technique to help identify an obstruction is side scan sonar coupled with multibeam acoustic swath survey systems. Reciprocal headings past the target can provide average coordinates within 20 ft to 30 ft of the true obstruction location using DGPS code phase positioning. Divers can easily find targets at this accuracy provided a buoy can be deployed this close. Side scan can also locate the diver over the target by observing the trace of the air bubble reflections in the side scan record. The safety of the divers must be ensured with this procedure. Following a positive location, divers usually move the buoy sinker to the target for more precise horizontal positioning by a survey vessel. The new location of the marker buoy may be plumbed over the survey vessel bow and marked with an event from the navigation system. The improved horizontal coordinate is obtained from the vessel heading, magnetic declination, and distance to the bow from the antenna. In the vertical, the pinnacle elevation is most accurately determined by a bar sweep. Further elevations can be obtained by other high-resolution sensing equipment or physical inspection by diver. Targeted obstructions or objects can be removed or cleared by dredging, blasting, or recovery. Stealth-like objects, such as rock shards remaining after blasting, may be difficult to detect with standard, vertically-mounted, single-beam survey echo sounders. The return energy is buried within the noise level and sensitivity adjustments are not capable of distinguishing the object from the noise--see Figure Q-13. Very little of the pinnacled object is capable of reflecting sonic energy back to the transducer. However, there is a greater degree of side reflection if a side scan or multibeam system is used.

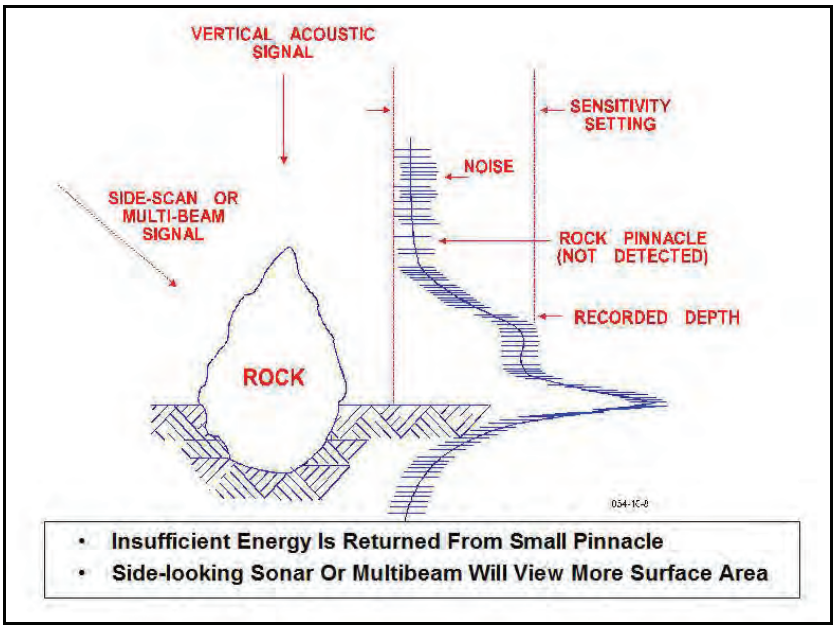

Figure Q-13. Acoustic return from a stealth-like object.

Multibeam and side scan imagery can be used to enhance the detection of underwater objects. This is illustrated in Figure Q-14 where an object is detected by both the multibeam array and the side scan imagery. The side scan imagery can also be overlayed onto the bathymetric data set, as illustrated in Figure Q-15.

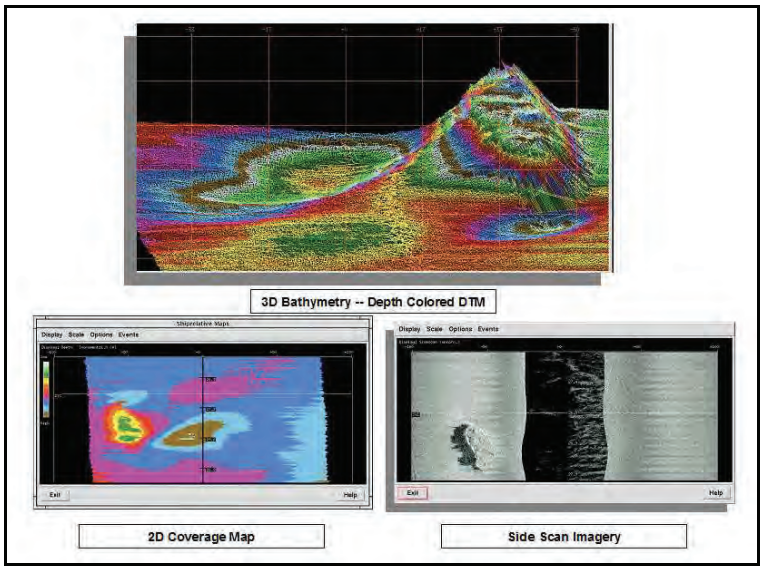

Figure Q-14. Combined Odom Echoscan multibeam and side scan imagery. (Odom Hydrographic Systems)

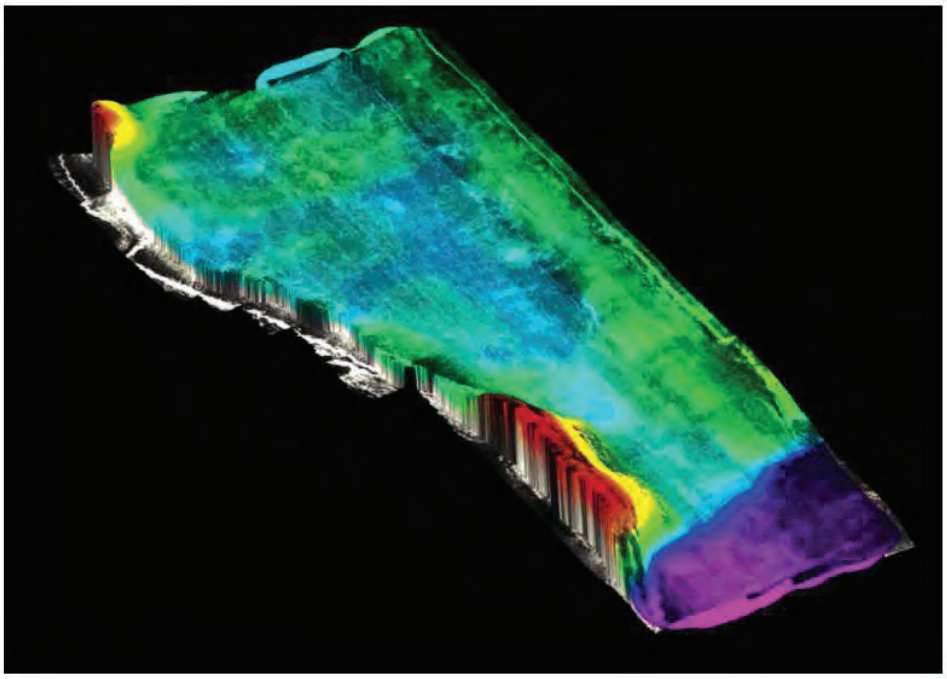

Figure Q-15. 3-D multibeam bathymetry with side scan imagery overlay. (Odom Hydrographic Systems)

Q-5. Magnetometer Surveys. Detection of ferromagnetic objects near the sea floor is possible through the measurement of magnetic anomalies with a magnetometer. Typical applications include detection of sunken ships, pipelines, communication cables, and other items that could hinder navigation or use of the sea floor.

a. Magnetometers are relatively simple to operate. The sensor head is towed behind the survey vessel at a distance of several boat lengths. If operations are conducted in shallow water, a buoy may be attached to the fish to prevent sinkage and to keep it at a consistent depth. Output on shipboard is real time in the form of a single line scribed on a strip chart. A variation in the line's position is an indication of the nearby presence of ferrous objects.

b. Magnetometers may be operated in towed pairs, termed gradiometers, which will measure the rate of change of magnetic lines, permitting approximate positioning of magnetic features on the bottom. Tow cables should be long enough to place the survey ship at sufficient distance so it will not affect readings.

Q-6 SonarWiz 5. Quality Control and Quality Assurance Criteria.

Table Q-1. Quality Control and Quality Assurance Criteria for Side Scan Surveys

	Navigation & Dredging Support Surveys Bottom Material Classification	
	Hard	Soft
RECOMMENDED COVERAGE	200%	100%
RECOMMENDED ACOUSTIC HITS	3 minimum	3
QA PERFORMANCE TEST	1/day	1/day

GLOSSARY

Abbreviations and Acronyms

1D or 1-D .....One-Dimensional
2D or 2-D .....Two-dimensional
3D or 3-D .....Three-dimensional
AD.....After Dredge
A-E.....Architect-Engineer
ACSM .....American Congress on Surveying and Mapping
ADCIRC .....Advanced Circulation model
AEA .....Average End Area
AEC/CAD .....Architectural, Engineering, and Construction CAD (Standard)
AGC .....Army Geospatial Center
ARP.....Antenna Reference Point
ASCE .....American Society of Civil Engineers
ASPRS .....American Society for Photogrammetry and Remote Sensing
BD.....Before Dredge
BFE .....Base Flood Elevation
c/c.....Center to Center
CAD .....Computer Aided Design
CADD .....Computer Aided Drafting and Design
CCR .....Channel Condition Report
CD .....Crew Day
CEPD .....Comprehensive Evaluation of Project Datums
CERC .....Coastal Engineering Research Center (CHL)
CH.....Certified Hydrographer
CHL .....Coastal and Hydraulics Laboratory
CHS.....Canadian Hydrographic Service
COP .....Community of Practice
COR .....Contracting Officer's Representative

CSV .....Cross Sections and Volumes

CTD .....Conductivity, Temperature, Depth

CW .....Civil Works

cf .....Cubic Foot

cy.....Cubic Yards

DFIRM.....Digital Flood Insurance Rate Map

CEFMS .....Corps of Engineers Financial Management System

CEP .....Circular Error Probable

CFR.....Code of Federal Regulations

CHIRP.....Compressed High Intensity Radar Pulse

CHL.....Coastal and Hydraulics Laboratory

CHS.....Canadian Hydrographic Service

cm .....Centimeter

COEMLW.....Corps of Engineers Mean Low Water

CONUS.....Continental United States

CO-OPS .....Center for Operational Oceanographic Products and Services

CORPSCON .....CORPS Convert

CORS .....Continuously Operating Reference Stations

COTS .....Commercial Off-The-Shelf

CRAB.....Coastal Amphibious Research Buggy

CRREL.....Cold Regions Research & Engineering Laboratory

CSDL .....Coast Survey Development Laboratory (NOS)

CTD.....Conductivity Temperature Depth

CUBE.....Combined Uncertainty and Bathymetry Estimator

CWIS .....Civil Works Information System

DA.....Department of the Army

dB.....Decibel

DDR.....Design Documentation Report

deg.....Degree

DEM.....Digital Elevation Model

demob.....Demobilization
DEP .....Department of Environmental Protection
DGPS .....Differential Global Positioning System
DMD .....Double Meridian Distance
DOD.....Department of Defense
DOP.....Dilution of Precision
DOT .....Department of Transportation
DRMS .....Deviations Root Mean Square
DTM.....Digital Terrain Model
EC .....Engineer Circular
ECDIS .....Electronic Chart Display and Information System
ECL.....Erosion Control Line
ECS .....Electronic Chart System
EDM.....Electronic Distance Measurement
EGES .....Enterprise Geographic Engineering Systems
EM.....Engineer Manual
EP.....Engineer Pamphlet
EPA.....Environmental Protection Agency
ER .....Engineer Regulation
ERDC.....Engineer Research and Development Center
ERS .....Ellipsoid Referenced Survey
ETL .....Engineer Technical Letter
ETL .....Engineer Topographic Laboratory
FEMA .....Federal Emergency Management Agency
FFP.....Firm Fixed Price
FGCC .....Federal Geodetic Control Committee
FGCS.....Federal Geodetic Control Subcommittee
FGDC.....Federal Geographic Data Committee
FIRM.....Flood Insurance Rate Map
ft .....Foot or Feet

FTE .....Full Time Equivalent

fps.....Feet per second

GDOP.....Geometric Dilution of Precision

GIS .....Geographic Information System

GLONASS .....GLObal Navigation Satellite System

GNSS .....Global Navigation Satellite System

GPR.....Ground Penetrating Radar

GPS .....Global Positioning System

GRS80.....Geodetic Reference System of 1980

H&H.....Hydraulics and Hydrology

HEC.....Hydrologic Engineering Center

HEC-RAS .....HEC-River Analysis System

HI. .....Height of Instrument

HDOP.....Horizontal Dilution of Precision

HP .....Horsepower

HPR.....Heave Pitch Roll

HQUSACE.....Headquarters, US Army Corps of Engineers

HSPP .....Hurricane and Shore Protection Project

HTRW.....Hazardous Toxic Radioactive Waste

IAPPK .....Inertial-Aided Post-Processed Kinematic

IDC.....Indefinite Delivery Contract

IENC .....Inland Electronic Navigational Chart

IGLD55 .....International Great Lakes Datum of 1955

IGLD85 .....International Great Lakes Datum of 1985

IHO .....International Hydrographic Organization

IMU.....Inertial Measurement Unit

IWW.....Intracoastal WaterWay

JALBTCX.....Joint Airborne LIDAR Bathymetry Technical Center of Expertise

kHz.....kilohertz

km .....Kilometer

kts.....Knots
KTD .....Kinematic Tidal Datum
LARC.....Lighter, Amphibious, Re-Supply, Cargo
lb .....Pound
LIDAR .....Light Detection And Ranging
LMSL .....Local Mean Sea Level
LPCP.....Local Project Control Point
LWD .....Low Water Datum
LWRP .....Low Water Reference Plane
m .....Meter
mi .....Mile
M&P.....Measurement & Payment
MACOM.....Major Army Command
MD .....Man Day
MGL.....Mean Gulf Level
MLG.....Mean Low Gulf
MHT .....Mean High Tide
MHW .....Mean High Water
MLLW. .....Mean Lower Low Water
MLT .....Mean Low Tide
MLW.....Mean Low Water
Mn.....Mean Tide Range
Mob.....Mobilization
MRU .....Motion Reference Unit
MSC .....Major Subordinate Command
MSE .....Mean Square Error
MSL. .....Mean Sea Level
MTL.....Mean Tide Level
MV or M/V .....Motor Vessel
MVD .....Mississippi Valley Division

NAD27.....North American Datum of 1927

NAD83.....North American Datum of 1983

NADCON .....North American Datum Conversion

nm .....Nanometer

NAVAID.....Navigation Aid

NAVCEN.....Navigation Center (US Coast Guard)

NAVD88.....North American Vertical Datum of 1988

NAVOCEANO .....US NAVal OCEANographic Office

NGS .....National Geodetic Survey

NGVD29.....National Geodetic Vertical Datum 1929

NOAA .....National Oceanic and Atmospheric Administration

NOS .....National Ocean Service

NSDI .....National Spatial Data Infrastructure

NSRS.....National Spatial Reference System

NTDE.....National Tidal Datum Epoch

NTE.....Not To Exceed

NWLON.....National Water Level Observation Network

NWLP .....National Water Level Program

OCONUS .....Outside the Continental United States

OCS.....Office of Coast Survey

O&M.....Operations and Maintenance

OTF .....On-The-Fly GPS (real time kinematic carrier)

OPUS .....On-Line Positioning User Service

ORD.....Ohio River Datum

PBM.....Permanent Bench Mark

PCS .....Project Condition Survey

PDF .....Portable Document Format

PE .....Professional Engineer

PED .....Preconstruction Engineering and Design

PFD .....Personal Flotation Device

PI.....Point of Intersection
PIANC .....Permanent International Association of Navigation Congresses
PID .....Position Identification
PLS .....Professional Land Surveyor
POB.....Point of Beginning
POD.....Print on Demand
POS/MV .....Positioning and Orientation System—Marine Vessels (Applanix Corp.)
PPCP .....Primary Project Control Point
PPK .....Post-Processed Kinematic
RPM .....Revolutions per Minute
P&S .....Plans and Specifications
ppm .....Parts per million
PPS.....Precise positioning service
ppt .....Parts per thousand
PRC .....Pseudo Range Corrections
PRIP .....Plant Replacement and Improvement Program
PROSPECT.....Proponent Sponsored Engineer Corps Training
QA.....Quality Assurance
QC .....Quality Control
RF .....Dario Frequency
RMS .....Root Mean Square
RMSE.....Root Mean Square Error
RTK.....Real Time Kinematic
RTN .....Real Time Network
S/A .....Selective Availability
SB or S/B .....Survey Boat
SV or S/V .....Survey Vessel
SAR.....Synthetic aperture radar
SDSFIE .....Spatial Data Standards for Facilities, Infrastructure, and Environment
SEP.....Spherical Error Probable

sf.....Square feet

SIM .....Site Information Modeling

SLD29.....Sea Level Datum of 1929

SPCS .....State Plane Coordinate System

sq ft.....Square foot

sqrt.....Square root

STA.....Station

SSS.....Side Scan Sonar

SV .....Sound Velocity

TBM .....Temporary Bench Mark

TCARI.....Tidal Constituent And Residual Interpolation

TEC.....Topographic Engineering Center

TIN.....Triangular Irregular Network

TM.....Transverse Mercator

THU .....Total Horizontal Uncertainty

TPU.....Total Propagated Uncertainty

TTN.....Topological Triangle Network

TVG .....Time Varied Gain

TVU .....Total Vertical Uncertainty

U/M.....Unit of measure

U/P .....Unit price

ULC .....USACE Learning Center

UNB.....University of New Brunswick

URL.....Universal Resource Locator

US (U.S.):.....United States

US .....United States

USACE .....US Army Corps of Engineers

U.S.C.....United States Code

USC&GS .....US Coast & Geodetic Survey

USCG.....US Coast Guard

USED .....US Engineer Datum

USGS .....US Geological Survey

UTC.....Universal Time Coordinated

UTM .....Universal Transverse Mercator

VEQ .....Variation in Estimated Quantities

VDatum.....(National) Vertical Datum

VDOP.....Vertical Dilution of Position

VRN .....Virtual Reference Network

WES .....Waterways Experiment Station

WGS84 .....World Geodetic System of 1984

WRDA .....Water Resources Development Act

WS.....Water Surface (elevation)

XYZ or X-Y-Z .....3D point coordinates

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PRELIMINARY SITE INVESTIGATION REPORT

DOYLE DRIVE OUTFALL IJKL
CRISSY FIELD, SAN FRANCISCO, CALIFORNIA

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CALTRANS EA 04-1637N1
CALTRANS PROJECT # 04-0002-0923-1

AUGUST 2013

TABLE OF CONTENTS

PRELIMINARY SITE INVESTIGATION REPORT Page

REPORT LIMITATIONS i

PROJECT TEAM ii

1.0 INTRODUCTION 1
- 1.1 Project Description and Proposed Improvements 1
- 1.2 General Objectives 1

2.0 BACKGROUND 1
- 2.1 Hazardous Waste Determination Criteria 1
- 2.2 Environmental Screening Levels 2

3.0 SCOPE OF SERVICES 3
- 3.1 Pre-field Activities 3
- 3.2 Field Activities 3

4.0 INVESTIGATIVE METHODS 4
- 4.1 Sampling Procedures 4
- 4.2 Laboratory Analyses 5
- 4.3 Laboratory QA/QC 6

5.0 INVESTIGATIVE RESULTS 6
- 5.1 Subsurface Conditions 6
- 5.2 Laboratory Analytical Results 6
- 5.3 Laboratory Quality Assurance/Quality Control 8

6.0 CONCLUSIONS 9
- 6.1 Soil 9
  - 6.1.1 CAM 17 Metals 9
  - 6.1.2 Organics 10
  - 6.1.3 Naturally-Occurring Asbestos 10
- 6.2 Sediment 11
  - 6.2.1 CAM 17 Metals 11
  - 6.2.2 Organics 11
- 6.3 Groundwater 11
- 6.4 Worker Protection 12

FIGURES

1. Vicinity Map
2. Site Plan

TABLES

1. Boring Coordinates
2. Summary of Lead Results – Soil/Sediment
3. Summary of CAM 17 Metals Results – Soil/Sediment
4. Summary of Organics Results – Soil/Sediment
5. Summary of NOA Results
6. Summary of Organics Results – Groundwater

APPENDICES

A. Laboratory Reports and Chain-of-custody Documentation
B. Metals Statistical Analysis

REPORT LIMITATIONS

This report has been prepared exclusively for the State of California Department of Transportation (Caltrans) District 4. The information contained herein is only valid as of the date of the report and will require an update to reflect additional information obtained.

This report is not a comprehensive site characterization and should not be construed as such. The findings as presented in this report are predicated on the results of the limited sampling and laboratory testing performed. In addition, the information obtained is not intended to address potential impacts related to sources other than those specified herein. Therefore, the report should be deemed conclusive with respect to only the information obtained. We make no warranty, express or implied, with respect to the content of this report or any subsequent reports, correspondence or consultation. Geocon strived to perform the services summarized herein in accordance with the local standard of care in the geographic region at the time the services were rendered.

The contents of this report reflect the views of the author who is responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the State of California or the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

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PRELIMINARY SITE INVESTIGATION REPORT

1.0 INTRODUCTION

This Preliminary Site Investigation Report for the Doyle Drive storm drain Outfall IJKL Project at Crissy Field near United States Route 101 (US-101) in San Francisco, California was prepared by Geocon Consultants, Inc. under California Department of Transportation (Caltrans) Contract No. 04A3578 and Task Order No. 51 (TO-51), EA 04-1637N1.

1.1 Project Description and Proposed Improvements

The IJKL outfall project proposes to improve the Doyle Drive storm drain outfall in San Francisco, California near Post Mile PM 9.0 on US-101. Proposed activities include the excavation of soil at the current outfall terminus at Crissy Field Beach and the construction of an approximately 160-foot drainage extension into the San Francisco Bay. Work will take place within the United States Department of the Interior and Presidio Land Trust right-of-ways. The project location is depicted on the attached Vicinity Map, Figure 1.

1.2 General Objectives

The purpose of the site investigation was to evaluate concentrations of California Assessment Manual 17 (CAM 17) metals, total petroleum hydrocarbons as diesel (TPHd), as motor oil (TPHmo), and as gasoline (TPHg), benzene, toluene, ethylbenzene and xylenes (BTEX), volatile organic compounds (VOCs), polychlorinated biphenyls (PCBs), naturally-occuring asbestos (NOA), and pH in soil as well as groundwater samples for CAM 17 metals, TPHg/d/mo, and BTEX at the Crissy Field Beach and inland of Crissy Field near Mason Street. Offshore sediment samples were to be evaluated for CAM 17 metals, TPHd/mo/g, BTEX, PCBs, and semivolatile organic compounds (SVOCs).

The information obtained from this investigation will be used by Caltrans to evaluate soil handling practices, worker health and safety, and soil and groundwater reuse and disposal options.

2.0 BACKGROUND

2.1 Hazardous Waste Determination Criteria

Regulatory criteria to classify a waste as California hazardous for handling and disposal purposes are contained in the CCR, Title 22, Division 4.5, Chapter 11, Article 3, §66261.24. Criteria to classify a waste as Resource, Conservation, and Recovery Act (RCRA) hazardous are contained in Chapter 40 of the Code of Federal Regulations (40 CFR), Section 261.

For waste containing metals, the waste is classified as California hazardous when: 1) the representative total metal content equals or exceeds the respective Total Threshold Limit Concentration (TTLC); or 2) the representative soluble metal content equals or exceeds the respective Soluble Threshold Limit Concentration (STLC) based on the standard Waste Extraction Test (WET). A waste has the potential of exceeding the STLC when the waste's total metal content is greater than or equal to ten times the respective STLC value since the WET uses a 1:10 dilution ratio. Hence, when a total metal is detected at a concentration greater than or equal to ten times the respective STLC, and assuming that 100 percent of the total metals are soluble, soluble metal analysis is required. A material is classified as RCRA hazardous, or Federal hazardous, when the representative soluble metal content equals or exceeds the Federal regulatory level based on the Toxicity Characteristic Leaching Procedure (TCLP).

The above regulatory criteria are based on chemical concentrations. Wastes may also be classified as hazardous based on other criteria such as ignitability and corrosivity; however, for the purposes of this investigation, toxicity (i.e., representative lead concentrations) is the primary factor considered for waste classification since waste generated during the construction activities would not likely warrant testing for ignitability or other criteria. Waste that is classified as either California hazardous or RCRA hazardous requires management as a hazardous waste.

2.2 Environmental Screening Levels

The San Francisco Bay Regional Water Quality Control Board (SFRWQCB) has prepared a technical report entitled *Screening For Environmental Concerns At Sites With Contaminated Soil and Groundwater, Interim Final* (updated May 2013), which presents Environmental Screening Levels (ESLs) for soil, groundwater, soil gas, and surface water, to assist in evaluating sites impacted by releases of hazardous chemicals. The ESLs are conservative values for more than 100 commonly detected contaminants which may be used to compare with environmental data collected at a site. "The ESLs are intended to help expedite the identification and evaluation of potential environmental concerns at sites where contamination has been identified. Data collected at a site can be directly compared to the ESLs, and the need for additional actions quickly determined" (RWQCB May 2013). ESLs are strictly risk assessment tools and "not intended to serve as a rule to determine if a waste is hazardous under the state or federal regulations (RWQCB May 2013)."

Residential and commercial/industrial land use ESLs are commonly used by contractors, soil trucking companies, and private and commercial land owners as default acceptance criteria to evaluate suitability of import soil material. The most conservative ESL tables were used for this characterization: Table A – Shallow Soil [≤3 meters below ground surface (bgs)] – Groundwater is a Current or Potential Drinking Water Resource, Table B – Shallow Soil [≤3 meters below ground surface (bgs)] – Groundwater is not a Current or Potential Drinking Water Resource, Table E – Indoor Air and Soil Gas (Vapor Intrusion Concerns), and Table K-3 – Direct Exposure Soil Screening Levels

Construction Trench Worker Exposure Scenario. The respective ESLs are listed at the end of Tables 3, 4, and 6 for comparative purposes.

3.0 SCOPE OF SERVICES

The scope of services performed under TO-51, EA 04-1637N1 included the following:

3.1 Pre-field Activities

- Prepared the *Preliminary Site Investigation Workplan* and *Health and Safety Plan*, dated June 2013.
- Retained the services of Cruz Brothers Locators to provide utility clearance services prior to field operations.
- Retained the services of Gregg Drilling and Testing, Inc., a Caltrans-approved drilling contractor.
- Retained the services of Advanced Technology Laboratories, Las Vegas (ATL-LV), a Caltrans-approved and California-certified analytical laboratory, to perform the chemical analyses of soil and groundwater samples.
- Retained the services of EMSL, Inc., a Caltrans-approved and California-certified analytical laboratory, to perform the asbestos analysis of soil samples.
- Notified Underground Service Alert (USA) at least 48 hours prior to field work.

3.2 Field Activities

The field investigation was performed on June 26 and 27, 2013, by Geocon staff. The following field activities were performed during the sampling efforts:

- Advanced 4 soil borings at the project location using hand-auger and direct-push drilling techniques to collect soil and groundwater samples. The borings were advanced to a maximum depth of 11.5 feet.
- Collected 3 surface sediment samples from the San Francisco Bay immediately offshore of Crissy Field Beach using a stainless steel sediment core sampling device.

All samples were transported to California-certified environmental laboratories for analysis under standard chain-of-custody (COC) documentation.

4.0 INVESTIGATIVE METHODS

4.1 Sampling Procedures

Soil or sediment samples were collected from 7 locations identified by the Caltrans TO Managers using direct-push sample rig, hand-auger, or sediment core sampling techniques. Sampling coordinates are presented on Table 1 and locations are shown on the Site Plan, Figure 2.

Soil samples collected using a hand-auger (B1-0, B1-1.5, B1-3, B2-0, B2-1.5, and B2-3.0) or sediment core device (B5, B6, and B7) were placed in stainless steel tubes and sealed with Teflon tape and plastic lids prior to being stored in a chest cooled with ice.

Soil samples collected using a track-mounted direct-push sample rig (B1 to B4) were obtained by hydraulically advancing a two-inch-diameter, four-foot-long stainless steel core-barrel sampler lined with an acetate sample tube into undisturbed soil. Soil samples were collected for laboratory analysis by cutting an approximately six-inch-long section of the acetate tube from the target sample depth, capping the ends with Teflon tape and plastic end caps, and then placing the sample tube in a chest cooled with ice for storage and delivery to the analytical laboratory.

Grab-groundwater samples were collected from borings B2 and B3 by retrieving groundwater through ¼-inch-diameter disposable polyethylene tubing fitted with a check valve. Samples were then transferred to the appropriate sample containers and placed in a chest cooled with ice.

Sample containers were labeled and transported to a Caltrans-approved, certified environmental laboratory using standard COC documentation. Soil borings were back-filled to near-surface with bentonite slurry.

Geocon provided QA/QC procedures during the field activities. These procedures included washing the sampling equipment with a Liqui-Nox® solution followed by a double rinse with deionized water. The equipment rinse blanks were collected by pouring deionized water over the cleaned sampling equipment and collecting it into a sample container for laboratory analysis. A trip blank sample was transported with the groundwater samples to be analyzed for TPHg and submitted to the laboratory for analysis. Decontamination water was disposed of to the ground surface within Caltrans right-of-way in a manner not to create runoff, away from drain inlets or potential water bodies.

4.2 Laboratory Analyses

Laboratory analyses were performed by ATL-LV and EMSL under both standard and expedited (72- hour) turnaround-time (TAT) per the Task Order Managers. The laboratory reports and COC documentation are included as Appendix A.

The soil samples were analyzed as follows:

- 15 samples for total lead using EPA Test Method 6010 ICAP.
- 5 samples for CAM 17 metals according to EPA Test Methods 6010 ICAP and 7471.
- 1 sample with total lead concentrations equal to or exceeding 50 mg/kg (i.e. equal to or exceeding ten times the STLC of 5.0 mg/l) was further analyzed for WET lead.
- 4 samples for TPHd/mo using EPA Test Method 8015B.
- 4 samples for TPHg using EPA Test Method 8015B.
- 4 samples for BTEX using EPA Test Method 8260B.
- 12 samples for VOCs using EPA Test Method 8260B.
- 8 samples for PCBs using EPA Test Method 8082.
- 4 samples for pH using EPA Test Method 9045C.

The 3 sediment samples were analyzed as follows:

- CAM 17 metals according to EPA Test Methods 6010 ICAP and 7471.
- TPHd/mo using EPA Test Method 8015B.
- TPHg using EPA Test Method 8015B.
- BTEX using EPA Test Method 8260B.
- PCBs using EPA Test Method 8082.
- SVOCs using EPA Test Method 8270C.

The 3 groundwater samples were analyzed for:

- TPHg using EPA Test Method 8015B.
- BTEX using EPA Test Method 8260B
- VOCs using EPA Test Method 8260B.

QA/QC samples:

- 2 equipment rinse blank samples were analyzed for total lead using EPA Test Method 6010B.
- 1 trip blank sample was analyzed for TPHg using EPA Test Method 8015B.

4.3 Laboratory QA/QC

QA/QC procedures were performed for each method of analysis with specificity for each analyte listed in the test method's QA/QC. The laboratory QA/QC procedures included the following:

- One method blank for every ten samples, batch of samples or type of matrix, whichever was more frequent.
- One sample analyzed in duplicate for every ten samples, batch of samples or type of matrix, whichever was more frequent.
- One spiked sample for every ten samples, batch of samples or type of matrix; whichever was more frequent, with spike made at ten times the detection limit or at the analyte level.

Prior to submitting the samples to the laboratory, the COC documentation was reviewed for accuracy and completeness.

5.0 INVESTIGATIVE RESULTS

5.1 Subsurface Conditions

Observations during field activities indicated that soil in the areas of borings B1 and B2 (near Mason Street) consisted of sand to a depth of 0.5 foot. Black, damp sand and silt were present to a depth of 6 feet, and firm to dense very moist to saturated dark brown silty sand was observed from 6 to 11.5 feet. Boring B1 also included serpentenite, possibly a fill material, at approximately 1.5 feet.

Borings B3 and B4 were located on Crissy Field beach and consisted of medium loose white sand site to a depth of approximately 1.5 feet, white to light brown coarse sand to 4 feet, and firm, light to medium brown moist to saturated sand to 10.5 feet.

Borings B5 to B7 were located offshore from Crissy Field and consisted of dark brown Bay mud with organic matter to 0.5 foot.

Groundwater was encountered at an approximate depth of 11 feet in boring B2 and at approximately 9 feet in boring B3. Grab-groundwater samples were collected for TPHg/BTEX and VOCS analyses from borings B2 and B3; however, recharge was insufficient to enable additional sample collection for further analyses. Groundwater was not encountered in borings B1 and B4 in sufficient quantities to allow sample collection as outlined in the workplan.

5.2 Laboratory Analytical Results

The analytical results are summarized in Tables 2 to 5 and are summarized below:

Soil Sample Results:

- The following metals were not detected above their respective laboratory reporting limits: antimony, beryllium, cadmium, mercury, molybdenum, selenium, silver, and thallium.
- Total lead was reported at concentrations ranging from <2.0 to 66 mg/kg.
- WET lead was reported at a concentration of 3.5 mg/l.
- Remaining CAM 17 metals were reported in the samples at total concentrations below ten times their respective STLCs.
- TPHg was not detected at or above the laboratory detection limit of 1.0 mg/kg.
- TPHd was reported at concentrations ranging from 1.1 to 2.6 mg/kg.
- TPHmo was reported at concentrations of 1.2 to 5.1 mg/kg.
- BTEX were not detected at or above the laboratory reporting limits.
- VOCs were not detected at or above the laboratory reporting limits.
- PCBs were not detected at or above the laboratory reporting limits.
- pH values ranged from 7.7 to 9.3.

Sediment Sample Results:

- The following metals were not detected above their respective laboratory reporting limits: antimony, beryllium, cadmium, mercury, molybdenum, selenium, silver, and thallium.
- Remaining CAM 17 metals were reported in the samples at total concentrations below ten times their respective STLCs.
- TPHg was not detected at or above the laboratory detection limit of 1.0 mg/kg.
- TPHd was reported at concentrations ranging from 2.8 to 5.6 mg/kg.
- TPHmo was reported at concentrations of 5.4 to 14 mg/kg.
- BTEX were not detected at or above the laboratory reporting limits.
- SVOCs were not detected at or above the laboratory reporting limits.
- PCBs were not detected at or above the laboratory reporting limits.

Groundwater Sample Results:

- TPHg/BTEX were not detected at or above the reporting limits.
- VOCs were not reported at or above the laboratory reporting limits.

QA/QC Sample Results:

- Total lead was not detected at or above the laboratory reporting limit of 0.0050 mg/l in the equipment rinse blank samples.
- TPHg was not detected at or above the laboratory reporting limit of 0.050 mg/l in the trip blank sample.

5.3 Laboratory Quality Assurance/Quality Control

We reviewed the QA/QC results provided with the laboratory analytical reports. The data indicate non-detect results for the method blanks at or above reporting limits. The Matrix Spike (MS) and/or Matrix Spike Duplicate (MSD) were outside recovery criteria for several samples, possibly due to matrix interference, however the associated laboratory control sample recoveries were acceptable. The relative percent differences (RPD) for MS/MSD were outside of recovery limits for several samples; however, the analytical batches were validated by the laboratory control samples. Remaining samples and internal laboratory QA/QC samples showed acceptable recoveries and relative percent differences (RPDs). Based on this limited data review, no additional qualifications of the soil data are necessary, and the data are of sufficient quality for the purposes of this report.

6.0 CONCLUSIONS

6.1 Soil

6.1.1 CAM 17 Metals

With the exception of lead, CAM 17 metals were reported in the samples at total concentrations below ten times their respective STLCs. The reported total lead concentrations are less than the TTLC of 1,000 mg/kg and the WET lead concentration is less than 5 mg/l. Accordingly, excavated soil would be classified as non-hazardous based on lead content.

The CAM 17 metals concentrations in site soil were compared to ESLs. Arsenic was reported at concentrations greater than one or more ESL values.

The upper one-sided 95% upper confidence limit (UCL) of the arithmetic mean is defined as the value that, when calculated repeatedly for randomly drawn subsets of site data, equals or exceeds the true mean 95% of the time. The UCLs of the arithmetic mean concentration are used as the mean concentrations because it is not possible to know the true mean due to the essentially infinite number of soil samples that could be collected from a site. The UCLs therefore account for uncertainties due to limited sampling data. As data become less limited at a site, uncertainties decrease, and the UCLs move closer to the true mean.

Because concentrations of arsenic exceeded one or more ESL, non-parametric bootstrap techniques were used to calculate the UCLs. Risk assessment characterization is based on the 95% UCL of the soil for the site; this is in accordance with the Risk Assessment Guidance for Superfund (RAGS) Volume 1 Documentation for Exposure Assessment.

The bootstrap test results are included in Appendix B. ESLs, UCLs, and published background concentrations for arsenic are summarized in the table below:

Metal	Maximum	95% UCL	Shallow Soil Residential ESL	Shallow Soil Commercial/ Industrial ESL	Worker Direct Exposure ESL	PUBLISHED BACKGROUND MEAN[1]	PUBLISHED BACKGROUND RANGE [1]
Arsenic	3.7	3.27	0.39	0.96	10	3.5	0.6 to 11.0

Concentrations reported in mg/kg

[1] Kearney Foundation of Soil Science, March 1996

The 95% UCL arsenic concentration is greater than the residential and commercial land use ESLs; however, it is less than the construction exposure ESL and within the published background range.

The SFRWQCB *November 2007 Update to Environmental Screening Levels (ESLs) Technical Document* states that ambient background concentrations of arsenic typically exceed risk-based screening levels. In such instances, it may be more appropriate to compare site data to regionally specific established background levels.

Based on the reported results for arsenic, offsite reuse or disposal of excavated soil may be restricted based on arsenic content, depending on proposed use.

6.1.2 Organics

TPHd and TPHmo were reported in samples at concentrations below the ESLs.

TPHg, BTEX, VOCs, and PCBs were not detected at or above the laboratory reporting limits.

Organics results for soil samples and corresponding ESL values are summarized in Table 4.

6.1.3 Naturally-Occurring Asbestos

Twelve soil samples were collected from the site and analyzed for asbestos by CARB Test Method 435 using polarized light microscopy (PLM) and at a target sensitivity of 0.25% asbestos. Chrysotile asbestos was reported at 1.25% in one sample (B1-1.5) collected near Mason Street. Three samples (B1-3.0, B4-6.0, and B4-7.5) were reported to contain trace (<0.25% chrysotile) asbestos. The remaining eight samples were reported to be non-detect for asbestos.

ATCM 93105 sets forth measures to be followed for the investigation and control of naturally occurring asbestos for construction sites. ATCM 93105 allows for the mathematical averaging of analytical results from a soil mass in order to determine the average asbestos content. Convention is to use one-half of the reporting or detection limit as the assumed contaminant content for soils when averaging results. Thus for averaging purposes, the eight samples reported as non-detect as well as the trace quantity result were assumed to contain 0.125% asbestos, and the average of the twelve samples collected from the site is 0.219%, less than the 0.25% regulatory threshold.

There are no restrictions on the reuse of soil containing NOA at less than 0.25% asbestos if it stays on the site. If soil known to contain NOA at less than 0.25% is disposed of offsite, we recommend that the receiver be notified that the material contains NOA at less than 0.25%. Additionally, it is Caltrans policy that a contractor have an asbestos compliance plan in place on projects where personnel may be in contact with materials known to contain NOA and that wet methods be employed to minimize the potential for airborne asbestos. A summary of NOA results is included in Table 5.

6.2 Sediment

6.2.1 CAM 17 Metals

CAM 17 metals were reported in the samples at total concentrations below ten times their respective STLCs. The CAM 17 metals concentrations in site soil were compared to ESLs. Arsenic was reported at concentrations greater than one or more ESL values.

Because of the limited sample population, UCLs for arsenic in sediment samples could not be calculated. Maximum arsenic concentration and published background concentrations for arsenic are summarized in the table below:

Metal	Maximum	Shallow Soil Residential ESL	Shallow Soil Commercial/ Industrial ESL	Worker Direct Exposure ESL	PUBLISHED BACKGROUND MEAN[1]	PUBLISHED BACKGROUND RANGE [1]
Arsenic	2.5	0.39	0.96	10	3.5	0.6 to 11.0

Concentrations reported in mg/kg

[1] Kearney Foundation of Soil Science, March 1996

The maximum arsenic concentration is greater than the residential and commercial land use ESLs; however, it is less than the construction exposure ESL and within the published background range.

Based on the reported results for arsenic, offsite reuse or disposal of excavated soil may be restricted based on arsenic content, depending on proposed use.

Metals results for sediment samples are summarized in Table 3.

6.2.2 Organics

TPHd and TPHmo were reported in samples at concentrations below the ESLs.

TPHg, BTEX, SVOCs and PCBs were not detected at or above the laboratory reporting limits.

Organics results for sediment samples and corresponding ESL values are summarized in Table 4.

6.3 Groundwater

Grab groundwater samples were collected from borings B2, and B3 and analyzed for organic compounds. TPHg, BTEX, and VOCs were not detected at or above the laboratory reporting limits.

Organic compounds results for groundwater samples and corresponding ESL values are summarized in Table 5.

6.4 Worker Protection

The contractor(s) should prepare a project-specific health and safety plan to prevent or minimize worker exposure to metals, organic compounds, and NOA in soil as well as organic compounds in groundwater. The plan should include protocols for environmental and personnel monitoring, requirements for personal protective equipment, and other health and safety protocols and procedures for the handling of soil and groundwater.

N

0 1/2

Scale in Miles

GEOCON CONSULTANTS, INC.

6671 BRISA STREET – LIVERMORE, CA 94550
PHONE 925.371.5900 – FAX 925.371.5915

Doyle Drive Outfall IJKL Project

San Francisco, California

GEOCON Proj. No. E8560-02-51

Task Order No. 51

VICINITY MAP

August 2013

Figure 1

GEOCON CONSULTANTS, INC.

6671 BRISA STREET, LIVERMORE, CA 94550; PHONE 925 371-5900 - FAX 925 371-5915

Doyle Drive Outfall IJKL Project		
San Francisco, California	**SITE PLAN**	
GEOCON Proj. No. E8560-02-51		
EA No. 04-1637N1	August 2013	Figure 2

SITE0713.DWG

TABLE 1
Boring Coordinates
Crissy Field Outfall
San Francisco, California

Boring	Northing	Easting
B1	2,121,071.882	5,993,233.321
B2	2,121,039.617	5,993,321.844
B3	2,121,738.664	5,993,781.259
B4	2,121,760.104	5,993,867.450
B5	2,121,913.322	5,993,900.622
B6	2,121,911.504	5,993,973.329
B7	2,122,043.808	5,994,035.584

Coordinates shown in feet, NAD 83, Zone 3

TABLE 2
Summary of Lead Results - Soil/Sediment
Crissy Field Outfall
San Francisco, California

Sample ID	Sample Depth (feet)	Total Lead (mg/kg)	WET Lead (mg/l)	pH
B1-0.5	0.5 to 1	14	---	---
B1-1.5	1.5 to 2	37	---	---
B1-3.0	3 to 3.5	<2.0	---	7.7
B1-6.0	6 to 6.5	<2.0	---	---
B1-9.0	9 to 9.5	<2.0	---	---
B2-0.5	0.5 to 1	66	3.5	---
B2-3.0	3 to 3.5	9.2	---	7.8
B2-6.0	6 to 6.5	3.6	---	---
B2-11.0	11 to 11.5	<2.0	---	---
B3-0.5	0.5 to 1	11	---	---
B3-1.5	1.5 to 2	4.4	---	---
B3-3.0	3 to 3.5	3.0	---	8.9
B3-6.0	6 to 6.5	2.8	---	---
B3-9.0	9 to 9.5	3.1	---	---
B4-0.5	0.5 to 1	3.4	---	---
B4-1.5	1.5 to 2	3.2	---	---
B4-3.0	3 to 3.5	2.0	---	9.3
B4-6.0	6 to 6.5	2.3	---	---
B4-7.5	7.5 to 8	2.7	---	---
B4-10	10 to 10.5	6.6	---	---
B5	Sediment	3.9	---	---
B6	Sediment	3.9	---	---
B7	Sediment	3.8	---	---
Equipment Blank 1		<0.0050	---	---
Equipment Blank 2		<0.0050	---	---
	Hazardous Waste Criteria			
	TTLC (mg/kg)	1,000	---	---
	STLC (mg/l)	---	5.0	---
	TCLP (mg/l)	---	---	---

Notes:
mg/kg = Milligrams per kilogram
WET = Waste Extraction Test using citric acid as the extraction fluid
TTLC = Total Threshold Limit Concentration
STLC = Soluble Threshold Limit Concentration

TABLE 3
Summary of CAM 17 Metals Results - Soil
Crissy Field Outfall
San Francisco, California

Sample ID	Sample Depth (ft)	Antimony	Arsenic	Barium	Beryllium	Cadmium	Chromium	Cobalt	Copper	Lead	Mercury	Molybdenum	Nickel	Selenium	Silver	Thallium	Vanadium	Zinc
B1-0.5	0.5 to 1	<2.0	2.5	120	<1.0	<1.0	20	8.9	22	14	<0.10	<1.0	35	<1.0	<1.0	<1.0	39	32
B2-1.5	1.5 to 2	<2.0	2.1	21	<1.0	<1.0	45	4.9	3.8	27	<0.099	<1.0	26	<1.0	<1.0	<1.0	29	26
B3-1.5	1.5 to 2	<2.0	3.7	32	<1.0	<1.0	37	5.3	6.9	4.4	<0.10	<1.0	25	<1.0	<1.0	<1.0	21	17
B4-1.5	1.5 to 2	<2.0	2.8	9.2	<1.0	<1.0	21	3.9	2.4	3.2	<0.10	<1.0	19	<1.0	<1.0	<1.0	18	13
B4-10	10 to 10.5	<2.0	3.2	8.3	<1.0	<1.0	37	4.7	4.2	6.6	<0.10	<1.0	32	<1.0	<1.0	<1.0	17	16
B5	Sediment	<2.0	2.4	9.2	<1.0	<1.0	28	4.9	3.4	3.9	<0.10	<1.0	28	<1.0	<1.0	<1.0	17	19
B6	Sediment	<2.0	2.4	8.5	<1.0	<1.0	31	4.9	3.4	3.9	<0.10	<1.0	27	<1.0	<1.0	<1.0	17	19
B7	Sediment	<2.0	2.5	9.0	<1.0	<1.0	25	4.6	3.8	3.8	<0.10	<1.0	24	<1.0	<1.0	<1.0	16	19
ESLs																		
Residential Land Use		20	0.39	750	4.0	12	750	23	230	80	6.7	40	150	10	20	0.78	200	600
Commercial/Industrial Land Use		40	0.96	1,500	8.0	12	750	80	230	320	10	40	150	10	40	10	200	600
Construction Worker Exposure		120	10	61,000	180	110	460,000	49	12,000	320	27	1,500	6,100	1,500	1,500	3.1	1,500	93,000
Hazardous Waste Criteria																		
TTLC (mg/kg)		500	500	10,000	75	100	2,500	8,000	2,500	1,000	20	3,500	2,000	100	500	700	2,400	5,000
STLC (mg/l)		15	5.0	100	0.75	1.0	5.0	80	25	5.0	0.2	350	20	1.0	5.0	7.0	24	250
TCLP (mg/l)		---	5.0	100	---	1.0	6.0	---	---	5.0	0.2	---	---	1.0	5.0	---	---	---

Notes:

Results are shown in milligrams per kilogram (mg/kg).
Values listed for chromium are for Chromium III, as there is no standard for total chromium.
< = Analyte was not detected above the laboratory reporting limit.
ESLs = Environmental Screening Levels, Tables A-1, A-2, and K-3, SFRWQCB, Revised May 2013.
TTLC = total threshold limit concentration
STLC = soluble threshold limit concentration
TCLP = toxicity characteristic leaching procedure

TABLE 4
Summary of Organics Results - Soil/Sediment
Crissy Field Outfall
San Francisco, California

Sample ID	Sample Depth (ft)	TPHd (mg/kg)	TPHmo (mg/kg)	TPHg (mg/kg)	BTEX (ug/kg)	VOCs (ug/kg)	SVOCs (ug/kg)	PCBs (ug/kg)
B1-1.5	1.5 to 2	---	---	<1.0	ND	ND	---	ND
B1-3.0	3 to 3.5	2.6	5.1	---	---	ND	---	ND
B1-6.0	6 to 6.5	---	---	---	---	ND	---	---
B2-1.5	1.5 to 2	---	---	<1.0	ND	ND	---	ND
B2-3.0	3 to 3.5	1.5	2.4	---	---	ND	---	ND
B2-6.0	6 to 6.5	---	---	---	---	ND	---	---
B3-1.5	1.5 to 2	---	---	<1.0	ND	ND	---	ND
B3-3.0	3 to 3.5	1.7	2.1	---	---	ND	---	ND
B3-6.0	6 to 6.5	---	---	---	---	ND	---	---
B4-1.5	1.5 to 2	---	---	<1.0	ND	ND	---	ND
B4-3.0	3 to 3.5	1.1	1.2	---	---	ND	---	ND
B4-6.0	6 to 6.5	---	---	---	---	ND	---	---
B5	Sediment	3.1	6.3	<1.0	ND	---	ND	ND
B6	Sediment	2.8	5.4	<1.0	ND	---	ND	ND
B7	Sediment	5.6	14	<1.0	ND	---	ND	ND
	ESLs							
	Residential	100	500	100	---	---	---	---
	Commercial/Industrial	500	2,500	500	---	---	---	---
	Construction Exposure	900	28,000	1,800	---	---	---	---

Notes:
mg/kg = milligrams per kilogram
µg/kg = micrograms per kilogram
TPHd = Total petroleum hydrocarbons as diesel
TPHmo = Total petroleum hydrocarbons as motor oil
TPHg = Total petroleum hydrocarbons as gasoline
BTEX = Benzene, toluene, ethylbenzene, and xylenes
VOCs = Volatile organic compounds
SVOCs = Semivolatile organic compounds
PCBs = Poly-chlorinated biphenyls
--- = Not analyzed or no standard for this compound
< = Not detected above the stated laboratory reporting limit
ND = None detected
ESLs ESLs = Environmental Screening Levels, Tables A-1, A-2, and K-3, SFRWQCB, Revised May 2013.

TABLE 5
Summary of NOA Results - Soil
Crissy Field Outfall
San Francisco, California

Sample ID	Sample Depth (feet)	Asbestos Content (% dry weight)
B1-1.5	1.5 to 2	1.25% Chrysotile
B1-3.0	3 to 3.5	<0.25% Chrysotile
B1-6.0	6 to 6.5	ND
B2-0.5	0.5 to 1	ND
B2-1.5	1.5 to 2	ND
B2-11.0	11 to 11.5	ND
B3-1.5	1.5 to 2	ND
B3-3.0	3 to 3.5	ND
B3-6.0	6 to 6.5	ND
B4-1.5	1.5 to 2	ND
B4-6.0	6 to 6.5	<0.25% Chrysotile
B4-7.5	7.5 to 8	<0.25% Chrysotile

ND = None detected at 0.25% target analytical sensitivity.

TABLE 6
Summary of Organics Results - Groundwater
Crissy Field Outfall
San Francisco, California

Sample ID	TPHg/BTEX (mg/l)	VOCs (µg/l)
B2-GW	ND	ND
B3-GW	ND	ND
Trip Blank	<0.050 TPHg	
ESLs		
GW is current/potential source	---	---
GW not current/potential source	---	---
Surface Water - Freshwater	---	---
Surface Water - Marine	---	---
Surface Water - Estuarine	---	---

Notes:
mg/l = milligrams per kilogram
µg/l = micrograms per kilogram
TPHg = Total petroleum hydrocarbons as gasoline
BTEX = Benzene, toluene, ethylbenzene, and xylenes
VOCs = Volatile Organic Compounds
--- = Not Analyzed or no standard exists
< = Not detected above the stated laboratory reporting limit
ND = None detected
ESLs = Environmental Screening Levels (Tables F-1a, F-1b, and F-2a through F-2c) Revised May 2013.

APPENDIX A

July 08, 2013

Chris Merritt
Geocon Consultants, Inc.
6671 Brisa Street
Livermore, CA 94550

TEL: (925) 371-5900
FAX: (925) 371-5915

CA-ELAP No.: 2676
NV Cert. No.: NV-009222007A

Workorder No.: N010467

RE: Caltrans-CrissyField Outfall, E8560-02-51

Attention: Chris Merritt

Enclosed are the results for sample(s) received on June 27, 2013 by Advanced Technology Laboratories, Inc. . The sample(s) are tested for the parameters as indicated in the enclosed chain of custody in accordance with the applicable laboratory certifications.

Thank you for the opportunity to service the needs of your company.

Please feel free to call me at (702) 307-2659 if I can be of further assistance to your company.

Sincerely,

Jose Tenorio Jr.
Laboratory Director

The cover letter is an integral part of this analytical report. This Laboratory Report cannot be reproduced in part or in its entirety without written permission from the client and Advanced Technology Laboratories - Las Vegas.

Advanced Technology Laboratories, Inc. **Date:** *08-Jul-13*

CLIENT: Geocon Consultants, Inc.
Project: Caltrans-CrissyField Outfall, E8560-02-51
Lab Order: N010467

CASE NARRATIVE

SAMPLE RECEIVING/GENERAL COMMENTS:

Samples were received intact with proper chain of custody documentation.

Cooler temperature and sample preservation were verified upon receipt of samples if applicable.

Information on sample receipt conditions including discrepancies can be found in attached Sample Receipt Checklist Form.

Samples were analyzed within method holding time.

Analytical Comments for EPA 6010B:

Matrix Spike (MS) and Matrix Spike Duplicate (MSD) are outside recovery criteria for Antimony possibly due to matrix interference. The associated Laboratory Control Sample (LCS) recovery was acceptable.

Analytical Comments for EPA 8270C:

Matrix Spike (MS) and Matrix Spike Duplicate (MSD) are outside recovery criteria for some analytes possibly due to matrix interference. The associated Laboratory Control Sample (LCS) recovery was acceptable.

RPD for Matrix Spike (MS)/Matrix Spike Duplicate (MSD) is outside criteria possibly due to non-homogeneity of sample; however, the analytical batch was validated by the Laboratory Control Sample (LCS).

Advanced Technology Laboratories, Inc.
3151 W. Post Rd Las Vegas, NV 89118 Tel: 702-307-2659 Fax: 702-307-2691

Advanced Technology Laboratories, Inc.

Date: *08-Jul-13*

CLIENT: Geocon Consultants, Inc.
Project: Caltrans-CrissyField Outfall, E8560-02-51
Lab Order: N010467
Contract No:

Work Order Sample Summary

Lab Sample ID	Client Sample ID	Matrix	Collection Date	Date Received	Date Reported
N010467-001A	B5	Soil	6/26/2013 8:30:00 AM	6/27/2013	7/8/2013
N010467-001B	B5	Soil	6/26/2013 8:30:00 AM	6/27/2013	7/8/2013
N010467-002A	B6	Soil	6/26/2013 8:28:00 AM	6/27/2013	7/8/2013
N010467-002B	B6	Soil	6/26/2013 8:28:00 AM	6/27/2013	7/8/2013
N010467-003A	B7	Soil	6/26/2013 8:10:00 AM	6/27/2013	7/8/2013
N010467-003B	B7	Soil	6/26/2013 8:10:00 AM	6/27/2013	7/8/2013
N010467-004A	EB	Water	6/26/2013 9:30:00 AM	6/27/2013	7/8/2013

Advanced Technology Laboratories, Inc.
3151 W. Post Rd Las Vegas, NV 89118 Tel: 702-307-2659 Fax: 702-307-2691

CLIENT: Geocon Consultants, Inc.
Lab Order: N010467
Project: Caltrans-CrissyField Outfall, E8560-02-51
Lab ID: N010467-001

Client Sample ID: B5
Collection Date: 6/26/2013 8:30:00 AM
Matrix: SOIL

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
SEMIVOLATILE ORGANIC COMPOUNDS BY GC/MS						
EPA 3550B				**EPA 8270C**		
RunID: MS3_130701A	QC Batch: 43311				PrepDate: 6/28/2013	Analyst: **MDM**
1,2,4-Trichlorobenzene	ND	330		µg/Kg	1	7/1/2013 12:43 PM
1,2-Dichlorobenzene	ND	330		µg/Kg	1	7/1/2013 12:43 PM
1,3-Dichlorobenzene	ND	330		µg/Kg	1	7/1/2013 12:43 PM
1,4-Dichlorobenzene	ND	330		µg/Kg	1	7/1/2013 12:43 PM
2,4,5-Trichlorophenol	ND	330		µg/Kg	1	7/1/2013 12:43 PM
2,4,6-Trichlorophenol	ND	330		µg/Kg	1	7/1/2013 12:43 PM
2,4-Dichlorophenol	ND	1600		µg/Kg	1	7/1/2013 12:43 PM
2,4-Dimethylphenol	ND	330		µg/Kg	1	7/1/2013 12:43 PM
2,4-Dinitrophenol	ND	1600		µg/Kg	1	7/1/2013 12:43 PM
2,4-Dinitrotoluene	ND	330		µg/Kg	1	7/1/2013 12:43 PM
2,6-Dinitrotoluene	ND	330		µg/Kg	1	7/1/2013 12:43 PM
2-Chloronaphthalene	ND	330		µg/Kg	1	7/1/2013 12:43 PM
2-Chlorophenol	ND	330		µg/Kg	1	7/1/2013 12:43 PM
2-Methylnaphthalene	ND	330		µg/Kg	1	7/1/2013 12:43 PM
2-Methylphenol	ND	330		µg/Kg	1	7/1/2013 12:43 PM
2-Nitroaniline	ND	1600		µg/Kg	1	7/1/2013 12:43 PM
2-Nitrophenol	ND	330		µg/Kg	1	7/1/2013 12:43 PM
3,3´-Dichlorobenzidine	ND	660		µg/Kg	1	7/1/2013 12:43 PM
3-Nitroaniline	ND	1600		µg/Kg	1	7/1/2013 12:43 PM
4,6-Dinitro-2-methylphenol	ND	1600		µg/Kg	1	7/1/2013 12:43 PM
4-Bromophenyl-phenylether	ND	330		µg/Kg	1	7/1/2013 12:43 PM
4-Chloro-3-methylphenol	ND	660		µg/Kg	1	7/1/2013 12:43 PM
4-Chloroaniline	ND	660		µg/Kg	1	7/1/2013 12:43 PM
4-Chlorophenyl-phenylether	ND	330		µg/Kg	1	7/1/2013 12:43 PM
4-Methylphenol	ND	330		µg/Kg	1	7/1/2013 12:43 PM
4-Nitroaniline	ND	1600		µg/Kg	1	7/1/2013 12:43 PM
4-Nitrophenol	ND	1600		µg/Kg	1	7/1/2013 12:43 PM
Acenaphthene	ND	330		µg/Kg	1	7/1/2013 12:43 PM
Acenaphthylene	ND	330		µg/Kg	1	7/1/2013 12:43 PM
Anthracene	ND	330		µg/Kg	1	7/1/2013 12:43 PM
Benzidine (M)	ND	1600		µg/Kg	1	7/1/2013 12:43 PM
Benzo(a)anthracene	ND	330		µg/Kg	1	7/1/2013 12:43 PM
Benzo(a)pyrene	ND	330		µg/Kg	1	7/1/2013 12:43 PM
Benzo(b)fluoranthene	ND	330		µg/Kg	1	7/1/2013 12:43 PM
Benzo(g,h,i)perylene	ND	330		µg/Kg	1	7/1/2013 12:43 PM
Benzo(k)fluoranthene	ND	330		µg/Kg	1	7/1/2013 12:43 PM

Qualifiers:

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H	Holding times for preparation or analysis exceeded	ND	Not Detected at the Reporting Limit
S	Spike/Surrogate outside of limits due to matrix interference		Results are wet unless otherwise specified
DO	Surrogate Diluted Out		

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Lab ID: N010467-001

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SEMIVOLATILE ORGANIC COMPOUNDS BY GC/MS						
EPA 3550B				**EPA 8270C**		
RunID: MS3_130701A	QC Batch: 43311				PrepDate: 6/28/2013	Analyst: **MDM**
Benzoic acid	ND	1600		µg/Kg	1	7/1/2013 12:43 PM
Benzyl alcohol	ND	660		µg/Kg	1	7/1/2013 12:43 PM
Bis(2-chloroethoxy)methane	ND	330		µg/Kg	1	7/1/2013 12:43 PM
Bis(2-chloroethyl)ether	ND	330		µg/Kg	1	7/1/2013 12:43 PM
Bis(2-chloroisopropyl)ether	ND	330		µg/Kg	1	7/1/2013 12:43 PM
Bis(2-ethylhexyl)phthalate	ND	330		µg/Kg	1	7/1/2013 12:43 PM
Butylbenzylphthalate	ND	330		µg/Kg	1	7/1/2013 12:43 PM
Chrysene	ND	330		µg/Kg	1	7/1/2013 12:43 PM
Di-n-butylphthalate	ND	330		µg/Kg	1	7/1/2013 12:43 PM
Di-n-octylphthalate	ND	330		µg/Kg	1	7/1/2013 12:43 PM
Dibenz(a,h)anthracene	ND	330		µg/Kg	1	7/1/2013 12:43 PM
Dibenzofuran	ND	330		µg/Kg	1	7/1/2013 12:43 PM
Diethylphthalate	ND	330		µg/Kg	1	7/1/2013 12:43 PM
Dimethylphthalate	ND	330		µg/Kg	1	7/1/2013 12:43 PM
Fluoranthene	ND	330		µg/Kg	1	7/1/2013 12:43 PM
Fluorene	ND	330		µg/Kg	1	7/1/2013 12:43 PM
Hexachlorobenzene	ND	330		µg/Kg	1	7/1/2013 12:43 PM
Hexachlorobutadiene	ND	660		µg/Kg	1	7/1/2013 12:43 PM
Hexachlorocyclopentadiene	ND	660		µg/Kg	1	7/1/2013 12:43 PM
Hexachloroethane	ND	330		µg/Kg	1	7/1/2013 12:43 PM
Indeno(1,2,3-cd)pyrene	ND	330		µg/Kg	1	7/1/2013 12:43 PM
Isophorone	ND	330		µg/Kg	1	7/1/2013 12:43 PM
N-Nitrosodi-n-propylamine	ND	330		µg/Kg	1	7/1/2013 12:43 PM
N-Nitrosodiphenylamine	ND	330		µg/Kg	1	7/1/2013 12:43 PM
Naphthalene	ND	330		µg/Kg	1	7/1/2013 12:43 PM
Nitrobenzene	ND	330		µg/Kg	1	7/1/2013 12:43 PM
Pentachlorophenol	ND	1600		µg/Kg	1	7/1/2013 12:43 PM
Phenanthrene	ND	330		µg/Kg	1	7/1/2013 12:43 PM
Phenol	ND	330		µg/Kg	1	7/1/2013 12:43 PM
Pyrene	ND	330		µg/Kg	1	7/1/2013 12:43 PM
Surr: 1,2-Dichlorobenzene-d4	42.6	23-120		%REC	1	7/1/2013 12:43 PM
Surr: 2,4,6-Tribromophenol	72.7	24-134		%REC	1	7/1/2013 12:43 PM
Surr: 2-Chlorophenol-d4	54.4	28-120		%REC	1	7/1/2013 12:43 PM
Surr: 2-Fluorobiphenyl	55.4	32-120		%REC	1	7/1/2013 12:43 PM
Surr: 2-Fluorophenol	54.9	29-120		%REC	1	7/1/2013 12:43 PM
Surr: 4-Terphenyl-d14	81.9	51-128		%REC	1	7/1/2013 12:43 PM

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- DO Surrogate Diluted Out
- E Value above quantitation range
- ND Not Detected at the Reporting Limit

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Lab ID: N010467-001

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Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
SEMIVOLATILE ORGANIC COMPOUNDS BY GC/MS						
EPA 3550B				**EPA 8270C**		
RunID: MS3_130701A	QC Batch: 43311			PrepDate:	6/28/2013	Analyst: **MDM**
Surr: Nitrobenzene-d5	59.2	29-120		%REC	1	7/1/2013 12:43 PM
Surr: Phenol-d5	56.9	28-120		%REC	1	7/1/2013 12:43 PM
VOLATILE ORGANIC COMPOUNDS BY GC/MS						
				EPA 8260B		
RunID: MS1_130627A	QC Batch: D13VS038			PrepDate:		Analyst: **QBM**
Benzene	ND	5.0		µg/Kg	1	6/27/2013 05:21 PM
Ethylbenzene	ND	5.0		µg/Kg	1	6/27/2013 05:21 PM
m,p-Xylene	ND	10		µg/Kg	1	6/27/2013 05:21 PM
o-Xylene	ND	5.0		µg/Kg	1	6/27/2013 05:21 PM
Toluene	ND	5.0		µg/Kg	1	6/27/2013 05:21 PM
Surr: 1,2-Dichloroethane-d4	81.4	63-139		%REC	1	6/27/2013 05:21 PM
Surr: 4-Bromofluorobenzene	86.1	75-124		%REC	1	6/27/2013 05:21 PM
Surr: Dibromofluoromethane	92.6	70-133		%REC	1	6/27/2013 05:21 PM
Surr: Toluene-d8	103	80-123		%REC	1	6/27/2013 05:21 PM
DIESEL & MOTOR OIL RANGE ORGANICS BY GC/FID						
EPA 3550B				**EPA 8015B**		
RunID: GC3_130701A	QC Batch: 43322			PrepDate:	7/1/2013	Analyst: **MDM**
DRO	3.1	1.0		mg/Kg	1	7/1/2013 05:09 PM
ORO	6.3	1.0		mg/Kg	1	7/1/2013 05:09 PM
Surr: p-Terphenyl	97.9	59-127		%REC	1	7/1/2013 05:09 PM
PCBS BY GC/ECD						
EPA 3550B				**EPA 8082**		
RunID: GC7_130702A	QC Batch: 43312			PrepDate:	6/28/2013	Analyst: **MDM**
Aroclor 1016	ND	17		µg/Kg	1	7/2/2013 02:02 PM
Aroclor 1221	ND	33		µg/Kg	1	7/2/2013 02:02 PM
Aroclor 1232	ND	17		µg/Kg	1	7/2/2013 02:02 PM
Aroclor 1242	ND	17		µg/Kg	1	7/2/2013 02:02 PM
Aroclor 1248	ND	17		µg/Kg	1	7/2/2013 02:02 PM
Aroclor 1254	ND	17		µg/Kg	1	7/2/2013 02:02 PM
Aroclor 1260	ND	17		µg/Kg	1	7/2/2013 02:02 PM
Surr: Decachlorobiphenyl	85.3	40-146		%REC	1	7/2/2013 02:02 PM
Surr: Tetrachloro-m-xylene	59.6	32-109		%REC	1	7/2/2013 02:02 PM

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- ND Not Detected at the Reporting Limit

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Advanced Technology Laboratories, Inc.

ANALYTICAL RESULTS

Print Date: *08-Jul-13*

CLIENT:	Geocon Consultants, Inc.	**Client Sample ID:**	B5
Lab Order:	N010467	**Collection Date:**	6/26/2013 8:30:00 AM
Project:	Caltrans-CrissyField Outfall, E8560-02-51	**Matrix:**	SOIL
Lab ID:	N010467-001		

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
GASOLINE RANGE ORGANICS BY GC/FID						
				EPA 8015B		
RunID: GC4_130627B	QC Batch: E13VS069			PrepDate:		Analyst: **QBM**
GRO	ND	1.0		mg/Kg	1	6/27/2013 03:03 PM
Surr: Chlorobenzene - d5	98.1	51-136		%REC	1	6/27/2013 03:03 PM
MERCURY BY COLD VAPOR TECHNIQUE						
	EPA 7471			**EPA 7471A**		
RunID: AA1_130627B	QC Batch: 43302			PrepDate:	6/27/2013	Analyst: **LCC**
Mercury	ND	0.10		mg/Kg	1	6/27/2013
ICP METALS						
	EPA 3050B			**EPA 6010B**		
RunID: ICP2_130708A	QC Batch: 43320			PrepDate:	7/1/2013	Analyst: **admin**
Antimony	ND	2.0		mg/Kg	1	7/8/2013 10:50 AM
Arsenic	2.4	1.0		mg/Kg	1	7/8/2013 10:50 AM
Barium	9.2	1.0		mg/Kg	1	7/8/2013 10:50 AM
Beryllium	ND	1.0		mg/Kg	1	7/8/2013 10:50 AM
Cadmium	ND	1.0		mg/Kg	1	7/8/2013 10:50 AM
Chromium	28	1.0		mg/Kg	1	7/8/2013 10:50 AM
Cobalt	4.9	1.0		mg/Kg	1	7/8/2013 10:50 AM
Copper	3.4	2.0		mg/Kg	1	7/8/2013 10:50 AM
Lead	3.9	1.0		mg/Kg	1	7/8/2013 10:50 AM
Molybdenum	ND	1.0		mg/Kg	1	7/8/2013 10:50 AM
Nickel	28	1.0		mg/Kg	1	7/8/2013 10:50 AM
Selenium	ND	1.0		mg/Kg	1	7/8/2013 10:50 AM
Silver	ND	1.0		mg/Kg	1	7/8/2013 10:50 AM
Thallium	ND	1.0		mg/Kg	1	7/8/2013 10:50 AM
Vanadium	17	1.0		mg/Kg	1	7/8/2013 10:50 AM
Zinc	19	1.0		mg/Kg	1	7/8/2013 10:50 AM

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CLIENT: Geocon Consultants, Inc.
Lab Order: N010467
Project: Caltrans-CrissyField Outfall, E8560-02-51
Lab ID: N010467-002

Client Sample ID: B6
Collection Date: 6/26/2013 8:28:00 AM
Matrix: SOIL

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
SEMIVOLATILE ORGANIC COMPOUNDS BY GC/MS						
EPA 3550B				**EPA 8270C**		
RunID: MS3_130701A	QC Batch: 43311				PrepDate: 6/28/2013	Analyst: **MDM**
1,2,4-Trichlorobenzene	ND	330		µg/Kg	1	7/1/2013 01:38 PM
1,2-Dichlorobenzene	ND	330		µg/Kg	1	7/1/2013 01:38 PM
1,3-Dichlorobenzene	ND	330		µg/Kg	1	7/1/2013 01:38 PM
1,4-Dichlorobenzene	ND	330		µg/Kg	1	7/1/2013 01:38 PM
2,4,5-Trichlorophenol	ND	330		µg/Kg	1	7/1/2013 01:38 PM
2,4,6-Trichlorophenol	ND	330		µg/Kg	1	7/1/2013 01:38 PM
2,4-Dichlorophenol	ND	1600		µg/Kg	1	7/1/2013 01:38 PM
2,4-Dimethylphenol	ND	330		µg/Kg	1	7/1/2013 01:38 PM
2,4-Dinitrophenol	ND	1600		µg/Kg	1	7/1/2013 01:38 PM
2,4-Dinitrotoluene	ND	330		µg/Kg	1	7/1/2013 01:38 PM
2,6-Dinitrotoluene	ND	330		µg/Kg	1	7/1/2013 01:38 PM
2-Chloronaphthalene	ND	330		µg/Kg	1	7/1/2013 01:38 PM
2-Chlorophenol	ND	330		µg/Kg	1	7/1/2013 01:38 PM
2-Methylnaphthalene	ND	330		µg/Kg	1	7/1/2013 01:38 PM
2-Methylphenol	ND	330		µg/Kg	1	7/1/2013 01:38 PM
2-Nitroaniline	ND	1600		µg/Kg	1	7/1/2013 01:38 PM
2-Nitrophenol	ND	330		µg/Kg	1	7/1/2013 01:38 PM
3,3´-Dichlorobenzidine	ND	660		µg/Kg	1	7/1/2013 01:38 PM
3-Nitroaniline	ND	1600		µg/Kg	1	7/1/2013 01:38 PM
4,6-Dinitro-2-methylphenol	ND	1600		µg/Kg	1	7/1/2013 01:38 PM
4-Bromophenyl-phenylether	ND	330		µg/Kg	1	7/1/2013 01:38 PM
4-Chloro-3-methylphenol	ND	660		µg/Kg	1	7/1/2013 01:38 PM
4-Chloroaniline	ND	660		µg/Kg	1	7/1/2013 01:38 PM
4-Chlorophenyl-phenylether	ND	330		µg/Kg	1	7/1/2013 01:38 PM
4-Methylphenol	ND	330		µg/Kg	1	7/1/2013 01:38 PM
4-Nitroaniline	ND	1600		µg/Kg	1	7/1/2013 01:38 PM
4-Nitrophenol	ND	1600		µg/Kg	1	7/1/2013 01:38 PM
Acenaphthene	ND	330		µg/Kg	1	7/1/2013 01:38 PM
Acenaphthylene	ND	330		µg/Kg	1	7/1/2013 01:38 PM
Anthracene	ND	330		µg/Kg	1	7/1/2013 01:38 PM
Benzidine (M)	ND	1600		µg/Kg	1	7/1/2013 01:38 PM
Benzo(a)anthracene	ND	330		µg/Kg	1	7/1/2013 01:38 PM
Benzo(a)pyrene	ND	330		µg/Kg	1	7/1/2013 01:38 PM
Benzo(b)fluoranthene	ND	330		µg/Kg	1	7/1/2013 01:38 PM
Benzo(g,h,i)perylene	ND	330		µg/Kg	1	7/1/2013 01:38 PM
Benzo(k)fluoranthene	ND	330		µg/Kg	1	7/1/2013 01:38 PM

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Butylbenzylphthalate	ND	330		µg/Kg	1	7/1/2013 01:38 PM
Chrysene	ND	330		µg/Kg	1	7/1/2013 01:38 PM
Di-n-butylphthalate	ND	330		µg/Kg	1	7/1/2013 01:38 PM
Di-n-octylphthalate	ND	330		µg/Kg	1	7/1/2013 01:38 PM
Dibenz(a,h)anthracene	ND	330		µg/Kg	1	7/1/2013 01:38 PM
Dibenzofuran	ND	330		µg/Kg	1	7/1/2013 01:38 PM
Diethylphthalate	ND	330		µg/Kg	1	7/1/2013 01:38 PM
Dimethylphthalate	ND	330		µg/Kg	1	7/1/2013 01:38 PM
Fluoranthene	ND	330		µg/Kg	1	7/1/2013 01:38 PM
Fluorene	ND	330		µg/Kg	1	7/1/2013 01:38 PM
Hexachlorobenzene	ND	330		µg/Kg	1	7/1/2013 01:38 PM
Hexachlorobutadiene	ND	660		µg/Kg	1	7/1/2013 01:38 PM
Hexachlorocyclopentadiene	ND	660		µg/Kg	1	7/1/2013 01:38 PM
Hexachloroethane	ND	330		µg/Kg	1	7/1/2013 01:38 PM
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Isophorone	ND	330		µg/Kg	1	7/1/2013 01:38 PM
N-Nitrosodi-n-propylamine	ND	330		µg/Kg	1	7/1/2013 01:38 PM
N-Nitrosodiphenylamine	ND	330		µg/Kg	1	7/1/2013 01:38 PM
Naphthalene	ND	330		µg/Kg	1	7/1/2013 01:38 PM
Nitrobenzene	ND	330		µg/Kg	1	7/1/2013 01:38 PM
Pentachlorophenol	ND	1600		µg/Kg	1	7/1/2013 01:38 PM
Phenanthrene	ND	330		µg/Kg	1	7/1/2013 01:38 PM
Phenol	ND	330		µg/Kg	1	7/1/2013 01:38 PM
Pyrene	ND	330		µg/Kg	1	7/1/2013 01:38 PM
Surr: 1,2-Dichlorobenzene-d4	46.2	23-120		%REC	1	7/1/2013 01:38 PM
Surr: 2,4,6-Tribromophenol	74.3	24-134		%REC	1	7/1/2013 01:38 PM
Surr: 2-Chlorophenol-d4	55.8	28-120		%REC	1	7/1/2013 01:38 PM
Surr: 2-Fluorobiphenyl	57.2	32-120		%REC	1	7/1/2013 01:38 PM
Surr: 2-Fluorophenol	57.8	29-120		%REC	1	7/1/2013 01:38 PM
Surr: 4-Terphenyl-d14	79.5	51-128		%REC	1	7/1/2013 01:38 PM

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RunID: MS3_130701A	QC Batch: 43311			PrepDate:	6/28/2013	Analyst: **MDM**
Surr: Nitrobenzene-d5	62.0	29-120		%REC	1	7/1/2013 01:38 PM
Surr: Phenol-d5	59.1	28-120		%REC	1	7/1/2013 01:38 PM
VOLATILE ORGANIC COMPOUNDS BY GC/MS						
				EPA 8260B		
RunID: MS1_130627A	QC Batch: D13VS038			PrepDate:		Analyst: **QBM**
Benzene	ND	5.0		µg/Kg	1	6/27/2013 05:43 PM
Ethylbenzene	ND	5.0		µg/Kg	1	6/27/2013 05:43 PM
m,p-Xylene	ND	10		µg/Kg	1	6/27/2013 05:43 PM
o-Xylene	ND	5.0		µg/Kg	1	6/27/2013 05:43 PM
Toluene	ND	5.0		µg/Kg	1	6/27/2013 05:43 PM
Surr: 1,2-Dichloroethane-d4	84.6	63-139		%REC	1	6/27/2013 05:43 PM
Surr: 4-Bromofluorobenzene	88.3	75-124		%REC	1	6/27/2013 05:43 PM
Surr: Dibromofluoromethane	95.2	70-133		%REC	1	6/27/2013 05:43 PM
Surr: Toluene-d8	106	80-123		%REC	1	6/27/2013 05:43 PM
DIESEL & MOTOR OIL RANGE ORGANICS BY GC/FID						
EPA 3550B				**EPA 8015B**		
RunID: GC3_130701A	QC Batch: 43322			PrepDate:	7/1/2013	Analyst: **MDM**
DRO	2.8	1.0		mg/Kg	1	7/1/2013 05:37 PM
ORO	5.4	1.0		mg/Kg	1	7/1/2013 05:37 PM
Surr: p-Terphenyl	104	59-127		%REC	1	7/1/2013 05:37 PM
PCBS BY GC/ECD						
EPA 3550B				**EPA 8082**		
RunID: GC7_130702A	QC Batch: 43312			PrepDate:	6/28/2013	Analyst: **MDM**
Aroclor 1016	ND	16		µg/Kg	1	7/2/2013 02:32 PM
Aroclor 1221	ND	33		µg/Kg	1	7/2/2013 02:32 PM
Aroclor 1232	ND	16		µg/Kg	1	7/2/2013 02:32 PM
Aroclor 1242	ND	16		µg/Kg	1	7/2/2013 02:32 PM
Aroclor 1248	ND	16		µg/Kg	1	7/2/2013 02:32 PM
Aroclor 1254	ND	16		µg/Kg	1	7/2/2013 02:32 PM
Aroclor 1260	ND	16		µg/Kg	1	7/2/2013 02:32 PM
Surr: Decachlorobiphenyl	62.4	40-146		%REC	1	7/2/2013 02:32 PM
Surr: Tetrachloro-m-xylene	48.6	32-109		%REC	1	7/2/2013 02:32 PM

Qualifiers:
- B Analyte detected in the associated Method Blank
- H Holding times for preparation or analysis exceeded
- S Spike/Surrogate outside of limits due to matrix interference
- DO Surrogate Diluted Out
- E Value above quantitation range
- ND Not Detected at the Reporting Limit

Results are wet unless otherwise specified

Advanced Technology Laboratories, Inc.

ANALYTICAL RESULTS

Print Date: *08-Jul-13*

CLIENT: Geocon Consultants, Inc.
Lab Order: N010467
Project: Caltrans-CrissyField Outfall, E8560-02-51
Lab ID: N010467-002

Client Sample ID: B6
Collection Date: 6/26/2013 8:28:00 AM
Matrix: SOIL

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
GASOLINE RANGE ORGANICS BY GC/FID						
				EPA 8015B		
RunID: GC4_130627B	QC Batch: E13VS069			PrepDate:		Analyst: **QBM**
GRO	ND	1.0		mg/Kg	1	6/27/2013 03:34 PM
Surr: Chlorobenzene - d5	103	51-136		%REC	1	6/27/2013 03:34 PM
MERCURY BY COLD VAPOR TECHNIQUE						
	EPA 7471			**EPA 7471A**		
RunID: AA1_130627B	QC Batch: 43302			PrepDate:	6/27/2013	Analyst: **LCC**
Mercury	ND	0.10		mg/Kg	1	6/27/2013
ICP METALS						
	EPA 3050B			**EPA 6010B**		
RunID: ICP2_130708A	QC Batch: 43320			PrepDate:	7/1/2013	Analyst: **admin**
Antimony	ND	2.0		mg/Kg	1	7/8/2013 10:56 AM
Arsenic	2.4	1.0		mg/Kg	1	7/8/2013 10:56 AM
Barium	8.5	1.0		mg/Kg	1	7/8/2013 10:56 AM
Beryllium	ND	1.0		mg/Kg	1	7/8/2013 10:56 AM
Cadmium	ND	1.0		mg/Kg	1	7/8/2013 10:56 AM
Chromium	31	1.0		mg/Kg	1	7/8/2013 10:56 AM
Cobalt	4.9	1.0		mg/Kg	1	7/8/2013 10:56 AM
Copper	3.4	2.0		mg/Kg	1	7/8/2013 10:56 AM
Lead	3.9	1.0		mg/Kg	1	7/8/2013 10:56 AM
Molybdenum	ND	1.0		mg/Kg	1	7/8/2013 10:56 AM
Nickel	27	1.0		mg/Kg	1	7/8/2013 10:56 AM
Selenium	ND	1.0		mg/Kg	1	7/8/2013 10:56 AM
Silver	ND	1.0		mg/Kg	1	7/8/2013 10:56 AM
Thallium	ND	1.0		mg/Kg	1	7/8/2013 10:56 AM
Vanadium	17	1.0		mg/Kg	1	7/8/2013 10:56 AM
Zinc	19	1.0		mg/Kg	1	7/8/2013 10:56 AM

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range
H	Holding times for preparation or analysis exceeded	ND	Not Detected at the Reporting Limit
S	Spike/Surrogate outside of limits due to matrix interference		Results are wet unless otherwise specified
DO	Surrogate Diluted Out		

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CLIENT: Geocon Consultants, Inc.
Lab Order: N010467
Project: Caltrans-CrissyField Outfall, E8560-02-51
Lab ID: N010467-003

Client Sample ID: B7
Collection Date: 6/26/2013 8:10:00 AM
Matrix: SOIL

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
SEMIVOLATILE ORGANIC COMPOUNDS BY GC/MS						
EPA 3550B				**EPA 8270C**		
RunID: MS3_130701A	QC Batch: 43311				PrepDate: 6/28/2013	Analyst: **MDM**
1,2,4-Trichlorobenzene	ND	330		µg/Kg	1	7/1/2013 02:06 PM
1,2-Dichlorobenzene	ND	330		µg/Kg	1	7/1/2013 02:06 PM
1,3-Dichlorobenzene	ND	330		µg/Kg	1	7/1/2013 02:06 PM
1,4-Dichlorobenzene	ND	330		µg/Kg	1	7/1/2013 02:06 PM
2,4,5-Trichlorophenol	ND	330		µg/Kg	1	7/1/2013 02:06 PM
2,4,6-Trichlorophenol	ND	330		µg/Kg	1	7/1/2013 02:06 PM
2,4-Dichlorophenol	ND	1700		µg/Kg	1	7/1/2013 02:06 PM
2,4-Dimethylphenol	ND	330		µg/Kg	1	7/1/2013 02:06 PM
2,4-Dinitrophenol	ND	1700		µg/Kg	1	7/1/2013 02:06 PM
2,4-Dinitrotoluene	ND	330		µg/Kg	1	7/1/2013 02:06 PM
2,6-Dinitrotoluene	ND	330		µg/Kg	1	7/1/2013 02:06 PM
2-Chloronaphthalene	ND	330		µg/Kg	1	7/1/2013 02:06 PM
2-Chlorophenol	ND	330		µg/Kg	1	7/1/2013 02:06 PM
2-Methylnaphthalene	ND	330		µg/Kg	1	7/1/2013 02:06 PM
2-Methylphenol	ND	330		µg/Kg	1	7/1/2013 02:06 PM
2-Nitroaniline	ND	1700		µg/Kg	1	7/1/2013 02:06 PM
2-Nitrophenol	ND	330		µg/Kg	1	7/1/2013 02:06 PM
3,3´-Dichlorobenzidine	ND	660		µg/Kg	1	7/1/2013 02:06 PM
3-Nitroaniline	ND	1700		µg/Kg	1	7/1/2013 02:06 PM
4,6-Dinitro-2-methylphenol	ND	1700		µg/Kg	1	7/1/2013 02:06 PM
4-Bromophenyl-phenylether	ND	330		µg/Kg	1	7/1/2013 02:06 PM
4-Chloro-3-methylphenol	ND	660		µg/Kg	1	7/1/2013 02:06 PM
4-Chloroaniline	ND	660		µg/Kg	1	7/1/2013 02:06 PM
4-Chlorophenyl-phenylether	ND	330		µg/Kg	1	7/1/2013 02:06 PM
4-Methylphenol	ND	330		µg/Kg	1	7/1/2013 02:06 PM
4-Nitroaniline	ND	1700		µg/Kg	1	7/1/2013 02:06 PM
4-Nitrophenol	ND	1700		µg/Kg	1	7/1/2013 02:06 PM
Acenaphthene	ND	330		µg/Kg	1	7/1/2013 02:06 PM
Acenaphthylene	ND	330		µg/Kg	1	7/1/2013 02:06 PM
Anthracene	ND	330		µg/Kg	1	7/1/2013 02:06 PM
Benzidine (M)	ND	1700		µg/Kg	1	7/1/2013 02:06 PM
Benzo(a)anthracene	ND	330		µg/Kg	1	7/1/2013 02:06 PM
Benzo(a)pyrene	ND	330		µg/Kg	1	7/1/2013 02:06 PM
Benzo(b)fluoranthene	ND	330		µg/Kg	1	7/1/2013 02:06 PM
Benzo(g,h,i)perylene	ND	330		µg/Kg	1	7/1/2013 02:06 PM
Benzo(k)fluoranthene	ND	330		µg/Kg	1	7/1/2013 02:06 PM

Qualifiers:
- B Analyte detected in the associated Method Blank
- H Holding times for preparation or analysis exceeded
- S Spike/Surrogate outside of limits due to matrix interference
- DO Surrogate Diluted Out
- E Value above quantitation range
- ND Not Detected at the Reporting Limit

Results are wet unless otherwise specified

CLIENT: Geocon Consultants, Inc.
Lab Order: N010467
Project: Caltrans-CrissyField Outfall, E8560-02-51
Lab ID: N010467-003

Client Sample ID: B7
Collection Date: 6/26/2013 8:10:00 AM
Matrix: SOIL

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
SEMIVOLATILE ORGANIC COMPOUNDS BY GC/MS						
EPA 3550B				**EPA 8270C**		
RunID: MS3_130701A	QC Batch: 43311				PrepDate: 6/28/2013	Analyst: **MDM**
Benzoic acid	ND	1700		µg/Kg	1	7/1/2013 02:06 PM
Benzyl alcohol	ND	660		µg/Kg	1	7/1/2013 02:06 PM
Bis(2-chloroethoxy)methane	ND	330		µg/Kg	1	7/1/2013 02:06 PM
Bis(2-chloroethyl)ether	ND	330		µg/Kg	1	7/1/2013 02:06 PM
Bis(2-chloroisopropyl)ether	ND	330		µg/Kg	1	7/1/2013 02:06 PM
Bis(2-ethylhexyl)phthalate	ND	330		µg/Kg	1	7/1/2013 02:06 PM
Butylbenzylphthalate	ND	330		µg/Kg	1	7/1/2013 02:06 PM
Chrysene	ND	330		µg/Kg	1	7/1/2013 02:06 PM
Di-n-butylphthalate	ND	330		µg/Kg	1	7/1/2013 02:06 PM
Di-n-octylphthalate	ND	330		µg/Kg	1	7/1/2013 02:06 PM
Dibenz(a,h)anthracene	ND	330		µg/Kg	1	7/1/2013 02:06 PM
Dibenzofuran	ND	330		µg/Kg	1	7/1/2013 02:06 PM
Diethylphthalate	ND	330		µg/Kg	1	7/1/2013 02:06 PM
Dimethylphthalate	ND	330		µg/Kg	1	7/1/2013 02:06 PM
Fluoranthene	ND	330		µg/Kg	1	7/1/2013 02:06 PM
Fluorene	ND	330		µg/Kg	1	7/1/2013 02:06 PM
Hexachlorobenzene	ND	330		µg/Kg	1	7/1/2013 02:06 PM
Hexachlorobutadiene	ND	660		µg/Kg	1	7/1/2013 02:06 PM
Hexachlorocyclopentadiene	ND	660		µg/Kg	1	7/1/2013 02:06 PM
Hexachloroethane	ND	330		µg/Kg	1	7/1/2013 02:06 PM
Indeno(1,2,3-cd)pyrene	ND	330		µg/Kg	1	7/1/2013 02:06 PM
Isophorone	ND	330		µg/Kg	1	7/1/2013 02:06 PM
N-Nitrosodi-n-propylamine	ND	330		µg/Kg	1	7/1/2013 02:06 PM
N-Nitrosodiphenylamine	ND	330		µg/Kg	1	7/1/2013 02:06 PM
Naphthalene	ND	330		µg/Kg	1	7/1/2013 02:06 PM
Nitrobenzene	ND	330		µg/Kg	1	7/1/2013 02:06 PM
Pentachlorophenol	ND	1700		µg/Kg	1	7/1/2013 02:06 PM
Phenanthrene	ND	330		µg/Kg	1	7/1/2013 02:06 PM
Phenol	ND	330		µg/Kg	1	7/1/2013 02:06 PM
Pyrene	ND	330		µg/Kg	1	7/1/2013 02:06 PM
Surr: 1,2-Dichlorobenzene-d4	51.3	23-120		%REC	1	7/1/2013 02:06 PM
Surr: 2,4,6-Tribromophenol	77.1	24-134		%REC	1	7/1/2013 02:06 PM
Surr: 2-Chlorophenol-d4	63.2	28-120		%REC	1	7/1/2013 02:06 PM
Surr: 2-Fluorobiphenyl	64.3	32-120		%REC	1	7/1/2013 02:06 PM
Surr: 2-Fluorophenol	63.2	29-120		%REC	1	7/1/2013 02:06 PM
Surr: 4-Terphenyl-d14	89.4	51-128		%REC	1	7/1/2013 02:06 PM

Qualifiers:
- B Analyte detected in the associated Method Blank
- H Holding times for preparation or analysis exceeded
- S Spike/Surrogate outside of limits due to matrix interference
- DO Surrogate Diluted Out
- E Value above quantitation range
- ND Not Detected at the Reporting Limit

Results are wet unless otherwise specified

CLIENT: Geocon Consultants, Inc.
Lab Order: N010467
Project: Caltrans-CrissyField Outfall, E8560-02-51
Lab ID: N010467-003

Client Sample ID: B7
Collection Date: 6/26/2013 8:10:00 AM
Matrix: SOIL

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
SEMIVOLATILE ORGANIC COMPOUNDS BY GC/MS						
EPA 3550B				**EPA 8270C**		
RunID: MS3_130701A	QC Batch: 43311			PrepDate:	6/28/2013	Analyst: **MDM**
Surr: Nitrobenzene-d5	68.8	29-120		%REC	1	7/1/2013 02:06 PM
Surr: Phenol-d5	65.1	28-120		%REC	1	7/1/2013 02:06 PM
VOLATILE ORGANIC COMPOUNDS BY GC/MS						
				EPA 8260B		
RunID: MS1_130627A	QC Batch: D13VS038			PrepDate:		Analyst: **QBM**
Benzene	ND	5.0		µg/Kg	1	6/27/2013 06:06 PM
Ethylbenzene	ND	5.0		µg/Kg	1	6/27/2013 06:06 PM
m,p-Xylene	ND	10		µg/Kg	1	6/27/2013 06:06 PM
o-Xylene	ND	5.0		µg/Kg	1	6/27/2013 06:06 PM
Toluene	ND	5.0		µg/Kg	1	6/27/2013 06:06 PM
Surr: 1,2-Dichloroethane-d4	87.9	63-139		%REC	1	6/27/2013 06:06 PM
Surr: 4-Bromofluorobenzene	83.1	75-124		%REC	1	6/27/2013 06:06 PM
Surr: Dibromofluoromethane	93.5	70-133		%REC	1	6/27/2013 06:06 PM
Surr: Toluene-d8	102	80-123		%REC	1	6/27/2013 06:06 PM
DIESEL & MOTOR OIL RANGE ORGANICS BY GC/FID						
EPA 3550B				**EPA 8015B**		
RunID: GC3_130701A	QC Batch: 43322			PrepDate:	7/1/2013	Analyst: **MDM**
DRO	5.6	1.0		mg/Kg	1	7/1/2013 06:04 PM
ORO	14	1.0		mg/Kg	1	7/1/2013 06:04 PM
Surr: p-Terphenyl	94.2	59-127		%REC	1	7/1/2013 06:04 PM
PCBS BY GC/ECD						
EPA 3550B				**EPA 8082**		
RunID: GC7_130702A	QC Batch: 43312			PrepDate:	6/28/2013	Analyst: **MDM**
Aroclor 1016	ND	17		µg/Kg	1	7/2/2013 03:31 PM
Aroclor 1221	ND	33		µg/Kg	1	7/2/2013 03:31 PM
Aroclor 1232	ND	17		µg/Kg	1	7/2/2013 03:31 PM
Aroclor 1242	ND	17		µg/Kg	1	7/2/2013 03:31 PM
Aroclor 1248	ND	17		µg/Kg	1	7/2/2013 03:31 PM
Aroclor 1254	ND	17		µg/Kg	1	7/2/2013 03:31 PM
Aroclor 1260	ND	17		µg/Kg	1	7/2/2013 03:31 PM
Surr: Decachlorobiphenyl	78.5	40-146		%REC	1	7/2/2013 03:31 PM
Surr: Tetrachloro-m-xylene	50.5	32-109		%REC	1	7/2/2013 03:31 PM

Qualifiers:
- B Analyte detected in the associated Method Blank
- H Holding times for preparation or analysis exceeded
- S Spike/Surrogate outside of limits due to matrix interference
- DO Surrogate Diluted Out
- E Value above quantitation range
- ND Not Detected at the Reporting Limit

Results are wet unless otherwise specified

Advanced Technology Laboratories, Inc.

ANALYTICAL RESULTS

Print Date: *08-Jul-13*

CLIENT: Geocon Consultants, Inc.
Lab Order: N010467
Project: Caltrans-CrissyField Outfall, E8560-02-51
Lab ID: N010467-003

Client Sample ID: B7
Collection Date: 6/26/2013 8:10:00 AM
Matrix: SOIL

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
GASOLINE RANGE ORGANICS BY GC/FID						
			EPA 8015B			
RunID: GC4_130627B	QC Batch: E13VS069			PrepDate:		Analyst: **QBM**
GRO	ND	1.0		mg/Kg	1	6/27/2013 04:06 PM
Surr: Chlorobenzene - d5	102	51-136		%REC	1	6/27/2013 04:06 PM
MERCURY BY COLD VAPOR TECHNIQUE						
	EPA 7471			**EPA 7471A**		
RunID: AA1_130627B	QC Batch: 43302			PrepDate:	6/27/2013	Analyst: **LCC**
Mercury	ND	0.10		mg/Kg	1	6/27/2013
ICP METALS						
	EPA 3050B			**EPA 6010B**		
RunID: ICP2_130708A	QC Batch: 43320			PrepDate:	7/1/2013	Analyst: **admin**
Antimony	ND	2.0		mg/Kg	1	7/8/2013 11:50 AM
Arsenic	2.5	1.0		mg/Kg	1	7/8/2013 11:50 AM
Barium	9.0	1.0		mg/Kg	1	7/8/2013 11:50 AM
Beryllium	ND	1.0		mg/Kg	1	7/8/2013 11:50 AM
Cadmium	ND	1.0		mg/Kg	1	7/8/2013 11:50 AM
Chromium	25	1.0		mg/Kg	1	7/8/2013 11:50 AM
Cobalt	4.6	1.0		mg/Kg	1	7/8/2013 11:50 AM
Copper	3.8	2.0		mg/Kg	1	7/8/2013 11:50 AM
Lead	3.8	1.0		mg/Kg	1	7/8/2013 11:50 AM
Molybdenum	ND	1.0		mg/Kg	1	7/8/2013 11:50 AM
Nickel	24	1.0		mg/Kg	1	7/8/2013 11:50 AM
Selenium	ND	1.0		mg/Kg	1	7/8/2013 11:50 AM
Silver	ND	1.0		mg/Kg	1	7/8/2013 11:50 AM
Thallium	ND	1.0		mg/Kg	1	7/8/2013 11:50 AM
Vanadium	16	1.0		mg/Kg	1	7/8/2013 11:50 AM
Zinc	19	1.0		mg/Kg	1	7/8/2013 11:50 AM

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range
H	Holding times for preparation or analysis exceeded	ND	Not Detected at the Reporting Limit
S	Spike/Surrogate outside of limits due to matrix interference		Results are wet unless otherwise specified
DO	Surrogate Diluted Out		

Advanced Technology Laboratories, Inc.
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ANALYTICAL RESULTS

Advanced Technology Laboratories, Inc.

Print Date: *08-Jul-13*

CLIENT:	Geocon Consultants, Inc.	**Client Sample ID:**	EB
Lab Order:	N010467	**Collection Date:**	6/26/2013 9:30:00 AM
Project:	Caltrans-CrissyField Outfall, E8560-02-51	**Matrix:**	WATER
Lab ID:	N010467-004		

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
ICP METALS						
	EPA 3010A			**EPA 6010B**		
RunID: ICP2_130703C	QC Batch: 43325			PrepDate:	7/1/2013	Analyst: **WLS**
Lead	ND	0.0050		mg/L	1	7/3/2013 01:34 PM

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range
H	Holding times for preparation or analysis exceeded	ND	Not Detected at the Reporting Limit
S	Spike/Surrogate outside of limits due to matrix interference		Results are wet unless otherwise specified
DO	Surrogate Diluted Out		

Advanced Technology Laboratories, Inc.

3151 W. Post Rd Las Vegas, NV 89118 Tel: 702-307-2659 Fax: 702-307-2691

CLIENT: Geocon Consultants, Inc.
Work Order: N010467
Project: Caltrans-CrissyField Outfall, E8560-02-51

ANALYTICAL QC SUMMARY REPORT

TestCode: 6010_S

Sample ID: **LCS-43320** SampType: **LCS** TestCode: **6010_S** Units: **mg/Kg** Prep Date: **7/1/2013** RunNo: **89481**
Client ID: **LCSS** Batch ID: **43320** TestNo: **EPA 6010B** **EPA 3050B** Analysis Date: **7/8/2013** SeqNo: **1606097**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Antimony	49.064	2.0	50.08	0	98.0	80	120				
Arsenic	48.088	1.0	50.08	0	96.0	80	120				
Barium	48.973	1.0	50.08	0	97.8	80	120				
Beryllium	47.754	1.0	50.08	0	95.4	80	120				
Cadmium	47.851	1.0	50.08	0	95.6	80	120				
Chromium	48.055	1.0	50.08	0	96.0	80	120				
Cobalt	47.024	1.0	50.08	0	93.9	80	120				
Copper	48.754	2.0	50.08	0	97.4	80	120				
Lead	49.212	1.0	50.08	0	98.3	80	120				
Molybdenum	49.812	1.0	50.08	0	99.5	80	120				
Nickel	46.314	1.0	50.08	0	92.5	80	120				
Selenium	43.543	1.0	50.08	0	87.0	80	120				
Silver	47.387	1.0	50.08	0	94.6	80	120				
Thallium	47.657	1.0	50.08	0	95.2	80	120				
Vanadium	49.162	1.0	50.08	0	98.2	80	120				
Zinc	47.124	1.0	50.08	0	94.1	80	120				

Sample ID: **N010478-001B-DUP** SampType: **DUP** TestCode: **6010_S** Units: **mg/Kg** Prep Date: **7/1/2013** RunNo: **89481**
Client ID: **ZZZZZZ** Batch ID: **43320** TestNo: **EPA 6010B** **EPA 3050B** Analysis Date: **7/8/2013** SeqNo: **1606099**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Antimony	ND	2.0						0	0	20	
Arsenic	3.371	1.0						3.293	2.35	20	
Barium	116.125	1.0						113.2	2.57	20	
Beryllium	0.179	1.0						0.1775	0	20	
Cadmium	ND	1.0						0	0	20	
Chromium	13.153	1.0						12.81	2.62	20	
Cobalt	5.009	1.0						4.778	4.73	20	

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range	H	Holding times for preparation or analysis exceeded
ND	Not Detected at the Reporting Limit	R	RPD outside accepted recovery limits	S	Spike/Surrogate outside of limits due to matrix interference
DO	Surrogate Diluted Out		Calculations are based on raw values		

CLIENT: Geocon Consultants, Inc.
Work Order: N010467
Project: Caltrans-CrissyField Outfall, E8560-02-51

ANALYTICAL QC SUMMARY REPORT

TestCode: 6010_S

Sample ID: **N010478-001B-DUP** SampType: **DUP** TestCode: **6010_S** Units: **mg/Kg** Prep Date: **7/1/2013** RunNo: **89481**
Client ID: **ZZZZZZ** Batch ID: **43320** TestNo: **EPA 6010B** **EPA 3050B** Analysis Date: **7/8/2013** SeqNo: **1606099**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Copper	8.084	2.0						7.762	4.06	20	
Lead	4.539	1.0						5.019	10.0	20	
Molybdenum	0.234	1.0						0.2296	0	20	
Nickel	10.852	1.0						10.67	1.68	20	
Selenium	ND	1.0						0	0	20	
Silver	ND	1.0						0	0	20	
Thallium	ND	1.0						0	0	20	
Vanadium	20.752	1.0						20.46	1.40	20	
Zinc	25.402	1.0						25.39	0.0635	20	

Sample ID: **N010478-001B-MS** SampType: **MS** TestCode: **6010_S** Units: **mg/Kg** Prep Date: **7/1/2013** RunNo: **89481**
Client ID: **ZZZZZZ** Batch ID: **43320** TestNo: **EPA 6010B** **EPA 3050B** Analysis Date: **7/8/2013** SeqNo: **1606102**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Antimony	34.978	2.0	50.05	0	69.9	75	125				S
Arsenic	47.485	1.0	50.05	3.293	88.3	75	125				
Barium	169.219	1.0	50.05	113.2	112	75	125				
Beryllium	43.128	1.0	50.05	0.1775	85.8	75	125				
Cadmium	40.882	1.0	50.05	0	81.7	75	125				
Chromium	56.081	1.0	50.05	12.81	86.4	75	125				
Cobalt	46.630	1.0	50.05	4.778	83.6	75	125				
Copper	53.647	2.0	50.05	7.762	91.7	75	125				
Lead	47.841	1.0	50.05	5.019	85.6	75	125				
Molybdenum	41.534	1.0	50.05	0.2296	82.5	75	125				
Nickel	51.169	1.0	50.05	10.67	80.9	75	125				
Selenium	39.535	1.0	50.05	0	79.0	75	125				
Silver	42.601	1.0	50.05	0	85.1	75	125				
Thallium	38.792	1.0	50.05	0	77.5	75	125				
Vanadium	67.829	1.0	50.05	20.46	94.6	75	125				
Zinc	69.990	1.0	50.05	25.39	89.1	75	125				

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range	H	Holding times for preparation or analysis exceeded
ND	Not Detected at the Reporting Limit	R	RPD outside accepted recovery limits	S	Spike/Surrogate outside of limits due to matrix interference
DO	Surrogate Diluted Out		Calculations are based on raw values		

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CLIENT: Geocon Consultants, Inc.
Work Order: N010467
Project: Caltrans-CrissyField Outfall, E8560-02-51

ANALYTICAL QC SUMMARY REPORT

TestCode: 6010_S

Sample ID: **N010478-001B-MSD** SampType: **MSD** TestCode: **6010_S** Units: **mg/Kg** Prep Date: **7/1/2013** RunNo: **89481**
Client ID: **ZZZZZZ** Batch ID: **43320** TestNo: **EPA 6010B** **EPA 3050B** Analysis Date: **7/8/2013** SeqNo: **1606103**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Antimony	34.502	2.0	50.23	0	68.7	75	125	34.98	1.37	20	S
Arsenic	48.194	1.0	50.23	3.293	89.4	75	125	47.48	1.48	20	
Barium	161.199	1.0	50.23	113.2	95.6	75	125	169.2	4.85	20	
Beryllium	43.337	1.0	50.23	0.1775	85.9	75	125	43.13	0.485	20	
Cadmium	41.072	1.0	50.23	0	81.8	75	125	40.88	0.466	20	
Chromium	56.244	1.0	50.23	12.81	86.5	75	125	56.08	0.290	20	
Cobalt	47.012	1.0	50.23	4.778	84.1	75	125	46.63	0.816	20	
Copper	53.893	2.0	50.23	7.762	91.8	75	125	53.65	0.458	20	
Lead	46.043	1.0	50.23	5.019	81.7	75	125	47.84	3.83	20	
Molybdenum	41.630	1.0	50.23	0.2296	82.4	75	125	41.53	0.231	20	
Nickel	51.924	1.0	50.23	10.67	82.1	75	125	51.17	1.47	20	
Selenium	40.055	1.0	50.23	0	79.7	75	125	39.54	1.30	20	
Silver	42.676	1.0	50.23	0	85.0	75	125	42.60	0.177	20	
Thallium	38.947	1.0	50.23	0	77.5	75	125	38.79	0.399	20	
Vanadium	68.699	1.0	50.23	20.46	96.0	75	125	67.83	1.28	20	
Zinc	70.931	1.0	50.23	25.39	90.7	75	125	69.99	1.33	20	

Sample ID: **MB2-43320** SampType: **MBLK** TestCode: **6010_S** Units: **mg/Kg** Prep Date: RunNo: **89481**
Client ID: **PBS** Batch ID: **43320** TestNo: **EPA 6010B** **EPA 3050B** Analysis Date: **7/8/2013** SeqNo: **1606113**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Antimony	ND	2.0									
Arsenic	ND	1.0									
Barium	ND	1.0									
Beryllium	ND	1.0									
Cadmium	ND	1.0									
Chromium	ND	1.0									
Cobalt	ND	1.0									
Copper	ND	2.0									
Lead	ND	1.0									

Qualifiers:

B Analyte detected in the associated Method Blank
ND Not Detected at the Reporting Limit
DO Surrogate Diluted Out
E Value above quantitation range
R RPD outside accepted recovery limits
Calculations are based on raw values
H Holding times for preparation or analysis exceeded
S Spike/Surrogate outside of limits due to matrix interference

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Work Order: N010467
Project: Caltrans-CrissyField Outfall, E8560-02-51

ANALYTICAL QC SUMMARY REPORT

TestCode: 6010_S

Sample ID: **MB2-43320** SampType: **MBLK** TestCode: **6010_S** Units: **mg/Kg** Prep Date: RunNo: **89481**
Client ID: **PBS** Batch ID: **43320** TestNo: **EPA 6010B** **EPA 3050B** Analysis Date: **7/8/2013** SeqNo: **1606113**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Molybdenum	ND	1.0									
Nickel	ND	1.0									
Selenium	ND	1.0									
Silver	ND	1.0									
Thallium	ND	1.0									
Vanadium	ND	1.0									
Zinc	ND	1.0									

Sample ID: **N010467-003B-DUP** SampType: **DUP** TestCode: **6010_S** Units: **mg/Kg** Prep Date: **7/1/2013** RunNo: **89481**
Client ID: **ZZZZZZ** Batch ID: **43320** TestNo: **EPA 6010B** **EPA 3050B** Analysis Date: **7/8/2013** SeqNo: **1606116**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Antimony	ND	2.0						0	0	20	
Arsenic	2.112	1.0						2.453	14.9	20	
Barium	9.594	1.0						9.006	6.32	20	
Beryllium	ND	1.0						0	0	20	
Cadmium	ND	1.0						0	0	20	
Chromium	22.816	1.0						24.86	8.59	20	
Cobalt	4.134	1.0						4.605	10.8	20	
Copper	3.532	2.0						3.755	6.12	20	
Lead	3.505	1.0						3.805	8.19	20	
Molybdenum	ND	1.0						0	0	20	
Nickel	23.860	1.0						24.49	2.60	20	
Selenium	ND	1.0						0	0	20	
Silver	ND	1.0						0	0	20	
Thallium	ND	1.0						0	0	20	
Vanadium	14.944	1.0						16.27	8.46	20	
Zinc	18.103	1.0						18.52	2.27	20	

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range	H	Holding times for preparation or analysis exceeded
ND	Not Detected at the Reporting Limit	R	RPD outside accepted recovery limits	S	Spike/Surrogate outside of limits due to matrix interference
DO	Surrogate Diluted Out		Calculations are based on raw values		

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Work Order: N010467
Project: Caltrans-CrissyField Outfall, E8560-02-51

ANALYTICAL QC SUMMARY REPORT

TestCode: 6010_S

Sample ID: **N010467-003B-MS** SampType: **MS** TestCode: **6010_S** Units: **mg/Kg** Prep Date: **7/1/2013** RunNo: **89481**
Client ID: **ZZZZZZ** Batch ID: **43320** TestNo: **EPA 6010B** **EPA 3050B** Analysis Date: **7/8/2013** SeqNo: **1606117**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Antimony	40.172	2.0	49.98	0	80.4	75	125				
Arsenic	49.194	1.0	49.98	2.453	93.5	75	125				
Barium	58.341	1.0	49.98	9.006	98.7	75	125				
Beryllium	44.862	1.0	49.98	0	89.8	75	125				
Cadmium	44.145	1.0	49.98	0	88.3	75	125				
Chromium	76.660	1.0	49.98	24.86	104	75	125				
Cobalt	48.256	1.0	49.98	4.605	87.3	75	125				
Copper	51.751	2.0	49.98	3.755	96.0	75	125				
Lead	48.536	1.0	49.98	3.805	89.5	75	125				
Molybdenum	44.772	1.0	49.98	0	89.6	75	125				
Nickel	70.568	1.0	49.98	24.49	92.2	75	125				
Selenium	41.402	1.0	49.98	0	82.8	75	125				
Silver	44.445	1.0	49.98	0	88.9	75	125				
Thallium	42.005	1.0	49.98	0	84.1	75	125				
Vanadium	66.136	1.0	49.98	16.27	99.8	75	125				
Zinc	61.930	1.0	49.98	18.52	86.9	75	125				

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range	H	Holding times for preparation or analysis exceeded
ND	Not Detected at the Reporting Limit	R	RPD outside accepted recovery limits	S	Spike/Surrogate outside of limits due to matrix interference
DO	Surrogate Diluted Out		Calculations are based on raw values		

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Project: Caltrans-CrissyField Outfall, E8560-02-51

ANALYTICAL QC SUMMARY REPORT

TestCode: 6010_W

Sample ID: **MB-43325** SampType: **MBLK** TestCode: **6010_W** Units: **mg/L** Prep Date: **7/1/2013** RunNo: **89462**
Client ID: **PBW** Batch ID: **43325** TestNo: **EPA 6010B** **EPA 3010A** Analysis Date: **7/3/2013** SeqNo: **1605051**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Lead	ND	0.0050									

Sample ID: **LCS-43325** SampType: **LCS** TestCode: **6010_W** Units: **mg/L** Prep Date: **7/1/2013** RunNo: **89462**
Client ID: **LCSW** Batch ID: **43325** TestNo: **EPA 6010B** **EPA 3010A** Analysis Date: **7/3/2013** SeqNo: **1605052**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Lead	0.493	0.0050	0.5000	0	98.6	85	115				

Sample ID: **N010467-004A-MS** SampType: **MS** TestCode: **6010_W** Units: **mg/L** Prep Date: **7/1/2013** RunNo: **89462**
Client ID: **ZZZZZZ** Batch ID: **43325** TestNo: **EPA 6010B** **EPA 3010A** Analysis Date: **7/3/2013** SeqNo: **1605056**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Lead	0.488	0.0050	0.5000	0.003660	96.9	75	125				

Sample ID: **N010467-004A-MSD** SampType: **MSD** TestCode: **6010_W** Units: **mg/L** Prep Date: **7/1/2013** RunNo: **89462**
Client ID: **ZZZZZZ** Batch ID: **43325** TestNo: **EPA 6010B** **EPA 3010A** Analysis Date: **7/3/2013** SeqNo: **1605057**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Lead	0.488	0.0050	0.5000	0.003660	96.9	75	125	0.4880	0.00560	20	

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range	H	Holding times for preparation or analysis exceeded
ND	Not Detected at the Reporting Limit	R	RPD outside accepted recovery limits	S	Spike/Surrogate outside of limits due to matrix interference
DO	Surrogate Diluted Out		Calculations are based on raw values		

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ANALYTICAL QC SUMMARY REPORT

TestCode: 7471_S

Sample ID: **LCS-43302** SampType: **LCS** TestCode: **7471_S** Units: **mg/Kg** Prep Date: **6/27/2013** RunNo: **89390**
Client ID: **LCSS** Batch ID: **43302** TestNo: **EPA 7471A** **EPA 7471** Analysis Date: **6/27/2013** SeqNo: **1601278**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Mercury	0.481	0.10	0.4167	0	115	80	120				

Sample ID: **MB-43302** SampType: **MBLK** TestCode: **7471_S** Units: **mg/Kg** Prep Date: **6/27/2013** RunNo: **89390**
Client ID: **PBS** Batch ID: **43302** TestNo: **EPA 7471A** **EPA 7471** Analysis Date: **6/27/2013** SeqNo: **1601279**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Mercury	ND	0.10									

Sample ID: **N010467-001B-DUP** SampType: **DUP** TestCode: **7471_S** Units: **mg/Kg** Prep Date: **6/27/2013** RunNo: **89390**
Client ID: **ZZZZZZ** Batch ID: **43302** TestNo: **EPA 7471A** **EPA 7471** Analysis Date: **6/27/2013** SeqNo: **1601281**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Mercury	ND	0.10						0.03941	0	20	

Sample ID: **N010467-001B-MS** SampType: **MS** TestCode: **7471_S** Units: **mg/Kg** Prep Date: **6/27/2013** RunNo: **89390**
Client ID: **ZZZZZZ** Batch ID: **43302** TestNo: **EPA 7471A** **EPA 7471** Analysis Date: **6/27/2013** SeqNo: **1601282**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Mercury	0.496	0.10	0.4181	0.03941	109	75	125				

Sample ID: **N010467-001B-MSD** SampType: **MSD** TestCode: **7471_S** Units: **mg/Kg** Prep Date: **6/27/2013** RunNo: **89390**
Client ID: **ZZZZZZ** Batch ID: **43302** TestNo: **EPA 7471A** **EPA 7471** Analysis Date: **6/27/2013** SeqNo: **1601283**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Mercury	0.491	0.10	0.4167	0.03941	108	75	125	0.4957	1.04	20	

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range	H	Holding times for preparation or analysis exceeded
ND	Not Detected at the Reporting Limit	R	RPD outside accepted recovery limits	S	Spike/Surrogate outside of limits due to matrix interference
DO	Surrogate Diluted Out		Calculations are based on raw values		

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Project: Caltrans-CrissyField Outfall, E8560-02-51

ANALYTICAL QC SUMMARY REPORT

TestCode: 8015_S_DM LL

Sample ID: **LCS-43322** SampType: **LCS** TestCode: **8015_S_DM L** Units: **mg/Kg** Prep Date: **7/1/2013** RunNo: **89430**
Client ID: **LCSS** Batch ID: **43322** TestNo: **EPA 8015B** **EPA 3550B** Analysis Date: **7/1/2013** SeqNo: **1602896**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
DRO	63.133	1.0	83.30	0	75.8	52	126				
Surr: p-Terphenyl	6.780		6.670		102	59	127				

Sample ID: **N010479-003A-DUP** SampType: **DUP** TestCode: **8015_S_DM L** Units: **mg/Kg** Prep Date: **7/1/2013** RunNo: **89430**
Client ID: **ZZZZZZ** Batch ID: **43322** TestNo: **EPA 8015B** **EPA 3550B** Analysis Date: **7/1/2013** SeqNo: **1602901**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
DRO	1.851	1.0						2.585	33.1	20	R
ORO	3.776	1.0						5.067	29.2	20	R
Surr: p-Terphenyl	6.224		6.672		93.3	59	127		0		

Sample ID: **N010467-003A-MS** SampType: **MS** TestCode: **8015_S_DM L** Units: **mg/Kg** Prep Date: **7/1/2013** RunNo: **89430**
Client ID: **ZZZZZZ** Batch ID: **43322** TestNo: **EPA 8015B** **EPA 3550B** Analysis Date: **7/1/2013** SeqNo: **1602905**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
DRO	69.433	1.0	83.11	5.620	76.8	13	129				
Surr: p-Terphenyl	7.405		6.654		111	59	127				

Sample ID: **N010467-003A-MSD** SampType: **MSD** TestCode: **8015_S_DM L** Units: **mg/Kg** Prep Date: **7/1/2013** RunNo: **89430**
Client ID: **ZZZZZZ** Batch ID: **43322** TestNo: **EPA 8015B** **EPA 3550B** Analysis Date: **7/1/2013** SeqNo: **1602906**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
DRO	67.352	1.0	83.44	5.620	74.0	13	129	69.43	3.04	20	
Surr: p-Terphenyl	7.668		6.681		115	59	127		0		

Sample ID: **MB-43322** SampType: **MBLK** TestCode: **8015_S_DM L** Units: **mg/Kg** Prep Date: **7/1/2013** RunNo: **89430**
Client ID: **PBS** Batch ID: **43322** TestNo: **EPA 8015B** **EPA 3550B** Analysis Date: **7/1/2013** SeqNo: **1602907**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range	H	Holding times for preparation or analysis exceeded
ND	Not Detected at the Reporting Limit	R	RPD outside accepted recovery limits	S	Spike/Surrogate outside of limits due to matrix interference
DO	Surrogate Diluted Out		Calculations are based on raw values		

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ANALYTICAL QC SUMMARY REPORT

TestCode: 8015_S_DM LL

Sample ID: **MB-43322** SampType: **MBLK** TestCode: **8015_S_DM L** Units: **mg/Kg** Prep Date: **7/1/2013** RunNo: **89430**
Client ID: **PBS** Batch ID: **43322** TestNo: **EPA 8015B** **EPA 3550B** Analysis Date: **7/1/2013** SeqNo: **1602907**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
DRO	ND	1.0									
ORO	ND	1.0									
Surr: p-Terphenyl	7.320		6.670		110	59	127				

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range	H	Holding times for preparation or analysis exceeded
ND	Not Detected at the Reporting Limit	R	RPD outside accepted recovery limits	S	Spike/Surrogate outside of limits due to matrix interference
DO	Surrogate Diluted Out		Calculations are based on raw values		

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Project: Caltrans-CrissyField Outfall, E8560-02-51

ANALYTICAL QC SUMMARY REPORT

TestCode: 8015GAS_S

Sample ID: **E130627BLCS** SampType: **LCS** TestCode: **8015GAS_S** Units: **mg/Kg** Prep Date: RunNo: **89398**
Client ID: **LCSS** Batch ID: **E13VS069** TestNo: **EPA 8015B** Analysis Date: **6/27/2013** SeqNo: **1601404**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
GRO	5.000	1.0	5.000	0	100	77	122				
Surr: Chlorobenzene - d5	98.054		100.0		98.1	51	136				

Sample ID: **E130627BMB1** SampType: **MBLK** TestCode: **8015GAS_S** Units: **mg/Kg** Prep Date: RunNo: **89398**
Client ID: **PBS** Batch ID: **E13VS069** TestNo: **EPA 8015B** Analysis Date: **6/27/2013** SeqNo: **1601406**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
GRO	0.063	1.0									
Surr: Chlorobenzene - d5	100.221		100.0		100	51	136				

Sample ID: **N010467-003ADUP** SampType: **DUP** TestCode: **8015GAS_S** Units: **mg/Kg** Prep Date: RunNo: **89398**
Client ID: **ZZZZZZ** Batch ID: **E13VS069** TestNo: **EPA 8015B** Analysis Date: **6/27/2013** SeqNo: **1601410**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
GRO	0.054	1.0						0.05500	0	20	
Surr: Chlorobenzene - d5	102.900		100.0		103	51	136		0		

Sample ID: **N010467-002AMS** SampType: **MS** TestCode: **8015GAS_S** Units: **mg/Kg** Prep Date: RunNo: **89398**
Client ID: **ZZZZZZ** Batch ID: **E13VS069** TestNo: **EPA 8015B** Analysis Date: **6/27/2013** SeqNo: **1601497**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
GRO	4.602	1.0	5.000	0.05300	91.0	41	132				
Surr: Chlorobenzene - d5	90.002		100.0		90.0	51	136				

Sample ID: **N010467-002AMSD** SampType: **MSD** TestCode: **8015GAS_S** Units: **mg/Kg** Prep Date: RunNo: **89398**
Client ID: **ZZZZZZ** Batch ID: **E13VS069** TestNo: **EPA 8015B** Analysis Date: **6/27/2013** SeqNo: **1601498**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
GRO	4.219	1.0	5.000	0.05300	83.3	41	132	4.602	8.68	20	

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range	H	Holding times for preparation or analysis exceeded
ND	Not Detected at the Reporting Limit	R	RPD outside accepted recovery limits	S	Spike/Surrogate outside of limits due to matrix interference
DO	Surrogate Diluted Out		Calculations are based on raw values		

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ANALYTICAL QC SUMMARY REPORT

TestCode: 8015GAS_S

Sample ID: **N010467-002AMSD** SampType: **MSD** TestCode: **8015GAS_S** Units: **mg/Kg** Prep Date: RunNo: **89398**
Client ID: **ZZZZZZ** Batch ID: **E13VS069** TestNo: **EPA 8015B** Analysis Date: **6/27/2013** SeqNo: **1601498**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Surr: Chlorobenzene - d5	90.265		100.0		90.3	51	136		0		

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range	H	Holding times for preparation or analysis exceeded
ND	Not Detected at the Reporting Limit	R	RPD outside accepted recovery limits	S	Spike/Surrogate outside of limits due to matrix interference
DO	Surrogate Diluted Out		Calculations are based on raw values		

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Project: Caltrans-CrissyField Outfall, E8560-02-51

ANALYTICAL QC SUMMARY REPORT

TestCode: 8082_S

Sample ID: **LCS-43312** SampType: **LCS** TestCode: **8082_S** Units: **µg/Kg** Prep Date: **6/28/2013** RunNo: **89465**
Client ID: **LCSS** Batch ID: **43312** TestNo: **EPA 8082** **EPA 3550B** Analysis Date: **7/2/2013** SeqNo: **1604395**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Aroclor 1016	131.470	16	166.7	0	78.9	56	121				
Aroclor 1260	142.042	16	166.7	0	85.2	62	121				
Surr: Decachlorobiphenyl	15.840		16.67		95.0	40	146				
Surr: Tetrachloro-m-xylene	10.386		16.67		62.3	32	109				

Sample ID: **MB-43312** SampType: **MBLK** TestCode: **8082_S** Units: **µg/Kg** Prep Date: **6/28/2013** RunNo: **89465**
Client ID: **PBS** Batch ID: **43312** TestNo: **EPA 8082** **EPA 3550B** Analysis Date: **7/2/2013** SeqNo: **1604396**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Aroclor 1016	ND	16									
Aroclor 1221	ND	33									
Aroclor 1232	ND	16									
Aroclor 1242	ND	16									
Aroclor 1248	ND	16									
Aroclor 1254	ND	16									
Aroclor 1260	ND	16									
Surr: Decachlorobiphenyl	16.076		16.67		96.4	40	146				
Surr: Tetrachloro-m-xylene	10.276		16.67		61.6	32	109				

Sample ID: **N010467-002A-DUP** SampType: **DUP** TestCode: **8082_S** Units: **µg/Kg** Prep Date: **6/28/2013** RunNo: **89465**
Client ID: **ZZZZZZ** Batch ID: **43312** TestNo: **EPA 8082** **EPA 3550B** Analysis Date: **7/2/2013** SeqNo: **1604399**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Aroclor 1016	ND	17						0	0	20	
Aroclor 1221	ND	33						0	0	20	
Aroclor 1232	ND	17						0	0	20	
Aroclor 1242	ND	17						0	0	20	
Aroclor 1248	ND	17						0	0	20	
Aroclor 1254	ND	17						0	0	20	
Aroclor 1260	ND	17						0	0	20	

Qualifiers:

B Analyte detected in the associated Method Blank
ND Not Detected at the Reporting Limit
DO Surrogate Diluted Out
E Value above quantitation range
R RPD outside accepted recovery limits
Calculations are based on raw values
H Holding times for preparation or analysis exceeded
S Spike/Surrogate outside of limits due to matrix interference

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ANALYTICAL QC SUMMARY REPORT

TestCode: 8082_S

Sample ID: **N010467-002A-DUP** SampType: **DUP** TestCode: **8082_S** Units: **µg/Kg** Prep Date: **6/28/2013** RunNo: **89465**
Client ID: **ZZZZZZ** Batch ID: **43312** TestNo: **EPA 8082** **EPA 3550B** Analysis Date: **7/2/2013** SeqNo: **1604399**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Surr: Decachlorobiphenyl	11.095		16.69		66.5	40	146		0		
Surr: Tetrachloro-m-xylene	9.047		16.69		54.2	32	109		0		

Sample ID: **N010478-002I-MS** SampType: **MS** TestCode: **8082_S** Units: **µg/Kg** Prep Date: **6/28/2013** RunNo: **89465**
Client ID: **ZZZZZZ** Batch ID: **43312** TestNo: **EPA 8082** **EPA 3550B** Analysis Date: **7/2/2013** SeqNo: **1604402**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Aroclor 1016	154.596	16	166.6	0	92.8	43	142				
Aroclor 1260	146.558	16	166.6	0	88.0	34	146				
Surr: Decachlorobiphenyl	14.316		16.66		85.9	40	146				
Surr: Tetrachloro-m-xylene	9.900		16.66		59.4	32	109				

Sample ID: **N010478-002I-MSD** SampType: **MSD** TestCode: **8082_S** Units: **µg/Kg** Prep Date: **6/28/2013** RunNo: **89465**
Client ID: **ZZZZZZ** Batch ID: **43312** TestNo: **EPA 8082** **EPA 3550B** Analysis Date: **7/2/2013** SeqNo: **1604403**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Aroclor 1016	158.651	17	166.9	0	95.1	43	142	154.6	2.59	20	
Aroclor 1260	151.469	17	166.9	0	90.8	34	146	146.6	3.30	20	
Surr: Decachlorobiphenyl	14.887		16.69		89.2	40	146		0		
Surr: Tetrachloro-m-xylene	9.969		16.69		59.7	32	109		0		

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range	H	Holding times for preparation or analysis exceeded
ND	Not Detected at the Reporting Limit	R	RPD outside accepted recovery limits	S	Spike/Surrogate outside of limits due to matrix interference
DO	Surrogate Diluted Out		Calculations are based on raw values		

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ANALYTICAL QC SUMMARY REPORT

TestCode: 8260SOIL

Sample ID: **D130627LCS** SampType: **LCS** TestCode: **8260SOIL** Units: **µg/Kg** Prep Date: RunNo: **89410**
Client ID: **LCSS** Batch ID: **D13VS038** TestNo: **EPA 8260B** Analysis Date: **6/27/2013** SeqNo: **1602248**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Benzene	37.950	5.0	40.00	0	94.9	80	120				
Ethylbenzene	38.770	5.0	40.00	0	96.9	80	120				
m,p-Xylene	81.240	10	80.00	0	102	80	121				
o-Xylene	41.660	5.0	40.00	0	104	80	120				
Toluene	37.900	5.0	40.00	0	94.8	80	120				
Surr: 1,2-Dichloroethane-d4	46.040		50.00		92.1	63	139				
Surr: 4-Bromofluorobenzene	51.130		50.00		102	75	124				
Surr: Dibromofluoromethane	49.120		50.00		98.2	70	133				
Surr: Toluene-d8	48.840		50.00		97.7	80	123				

Sample ID: **N010442-008AMS** SampType: **MS** TestCode: **8260SOIL** Units: **µg/Kg** Prep Date: RunNo: **89410**
Client ID: **ZZZZZZ** Batch ID: **D13VS038** TestNo: **EPA 8260B** Analysis Date: **6/27/2013** SeqNo: **1602249**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Benzene	41.640	5.0	40.00	0	104	72	122				
Ethylbenzene	39.130	5.0	40.00	0	97.8	65	120				
m,p-Xylene	83.500	10	80.00	0	104	65	120				
o-Xylene	44.150	5.0	40.00	0	110	67	118				
Toluene	40.190	5.0	40.00	0	100	68	120				
Surr: 1,2-Dichloroethane-d4	56.210		50.00		112	63	139				
Surr: 4-Bromofluorobenzene	53.870		50.00		108	75	124				
Surr: Dibromofluoromethane	55.220		50.00		110	70	133				
Surr: Toluene-d8	49.760		50.00		99.5	80	123				

Sample ID: **N010442-008AMSD** SampType: **MSD** TestCode: **8260SOIL** Units: **µg/Kg** Prep Date: RunNo: **89410**
Client ID: **ZZZZZZ** Batch ID: **D13VS038** TestNo: **EPA 8260B** Analysis Date: **6/27/2013** SeqNo: **1602250**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Benzene	39.420	5.0	40.00	0	98.6	72	122	41.64	5.48	20	
Ethylbenzene	35.990	5.0	40.00	0	90.0	65	120	39.13	8.36	20	

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range	H	Holding times for preparation or analysis exceeded
ND	Not Detected at the Reporting Limit	R	RPD outside accepted recovery limits	S	Spike/Surrogate outside of limits due to matrix interference
DO	Surrogate Diluted Out		Calculations are based on raw values		

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ANALYTICAL QC SUMMARY REPORT

TestCode: 8260SOIL

Sample ID: **N010442-008AMSD** SampType: **MSD** TestCode: **8260SOIL** Units: **µg/Kg** Prep Date: RunNo: **89410**
Client ID: **ZZZZZZ** Batch ID: **D13VS038** TestNo: **EPA 8260B** Analysis Date: **6/27/2013** SeqNo: **1602250**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
m,p-Xylene	76.050	10	80.00	0	95.1	65	120	83.50	9.34	20	
o-Xylene	40.250	5.0	40.00	0	101	67	118	44.15	9.24	20	
Toluene	38.780	5.0	40.00	0	97.0	68	120	40.19	3.57	20	
Surr: 1,2-Dichloroethane-d4	52.540		50.00		105	63	139		0		
Surr: 4-Bromofluorobenzene	51.300		50.00		103	75	124		0		
Surr: Dibromofluoromethane	52.550		50.00		105	70	133		0		
Surr: Toluene-d8	50.290		50.00		101	80	123		0		

Sample ID: **N010442-013AMS** SampType: **MS** TestCode: **8260SOIL** Units: **µg/Kg** Prep Date: RunNo: **89410**
Client ID: **ZZZZZZ** Batch ID: **D13VS038** TestNo: **EPA 8260B** Analysis Date: **6/27/2013** SeqNo: **1602251**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Benzene	40.050	5.0	40.00	0	100	72	122				
Ethylbenzene	37.300	5.0	40.00	0	93.3	65	120				
m,p-Xylene	78.830	10	80.00	0	98.5	65	120				
o-Xylene	41.050	5.0	40.00	0	103	67	118				
Toluene	38.810	5.0	40.00	0	97.0	68	120				
Surr: 1,2-Dichloroethane-d4	52.430		50.00		105	63	139				
Surr: 4-Bromofluorobenzene	52.960		50.00		106	75	124				
Surr: Dibromofluoromethane	54.280		50.00		109	70	133				
Surr: Toluene-d8	50.430		50.00		101	80	123				

Sample ID: **D130627MB3** SampType: **MBLK** TestCode: **8260SOIL** Units: **µg/Kg** Prep Date: RunNo: **89410**
Client ID: **PBS** Batch ID: **D13VS038** TestNo: **EPA 8260B** Analysis Date: **6/27/2013** SeqNo: **1602254**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Benzene	ND	5.0									
Ethylbenzene	ND	5.0									
m,p-Xylene	ND	10									
o-Xylene	ND	5.0									

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range	H	Holding times for preparation or analysis exceeded
ND	Not Detected at the Reporting Limit	R	RPD outside accepted recovery limits	S	Spike/Surrogate outside of limits due to matrix interference
DO	Surrogate Diluted Out		Calculations are based on raw values		

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ANALYTICAL QC SUMMARY REPORT

TestCode: 8260SOIL

Sample ID: **D130627MB3** SampType: **MBLK** TestCode: **8260SOIL** Units: **µg/Kg** Prep Date: RunNo: **89410**
Client ID: **PBS** Batch ID: **D13VS038** TestNo: **EPA 8260B** Analysis Date: **6/27/2013** SeqNo: **1602254**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Toluene	ND	5.0									
Surr: 1,2-Dichloroethane-d4	44.500		50.00		89.0	63	139				
Surr: 4-Bromofluorobenzene	47.820		50.00		95.6	75	124				
Surr: Dibromofluoromethane	45.090		50.00		90.2	70	133				
Surr: Toluene-d8	48.930		50.00		97.9	80	123				

Sample ID: **N010442-018ADUP** SampType: **DUP** TestCode: **8260SOIL** Units: **µg/Kg** Prep Date: RunNo: **89410**
Client ID: **ZZZZZZ** Batch ID: **D13VS038** TestNo: **EPA 8260B** Analysis Date: **6/27/2013** SeqNo: **1602262**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Benzene	ND	5.0						0	0	20	
Ethylbenzene	ND	5.0						0	0	20	
m,p-Xylene	ND	10						0	0	20	
o-Xylene	ND	5.0						0	0	20	
Toluene	ND	5.0						0	0	20	
Surr: 1,2-Dichloroethane-d4	49.830		50.00		99.7	63	139		0		
Surr: 4-Bromofluorobenzene	51.800		50.00		104	75	124		0		
Surr: Dibromofluoromethane	50.120		50.00		100	70	133		0		
Surr: Toluene-d8	50.680		50.00		101	80	123		0		

Sample ID: **N010467-001ADUP** SampType: **DUP** TestCode: **8260SOIL** Units: **µg/Kg** Prep Date: RunNo: **89410**
Client ID: **ZZZZZZ** Batch ID: **D13VS038** TestNo: **EPA 8260B** Analysis Date: **6/27/2013** SeqNo: **1602269**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Benzene	ND	5.0						0	0	20	
Ethylbenzene	ND	5.0						0	0	20	
m,p-Xylene	ND	10						0	0	20	
o-Xylene	ND	5.0						0	0	20	
Toluene	ND	5.0						0	0	20	
Surr: 1,2-Dichloroethane-d4	44.940		50.00		89.9	63	139		0		

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range	H	Holding times for preparation or analysis exceeded
ND	Not Detected at the Reporting Limit	R	RPD outside accepted recovery limits	S	Spike/Surrogate outside of limits due to matrix interference
DO	Surrogate Diluted Out		Calculations are based on raw values		

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ANALYTICAL QC SUMMARY REPORT

TestCode: 8260SOIL

Sample ID: **N010467-001ADUP** SampType: **DUP** TestCode: **8260SOIL** Units: **µg/Kg** Prep Date: RunNo: **89410**
Client ID: **ZZZZZZ** Batch ID: **D13VS038** TestNo: **EPA 8260B** Analysis Date: **6/27/2013** SeqNo: **1602269**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Surr: 4-Bromofluorobenzene	44.160		50.00		88.3	75	124		0		
Surr: Dibromofluoromethane	50.110		50.00		100	70	133		0		
Surr: Toluene-d8	52.110		50.00		104	80	123		0		

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range	H	Holding times for preparation or analysis exceeded
ND	Not Detected at the Reporting Limit	R	RPD outside accepted recovery limits	S	Spike/Surrogate outside of limits due to matrix interference
DO	Surrogate Diluted Out		Calculations are based on raw values		

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ANALYTICAL QC SUMMARY REPORT

TestCode: 8270SOIL

Sample ID: **LCS-43311** SampType: **LCS** TestCode: **8270SOIL** Units: **µg/Kg** Prep Date: **6/28/2013** RunNo: **89421**
Client ID: **LCSS** Batch ID: **43311** TestNo: **EPA 8270C** **EPA 3550B** Analysis Date: **7/1/2013** SeqNo: **1602695**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
1,2,4-Trichlorobenzene	2235.667	330	3330	0	67.1	36	120				
1,2-Dichlorobenzene	2046.667	330	3330	0	61.5	32	120				
1,3-Dichlorobenzene	1902.333	330	3330	0	57.1	31	120				
1,4-Dichlorobenzene	1959.333	330	3330	0	58.8	32	120				
2,4,5-Trichlorophenol	2632.333	330	3330	0	79.0	53	120				
2,4,6-Trichlorophenol	2597.667	330	3330	0	78.0	47	120				
2,4-Dichlorophenol	2362.667	1600	3330	0	71.0	43	120				
2,4-Dimethylphenol	2488.000	330	3330	0	74.7	41	120				
2,4-Dinitrophenol	2350.667	1600	3330	0	70.6	30	138				
2,4-Dinitrotoluene	2747.000	330	3330	0	82.5	56	120				
2,6-Dinitrotoluene	2602.333	330	3330	0	78.1	54	120				
2-Chloronaphthalene	2353.667	330	3330	0	70.7	41	120				
2-Chlorophenol	2257.000	330	3330	0	67.8	37	120				
2-Methylnaphthalene	2250.000	330	3330	0	67.6	34	121				
2-Methylphenol	2618.333	330	3330	0	78.6	37	120				
2-Nitroaniline	3231.667	1600	3330	0	97.0	58	122				
2-Nitrophenol	2327.000	330	3330	0	69.9	39	120				
3,3´-Dichlorobenzidine	4457.333	660	6660	0	66.9	43	120				
3-Nitroaniline	2667.667	1600	3330	0	80.1	59	120				
4,6-Dinitro-2-methylphenol	2670.000	1600	3330	0	80.2	55	126				
4-Bromophenyl-phenylether	2894.667	330	3330	0	86.9	57	120				
4-Chloro-3-methylphenol	2796.333	660	3330	0	84.0	50	120				
4-Chloroaniline	2060.333	660	3330	0	61.9	35	120				
4-Chlorophenyl-phenylether	2719.000	330	3330	0	81.7	49	120				
4-Methylphenol	2504.667	330	3330	0	75.2	43	120				
4-Nitroaniline	2413.333	1600	3330	0	72.5	52	121				
4-Nitrophenol	3255.333	1600	3330	0	97.8	45	121				
Acenaphthene	2444.333	330	3330	0	73.4	47	120				
Acenaphthylene	2589.667	330	3330	0	77.8	48	121				
Anthracene	2778.333	330	3330	0	83.4	52	126				

Qualifiers:

B Analyte detected in the associated Method Blank
ND Not Detected at the Reporting Limit
DO Surrogate Diluted Out
E Value above quantitation range
R RPD outside accepted recovery limits
Calculations are based on raw values
H Holding times for preparation or analysis exceeded
S Spike/Surrogate outside of limits due to matrix interference

Advanced Technology Laboratories, Inc.
3151 W. Post Rd Las Vegas, NV 89118 Tel: 702-307-2659 Fax: 702-307-2691

CLIENT: Geocon Consultants, Inc.
Work Order: N010467
Project: Caltrans-CrissyField Outfall, E8560-02-51

ANALYTICAL QC SUMMARY REPORT

TestCode: 8270SOIL

Sample ID: **LCS-43311** SampType: **LCS** TestCode: **8270SOIL** Units: **µg/Kg** Prep Date: **6/28/2013** RunNo: **89421**
Client ID: **LCSS** Batch ID: **43311** TestNo: **EPA 8270C** **EPA 3550B** Analysis Date: **7/1/2013** SeqNo: **1602695**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Benzidine (M)	3871.667	1600	6660	0	58.1	3	143				
Benzo(a)anthracene	2693.000	330	3330	0	80.9	63	132				
Benzo(a)pyrene	2650.000	330	3330	0	79.6	34	132				
Benzo(b)fluoranthene	2888.333	330	3330	0	86.7	61	141				
Benzo(g,h,i)perylene	2817.333	330	3330	0	84.6	61	139				
Benzo(k)fluoranthene	2620.667	330	3330	0	78.7	58	141				
Benzoic acid	1791.667	1600	3330	0	53.8	23	120				
Benzyl alcohol	2345.667	660	3330	0	70.4	37	120				
Bis(2-chloroethoxy)methane	2547.000	330	3330	0	76.5	45	120				
Bis(2-chloroethyl)ether	2342.333	330	3330	0	70.3	36	120				
Bis(2-chloroisopropyl)ether	2490.000	330	3330	0	74.8	30	120				
Bis(2-ethylhexyl)phthalate	3237.000	330	3330	0	97.2	65	135				
Butylbenzylphthalate	3303.000	330	3330	0	99.2	37	137				
Chrysene	2806.000	330	3330	0	84.3	58	145				
Di-n-butylphthalate	3220.667	330	3330	0	96.7	56	129				
Di-n-octylphthalate	3576.333	330	3330	0	107	58	146				
Dibenz(a,h)anthracene	3035.667	330	3330	0	91.2	48	120				
Dibenzofuran	2515.333	330	3330	0	75.5	50	131				
Diethylphthalate	3191.333	330	3330	0	95.8	54	120				
Dimethylphthalate	2970.333	330	3330	0	89.2	63	139				
Fluoranthene	2862.333	330	3330	0	86.0	57	133				
Fluorene	2630.667	330	3330	0	79.0	50	123				
Hexachlorobenzene	2800.333	330	3330	0	84.1	56	120				
Hexachlorobutadiene	2529.000	660	3330	0	75.9	36	120				
Hexachlorocyclopentadiene	2376.667	660	3330	0	71.4	29	120				
Hexachloroethane	2119.333	330	3330	0	63.6	32	120				
Indeno(1,2,3-cd)pyrene	2925.000	330	3330	0	87.8	64	136				
Isophorone	2381.000	330	3330	0	71.5	49	120				
N-Nitrosodi-n-propylamine	2696.333	330	3330	0	81.0	43	120				
N-Nitrosodiphenylamine	2927.333	330	3330	0	87.9	62	120				

Qualifiers:

B Analyte detected in the associated Method Blank
ND Not Detected at the Reporting Limit
DO Surrogate Diluted Out
E Value above quantitation range
R RPD outside accepted recovery limits
Calculations are based on raw values
H Holding times for preparation or analysis exceeded
S Spike/Surrogate outside of limits due to matrix interference

Advanced Technology Laboratories, Inc.
3151 W. Post Rd Las Vegas, NV 89118 Tel: 702-307-2659 Fax: 702-307-2691

CLIENT: Geocon Consultants, Inc.
Work Order: N010467
Project: Caltrans-CrissyField Outfall, E8560-02-51

ANALYTICAL QC SUMMARY REPORT

TestCode: 8270SOIL

Sample ID: **LCS-43311** SampType: **LCS** TestCode: **8270SOIL** Units: **µg/Kg** Prep Date: **6/28/2013** RunNo: **89421**
Client ID: **LCSS** Batch ID: **43311** TestNo: **EPA 8270C** **EPA 3550B** Analysis Date: **7/1/2013** SeqNo: **1602695**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Naphthalene	2212.000	330	3330	0	66.4	40	120				
Nitrobenzene	2456.000	330	3330	0	73.8	38	120				
Pentachlorophenol	2574.667	1600	3330	0	77.3	46	120				
Phenanthrene	2732.667	330	3330	0	82.1	57	120				
Phenol	2387.000	330	3330	0	71.7	40	120				
Pyrene	2771.000	330	3330	0	83.2	57	130				
Surr: 1,2-Dichlorobenzene-d4	2133.667		3330		64.1	20	120				
Surr: 2,4,6-Tribromophenol	3033.000		3330		91.1	23	120				
Surr: 2-Chlorophenol-d4	2353.000		3330		70.7	24	134				
Surr: 2-Fluorobiphenyl	2541.333		3330		76.3	28	120				
Surr: 2-Fluorophenol	2365.667		3330		71.0	32	120				
Surr: 4-Terphenyl-d14	3085.000		3330		92.6	29	120				
Surr: Nitrobenzene-d5	2611.333		3330		78.4	51	128				
Surr: Phenol-d5	2486.667		3330		74.7	29	120				

Sample ID: **N010478-001J-MS** SampType: **MS** TestCode: **8270SOIL** Units: **µg/Kg** Prep Date: **6/28/2013** RunNo: **89421**
Client ID: **ZZZZZZ** Batch ID: **43311** TestNo: **EPA 8270C** **EPA 3550B** Analysis Date: **7/1/2013** SeqNo: **1602696**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
1,2,4-Trichlorobenzene	1402.000	330	3330	0	42.1	36	120				
1,2-Dichlorobenzene	1307.000	330	3330	0	39.2	32	120				
1,3-Dichlorobenzene	1227.000	330	3330	0	36.8	31	120				
1,4-Dichlorobenzene	1277.000	330	3330	0	38.3	32	120				
2,4,5-Trichlorophenol	2258.333	330	3330	0	67.8	53	120				
2,4,6-Trichlorophenol	2047.000	330	3330	0	61.5	47	120				
2,4-Dichlorophenol	1567.000	1600	3330	0	47.1	43	120				
2,4-Dimethylphenol	1607.000	330	3330	0	48.3	41	120				
2,4-Dinitrophenol	1384.667	1600	3330	0	41.6	30	138				
2,4-Dinitrotoluene	2437.000	330	3330	0	73.2	56	120				
2,6-Dinitrotoluene	2237.000	330	3330	0	67.2	54	120				

Qualifiers:

B Analyte detected in the associated Method Blank
ND Not Detected at the Reporting Limit
DO Surrogate Diluted Out
E Value above quantitation range
R RPD outside accepted recovery limits
Calculations are based on raw values
H Holding times for preparation or analysis exceeded
S Spike/Surrogate outside of limits due to matrix interference

Advanced Technology Laboratories, Inc.
3151 W. Post Rd Las Vegas, NV 89118 Tel: 702-307-2659 Fax: 702-307-2691

CLIENT: Geocon Consultants, Inc.
Work Order: N010467
Project: Caltrans-CrissyField Outfall, E8560-02-51

ANALYTICAL QC SUMMARY REPORT

TestCode: 8270SOIL

Sample ID: **N010478-001J-MS** SampType: **MS** TestCode: **8270SOIL** Units: **µg/Kg** Prep Date: **6/28/2013** RunNo: **89421**
Client ID: **ZZZZZZ** Batch ID: **43311** TestNo: **EPA 8270C** **EPA 3550B** Analysis Date: **7/1/2013** SeqNo: **1602696**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
2-Chloronaphthalene	1581.667	330	3330	0	47.5	41	120				
2-Chlorophenol	1432.667	330	3330	0	43.0	37	120				
2-Methylnaphthalene	1434.000	330	3330	0	43.1	34	121				
2-Methylphenol	1647.667	330	3330	0	49.5	37	120				
2-Nitroaniline	2725.667	1600	3330	0	81.9	58	122				
2-Nitrophenol	1479.333	330	3330	0	44.4	39	120				
3,3´-Dichlorobenzidine	4285.000	660	6660	0	64.3	43	120				
3-Nitroaniline	2227.333	1600	3330	0	66.9	59	120				
4,6-Dinitro-2-methylphenol	2241.333	1600	3330	0	67.3	55	126				
4-Bromophenyl-phenylether	2688.333	330	3330	0	80.7	57	120				
4-Chloro-3-methylphenol	2274.333	660	3330	0	68.3	50	120				
4-Chloroaniline	1315.333	660	3330	0	39.5	35	120				
4-Chlorophenyl-phenylether	2247.000	330	3330	0	67.5	49	120				
4-Methylphenol	1555.000	330	3330	0	46.7	43	120				
4-Nitroaniline	2221.000	1600	3330	0	66.7	52	121				
4-Nitrophenol	2836.333	1600	3330	0	85.2	45	121				
Acenaphthene	1813.000	330	3330	0	54.4	47	120				
Acenaphthylene	1894.333	330	3330	0	56.9	48	121				
Anthracene	2641.333	330	3330	0	79.3	52	126				
Benzidine (M)	941.333	1600	6660	0	14.1	3	143				
Benzo(a)anthracene	2659.000	330	3330	0	79.8	63	132				
Benzo(a)pyrene	2531.667	330	3330	0	76.0	34	132				
Benzo(b)fluoranthene	2667.333	330	3330	0	80.1	61	141				
Benzo(g,h,i)perylene	2585.667	330	3330	0	77.6	61	139				
Benzo(k)fluoranthene	2581.667	330	3330	0	77.5	58	141				
Benzoic acid	630.667	1600	3330	0	18.9	23	120				S
Benzyl alcohol	1529.667	660	3330	0	45.9	37	120				
Bis(2-chloroethoxy)methane	1621.333	330	3330	0	48.7	45	120				
Bis(2-chloroethyl)ether	1497.667	330	3330	0	45.0	36	120				
Bis(2-chloroisopropyl)ether	1624.000	330	3330	0	48.8	30	120				

Qualifiers:

B Analyte detected in the associated Method Blank
ND Not Detected at the Reporting Limit
DO Surrogate Diluted Out
E Value above quantitation range
R RPD outside accepted recovery limits
Calculations are based on raw values
H Holding times for preparation or analysis exceeded
S Spike/Surrogate outside of limits due to matrix interference

Advanced Technology Laboratories, Inc.
3151 W. Post Rd Las Vegas, NV 89118 Tel: 702-307-2659 Fax: 702-307-2691

CLIENT: Geocon Consultants, Inc.
Work Order: N010467
Project: Caltrans-CrissyField Outfall, E8560-02-51

ANALYTICAL QC SUMMARY REPORT

TestCode: 8270SOIL

Sample ID: **N010478-001J-MS** SampType: **MS** TestCode: **8270SOIL** Units: **µg/Kg** Prep Date: **6/28/2013** RunNo: **89421**
Client ID: **ZZZZZZ** Batch ID: **43311** TestNo: **EPA 8270C** **EPA 3550B** Analysis Date: **7/1/2013** SeqNo: **1602696**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Bis(2-ethylhexyl)phthalate	3094.000	330	3330	0	92.9	65	135				
Butylbenzylphthalate	3145.667	330	3330	0	94.5	37	137				
Chrysene	2747.000	330	3330	0	82.5	58	145				
Di-n-butylphthalate	3061.333	330	3330	0	91.9	56	129				
Di-n-octylphthalate	3232.667	330	3330	0	97.1	58	146				
Dibenz(a,h)anthracene	2802.000	330	3330	0	84.1	48	120				
Dibenzofuran	1975.000	330	3330	0	59.3	50	131				
Diethylphthalate	2905.333	330	3330	0	87.2	54	120				
Dimethylphthalate	2533.333	330	3330	0	76.1	63	139				
Fluoranthene	2686.333	330	3330	0	80.7	57	133				
Fluorene	2177.667	330	3330	0	65.4	50	123				
Hexachlorobenzene	2609.333	330	3330	0	78.4	56	120				
Hexachlorobutadiene	1650.667	660	3330	0	49.6	36	120				
Hexachlorocyclopentadiene	1490.000	660	3330	0	44.7	29	120				
Hexachloroethane	1387.000	330	3330	0	41.7	32	120				
Indeno(1,2,3-cd)pyrene	2677.333	330	3330	0	80.4	64	136				
Isophorone	1545.667	330	3330	0	46.4	49	120				S
N-Nitrosodi-n-propylamine	1717.667	330	3330	0	51.6	43	120				
N-Nitrosodiphenylamine	2805.000	330	3330	0	84.2	62	120				
Naphthalene	1408.667	330	3330	0	42.3	40	120				
Nitrobenzene	1599.667	330	3330	0	48.0	38	120				
Pentachlorophenol	2460.000	1600	3330	0	73.9	46	120				
Phenanthrene	2572.000	330	3330	0	77.2	57	120				
Phenol	1504.667	330	3330	0	45.2	40	120				
Pyrene	2618.667	330	3330	0	78.6	57	130				
Surr: 1,2-Dichlorobenzene-d4	1349.333		3330		40.5	20	120				
Surr: 2,4,6-Tribromophenol	2793.000		3330		83.9	23	120				
Surr: 2-Chlorophenol-d4	1510.667		3330		45.4	24	134				
Surr: 2-Fluorobiphenyl	1679.333		3330		50.4	28	120				
Surr: 2-Fluorophenol	1525.667		3330		45.8	32	120				

Qualifiers:

B Analyte detected in the associated Method Blank
ND Not Detected at the Reporting Limit
DO Surrogate Diluted Out
E Value above quantitation range
R RPD outside accepted recovery limits
Calculations are based on raw values
H Holding times for preparation or analysis exceeded
S Spike/Surrogate outside of limits due to matrix interference

Advanced Technology Laboratories, Inc.
3151 W. Post Rd Las Vegas, NV 89118 Tel: 702-307-2659 Fax: 702-307-2691

CLIENT: Geocon Consultants, Inc.
Work Order: N010467
Project: Caltrans-CrissyField Outfall, E8560-02-51

ANALYTICAL QC SUMMARY REPORT

TestCode: 8270SOIL

Sample ID: **N010478-001J-MS** SampType: **MS** TestCode: **8270SOIL** Units: **µg/Kg** Prep Date: **6/28/2013** RunNo: **89421**
Client ID: **ZZZZZZ** Batch ID: **43311** TestNo: **EPA 8270C** **EPA 3550B** Analysis Date: **7/1/2013** SeqNo: **1602696**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Surr: 4-Terphenyl-d14	2926.000		3330		87.9	29	120				
Surr: Nitrobenzene-d5	1680.000		3330		50.5	51	128				S
Surr: Phenol-d5	1562.000		3330		46.9	29	120				

Sample ID: **N010478-001J-MSD** SampType: **MSD** TestCode: **8270SOIL** Units: **µg/Kg** Prep Date: **6/28/2013** RunNo: **89421**
Client ID: **ZZZZZZ** Batch ID: **43311** TestNo: **EPA 8270C** **EPA 3550B** Analysis Date: **7/1/2013** SeqNo: **1602697**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
1,2,4-Trichlorobenzene	1959.279	330	3334	0	58.8	36	120	1402	33.2	20	R
1,2-Dichlorobenzene	1762.016	330	3334	0	52.8	32	120	1307	29.7	20	R
1,3-Dichlorobenzene	1658.211	330	3334	0	49.7	31	120	1227	29.9	20	R
1,4-Dichlorobenzene	1726.302	330	3334	0	51.8	32	120	1277	29.9	20	R
2,4,5-Trichlorophenol	2408.211	330	3334	0	72.2	53	120	2258	6.42	20	
2,4,6-Trichlorophenol	2345.794	330	3334	0	70.4	47	120	2047	13.6	20	
2,4-Dichlorophenol	2081.442	1700	3334	0	62.4	43	120	1567	28.2	20	R
2,4-Dimethylphenol	2180.908	330	3334	0	65.4	41	120	1607	30.3	20	R
2,4-Dinitrophenol	1379.840	1700	3334	0	41.4	30	138	1385	0	20	
2,4-Dinitrotoluene	2422.230	330	3334	0	72.6	56	120	2437	0.608	20	
2,6-Dinitrotoluene	2317.423	330	3334	0	69.5	54	120	2237	3.53	20	
2-Chloronaphthalene	2058.745	330	3334	0	61.7	41	120	1582	26.2	20	R
2-Chlorophenol	1910.881	330	3334	0	57.3	37	120	1433	28.6	20	R
2-Methylnaphthalene	2000.668	330	3334	0	60.0	34	121	1434	33.0	20	R
2-Methylphenol	2189.252	330	3334	0	65.7	37	120	1648	28.2	20	R
2-Nitroaniline	2797.063	1700	3334	0	83.9	58	122	2726	2.59	20	
2-Nitrophenol	2024.032	330	3334	0	60.7	39	120	1479	31.1	20	R
3,3´-Dichlorobenzidine	4205.607	660	6669	0	63.1	43	120	4285	1.87	20	
3-Nitroaniline	2348.798	1700	3334	0	70.4	59	120	2227	5.31	20	
4,6-Dinitro-2-methylphenol	2092.790	1700	3334	0	62.8	55	126	2241	6.85	20	
4-Bromophenyl-phenylether	2703.605	330	3334	0	81.1	57	120	2688	0.566	20	
4-Chloro-3-methylphenol	2498.999	660	3334	0	74.9	50	120	2274	9.41	20	

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range	H	Holding times for preparation or analysis exceeded
ND	Not Detected at the Reporting Limit	R	RPD outside accepted recovery limits	S	Spike/Surrogate outside of limits due to matrix interference
DO	Surrogate Diluted Out		Calculations are based on raw values		

Advanced Technology Laboratories, Inc.
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CLIENT: Geocon Consultants, Inc.
Work Order: N010467
Project: Caltrans-CrissyField Outfall, E8560-02-51

ANALYTICAL QC SUMMARY REPORT

TestCode: 8270SOIL

Sample ID: **N010478-001J-MSD** SampType: **MSD** TestCode: **8270SOIL** Units: **µg/Kg** Prep Date: **6/28/2013** RunNo: **89421**
Client ID: **ZZZZZZ** Batch ID: **43311** TestNo: **EPA 8270C** **EPA 3550B** Analysis Date: **7/1/2013** SeqNo: **1602697**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
4-Chloroaniline	1715.621	660	3334	0	51.5	35	120	1315	26.4	20	R
4-Chlorophenyl-phenylether	2418.224	330	3334	0	72.5	49	120	2247	7.34	20	
4-Methylphenol	2093.124	330	3334	0	62.8	43	120	1555	29.5	20	R
4-Nitroaniline	2119.493	1700	3334	0	63.6	52	121	2221	4.68	20	
4-Nitrophenol	2739.653	1700	3334	0	82.2	45	121	2836	3.47	20	
Acenaphthene	2189.586	330	3334	0	65.7	47	120	1813	18.8	20	
Acenaphthylene	2301.402	330	3334	0	69.0	48	121	1894	19.4	20	
Anthracene	2553.071	330	3334	0	76.6	52	126	2641	3.40	20	
Benzidine (M)	711.282	1700	6669	0	10.7	3	143	941.3	0	20	
Benzo(a)anthracene	2513.017	330	3334	0	75.4	63	132	2659	5.65	20	
Benzo(a)pyrene	2458.278	330	3334	0	73.7	34	132	2532	2.94	20	
Benzo(b)fluoranthene	2560.080	330	3334	0	76.8	61	141	2667	4.10	20	
Benzo(g,h,i)perylene	2522.363	330	3334	0	75.6	61	139	2586	2.48	20	
Benzo(k)fluoranthene	2511.015	330	3334	0	75.3	58	141	2582	2.77	20	
Benzoic acid	621.495	1700	3334	0	18.6	23	120	630.7	0	20	S
Benzyl alcohol	2012.684	660	3334	0	60.4	37	120	1530	27.3	20	R
Bis(2-chloroethoxy)methane	2238.652	330	3334	0	67.1	45	120	1621	32.0	20	R
Bis(2-chloroethyl)ether	2027.704	330	3334	0	60.8	36	120	1498	30.1	20	R
Bis(2-chloroisopropyl)ether	2084.780	330	3334	0	62.5	30	120	1624	24.8	20	R
Bis(2-ethylhexyl)phthalate	3021.362	330	3334	0	90.6	65	135	3094	2.38	20	
Butylbenzylphthalate	3095.127	330	3334	0	92.8	37	137	3146	1.62	20	
Chrysene	2624.499	330	3334	0	78.7	58	145	2747	4.56	20	
Di-n-butylphthalate	2910.547	330	3334	0	87.3	56	129	3061	5.05	20	
Di-n-octylphthalate	3075.100	330	3334	0	92.2	58	146	3233	5.00	20	
Dibenz(a,h)anthracene	2721.629	330	3334	0	81.6	48	120	2802	2.91	20	
Dibenzofuran	2250.000	330	3334	0	67.5	50	131	1975	13.0	20	
Diethylphthalate	2849.800	330	3334	0	85.5	54	120	2905	1.93	20	
Dimethylphthalate	2597.130	330	3334	0	77.9	63	139	2533	2.49	20	
Fluoranthene	2503.338	330	3334	0	75.1	57	133	2686	7.05	20	
Fluorene	2332.777	330	3334	0	70.0	50	123	2178	6.88	20	

Qualifiers:

B Analyte detected in the associated Method Blank
ND Not Detected at the Reporting Limit
DO Surrogate Diluted Out
E Value above quantitation range
R RPD outside accepted recovery limits
Calculations are based on raw values
H Holding times for preparation or analysis exceeded
S Spike/Surrogate outside of limits due to matrix interference

Advanced Technology Laboratories, Inc.
3151 W. Post Rd Las Vegas, NV 89118 Tel: 702-307-2659 Fax: 702-307-2691

CLIENT: Geocon Consultants, Inc.
Work Order: N010467
Project: Caltrans-CrissyField Outfall, E8560-02-51

ANALYTICAL QC SUMMARY REPORT

TestCode: 8270SOIL

Sample ID: **N010478-001J-MSD** SampType: **MSD** TestCode: **8270SOIL** Units: **µg/Kg** Prep Date: **6/28/2013** RunNo: **89421**
Client ID: **ZZZZZZ** Batch ID: **43311** TestNo: **EPA 8270C** **EPA 3550B** Analysis Date: **7/1/2013** SeqNo: **1602697**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Hexachlorobenzene	2597.797	330	3334	0	77.9	56	120	2609	0.443	20	
Hexachlorobutadiene	2248.331	660	3334	0	67.4	36	120	1651	30.7	20	R
Hexachlorocyclopentadiene	2058.745	660	3334	0	61.7	29	120	1490	32.1	20	R
Hexachloroethane	1851.802	330	3334	0	55.5	32	120	1387	28.7	20	R
Indeno(1,2,3-cd)pyrene	2602.804	330	3334	0	78.1	64	136	2677	2.82	20	
Isophorone	2078.438	330	3334	0	62.3	49	120	1546	29.4	20	R
N-Nitrosodi-n-propylamine	2264.686	330	3334	0	67.9	43	120	1718	27.5	20	R
N-Nitrosodiphenylamine	2744.993	330	3334	0	82.3	62	120	2805	2.16	20	
Naphthalene	1937.917	330	3334	0	58.1	40	120	1409	31.6	20	R
Nitrobenzene	2129.172	330	3334	0	63.9	38	120	1600	28.4	20	R
Pentachlorophenol	2311.415	1700	3334	0	69.3	46	120	2460	6.23	20	
Phenanthrene	2505.007	330	3334	0	75.1	57	120	2572	2.64	20	
Phenol	1996.996	330	3334	0	59.9	40	120	1505	28.1	20	R
Pyrene	2406.876	330	3334	0	72.2	57	130	2619	8.43	20	
Surr: 1,2-Dichlorobenzene-d4	1838.785		3334		55.1	20	120		0		
Surr: 2,4,6-Tribromophenol	2774.366		3334		83.2	23	120		0		
Surr: 2-Chlorophenol-d4	2032.043		3334		60.9	24	134		0		
Surr: 2-Fluorobiphenyl	2252.003		3334		67.5	28	120		0		
Surr: 2-Fluorophenol	2008.011		3334		60.2	32	120		0		
Surr: 4-Terphenyl-d14	2960.948		3334		88.8	29	120		0		
Surr: Nitrobenzene-d5	2272.363		3334		68.1	51	128		0		
Surr: Phenol-d5	2116.489		3334		63.5	29	120		0		

Sample ID: **MB-43311** SampType: **MBLK** TestCode: **8270SOIL** Units: **µg/Kg** Prep Date: **6/28/2013** RunNo: **89421**
Client ID: **PBS** Batch ID: **43311** TestNo: **EPA 8270C** **EPA 3550B** Analysis Date: **7/1/2013** SeqNo: **1602698**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
1,2,4-Trichlorobenzene	ND	330									
1,2-Dichlorobenzene	ND	330									
1,3-Dichlorobenzene	ND	330									

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range	H	Holding times for preparation or analysis exceeded
ND	Not Detected at the Reporting Limit	R	RPD outside accepted recovery limits	S	Spike/Surrogate outside of limits due to matrix interference
DO	Surrogate Diluted Out		Calculations are based on raw values		

Advanced Technology Laboratories, Inc.
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CLIENT: Geocon Consultants, Inc.
Work Order: N010467
Project: Caltrans-CrissyField Outfall, E8560-02-51

ANALYTICAL QC SUMMARY REPORT

TestCode: 8270SOIL

Sample ID:	**MB-43311**	SampType:	**MBLK**	TestCode:	**8270SOIL**	Units:	**µg/Kg**		Prep Date:	**6/28/2013**		RunNo:	**89421**		
Client ID:	**PBS**	Batch ID:	**43311**	TestNo:	**EPA 8270C**		**EPA 3550B**		Analysis Date:	**7/1/2013**		SeqNo:	**1602698**		
Analyte			Result	PQL	SPK value	SPK Ref Val		%REC	LowLimit	HighLimit	RPD Ref Val		%RPD	RPDLimit	Qual
1,4-Dichlorobenzene			ND	330											
2,4,5-Trichlorophenol			ND	330											
2,4,6-Trichlorophenol			ND	330											
2,4-Dichlorophenol			ND	1600											
2,4-Dimethylphenol			ND	330											
2,4-Dinitrophenol			ND	1600											
2,4-Dinitrotoluene			ND	330											
2,6-Dinitrotoluene			ND	330											
2-Chloronaphthalene			ND	330											
2-Chlorophenol			ND	330											
2-Methylnaphthalene			ND	330											
2-Methylphenol			ND	330											
2-Nitroaniline			ND	1600											
2-Nitrophenol			ND	330											
3,3´-Dichlorobenzidine			ND	660											
3-Nitroaniline			ND	1600											
4,6-Dinitro-2-methylphenol			ND	1600											
4-Bromophenyl-phenylether			ND	330											
4-Chloro-3-methylphenol			ND	660											
4-Chloroaniline			ND	660											
4-Chlorophenyl-phenylether			ND	330											
4-Methylphenol			ND	330											
4-Nitroaniline			ND	1600											
4-Nitrophenol			ND	1600											
Acenaphthene			ND	330											
Acenaphthylene			ND	330											
Anthracene			ND	330											
Benzidine (M)			ND	1600											
Benzo(a)anthracene			ND	330											
Benzo(a)pyrene			ND	330											

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range	H	Holding times for preparation or analysis exceeded
ND	Not Detected at the Reporting Limit	R	RPD outside accepted recovery limits	S	Spike/Surrogate outside of limits due to matrix interference
DO	Surrogate Diluted Out		Calculations are based on raw values		

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CLIENT: Geocon Consultants, Inc.
Work Order: N010467
Project: Caltrans-CrissyField Outfall, E8560-02-51

ANALYTICAL QC SUMMARY REPORT

TestCode: 8270SOIL

Sample ID: **MB-43311** SampType: **MBLK** TestCode: **8270SOIL** Units: **µg/Kg** Prep Date: **6/28/2013** RunNo: **89421**
Client ID: **PBS** Batch ID: **43311** TestNo: **EPA 8270C** **EPA 3550B** Analysis Date: **7/1/2013** SeqNo: **1602698**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Benzo(b)fluoranthene	ND	330									
Benzo(g,h,i)perylene	ND	330									
Benzo(k)fluoranthene	ND	330									
Benzoic acid	ND	1600									
Benzyl alcohol	ND	660									
Bis(2-chloroethoxy)methane	ND	330									
Bis(2-chloroethyl)ether	ND	330									
Bis(2-chloroisopropyl)ether	ND	330									
Bis(2-ethylhexyl)phthalate	ND	330									
Butylbenzylphthalate	ND	330									
Chrysene	ND	330									
Di-n-butylphthalate	ND	330									
Di-n-octylphthalate	ND	330									
Dibenz(a,h)anthracene	ND	330									
Dibenzofuran	ND	330									
Diethylphthalate	ND	330									
Dimethylphthalate	ND	330									
Fluoranthene	ND	330									
Fluorene	ND	330									
Hexachlorobenzene	ND	330									
Hexachlorobutadiene	ND	660									
Hexachlorocyclopentadiene	ND	660									
Hexachloroethane	ND	330									
Indeno(1,2,3-cd)pyrene	ND	330									
Isophorone	ND	330									
N-Nitrosodi-n-propylamine	ND	330									
N-Nitrosodiphenylamine	ND	330									
Naphthalene	ND	330									
Nitrobenzene	ND	330									
Pentachlorophenol	ND	1600									

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range	H	Holding times for preparation or analysis exceeded
ND	Not Detected at the Reporting Limit	R	RPD outside accepted recovery limits	S	Spike/Surrogate outside of limits due to matrix interference
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3151 W. Post Rd Las Vegas, NV 89118 Tel: 702-307-2659 Fax: 702-307-2691

CLIENT: Geocon Consultants, Inc.
Work Order: N010467
Project: Caltrans-CrissyField Outfall, E8560-02-51

ANALYTICAL QC SUMMARY REPORT

TestCode: 8270SOIL

Sample ID: **MB-43311** SampType: **MBLK** TestCode: **8270SOIL** Units: **µg/Kg** Prep Date: **6/28/2013** RunNo: **89421**
Client ID: **PBS** Batch ID: **43311** TestNo: **EPA 8270C** **EPA 3550B** Analysis Date: **7/1/2013** SeqNo: **1602698**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Phenanthrene	ND	330									
Phenol	ND	330									
Pyrene	ND	330									
Surr: 1,2-Dichlorobenzene-d4	2035.000		3330		61.1	23	120				
Surr: 2,4,6-Tribromophenol	2383.667		3330		71.6	24	134				
Surr: 2-Chlorophenol-d4	2215.667		3330		66.5	28	120				
Surr: 2-Fluorobiphenyl	2345.333		3330		70.4	32	120				
Surr: 2-Fluorophenol	2219.000		3330		66.6	29	120				
Surr: 4-Terphenyl-d14	3350.667		3330		101	51	128				
Surr: Nitrobenzene-d5	2384.333		3330		71.6	29	120				
Surr: Phenol-d5	2213.667		3330		66.5	28	120				

Sample ID: **N010467-001A-DUP** SampType: **DUP** TestCode: **8270SOIL** Units: **µg/Kg** Prep Date: **6/28/2013** RunNo: **89421**
Client ID: **ZZZZZZ** Batch ID: **43311** TestNo: **EPA 8270C** **EPA 3550B** Analysis Date: **7/1/2013** SeqNo: **1602701**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
1,2,4-Trichlorobenzene	ND	330						0	0	20	
1,2-Dichlorobenzene	ND	330						0	0	20	
1,3-Dichlorobenzene	ND	330						0	0	20	
1,4-Dichlorobenzene	ND	330						0	0	20	
2,4,5-Trichlorophenol	ND	330						0	0	20	
2,4,6-Trichlorophenol	ND	330						0	0	20	
2,4-Dichlorophenol	ND	1700						0	0	20	
2,4-Dimethylphenol	ND	330						0	0	20	
2,4-Dinitrophenol	ND	1700						0	0	20	
2,4-Dinitrotoluene	ND	330						0	0	20	
2,6-Dinitrotoluene	ND	330						0	0	20	
2-Chloronaphthalene	ND	330						0	0	20	
2-Chlorophenol	ND	330						0	0	20	
2-Methylnaphthalene	ND	330						0	0	20	

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range	H	Holding times for preparation or analysis exceeded
ND	Not Detected at the Reporting Limit	R	RPD outside accepted recovery limits	S	Spike/Surrogate outside of limits due to matrix interference
DO	Surrogate Diluted Out		Calculations are based on raw values		

Advanced Technology Laboratories, Inc.
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CLIENT: Geocon Consultants, Inc.
Work Order: N010467
Project: Caltrans-CrissyField Outfall, E8560-02-51

ANALYTICAL QC SUMMARY REPORT

TestCode: 8270SOIL

Sample ID: **N010467-001A-DUP** SampType: **DUP** TestCode: **8270SOIL** Units: **µg/Kg** Prep Date: **6/28/2013** RunNo: **89421**
Client ID: **ZZZZZZ** Batch ID: **43311** TestNo: **EPA 8270C** **EPA 3550B** Analysis Date: **7/1/2013** SeqNo: **1602701**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
2-Methylphenol	ND	330						0	0	20	
2-Nitroaniline	ND	1700						0	0	20	
2-Nitrophenol	ND	330						0	0	20	
3,3´-Dichlorobenzidine	ND	660						0	0	20	
3-Nitroaniline	ND	1700						0	0	20	
4,6-Dinitro-2-methylphenol	ND	1700						0	0	20	
4-Bromophenyl-phenylether	ND	330						0	0	20	
4-Chloro-3-methylphenol	ND	660						0	0	20	
4-Chloroaniline	ND	660						0	0	20	
4-Chlorophenyl-phenylether	ND	330						0	0	20	
4-Methylphenol	ND	330						0	0	20	
4-Nitroaniline	ND	1700						0	0	20	
4-Nitrophenol	ND	1700						0	0	20	
Acenaphthene	ND	330						0	0	20	
Acenaphthylene	ND	330						0	0	20	
Anthracene	ND	330						0	0	20	
Benzidine (M)	ND	1700						0	0	20	
Benzo(a)anthracene	ND	330						0	0	20	
Benzo(a)pyrene	ND	330						0	0	20	
Benzo(b)fluoranthene	ND	330						0	0	20	
Benzo(g,h,i)perylene	ND	330						0	0	20	
Benzo(k)fluoranthene	ND	330						0	0	20	
Benzoic acid	ND	1700						0	0	20	
Benzyl alcohol	ND	660						0	0	20	
Bis(2-chloroethoxy)methane	ND	330						0	0	20	
Bis(2-chloroethyl)ether	ND	330						0	0	20	
Bis(2-chloroisopropyl)ether	ND	330						0	0	20	
Bis(2-ethylhexyl)phthalate	ND	330						0	0	20	
Butylbenzylphthalate	ND	330						0	0	20	
Chrysene	ND	330						0	0	20	

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range	H	Holding times for preparation or analysis exceeded
ND	Not Detected at the Reporting Limit	R	RPD outside accepted recovery limits	S	Spike/Surrogate outside of limits due to matrix interference
DO	Surrogate Diluted Out		Calculations are based on raw values		

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3151 W. Post Rd Las Vegas, NV 89118 Tel: 702-307-2659 Fax: 702-307-2691

CLIENT: Geocon Consultants, Inc.
Work Order: N010467
Project: Caltrans-CrissyField Outfall, E8560-02-51

ANALYTICAL QC SUMMARY REPORT

TestCode: 8270SOIL

Sample ID: **N010467-001A-DUP** SampType: **DUP** TestCode: **8270SOIL** Units: **µg/Kg** Prep Date: **6/28/2013** RunNo: **89421**
Client ID: **ZZZZZZ** Batch ID: **43311** TestNo: **EPA 8270C** **EPA 3550B** Analysis Date: **7/1/2013** SeqNo: **1602701**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Di-n-butylphthalate	ND	330						0	0	20	
Di-n-octylphthalate	ND	330						0	0	20	
Dibenz(a,h)anthracene	ND	330						0	0	20	
Dibenzofuran	ND	330						0	0	20	
Diethylphthalate	ND	330						0	0	20	
Dimethylphthalate	ND	330						0	0	20	
Fluoranthene	ND	330						0	0	20	
Fluorene	ND	330						0	0	20	
Hexachlorobenzene	ND	330						0	0	20	
Hexachlorobutadiene	ND	660						0	0	20	
Hexachlorocyclopentadiene	ND	660						0	0	20	
Hexachloroethane	ND	330						0	0	20	
Indeno(1,2,3-cd)pyrene	ND	330						0	0	20	
Isophorone	ND	330						0	0	20	
N-Nitrosodi-n-propylamine	ND	330						0	0	20	
N-Nitrosodiphenylamine	ND	330						0	0	20	
Naphthalene	ND	330						0	0	20	
Nitrobenzene	ND	330						0	0	20	
Pentachlorophenol	ND	1700						0	0	20	
Phenanthrene	ND	330						0	0	20	
Phenol	ND	330						0	0	20	
Pyrene	ND	330						0	0	20	
Surr: 1,2-Dichlorobenzene-d4	1725.936		3339		51.7	23	120		0		
Surr: 2,4,6-Tribromophenol	2503.342		3339		75.0	24	134		0		
Surr: 2-Chlorophenol-d4	2028.075		3339		60.7	28	120		0		
Surr: 2-Fluorobiphenyl	2089.906		3339		62.6	32	120		0		
Surr: 2-Fluorophenol	2056.150		3339		61.6	29	120		0		
Surr: 4-Terphenyl-d14	2866.310		3339		85.8	51	128		0		
Surr: Nitrobenzene-d5	2252.674		3339		67.5	29	120		0		
Surr: Phenol-d5	2051.136		3339		61.4	28	120		0		

Qualifiers:

B Analyte detected in the associated Method Blank
ND Not Detected at the Reporting Limit
DO Surrogate Diluted Out
E Value above quantitation range
R RPD outside accepted recovery limits
Calculations are based on raw values
H Holding times for preparation or analysis exceeded
S Spike/Surrogate outside of limits due to matrix interference

Advanced Technology Laboratories, Inc.
3151 W. Post Rd Las Vegas, NV 89118 Tel: 702-307-2659 Fax: 702-307-2691

CHAIN OF CUSTODY RECORD

ADVANCED TECHNOLOGY LABORATORIES
3275 Walnut Ave., Signal Hill, CA 90755
Tel: (562) 989-4045 • Fax: (562) 989-4040

P.O.#: E8560-02-51 Quote #:

As the authorized agent of the below named company, I hereby purchase testing services from ATL as dictated below and guarantee payment in full.

Submitter (Print): CHRIS MERRITT

Signature: CHRIS MERRITT

Submitter - Please complete all SHADED areas and include QUOTE # above to ensure proper invoicing.

FOR LABORATORY USE ONLY:

Method of Transport: ☐ Client ☐ ATL ☐ FedEx ☐ OnTrac ☑ GSO ☐ Other:

Sample Condition Upon Receipt: 5.8°C ICE

1. CHILLED IR#1 Y☐ N☐ 4. SEALED Y☐ N☐
2. HEADSPACE (VOA) Y☐ N☐ 5. # OF SPLS MATCH COC Y☐ N☐
3. CONTAINER INTACT Y☐ N☐ 6. PRESERVED Y☐ N☐

Client: **Geocon Consultant, Inc.**
Address: 6671 Brisa Street
City: Livermore State: CA Zip Code: 94550
TEL: (925) 371-5900
FAX: (925) 371-5915

Project Name: CALTRANS-CHRISSYFIELD OUTFALL Project #: E8560-02-51 Sampler: (Printed Name) C. MERRITT, L. BEADLE (Signature) CHRIS MERRITT

Relinquished by: (Signature and Printed Name)	Date:	Time:	Received by: (Signature and Printed Name)	Date:	Time:
CHRIS MERRITT	6-26-13	1730	MCARTIN	6/27/13	0856

Bill To:
Attn: E-mail:
Company: SAME AS ABOVE
Address:
City: State: Zip:

Send Report To:
Attn: E-mail:
Company: SAME AS ABOVE
Addrress:
City: State: Zip:

Special Instructions/Comments: 8270C SVOC'S

Sample/Records - Archival & Disposal
Unless otherwise requested by client, all Samples and Hardcopy will be disposed Forty-five(45) days after generation of report - electronic copies retained for five(5) years.
Storage Fees (applies when storage is requested):
■ Sample : Forty-five(45) Days Complimentary - $2.00 / sample / mo thereafter.
Hardcopy Reports $17.50 per report.

CIRCLE or Write IN Analyses Needed — CIRCLE APPROPRIATE MATRIX

ITEM	BUSINESS HOURS 8:30 am to 5:30 pm: Lab No.	Sample Description: Sample I.D. / Location	Date	Time	8260-624 (Volatiles)	8015B(GRO) 8021(BTEX)	TO-15 / TO-14 / TO-3 / RSK-175	8270B-625(BNA) / 8310(PAHs)	8015B(DRO) 8015B(HC/D) TPH O	8081 OrgCl / 8141 OrgPO4 Pest	8082 PCBs	6010B / 7471-CAM Metals	6010B-200.7 Metals LEAD	6020B-200.8-1640 Metals	7199-218.6 (Hex. Chromium)	300(Anions) / 314 (Perchlorate)	SOIL/SEDIMENT/SLUDGE	SOLIDS/WIPES/FILTERS	WATER-DRINKING/GROUND	WATER-STORM/WASTE	AQUEOUS/LAYERED-OIL	TAT	Container(s) #	Container(s) Type	PRESERVATION	REMARKS
1	N010467-1	B5	6-26-13	0830		X		X	X		X	X					X					TAT 5	2	15	13	C	
2	2	B6	↓	0825		X		X	X		X	X					X					↓	2	↓	↓	↓	
3	3	B7	↓	0810		X		X	X		X	X					X					↓	2	↓	↓	↓	
4	4	EB	↓	0930									X							X		TAT 5	1	5	1	↓	
5																											
6																											
7																											
8																											
9																											
10																											

Q A / Q C: RTNE ☐ CT ☑ Legal ☐ SWRCB ☐ Logcode ____ OTHER ____

■ Samples Submitted AFTER 3:30 PM, are considered received the following business day at 8:30 AM.

Weekend, Holiday, Off Hours Work ASK for QUOTE

Container Types: 1=Tube 2=VOA 3=Liter 4=Pint 5=Jar 6=Tedlar 7= Canister

Material: 1=Glass 2=Plastic 3=Metal

Preservatives: 1=HCl, 2=HNO_3 3=H_2SO_4 4=4°C 5=$Zn(Ac)_2$ 6=NaOH 7=$Na_2S_2O_4$

TAT 0	TAT 1	TAT 2	TAT 3	TAT 4	TAT 5	TAT 10
☐ 300% SURCHARGE SAME BUSINESS DAY IF RCV'D BY 9:00 AM	☐ 100% SURCHARGE NEXT BUSINESS DAY 5:30 PM	☐ 50% SURCHARGE 2ND BUSINESS DAY 5:30 PM	☐ 30% SURCHARGE 3RD BUSINESS DAY 5:30 PM	☐ 20% SURCHARGE 4TH BUSINESS DAY 5:30 PM	☐ NO SURCHARGE 5 -7 BUSINESS DAYS 5:30 PM	☐ 10% DISCOUNT 10th BUSINESS DAY 5:30 PM

For RUSH TCLP/STLC, add 2 days to respective TAT.

Subcon. TATs 10-15 business days, Dioxin and Furans 21 business days.

Rev. 2012-0416

DISTRIBUTION: White with report, Yellow to folder, Pink to submitter.

Advanced Technology Laboratories, Inc.

Please review the checklist below. Any NO signifies non-compliance. Any non-compliance will be noted and must be understood as having an impact on the quality of the data. All tests will be performed as requested regardless of any compliance issues.

If you have any questions or further instruction, please contact our Project Coordinator at (702) 307-2659.

Cooler Received/Opened On:	6/27/2013	Workorder:	N010467
Rep sample Temp (Deg C):	5.8	IR Gun ID:	1
Temp Blank:	☐ Yes ☑ No		
Carrier name:	Golden State Overnight		
Last 4 digits of Tracking No.:	0416	Packing Material Used:	None
Cooling process:	☑ Ice ☐ Ice Pack ☐ Dry Ice ☐ Other ☐ None		

Sample Receipt Checklist

1. Shipping container/cooler in good condition?	Yes ☑	No ☐	Not Present ☐
2. Custody seals intact, signed, dated on shippping container/cooler?	Yes ☐	No ☐	Not Present ☑
3. Custody seals intact on sample bottles?	Yes ☐	No ☐	Not Present ☑
4. Chain of custody present?	Yes ☑	No ☐	
5. Sampler's name present in COC?	Yes ☑	No ☐	
6. Chain of custody signed when relinquished and received?	Yes ☑	No ☐	
7. Chain of custody agrees with sample labels?	Yes ☑	No ☐	
8. Samples in proper container/bottle?	Yes ☑	No ☐	
9. Sample containers intact?	Yes ☑	No ☐	
10. Sufficient sample volume for indicated test?	Yes ☑	No ☐	
11. All samples received within holding time?	Yes ☑	No ☐	
12. Temperature of rep sample or Temp Blank within acceptable limit?	Yes ☑	No ☐	NA ☐
13. Water - VOA vials have zero headspace?	Yes ☐	No ☐	NA ☑
14. Water - pH acceptable upon receipt? Example: pH > 12 for (CN,S); pH<2 for Metals	Yes ☑	No ☐	NA ☐
15. Did the bottle labels indicate correct preservatives used?	Yes ☑	No ☐	NA ☐
16. Were there Non-Conformance issues at login?	Yes ☐	No ☐	NA ☑
Was Client notified?	Yes ☐	No ☐	NA ☑

Comments:

Checklist Completed B MB for: HSG 6/28/13

Reviewed By: [signature]

GSO GOLDEN STATE OVERNIGHT

< WebShip > > > > >

800-322-5555 www.gso.com

Ship From:
GEOCON - LIVERMORE OFFICE
GEOCON, INC.
6671 BRISA STREET
LIVERMORE, CA 94550

Ship To:
SAMPLE RECEIVING
ADVANCED TECHNOLOGY LABS - LAS VEGAS
3151 W. POST ROAD
LAS VEGAS, NV 89118

COD:
$0.00

Reference:
E8560-02-51

Delivery Instructions:

Signature Type:
SIGNATURE REQUIRED

Tracking #: 522140416

CPS

LVS

LAS VEGAS

D89103B

13493889

Print Date : 06/26/13 14:55 PM

Package 1 of 1

Send Label To Printer | ☑ Print All | Edit Shipment | Finish

LABEL INSTRUCTIONS:

Do not copy or reprint this label for additional shipments - each package must have a unique barcode.

STEP 1 - Use the "Send Label to Printer" button on this page to print the shipping label on a laser or inkjet printer.
STEP 2 - Fold this page in half.
STEP 3 - Securely attach this label to your package, do not cover the barcode.
STEP 4 - Request an on-call pickup for your package, if you do not have scheduled daily pickup service or Drop-off your package at the nearest GSO drop box. Locate nearest GSO dropbox locations using this link.

ADDITIONAL OPTIONS:

Send Label Via Email | Create Return Label

TERMS AND CONDITIONS:

By giving us your shipment to deliver, you agree to all the service terms and conditions described in this section.
Our liability for loss or damage to any package is limited to your actual damages or $100 whichever is less, unless you pay for and declare a higher authorized value. If you declare a higher value and pay the additional charge, our liability will be the lesser of your declared value or the actual value of your loss or damage. In any event, we will not be liable for any damage, whether direct, incidental, special or consequential, in excess of the declared value of a shipment whether or not we had knowledge that such damage might be incurred including but not limited to loss of income or profit. We will not be liable for your acts or omissions, including but not limited to improper or insufficient packaging, securing, marking or addressing. Also, we will not be liable if you or the recipient violates any of the terms of our agreement. We will not be liable for loss, damage or delay caused by events we cannot control, including but not limited to acts of God, perils of the air, weather conditions, act of public enemies, war, strikes, or civil commotion. The highest declared value for our GSO Priority Letter or GSO Priority Package is $500. For other shipments the highest declared value is $10,000 unless your package contains items of "extraordinary value", in which case the highest declared value we allow is $500. Items of "extraordinary value" include, but or not limited to, artwork, jewelry, furs, precious metals, tickets, negotiable instruments and other items with intrinsic value.

July 09, 2013

Luann Beadle
Geocon Consultants, Inc.
6671 Brisa Street
Livermore, CA 94550

TEL: 925-371-5900 Ext 403
FAX: (925) 371-5915

CA-ELAP No.: 2676
NV Cert. No.: NV-009222007A

Workorder No.: N010479

RE: Crissy Field Outfall, E8560-02-51

Attention: Luann Beadle

Enclosed are the results for sample(s) received on June 28, 2013 by Advanced Technology Laboratories, Inc. . The sample(s) are tested for the parameters as indicated in the enclosed chain of custody in accordance with the applicable laboratory certifications.

Thank you for the opportunity to service the needs of your company.

Please feel free to call me at (702) 307-2659 if I can be of further assistance to your company.

Sincerely,

Jose Tenorio Jr.
Laboratory Director

The cover letter is an integral part of this analytical report. This Laboratory Report cannot be reproduced in part or in its entirety without written permission from the client and Advanced Technology Laboratories - Las Vegas.

Advanced Technology Laboratories, Inc. **Date:** *09-Jul-13*

CLIENT: Geocon Consultants, Inc.
Project: Crissy Field Outfall, E8560-02-51
Lab Order: N010479

CASE NARRATIVE

SAMPLE RECEIVING/GENERAL COMMENTS:

Samples were received intact with proper chain of custody documentation.

Cooler temperature and sample preservation were verified upon receipt of samples if applicable.

Information on sample receipt conditions including discrepancies can be found in attached Sample Receipt Checklist Form.

Samples were analyzed within method holding time.

Analytical Comments for EPA 6010B:

Matrix Spike (MS) and Matrix Spike Duplicate (MSD) are outside recovery criteria for Antimony on QC samples N010478-001B-MS and N010478-001B-MSD possibly due to matrix interference. The associated Laboratory Control Sample (LCS) recovery was acceptable.

Matrix Spike (MS) is outside recovery criteria for Lead on QC samples N010479-021AMS possibly due to matrix interference. The associated Laboratory Control Sample (LCS) recovery was acceptable.

RPD for Sample Duplicate (DUP) is outside criteria for samples N010479-002A-DUP and N010479-014A-DUP possibly due to non-homogeneity of sample; however, the Laboratory Control Sample (LCS) validated the analytical batch.

Analytical Comments for EPA 8015B DRO/ORO:

RPD for Sample Duplicate (DUP) is outside criteria for sample N010479-003A-DUP possibly due to non-homogeneity of sample; however, the Laboratory Control Sample (LCS) validated the analytical batch.

Advanced Technology Laboratories, Inc.
3151 W. Post Rd Las Vegas, NV 89118 Tel: 702-307-2659 Fax: 702-307-2691

Advanced Technology Laboratories, Inc.

Date: *09-Jul-13*

CLIENT: Geocon Consultants, Inc.
Project: Crissy Field Outfall, E8560-02-51
Lab Order: N010479
Contract No:

Work Order Sample Summary

Lab Sample ID	Client Sample ID	Matrix	Collection Date	Date Received	Date Reported
N010479-001A	B1-0.5	Soil	6/27/2013 10:10:00 AM	6/28/2013	7/9/2013
N010479-002A	B1-1.5	Soil	6/27/2013 10:15:00 AM	6/28/2013	7/9/2013
N010479-003A	B1-3.0	Soil	6/27/2013 10:20:00 AM	6/28/2013	7/9/2013
N010479-004A	B1-6.0	Soil	6/27/2013 10:25:00 AM	6/28/2013	7/9/2013
N010479-005A	B1-9.0	Soil	6/27/2013 10:25:00 AM	6/28/2013	7/9/2013
N010479-006A	B2-0.5	Soil	6/27/2013 11:05:00 AM	6/28/2013	7/9/2013
N010479-007A	B2-1.5	Soil	6/27/2013 11:10:00 AM	6/28/2013	7/9/2013
N010479-008A	B2-3.0	Soil	6/27/2013 11:20:00 AM	6/28/2013	7/9/2013
N010479-009A	B2-6.0	Soil	6/27/2013 11:40:00 AM	6/28/2013	7/9/2013
N010479-010A	B2-11.0	Soil	6/27/2013 11:50:00 AM	6/28/2013	7/9/2013
N010479-011A	B3-0.5	Soil	6/27/2013 8:20:00 AM	6/28/2013	7/9/2013
N010479-012A	B3-1.5	Soil	6/27/2013 8:25:00 AM	6/28/2013	7/9/2013
N010479-013A	B3-3.0	Soil	6/27/2013 8:35:00 AM	6/28/2013	7/9/2013
N010479-014A	B3-6.0	Soil	6/27/2013 8:40:00 AM	6/28/2013	7/9/2013
N010479-015A	B3-9.0	Soil	6/27/2013 8:40:00 AM	6/28/2013	7/9/2013
N010479-016A	B4-0.5	Soil	6/27/2013 8:55:00 AM	6/28/2013	7/9/2013
N010479-017A	B4-1.5	Soil	6/27/2013 8:55:00 AM	6/28/2013	7/9/2013
N010479-018A	B4-3.0	Soil	6/27/2013 9:00:00 AM	6/28/2013	7/9/2013
N010479-019A	B4-6.0	Soil	6/27/2013 9:05:00 AM	6/28/2013	7/9/2013
N010479-020A	B4-7.5	Soil	6/27/2013 9:05:00 AM	6/28/2013	7/9/2013
N010479-021A	B3-GW	Groundwater	6/27/2013 9:10:00 AM	6/28/2013	7/9/2013
N010479-022A	B2-GW	Groundwater	6/27/2013 12:00:00 PM	6/28/2013	7/9/2013
N010479-023A	B4-10	Soil	6/27/2013 12:00:00 PM	6/28/2013	7/9/2013
N010479-024A	Trip Blank	Water	6/27/2013	6/28/2013	7/9/2013
N010479-025A	Equipment Blank	Water	6/27/2013 4:00:00 PM	6/28/2013	7/9/2013

Advanced Technology Laboratories, Inc.
3151 W. Post Rd Las Vegas, NV 89118 Tel: 702-307-2659 Fax: 702-307-2691

Advanced Technology Laboratories, Inc.

ANALYTICAL RESULTS

Print Date: *09-Jul-13*

CLIENT:	Geocon Consultants, Inc.	**Client Sample ID:**	B1-0.5
Lab Order:	N010479	**Collection Date:**	6/27/2013 10:10:00 AM
Project:	Crissy Field Outfall, E8560-02-51	**Matrix:**	SOIL
Lab ID:	N010479-001		

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
MERCURY BY COLD VAPOR TECHNIQUE						
	EPA 7471			**EPA 7471A**		
RunID: AA1_130701B	QC Batch: 43313			PrepDate:	6/28/2013	Analyst: **LCC**
Mercury	ND	0.10		mg/Kg	1	7/1/2013
ICP METALS						
	EPA 3050B			**EPA 6010B**		
RunID: ICP2_130708A	QC Batch: 43320			PrepDate:	7/1/2013	Analyst: **WLS**
Antimony	ND	2.0		mg/Kg	1	7/8/2013 12:38 PM
Arsenic	2.5	1.0		mg/Kg	1	7/8/2013 12:38 PM
Barium	120	1.0		mg/Kg	1	7/8/2013 12:38 PM
Beryllium	ND	1.0		mg/Kg	1	7/8/2013 12:38 PM
Cadmium	ND	1.0		mg/Kg	1	7/8/2013 12:38 PM
Chromium	20	1.0		mg/Kg	1	7/8/2013 12:38 PM
Cobalt	8.9	1.0		mg/Kg	1	7/8/2013 12:38 PM
Copper	22	2.0		mg/Kg	1	7/8/2013 12:38 PM
Lead	14	1.0		mg/Kg	1	7/8/2013 12:38 PM
Molybdenum	ND	1.0		mg/Kg	1	7/8/2013 12:38 PM
Nickel	35	1.0		mg/Kg	1	7/8/2013 12:38 PM
Selenium	ND	1.0		mg/Kg	1	7/8/2013 12:38 PM
Silver	ND	1.0		mg/Kg	1	7/8/2013 12:38 PM
Thallium	ND	1.0		mg/Kg	1	7/8/2013 12:38 PM
Vanadium	39	1.0		mg/Kg	1	7/8/2013 12:38 PM
Zinc	32	1.0		mg/Kg	1	7/8/2013 12:38 PM

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range
H	Holding times for preparation or analysis exceeded	ND	Not Detected at the Reporting Limit
S	Spike/Surrogate outside of limits due to matrix interference		Results are wet unless otherwise specified
DO	Surrogate Diluted Out		

Advanced Technology Laboratories, Inc.

3151 W. Post Rd Las Vegas, NV 89118 Tel: 702-307-2659 Fax: 702-307-2691

Advanced Technology Laboratories, Inc.

ANALYTICAL RESULTS

Print Date: *09-Jul-13*

CLIENT:	Geocon Consultants, Inc.	**Client Sample ID:**	B1-1.5
Lab Order:	N010479	**Collection Date:**	6/27/2013 10:15:00 AM
Project:	Crissy Field Outfall, E8560-02-51	**Matrix:**	SOIL
Lab ID:	N010479-002		

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
VOLATILE ORGANIC COMPOUNDS BY GC/MS						
			EPA 8260B			
RunID: MS1_130702A	QC Batch: D13VS040			PrepDate:		Analyst: **QBM**
1,1,1,2-Tetrachloroethane	ND	5.0		µg/Kg	1	7/2/2013 04:21 PM
1,1,1-Trichloroethane	ND	5.0		µg/Kg	1	7/2/2013 04:21 PM
1,1,2,2-Tetrachloroethane	ND	5.0		µg/Kg	1	7/2/2013 04:21 PM
1,1,2-Trichloroethane	ND	5.0		µg/Kg	1	7/2/2013 04:21 PM
1,1-Dichloroethane	ND	5.0		µg/Kg	1	7/2/2013 04:21 PM
1,1-Dichloroethene	ND	5.0		µg/Kg	1	7/2/2013 04:21 PM
1,1-Dichloropropene	ND	5.0		µg/Kg	1	7/2/2013 04:21 PM
1,2,3-Trichlorobenzene	ND	5.0		µg/Kg	1	7/2/2013 04:21 PM
1,2,3-Trichloropropane	ND	5.0		µg/Kg	1	7/2/2013 04:21 PM
1,2,4-Trichlorobenzene	ND	5.0		µg/Kg	1	7/2/2013 04:21 PM
1,2,4-Trimethylbenzene	ND	5.0		µg/Kg	1	7/2/2013 04:21 PM
1,2-Dibromo-3-chloropropane	ND	10		µg/Kg	1	7/2/2013 04:21 PM
1,2-Dibromoethane	ND	5.0		µg/Kg	1	7/2/2013 04:21 PM
1,2-Dichlorobenzene	ND	5.0		µg/Kg	1	7/2/2013 04:21 PM
1,2-Dichloroethane	ND	5.0		µg/Kg	1	7/2/2013 04:21 PM
1,2-Dichloropropane	ND	5.0		µg/Kg	1	7/2/2013 04:21 PM
1,3,5-Trimethylbenzene	ND	5.0		µg/Kg	1	7/2/2013 04:21 PM
1,3-Dichlorobenzene	ND	5.0		µg/Kg	1	7/2/2013 04:21 PM
1,3-Dichloropropane	ND	5.0		µg/Kg	1	7/2/2013 04:21 PM
1,4-Dichlorobenzene	ND	5.0		µg/Kg	1	7/2/2013 04:21 PM
2,2-Dichloropropane	ND	5.0		µg/Kg	1	7/2/2013 04:21 PM
2-Chlorotoluene	ND	5.0		µg/Kg	1	7/2/2013 04:21 PM
4-Chlorotoluene	ND	5.0		µg/Kg	1	7/2/2013 04:21 PM
4-Isopropyltoluene	ND	5.0		µg/Kg	1	7/2/2013 04:21 PM
Benzene	ND	5.0		µg/Kg	1	7/2/2013 04:21 PM
Bromobenzene	ND	5.0		µg/Kg	1	7/2/2013 04:21 PM
Bromodichloromethane	ND	5.0		µg/Kg	1	7/2/2013 04:21 PM
Bromoform	ND	5.0		µg/Kg	1	7/2/2013 04:21 PM
Bromomethane	ND	5.0		µg/Kg	1	7/2/2013 04:21 PM
Carbon tetrachloride	ND	5.0		µg/Kg	1	7/2/2013 04:21 PM
Chlorobenzene	ND	5.0		µg/Kg	1	7/2/2013 04:21 PM
Chloroethane	ND	5.0		µg/Kg	1	7/2/2013 04:21 PM
Chloroform	ND	5.0		µg/Kg	1	7/2/2013 04:21 PM
Chloromethane	ND	5.0		µg/Kg	1	7/2/2013 04:21 PM
cis-1,2-Dichloroethene	ND	5.0		µg/Kg	1	7/2/2013 04:21 PM
cis-1,3-Dichloropropene	ND	5.0		µg/Kg	1	7/2/2013 04:21 PM

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range
H	Holding times for preparation or analysis exceeded	ND	Not Detected at the Reporting Limit
S	Spike/Surrogate outside of limits due to matrix interference		Results are wet unless otherwise specified
DO	Surrogate Diluted Out		

Advanced Technology Laboratories, Inc.

3151 W. Post Rd Las Vegas, NV 89118 Tel: 702-307-2659 Fax: 702-307-2691

CLIENT: Geocon Consultants, Inc.
Lab Order: N010479
Project: Crissy Field Outfall, E8560-02-51
Lab ID: N010479-002

Client Sample ID: B1-1.5
Collection Date: 6/27/2013 10:15:00 AM
Matrix: SOIL

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
VOLATILE ORGANIC COMPOUNDS BY GC/MS						
			EPA 8260B			
RunID: MS1_130702A	QC Batch: D13VS040			PrepDate:		Analyst: **QBM**
Dibromochloromethane	ND	5.0		µg/Kg	1	7/2/2013 04:21 PM
Dibromomethane	ND	5.0		µg/Kg	1	7/2/2013 04:21 PM
Dichlorodifluoromethane	ND	5.0		µg/Kg	1	7/2/2013 04:21 PM
Ethylbenzene	ND	5.0		µg/Kg	1	7/2/2013 04:21 PM
Hexachlorobutadiene	ND	5.0		µg/Kg	1	7/2/2013 04:21 PM
Isopropylbenzene	ND	5.0		µg/Kg	1	7/2/2013 04:21 PM
m,p-Xylene	ND	10		µg/Kg	1	7/2/2013 04:21 PM
Methylene chloride	ND	5.0		µg/Kg	1	7/2/2013 04:21 PM
n-Butylbenzene	ND	5.0		µg/Kg	1	7/2/2013 04:21 PM
n-Propylbenzene	ND	5.0		µg/Kg	1	7/2/2013 04:21 PM
Naphthalene	ND	5.0		µg/Kg	1	7/2/2013 04:21 PM
o-Xylene	ND	5.0		µg/Kg	1	7/2/2013 04:21 PM
sec-Butylbenzene	ND	5.0		µg/Kg	1	7/2/2013 04:21 PM
Styrene	ND	5.0		µg/Kg	1	7/2/2013 04:21 PM
tert-Butylbenzene	ND	5.0		µg/Kg	1	7/2/2013 04:21 PM
Tetrachloroethene	ND	5.0		µg/Kg	1	7/2/2013 04:21 PM
Toluene	ND	5.0		µg/Kg	1	7/2/2013 04:21 PM
trans-1,2-Dichloroethene	ND	5.0		µg/Kg	1	7/2/2013 04:21 PM
Trichloroethene	ND	5.0		µg/Kg	1	7/2/2013 04:21 PM
Trichlorofluoromethane	ND	5.0		µg/Kg	1	7/2/2013 04:21 PM
Vinyl chloride	ND	5.0		µg/Kg	1	7/2/2013 04:21 PM
Surr: 1,2-Dichloroethane-d4	105	63-139		%REC	1	7/2/2013 04:21 PM
Surr: 4-Bromofluorobenzene	92.4	75-124		%REC	1	7/2/2013 04:21 PM
Surr: Dibromofluoromethane	102	70-133		%REC	1	7/2/2013 04:21 PM
Surr: Toluene-d8	96.6	80-123		%REC	1	7/2/2013 04:21 PM
PCBS BY GC/ECD						
	EPA 3550B			**EPA 8082**		
RunID: GC7_130702B	QC Batch: 43333			PrepDate:	7/2/2013	Analyst: **MDM**
Aroclor 1016	ND	17		µg/Kg	1	7/3/2013 12:12 AM
Aroclor 1221	ND	33		µg/Kg	1	7/3/2013 12:12 AM
Aroclor 1232	ND	17		µg/Kg	1	7/3/2013 12:12 AM
Aroclor 1242	ND	17		µg/Kg	1	7/3/2013 12:12 AM
Aroclor 1248	ND	17		µg/Kg	1	7/3/2013 12:12 AM
Aroclor 1254	ND	17		µg/Kg	1	7/3/2013 12:12 AM
Aroclor 1260	ND	17		µg/Kg	1	7/3/2013 12:12 AM
Surr: Decachlorobiphenyl	85.8	40-146		%REC	1	7/3/2013 12:12 AM

Qualifiers:
- B Analyte detected in the associated Method Blank
- H Holding times for preparation or analysis exceeded
- S Spike/Surrogate outside of limits due to matrix interference
- DO Surrogate Diluted Out
- E Value above quantitation range
- ND Not Detected at the Reporting Limit

Results are wet unless otherwise specified

Advanced Technology Laboratories, Inc.

ANALYTICAL RESULTS

Print Date: *09-Jul-13*

CLIENT:	Geocon Consultants, Inc.	**Client Sample ID:**	B1-1.5
Lab Order:	N010479	**Collection Date:**	6/27/2013 10:15:00 AM
Project:	Crissy Field Outfall, E8560-02-51	**Matrix:**	SOIL
Lab ID:	N010479-002		

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
PCBS BY GC/ECD						
EPA 3550B				**EPA 8082**		
RunID: GC7_130702B	QC Batch: 43333			PrepDate:	7/2/2013	Analyst: **MDM**
Surr: Tetrachloro-m-xylene	80.0	32-109		%REC	1	7/3/2013 12:12 AM
GASOLINE RANGE ORGANICS BY GC/FID						
				EPA 8015B		
RunID: GC4_130702A	QC Batch: E13VS071			PrepDate:		Analyst: **QBM**
GRO	ND	1.0		mg/Kg	1	7/2/2013 11:03 AM
Surr: Chlorobenzene - d5	92.9	51-136		%REC	1	7/2/2013 11:03 AM
ICP METALS						
EPA 3050B				**EPA 6010B**		
RunID: ICP2_130702B	QC Batch: 43321			PrepDate:	7/1/2013	Analyst: **WLS**
Lead	37	2.0		mg/Kg	1	7/2/2013 03:10 PM

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range
H	Holding times for preparation or analysis exceeded	ND	Not Detected at the Reporting Limit
S	Spike/Surrogate outside of limits due to matrix interference		Results are wet unless otherwise specified
DO	Surrogate Diluted Out		

Advanced Technology Laboratories, Inc.

3151 W. Post Rd Las Vegas, NV 89118 Tel: 702-307-2659 Fax: 702-307-2691

CLIENT: Geocon Consultants, Inc.
Lab Order: N010479
Project: Crissy Field Outfall, E8560-02-51
Lab ID: N010479-003

Client Sample ID: B1-3.0
Collection Date: 6/27/2013 10:20:00 AM
Matrix: SOIL

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
PH						
				EPA 9045C		
RunID: WETCHEM_130628A	QC Batch: R89413			PrepDate:		Analyst: **LCC**
pH	7.7	0.10		pH Units	1	6/28/2013
Temp. at time of pH Analysis	25	0		pH Units	1	6/28/2013
VOLATILE ORGANIC COMPOUNDS BY GC/MS						
				EPA 8260B		
RunID: MS1_130702A	QC Batch: D13VS040			PrepDate:		Analyst: **QBM**
1,1,1,2-Tetrachloroethane	ND	5.0		µg/Kg	1	7/2/2013 08:03 PM
1,1,1-Trichloroethane	ND	5.0		µg/Kg	1	7/2/2013 08:03 PM
1,1,2,2-Tetrachloroethane	ND	5.0		µg/Kg	1	7/2/2013 08:03 PM
1,1,2-Trichloroethane	ND	5.0		µg/Kg	1	7/2/2013 08:03 PM
1,1-Dichloroethane	ND	5.0		µg/Kg	1	7/2/2013 08:03 PM
1,1-Dichloroethene	ND	5.0		µg/Kg	1	7/2/2013 08:03 PM
1,1-Dichloropropene	ND	5.0		µg/Kg	1	7/2/2013 08:03 PM
1,2,3-Trichlorobenzene	ND	5.0		µg/Kg	1	7/2/2013 08:03 PM
1,2,3-Trichloropropane	ND	5.0		µg/Kg	1	7/2/2013 08:03 PM
1,2,4-Trichlorobenzene	ND	5.0		µg/Kg	1	7/2/2013 08:03 PM
1,2,4-Trimethylbenzene	ND	5.0		µg/Kg	1	7/2/2013 08:03 PM
1,2-Dibromo-3-chloropropane	ND	10		µg/Kg	1	7/2/2013 08:03 PM
1,2-Dibromoethane	ND	5.0		µg/Kg	1	7/2/2013 08:03 PM
1,2-Dichlorobenzene	ND	5.0		µg/Kg	1	7/2/2013 08:03 PM
1,2-Dichloroethane	ND	5.0		µg/Kg	1	7/2/2013 08:03 PM
1,2-Dichloropropane	ND	5.0		µg/Kg	1	7/2/2013 08:03 PM
1,3,5-Trimethylbenzene	ND	5.0		µg/Kg	1	7/2/2013 08:03 PM
1,3-Dichlorobenzene	ND	5.0		µg/Kg	1	7/2/2013 08:03 PM
1,3-Dichloropropane	ND	5.0		µg/Kg	1	7/2/2013 08:03 PM
1,4-Dichlorobenzene	ND	5.0		µg/Kg	1	7/2/2013 08:03 PM
2,2-Dichloropropane	ND	5.0		µg/Kg	1	7/2/2013 08:03 PM
2-Chlorotoluene	ND	5.0		µg/Kg	1	7/2/2013 08:03 PM
4-Chlorotoluene	ND	5.0		µg/Kg	1	7/2/2013 08:03 PM
4-Isopropyltoluene	ND	5.0		µg/Kg	1	7/2/2013 08:03 PM
Benzene	ND	5.0		µg/Kg	1	7/2/2013 08:03 PM
Bromobenzene	ND	5.0		µg/Kg	1	7/2/2013 08:03 PM
Bromodichloromethane	ND	5.0		µg/Kg	1	7/2/2013 08:03 PM
Bromoform	ND	5.0		µg/Kg	1	7/2/2013 08:03 PM
Bromomethane	ND	5.0		µg/Kg	1	7/2/2013 08:03 PM
Carbon tetrachloride	ND	5.0		µg/Kg	1	7/2/2013 08:03 PM
Chlorobenzene	ND	5.0		µg/Kg	1	7/2/2013 08:03 PM

Qualifiers:
B Analyte detected in the associated Method Blank
H Holding times for preparation or analysis exceeded
S Spike/Surrogate outside of limits due to matrix interference
DO Surrogate Diluted Out
E Value above quantitation range
ND Not Detected at the Reporting Limit
Results are wet unless otherwise specified

Advanced Technology Laboratories, Inc.

ANALYTICAL RESULTS

Print Date: *09-Jul-13*

CLIENT:	Geocon Consultants, Inc.	**Client Sample ID:**	B1-3.0
Lab Order:	N010479	**Collection Date:**	6/27/2013 10:20:00 AM
Project:	Crissy Field Outfall, E8560-02-51	**Matrix:**	SOIL
Lab ID:	N010479-003		

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
VOLATILE ORGANIC COMPOUNDS BY GC/MS						
			EPA 8260B			
RunID: MS1_130702A	QC Batch: D13VS040			PrepDate:		Analyst: **QBM**
Chloroethane	ND	5.0		µg/Kg	1	7/2/2013 08:03 PM
Chloroform	ND	5.0		µg/Kg	1	7/2/2013 08:03 PM
Chloromethane	ND	5.0		µg/Kg	1	7/2/2013 08:03 PM
cis-1,2-Dichloroethene	ND	5.0		µg/Kg	1	7/2/2013 08:03 PM
cis-1,3-Dichloropropene	ND	5.0		µg/Kg	1	7/2/2013 08:03 PM
Dibromochloromethane	ND	5.0		µg/Kg	1	7/2/2013 08:03 PM
Dibromomethane	ND	5.0		µg/Kg	1	7/2/2013 08:03 PM
Dichlorodifluoromethane	ND	5.0		µg/Kg	1	7/2/2013 08:03 PM
Ethylbenzene	ND	5.0		µg/Kg	1	7/2/2013 08:03 PM
Hexachlorobutadiene	ND	5.0		µg/Kg	1	7/2/2013 08:03 PM
Isopropylbenzene	ND	5.0		µg/Kg	1	7/2/2013 08:03 PM
m,p-Xylene	ND	10		µg/Kg	1	7/2/2013 08:03 PM
Methylene chloride	ND	5.0		µg/Kg	1	7/2/2013 08:03 PM
n-Butylbenzene	ND	5.0		µg/Kg	1	7/2/2013 08:03 PM
n-Propylbenzene	ND	5.0		µg/Kg	1	7/2/2013 08:03 PM
Naphthalene	ND	5.0		µg/Kg	1	7/2/2013 08:03 PM
o-Xylene	ND	5.0		µg/Kg	1	7/2/2013 08:03 PM
sec-Butylbenzene	ND	5.0		µg/Kg	1	7/2/2013 08:03 PM
Styrene	ND	5.0		µg/Kg	1	7/2/2013 08:03 PM
tert-Butylbenzene	ND	5.0		µg/Kg	1	7/2/2013 08:03 PM
Tetrachloroethene	ND	5.0		µg/Kg	1	7/2/2013 08:03 PM
Toluene	ND	5.0		µg/Kg	1	7/2/2013 08:03 PM
trans-1,2-Dichloroethene	ND	5.0		µg/Kg	1	7/2/2013 08:03 PM
Trichloroethene	ND	5.0		µg/Kg	1	7/2/2013 08:03 PM
Trichlorofluoromethane	ND	5.0		µg/Kg	1	7/2/2013 08:03 PM
Vinyl chloride	ND	5.0		µg/Kg	1	7/2/2013 08:03 PM
Surr: 1,2-Dichloroethane-d4	106	63-139		%REC	1	7/2/2013 08:03 PM
Surr: 4-Bromofluorobenzene	82.3	75-124		%REC	1	7/2/2013 08:03 PM
Surr: Dibromofluoromethane	102	70-133		%REC	1	7/2/2013 08:03 PM
Surr: Toluene-d8	90.4	80-123		%REC	1	7/2/2013 08:03 PM
DIESEL & MOTOR OIL RANGE ORGANICS BY GC/FID						
	EPA 3550B			**EPA 8015B**		
RunID: GC3_130701A	QC Batch: 43322			PrepDate:	7/1/2013	Analyst: **MDM**
DRO	2.6	1.0		mg/Kg	1	7/1/2013 06:32 PM
ORO	5.1	1.0		mg/Kg	1	7/1/2013 06:32 PM
Surr: p-Terphenyl	104	59-127		%REC	1	7/1/2013 06:32 PM

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range
H	Holding times for preparation or analysis exceeded	ND	Not Detected at the Reporting Limit
S	Spike/Surrogate outside of limits due to matrix interference		Results are wet unless otherwise specified
DO	Surrogate Diluted Out		

Advanced Technology Laboratories, Inc.
3151 W. Post Rd Las Vegas, NV 89118 Tel: 702-307-2659 Fax: 702-307-2691

ANALYTICAL RESULTS

Advanced Technology Laboratories, Inc.

Print Date: *09-Jul-13*

CLIENT:	Geocon Consultants, Inc.	**Client Sample ID:**	B1-3.0
Lab Order:	N010479	**Collection Date:**	6/27/2013 10:20:00 AM
Project:	Crissy Field Outfall, E8560-02-51	**Matrix:**	SOIL
Lab ID:	N010479-003		

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
PCBS BY GC/ECD						
	EPA 3550B			**EPA 8082**		
RunID: GC7_130702B	QC Batch: 43333			PrepDate:	7/2/2013	Analyst: **MDM**
Aroclor 1016	ND	16		µg/Kg	1	7/3/2013 03:09 AM
Aroclor 1221	ND	33		µg/Kg	1	7/3/2013 03:09 AM
Aroclor 1232	ND	16		µg/Kg	1	7/3/2013 03:09 AM
Aroclor 1242	ND	16		µg/Kg	1	7/3/2013 03:09 AM
Aroclor 1248	ND	16		µg/Kg	1	7/3/2013 03:09 AM
Aroclor 1254	ND	16		µg/Kg	1	7/3/2013 03:09 AM
Aroclor 1260	ND	16		µg/Kg	1	7/3/2013 03:09 AM
Surr: Decachlorobiphenyl	69.7	40-146		%REC	1	7/3/2013 03:09 AM
Surr: Tetrachloro-m-xylene	51.7	32-109		%REC	1	7/3/2013 03:09 AM
ICP METALS						
	EPA 3050B			**EPA 6010B**		
RunID: ICP2_130702B	QC Batch: 43321			PrepDate:	7/1/2013	Analyst: **WLS**
Lead	ND	2.0		mg/Kg	1	7/2/2013 03:38 PM

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range
H	Holding times for preparation or analysis exceeded	ND	Not Detected at the Reporting Limit
S	Spike/Surrogate outside of limits due to matrix interference		Results are wet unless otherwise specified
DO	Surrogate Diluted Out		

Advanced Technology Laboratories, Inc.

3151 W. Post Rd Las Vegas, NV 89118 Tel: 702-307-2659 Fax: 702-307-2691

Advanced Technology Laboratories, Inc.

ANALYTICAL RESULTS

Print Date: *09-Jul-13*

CLIENT:	Geocon Consultants, Inc.	**Client Sample ID:**	B1-6.0
Lab Order:	N010479	**Collection Date:**	6/27/2013 10:25:00 AM
Project:	Crissy Field Outfall, E8560-02-51	**Matrix:**	SOIL
Lab ID:	N010479-004		

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
VOLATILE ORGANIC COMPOUNDS BY GC/MS						
			EPA 8260B			
RunID: MS1_130702A	QC Batch: D13VS040			PrepDate:		Analyst: **QBM**
1,1,1,2-Tetrachloroethane	ND	5.0		µg/Kg	1	7/2/2013 04:43 PM
1,1,1-Trichloroethane	ND	5.0		µg/Kg	1	7/2/2013 04:43 PM
1,1,2,2-Tetrachloroethane	ND	5.0		µg/Kg	1	7/2/2013 04:43 PM
1,1,2-Trichloroethane	ND	5.0		µg/Kg	1	7/2/2013 04:43 PM
1,1-Dichloroethane	ND	5.0		µg/Kg	1	7/2/2013 04:43 PM
1,1-Dichloroethene	ND	5.0		µg/Kg	1	7/2/2013 04:43 PM
1,1-Dichloropropene	ND	5.0		µg/Kg	1	7/2/2013 04:43 PM
1,2,3-Trichlorobenzene	ND	5.0		µg/Kg	1	7/2/2013 04:43 PM
1,2,3-Trichloropropane	ND	5.0		µg/Kg	1	7/2/2013 04:43 PM
1,2,4-Trichlorobenzene	ND	5.0		µg/Kg	1	7/2/2013 04:43 PM
1,2,4-Trimethylbenzene	ND	5.0		µg/Kg	1	7/2/2013 04:43 PM
1,2-Dibromo-3-chloropropane	ND	10		µg/Kg	1	7/2/2013 04:43 PM
1,2-Dibromoethane	ND	5.0		µg/Kg	1	7/2/2013 04:43 PM
1,2-Dichlorobenzene	ND	5.0		µg/Kg	1	7/2/2013 04:43 PM
1,2-Dichloroethane	ND	5.0		µg/Kg	1	7/2/2013 04:43 PM
1,2-Dichloropropane	ND	5.0		µg/Kg	1	7/2/2013 04:43 PM
1,3,5-Trimethylbenzene	ND	5.0		µg/Kg	1	7/2/2013 04:43 PM
1,3-Dichlorobenzene	ND	5.0		µg/Kg	1	7/2/2013 04:43 PM
1,3-Dichloropropane	ND	5.0		µg/Kg	1	7/2/2013 04:43 PM
1,4-Dichlorobenzene	ND	5.0		µg/Kg	1	7/2/2013 04:43 PM
2,2-Dichloropropane	ND	5.0		µg/Kg	1	7/2/2013 04:43 PM
2-Chlorotoluene	ND	5.0		µg/Kg	1	7/2/2013 04:43 PM
4-Chlorotoluene	ND	5.0		µg/Kg	1	7/2/2013 04:43 PM
4-Isopropyltoluene	ND	5.0		µg/Kg	1	7/2/2013 04:43 PM
Benzene	ND	5.0		µg/Kg	1	7/2/2013 04:43 PM
Bromobenzene	ND	5.0		µg/Kg	1	7/2/2013 04:43 PM
Bromodichloromethane	ND	5.0		µg/Kg	1	7/2/2013 04:43 PM
Bromoform	ND	5.0		µg/Kg	1	7/2/2013 04:43 PM
Bromomethane	ND	5.0		µg/Kg	1	7/2/2013 04:43 PM
Carbon tetrachloride	ND	5.0		µg/Kg	1	7/2/2013 04:43 PM
Chlorobenzene	ND	5.0		µg/Kg	1	7/2/2013 04:43 PM
Chloroethane	ND	5.0		µg/Kg	1	7/2/2013 04:43 PM
Chloroform	ND	5.0		µg/Kg	1	7/2/2013 04:43 PM
Chloromethane	ND	5.0		µg/Kg	1	7/2/2013 04:43 PM
cis-1,2-Dichloroethene	ND	5.0		µg/Kg	1	7/2/2013 04:43 PM
cis-1,3-Dichloropropene	ND	5.0		µg/Kg	1	7/2/2013 04:43 PM

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range
H	Holding times for preparation or analysis exceeded	ND	Not Detected at the Reporting Limit
S	Spike/Surrogate outside of limits due to matrix interference		Results are wet unless otherwise specified
DO	Surrogate Diluted Out		

Advanced Technology Laboratories, Inc.

3151 W. Post Rd Las Vegas, NV 89118 Tel: 702-307-2659 Fax: 702-307-2691

CLIENT: Geocon Consultants, Inc.
Lab Order: N010479
Project: Crissy Field Outfall, E8560-02-51
Lab ID: N010479-004

Client Sample ID: B1-6.0
Collection Date: 6/27/2013 10:25:00 AM
Matrix: SOIL

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
VOLATILE ORGANIC COMPOUNDS BY GC/MS						
			EPA 8260B			
RunID: MS1_130702A	QC Batch: D13VS040			PrepDate:		Analyst: **QBM**
Dibromochloromethane	ND	5.0		µg/Kg	1	7/2/2013 04:43 PM
Dibromomethane	ND	5.0		µg/Kg	1	7/2/2013 04:43 PM
Dichlorodifluoromethane	ND	5.0		µg/Kg	1	7/2/2013 04:43 PM
Ethylbenzene	ND	5.0		µg/Kg	1	7/2/2013 04:43 PM
Hexachlorobutadiene	ND	5.0		µg/Kg	1	7/2/2013 04:43 PM
Isopropylbenzene	ND	5.0		µg/Kg	1	7/2/2013 04:43 PM
m,p-Xylene	ND	10		µg/Kg	1	7/2/2013 04:43 PM
Methylene chloride	ND	5.0		µg/Kg	1	7/2/2013 04:43 PM
n-Butylbenzene	ND	5.0		µg/Kg	1	7/2/2013 04:43 PM
n-Propylbenzene	ND	5.0		µg/Kg	1	7/2/2013 04:43 PM
Naphthalene	ND	5.0		µg/Kg	1	7/2/2013 04:43 PM
o-Xylene	ND	5.0		µg/Kg	1	7/2/2013 04:43 PM
sec-Butylbenzene	ND	5.0		µg/Kg	1	7/2/2013 04:43 PM
Styrene	ND	5.0		µg/Kg	1	7/2/2013 04:43 PM
tert-Butylbenzene	ND	5.0		µg/Kg	1	7/2/2013 04:43 PM
Tetrachloroethene	ND	5.0		µg/Kg	1	7/2/2013 04:43 PM
Toluene	ND	5.0		µg/Kg	1	7/2/2013 04:43 PM
trans-1,2-Dichloroethene	ND	5.0		µg/Kg	1	7/2/2013 04:43 PM
Trichloroethene	ND	5.0		µg/Kg	1	7/2/2013 04:43 PM
Trichlorofluoromethane	ND	5.0		µg/Kg	1	7/2/2013 04:43 PM
Vinyl chloride	ND	5.0		µg/Kg	1	7/2/2013 04:43 PM
Surr: 1,2-Dichloroethane-d4	96.2	63-139		%REC	1	7/2/2013 04:43 PM
Surr: 4-Bromofluorobenzene	86.3	75-124		%REC	1	7/2/2013 04:43 PM
Surr: Dibromofluoromethane	97.7	70-133		%REC	1	7/2/2013 04:43 PM
Surr: Toluene-d8	94.4	80-123		%REC	1	7/2/2013 04:43 PM
ICP METALS						
	EPA 3050B			**EPA 6010B**		
RunID: ICP2_130702B	QC Batch: 43321			PrepDate:	7/1/2013	Analyst: **WLS**
Lead	ND	2.0		mg/Kg	1	7/2/2013 03:42 PM

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range
H	Holding times for preparation or analysis exceeded	ND	Not Detected at the Reporting Limit
S	Spike/Surrogate outside of limits due to matrix interference		Results are wet unless otherwise specified
DO	Surrogate Diluted Out		

ANALYTICAL RESULTS

Advanced Technology Laboratories, Inc.

Print Date: *09-Jul-13*

CLIENT:	Geocon Consultants, Inc.	**Client Sample ID:**	B1-9.0
Lab Order:	N010479	**Collection Date:**	6/27/2013 10:25:00 AM
Project:	Crissy Field Outfall, E8560-02-51	**Matrix:**	SOIL
Lab ID:	N010479-005		

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
ICP METALS						
	EPA 3050B			**EPA 6010B**		
RunID: ICP2_130702B	QC Batch: 43321			PrepDate:	7/1/2013	Analyst: **WLS**
Lead	ND	2.0		mg/Kg	1	7/2/2013 03:55 PM

Qualifiers:				
	B	Analyte detected in the associated Method Blank	E	Value above quantitation range
	H	Holding times for preparation or analysis exceeded	ND	Not Detected at the Reporting Limit
	S	Spike/Surrogate outside of limits due to matrix interference		Results are wet unless otherwise specified
	DO	Surrogate Diluted Out		

Advanced Technology Laboratories, Inc.

3151 W. Post Rd Las Vegas, NV 89118 Tel: 702-307-2659 Fax: 702-307-2691

ANALYTICAL RESULTS

Advanced Technology Laboratories, Inc.

Print Date: *09-Jul-13*

CLIENT:	Geocon Consultants, Inc.	**Client Sample ID:**	B2-0.5
Lab Order:	N010479	**Collection Date:**	6/27/2013 11:05:00 AM
Project:	Crissy Field Outfall, E8560-02-51	**Matrix:**	SOIL
Lab ID:	N010479-006		

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
ICP METALS						
	EPA 3050B			**EPA 6010B**		
RunID: ICP2_130702B	QC Batch: 43321			PrepDate:	7/1/2013	Analyst: **WLS**
Lead	66	2.0		mg/Kg	1	7/2/2013 03:59 PM

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range
H	Holding times for preparation or analysis exceeded	ND	Not Detected at the Reporting Limit
S	Spike/Surrogate outside of limits due to matrix interference		Results are wet unless otherwise specified
DO	Surrogate Diluted Out		

Advanced Technology Laboratories, Inc.

3151 W. Post Rd Las Vegas, NV 89118 Tel: 702-307-2659 Fax: 702-307-2691

CLIENT:	Geocon Consultants, Inc.	**Client Sample ID:**	B2-1.5
Lab Order:	N010479	**Collection Date:**	6/27/2013 11:10:00 AM
Project:	Crissy Field Outfall, E8560-02-51	**Matrix:**	SOIL
Lab ID:	N010479-007		

VOLATILE ORGANIC COMPOUNDS BY GC/MS

EPA 8260B

RunID: MS1_130702A QC Batch: D13VS040 PrepDate: Analyst: **QBM**

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
1,1,1,2-Tetrachloroethane	ND	5.0		µg/Kg	1	7/2/2013 05:06 PM
1,1,1-Trichloroethane	ND	5.0		µg/Kg	1	7/2/2013 05:06 PM
1,1,2,2-Tetrachloroethane	ND	5.0		µg/Kg	1	7/2/2013 05:06 PM
1,1,2-Trichloroethane	ND	5.0		µg/Kg	1	7/2/2013 05:06 PM
1,1-Dichloroethane	ND	5.0		µg/Kg	1	7/2/2013 05:06 PM
1,1-Dichloroethene	ND	5.0		µg/Kg	1	7/2/2013 05:06 PM
1,1-Dichloropropene	ND	5.0		µg/Kg	1	7/2/2013 05:06 PM
1,2,3-Trichlorobenzene	ND	5.0		µg/Kg	1	7/2/2013 05:06 PM
1,2,3-Trichloropropane	ND	5.0		µg/Kg	1	7/2/2013 05:06 PM
1,2,4-Trichlorobenzene	ND	5.0		µg/Kg	1	7/2/2013 05:06 PM
1,2,4-Trimethylbenzene	ND	5.0		µg/Kg	1	7/2/2013 05:06 PM
1,2-Dibromo-3-chloropropane	ND	10		µg/Kg	1	7/2/2013 05:06 PM
1,2-Dibromoethane	ND	5.0		µg/Kg	1	7/2/2013 05:06 PM
1,2-Dichlorobenzene	ND	5.0		µg/Kg	1	7/2/2013 05:06 PM
1,2-Dichloroethane	ND	5.0		µg/Kg	1	7/2/2013 05:06 PM
1,2-Dichloropropane	ND	5.0		µg/Kg	1	7/2/2013 05:06 PM
1,3,5-Trimethylbenzene	ND	5.0		µg/Kg	1	7/2/2013 05:06 PM
1,3-Dichlorobenzene	ND	5.0		µg/Kg	1	7/2/2013 05:06 PM
1,3-Dichloropropane	ND	5.0		µg/Kg	1	7/2/2013 05:06 PM
1,4-Dichlorobenzene	ND	5.0		µg/Kg	1	7/2/2013 05:06 PM
2,2-Dichloropropane	ND	5.0		µg/Kg	1	7/2/2013 05:06 PM
2-Chlorotoluene	ND	5.0		µg/Kg	1	7/2/2013 05:06 PM
4-Chlorotoluene	ND	5.0		µg/Kg	1	7/2/2013 05:06 PM
4-Isopropyltoluene	ND	5.0		µg/Kg	1	7/2/2013 05:06 PM
Benzene	ND	5.0		µg/Kg	1	7/2/2013 05:06 PM
Bromobenzene	ND	5.0		µg/Kg	1	7/2/2013 05:06 PM
Bromodichloromethane	ND	5.0		µg/Kg	1	7/2/2013 05:06 PM
Bromoform	ND	5.0		µg/Kg	1	7/2/2013 05:06 PM
Bromomethane	ND	5.0		µg/Kg	1	7/2/2013 05:06 PM
Carbon tetrachloride	ND	5.0		µg/Kg	1	7/2/2013 05:06 PM
Chlorobenzene	ND	5.0		µg/Kg	1	7/2/2013 05:06 PM
Chloroethane	ND	5.0		µg/Kg	1	7/2/2013 05:06 PM
Chloroform	ND	5.0		µg/Kg	1	7/2/2013 05:06 PM
Chloromethane	ND	5.0		µg/Kg	1	7/2/2013 05:06 PM
cis-1,2-Dichloroethene	ND	5.0		µg/Kg	1	7/2/2013 05:06 PM
cis-1,3-Dichloropropene	ND	5.0		µg/Kg	1	7/2/2013 05:06 PM

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range
H	Holding times for preparation or analysis exceeded	ND	Not Detected at the Reporting Limit
S	Spike/Surrogate outside of limits due to matrix interference		Results are wet unless otherwise specified
DO	Surrogate Diluted Out		

CLIENT: Geocon Consultants, Inc.
Lab Order: N010479
Project: Crissy Field Outfall, E8560-02-51
Lab ID: N010479-007

Client Sample ID: B2-1.5
Collection Date: 6/27/2013 11:10:00 AM
Matrix: SOIL

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
VOLATILE ORGANIC COMPOUNDS BY GC/MS						
			EPA 8260B			
RunID: MS1_130702A	QC Batch: D13VS040			PrepDate:		Analyst: **QBM**
Dibromochloromethane	ND	5.0		µg/Kg	1	7/2/2013 05:06 PM
Dibromomethane	ND	5.0		µg/Kg	1	7/2/2013 05:06 PM
Dichlorodifluoromethane	ND	5.0		µg/Kg	1	7/2/2013 05:06 PM
Ethylbenzene	ND	5.0		µg/Kg	1	7/2/2013 05:06 PM
Hexachlorobutadiene	ND	5.0		µg/Kg	1	7/2/2013 05:06 PM
Isopropylbenzene	ND	5.0		µg/Kg	1	7/2/2013 05:06 PM
m,p-Xylene	ND	10		µg/Kg	1	7/2/2013 05:06 PM
Methylene chloride	ND	5.0		µg/Kg	1	7/2/2013 05:06 PM
n-Butylbenzene	ND	5.0		µg/Kg	1	7/2/2013 05:06 PM
n-Propylbenzene	ND	5.0		µg/Kg	1	7/2/2013 05:06 PM
Naphthalene	ND	5.0		µg/Kg	1	7/2/2013 05:06 PM
o-Xylene	ND	5.0		µg/Kg	1	7/2/2013 05:06 PM
sec-Butylbenzene	ND	5.0		µg/Kg	1	7/2/2013 05:06 PM
Styrene	ND	5.0		µg/Kg	1	7/2/2013 05:06 PM
tert-Butylbenzene	ND	5.0		µg/Kg	1	7/2/2013 05:06 PM
Tetrachloroethene	ND	5.0		µg/Kg	1	7/2/2013 05:06 PM
Toluene	ND	5.0		µg/Kg	1	7/2/2013 05:06 PM
trans-1,2-Dichloroethene	ND	5.0		µg/Kg	1	7/2/2013 05:06 PM
Trichloroethene	ND	5.0		µg/Kg	1	7/2/2013 05:06 PM
Trichlorofluoromethane	ND	5.0		µg/Kg	1	7/2/2013 05:06 PM
Vinyl chloride	ND	5.0		µg/Kg	1	7/2/2013 05:06 PM
Surr: 1,2-Dichloroethane-d4	107	63-139		%REC	1	7/2/2013 05:06 PM
Surr: 4-Bromofluorobenzene	93.1	75-124		%REC	1	7/2/2013 05:06 PM
Surr: Dibromofluoromethane	106	70-133		%REC	1	7/2/2013 05:06 PM
Surr: Toluene-d8	100	80-123		%REC	1	7/2/2013 05:06 PM
PCBS BY GC/ECD						
	EPA 3550B			**EPA 8082**		
RunID: GC7_130702B	QC Batch: 43333			PrepDate:	7/2/2013	Analyst: **MDM**
Aroclor 1016	ND	16		µg/Kg	1	7/3/2013 03:39 AM
Aroclor 1221	ND	33		µg/Kg	1	7/3/2013 03:39 AM
Aroclor 1232	ND	16		µg/Kg	1	7/3/2013 03:39 AM
Aroclor 1242	ND	16		µg/Kg	1	7/3/2013 03:39 AM
Aroclor 1248	ND	16		µg/Kg	1	7/3/2013 03:39 AM
Aroclor 1254	ND	16		µg/Kg	1	7/3/2013 03:39 AM
Aroclor 1260	ND	16		µg/Kg	1	7/3/2013 03:39 AM
Surr: Decachlorobiphenyl	94.8	40-146		%REC	1	7/3/2013 03:39 AM

Qualifiers:
- B Analyte detected in the associated Method Blank
- H Holding times for preparation or analysis exceeded
- S Spike/Surrogate outside of limits due to matrix interference
- DO Surrogate Diluted Out
- E Value above quantitation range
- ND Not Detected at the Reporting Limit

Results are wet unless otherwise specified

ANALYTICAL RESULTS

Advanced Technology Laboratories, Inc.

Print Date: *09-Jul-13*

CLIENT:	Geocon Consultants, Inc.	**Client Sample ID:**	B2-1.5
Lab Order:	N010479	**Collection Date:**	6/27/2013 11:10:00 AM
Project:	Crissy Field Outfall, E8560-02-51	**Matrix:**	SOIL
Lab ID:	N010479-007		

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
PCBS BY GC/ECD						
	EPA 3550B			**EPA 8082**		
RunID: GC7_130702B	QC Batch: 43333			PrepDate:	7/2/2013	Analyst: **MDM**
Surr: Tetrachloro-m-xylene	56.5	32-109		%REC	1	7/3/2013 03:39 AM
GASOLINE RANGE ORGANICS BY GC/FID						
				EPA 8015B		
RunID: GC4_130702A	QC Batch: E13VS071			PrepDate:		Analyst: **QBM**
GRO	ND	1.0		mg/Kg	1	7/2/2013 11:34 AM
Surr: Chlorobenzene - d5	103	51-136		%REC	1	7/2/2013 11:34 AM
MERCURY BY COLD VAPOR TECHNIQUE						
	EPA 7471			**EPA 7471A**		
RunID: AA1_130701B	QC Batch: 43313			PrepDate:	6/28/2013	Analyst: **LCC**
Mercury	ND	0.099		mg/Kg	1	7/1/2013
ICP METALS						
	EPA 3050B			**EPA 6010B**		
RunID: ICP2_130708A	QC Batch: 43320			PrepDate:	7/1/2013	Analyst: **WLS**
Antimony	ND	2.0		mg/Kg	1	7/8/2013 12:44 PM
Arsenic	2.1	1.0		mg/Kg	1	7/8/2013 12:44 PM
Barium	21	1.0		mg/Kg	1	7/8/2013 12:44 PM
Beryllium	ND	1.0		mg/Kg	1	7/8/2013 12:44 PM
Cadmium	ND	1.0		mg/Kg	1	7/8/2013 12:44 PM
Chromium	45	1.0		mg/Kg	1	7/8/2013 12:44 PM
Cobalt	4.9	1.0		mg/Kg	1	7/8/2013 12:44 PM
Copper	3.8	2.0		mg/Kg	1	7/8/2013 12:44 PM
Lead	27	1.0		mg/Kg	1	7/8/2013 12:44 PM
Molybdenum	ND	1.0		mg/Kg	1	7/8/2013 12:44 PM
Nickel	26	1.0		mg/Kg	1	7/8/2013 12:44 PM
Selenium	ND	1.0		mg/Kg	1	7/8/2013 12:44 PM
Silver	ND	1.0		mg/Kg	1	7/8/2013 12:44 PM
Thallium	ND	1.0		mg/Kg	1	7/8/2013 12:44 PM
Vanadium	29	1.0		mg/Kg	1	7/8/2013 12:44 PM
Zinc	26	1.0		mg/Kg	1	7/8/2013 12:44 PM

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range
H	Holding times for preparation or analysis exceeded	ND	Not Detected at the Reporting Limit
S	Spike/Surrogate outside of limits due to matrix interference		Results are wet unless otherwise specified
DO	Surrogate Diluted Out		

Advanced Technology Laboratories, Inc.

3151 W. Post Rd Las Vegas, NV 89118 Tel: 702-307-2659 Fax: 702-307-2691

CLIENT: Geocon Consultants, Inc.
Lab Order: N010479
Project: Crissy Field Outfall, E8560-02-51
Lab ID: N010479-008

Client Sample ID: B2-3.0
Collection Date: 6/27/2013 11:20:00 AM
Matrix: SOIL

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
PH						
				EPA 9045C		
RunID: WETCHEM_130628A	QC Batch: R89413			PrepDate:		Analyst: **LCC**
pH	7.8	0.10		pH Units	1	6/28/2013
Temp. at time of pH Analysis	25	0		pH Units	1	6/28/2013
VOLATILE ORGANIC COMPOUNDS BY GC/MS						
				EPA 8260B		
RunID: MS1_130702A	QC Batch: D13VS040			PrepDate:		Analyst: **QBM**
1,1,1,2-Tetrachloroethane	ND	5.0		µg/Kg	1	7/2/2013 12:38 PM
1,1,1-Trichloroethane	ND	5.0		µg/Kg	1	7/2/2013 12:38 PM
1,1,2,2-Tetrachloroethane	ND	5.0		µg/Kg	1	7/2/2013 12:38 PM
1,1,2-Trichloroethane	ND	5.0		µg/Kg	1	7/2/2013 12:38 PM
1,1-Dichloroethane	ND	5.0		µg/Kg	1	7/2/2013 12:38 PM
1,1-Dichloroethene	ND	5.0		µg/Kg	1	7/2/2013 12:38 PM
1,1-Dichloropropene	ND	5.0		µg/Kg	1	7/2/2013 12:38 PM
1,2,3-Trichlorobenzene	ND	5.0		µg/Kg	1	7/2/2013 12:38 PM
1,2,3-Trichloropropane	ND	5.0		µg/Kg	1	7/2/2013 12:38 PM
1,2,4-Trichlorobenzene	ND	5.0		µg/Kg	1	7/2/2013 12:38 PM
1,2,4-Trimethylbenzene	ND	5.0		µg/Kg	1	7/2/2013 12:38 PM
1,2-Dibromo-3-chloropropane	ND	10		µg/Kg	1	7/2/2013 12:38 PM
1,2-Dibromoethane	ND	5.0		µg/Kg	1	7/2/2013 12:38 PM
1,2-Dichlorobenzene	ND	5.0		µg/Kg	1	7/2/2013 12:38 PM
1,2-Dichloroethane	ND	5.0		µg/Kg	1	7/2/2013 12:38 PM
1,2-Dichloropropane	ND	5.0		µg/Kg	1	7/2/2013 12:38 PM
1,3,5-Trimethylbenzene	ND	5.0		µg/Kg	1	7/2/2013 12:38 PM
1,3-Dichlorobenzene	ND	5.0		µg/Kg	1	7/2/2013 12:38 PM
1,3-Dichloropropane	ND	5.0		µg/Kg	1	7/2/2013 12:38 PM
1,4-Dichlorobenzene	ND	5.0		µg/Kg	1	7/2/2013 12:38 PM
2,2-Dichloropropane	ND	5.0		µg/Kg	1	7/2/2013 12:38 PM
2-Chlorotoluene	ND	5.0		µg/Kg	1	7/2/2013 12:38 PM
4-Chlorotoluene	ND	5.0		µg/Kg	1	7/2/2013 12:38 PM
4-Isopropyltoluene	ND	5.0		µg/Kg	1	7/2/2013 12:38 PM
Benzene	ND	5.0		µg/Kg	1	7/2/2013 12:38 PM
Bromobenzene	ND	5.0		µg/Kg	1	7/2/2013 12:38 PM
Bromodichloromethane	ND	5.0		µg/Kg	1	7/2/2013 12:38 PM
Bromoform	ND	5.0		µg/Kg	1	7/2/2013 12:38 PM
Bromomethane	ND	5.0		µg/Kg	1	7/2/2013 12:38 PM
Carbon tetrachloride	ND	5.0		µg/Kg	1	7/2/2013 12:38 PM
Chlorobenzene	ND	5.0		µg/Kg	1	7/2/2013 12:38 PM

Qualifiers:
B Analyte detected in the associated Method Blank
H Holding times for preparation or analysis exceeded
S Spike/Surrogate outside of limits due to matrix interference
DO Surrogate Diluted Out
E Value above quantitation range
ND Not Detected at the Reporting Limit
Results are wet unless otherwise specified

CLIENT:	Geocon Consultants, Inc.	**Client Sample ID:**	B2-3.0
Lab Order:	N010479	**Collection Date:**	6/27/2013 11:20:00 AM
Project:	Crissy Field Outfall, E8560-02-51	**Matrix:**	SOIL
Lab ID:	N010479-008		

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
VOLATILE ORGANIC COMPOUNDS BY GC/MS						
				EPA 8260B		
RunID: MS1_130702A	QC Batch: D13VS040			PrepDate:		Analyst: **QBM**
Chloroethane	ND	5.0		µg/Kg	1	7/2/2013 12:38 PM
Chloroform	ND	5.0		µg/Kg	1	7/2/2013 12:38 PM
Chloromethane	ND	5.0		µg/Kg	1	7/2/2013 12:38 PM
cis-1,2-Dichloroethene	ND	5.0		µg/Kg	1	7/2/2013 12:38 PM
cis-1,3-Dichloropropene	ND	5.0		µg/Kg	1	7/2/2013 12:38 PM
Dibromochloromethane	ND	5.0		µg/Kg	1	7/2/2013 12:38 PM
Dibromomethane	ND	5.0		µg/Kg	1	7/2/2013 12:38 PM
Dichlorodifluoromethane	ND	5.0		µg/Kg	1	7/2/2013 12:38 PM
Ethylbenzene	ND	5.0		µg/Kg	1	7/2/2013 12:38 PM
Hexachlorobutadiene	ND	5.0		µg/Kg	1	7/2/2013 12:38 PM
Isopropylbenzene	ND	5.0		µg/Kg	1	7/2/2013 12:38 PM
m,p-Xylene	ND	10		µg/Kg	1	7/2/2013 12:38 PM
Methylene chloride	ND	5.0		µg/Kg	1	7/2/2013 12:38 PM
n-Butylbenzene	ND	5.0		µg/Kg	1	7/2/2013 12:38 PM
n-Propylbenzene	ND	5.0		µg/Kg	1	7/2/2013 12:38 PM
Naphthalene	ND	5.0		µg/Kg	1	7/2/2013 12:38 PM
o-Xylene	ND	5.0		µg/Kg	1	7/2/2013 12:38 PM
sec-Butylbenzene	ND	5.0		µg/Kg	1	7/2/2013 12:38 PM
Styrene	ND	5.0		µg/Kg	1	7/2/2013 12:38 PM
tert-Butylbenzene	ND	5.0		µg/Kg	1	7/2/2013 12:38 PM
Tetrachloroethene	ND	5.0		µg/Kg	1	7/2/2013 12:38 PM
Toluene	ND	5.0		µg/Kg	1	7/2/2013 12:38 PM
trans-1,2-Dichloroethene	ND	5.0		µg/Kg	1	7/2/2013 12:38 PM
Trichloroethene	ND	5.0		µg/Kg	1	7/2/2013 12:38 PM
Trichlorofluoromethane	ND	5.0		µg/Kg	1	7/2/2013 12:38 PM
Vinyl chloride	ND	5.0		µg/Kg	1	7/2/2013 12:38 PM
Surr: 1,2-Dichloroethane-d4	96.4	63-139		%REC	1	7/2/2013 12:38 PM
Surr: 4-Bromofluorobenzene	90.8	75-124		%REC	1	7/2/2013 12:38 PM
Surr: Dibromofluoromethane	97.1	70-133		%REC	1	7/2/2013 12:38 PM
Surr: Toluene-d8	97.3	80-123		%REC	1	7/2/2013 12:38 PM
DIESEL & MOTOR OIL RANGE ORGANICS BY GC/FID						
	EPA 3550B			**EPA 8015B**		
RunID: GC3_130701A	QC Batch: 43322			PrepDate:	7/1/2013	Analyst: **MDM**
DRO	1.5	1.0		mg/Kg	1	7/1/2013 07:27 PM
ORO	2.4	1.0		mg/Kg	1	7/1/2013 07:27 PM
Surr: p-Terphenyl	97.1	59-127		%REC	1	7/1/2013 07:27 PM

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range
H	Holding times for preparation or analysis exceeded	ND	Not Detected at the Reporting Limit
S	Spike/Surrogate outside of limits due to matrix interference		Results are wet unless otherwise specified
DO	Surrogate Diluted Out		

ANALYTICAL RESULTS

Advanced Technology Laboratories, Inc.

Print Date: *09-Jul-13*

CLIENT:	Geocon Consultants, Inc.	**Client Sample ID:**	B2-3.0
Lab Order:	N010479	**Collection Date:**	6/27/2013 11:20:00 AM
Project:	Crissy Field Outfall, E8560-02-51	**Matrix:**	SOIL
Lab ID:	N010479-008		

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
PCBS BY GC/ECD						
	EPA 3550B			**EPA 8082**		
RunID: GC7_130702B	QC Batch: 43333			PrepDate:	7/2/2013	Analyst: **MDM**
Aroclor 1016	ND	16		µg/Kg	1	7/3/2013 04:08 AM
Aroclor 1221	ND	33		µg/Kg	1	7/3/2013 04:08 AM
Aroclor 1232	ND	16		µg/Kg	1	7/3/2013 04:08 AM
Aroclor 1242	ND	16		µg/Kg	1	7/3/2013 04:08 AM
Aroclor 1248	ND	16		µg/Kg	1	7/3/2013 04:08 AM
Aroclor 1254	ND	16		µg/Kg	1	7/3/2013 04:08 AM
Aroclor 1260	ND	16		µg/Kg	1	7/3/2013 04:08 AM
Surr: Decachlorobiphenyl	90.3	40-146		%REC	1	7/3/2013 04:08 AM
Surr: Tetrachloro-m-xylene	63.8	32-109		%REC	1	7/3/2013 04:08 AM
ICP METALS						
	EPA 3050B			**EPA 6010B**		
RunID: ICP2_130702B	QC Batch: 43321			PrepDate:	7/1/2013	Analyst: **WLS**
Lead	9.2	2.0		mg/Kg	1	7/2/2013 04:05 PM

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range
H	Holding times for preparation or analysis exceeded	ND	Not Detected at the Reporting Limit
S	Spike/Surrogate outside of limits due to matrix interference		Results are wet unless otherwise specified
DO	Surrogate Diluted Out		

Advanced Technology Laboratories, Inc.

3151 W. Post Rd Las Vegas, NV 89118 Tel: 702-307-2659 Fax: 702-307-2691

Advanced Technology Laboratories, Inc.

ANALYTICAL RESULTS

Print Date: *09-Jul-13*

CLIENT:	Geocon Consultants, Inc.	**Client Sample ID:**	B2-6.0
Lab Order:	N010479	**Collection Date:**	6/27/2013 11:40:00 AM
Project:	Crissy Field Outfall, E8560-02-51	**Matrix:**	SOIL
Lab ID:	N010479-009		

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
VOLATILE ORGANIC COMPOUNDS BY GC/MS						
			EPA 8260B			
RunID: MS1_130702A	QC Batch: D13VS040			PrepDate:		Analyst: **QBM**
1,1,1,2-Tetrachloroethane	ND	5.0		µg/Kg	1	7/2/2013 08:25 PM
1,1,1-Trichloroethane	ND	5.0		µg/Kg	1	7/2/2013 08:25 PM
1,1,2,2-Tetrachloroethane	ND	5.0		µg/Kg	1	7/2/2013 08:25 PM
1,1,2-Trichloroethane	ND	5.0		µg/Kg	1	7/2/2013 08:25 PM
1,1-Dichloroethane	ND	5.0		µg/Kg	1	7/2/2013 08:25 PM
1,1-Dichloroethene	ND	5.0		µg/Kg	1	7/2/2013 08:25 PM
1,1-Dichloropropene	ND	5.0		µg/Kg	1	7/2/2013 08:25 PM
1,2,3-Trichlorobenzene	ND	5.0		µg/Kg	1	7/2/2013 08:25 PM
1,2,3-Trichloropropane	ND	5.0		µg/Kg	1	7/2/2013 08:25 PM
1,2,4-Trichlorobenzene	ND	5.0		µg/Kg	1	7/2/2013 08:25 PM
1,2,4-Trimethylbenzene	ND	5.0		µg/Kg	1	7/2/2013 08:25 PM
1,2-Dibromo-3-chloropropane	ND	10		µg/Kg	1	7/2/2013 08:25 PM
1,2-Dibromoethane	ND	5.0		µg/Kg	1	7/2/2013 08:25 PM
1,2-Dichlorobenzene	ND	5.0		µg/Kg	1	7/2/2013 08:25 PM
1,2-Dichloroethane	ND	5.0		µg/Kg	1	7/2/2013 08:25 PM
1,2-Dichloropropane	ND	5.0		µg/Kg	1	7/2/2013 08:25 PM
1,3,5-Trimethylbenzene	ND	5.0		µg/Kg	1	7/2/2013 08:25 PM
1,3-Dichlorobenzene	ND	5.0		µg/Kg	1	7/2/2013 08:25 PM
1,3-Dichloropropane	ND	5.0		µg/Kg	1	7/2/2013 08:25 PM
1,4-Dichlorobenzene	ND	5.0		µg/Kg	1	7/2/2013 08:25 PM
2,2-Dichloropropane	ND	5.0		µg/Kg	1	7/2/2013 08:25 PM
2-Chlorotoluene	ND	5.0		µg/Kg	1	7/2/2013 08:25 PM
4-Chlorotoluene	ND	5.0		µg/Kg	1	7/2/2013 08:25 PM
4-Isopropyltoluene	ND	5.0		µg/Kg	1	7/2/2013 08:25 PM
Benzene	ND	5.0		µg/Kg	1	7/2/2013 08:25 PM
Bromobenzene	ND	5.0		µg/Kg	1	7/2/2013 08:25 PM
Bromodichloromethane	ND	5.0		µg/Kg	1	7/2/2013 08:25 PM
Bromoform	ND	5.0		µg/Kg	1	7/2/2013 08:25 PM
Bromomethane	ND	5.0		µg/Kg	1	7/2/2013 08:25 PM
Carbon tetrachloride	ND	5.0		µg/Kg	1	7/2/2013 08:25 PM
Chlorobenzene	ND	5.0		µg/Kg	1	7/2/2013 08:25 PM
Chloroethane	ND	5.0		µg/Kg	1	7/2/2013 08:25 PM
Chloroform	ND	5.0		µg/Kg	1	7/2/2013 08:25 PM
Chloromethane	ND	5.0		µg/Kg	1	7/2/2013 08:25 PM
cis-1,2-Dichloroethene	ND	5.0		µg/Kg	1	7/2/2013 08:25 PM
cis-1,3-Dichloropropene	ND	5.0		µg/Kg	1	7/2/2013 08:25 PM

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range
H	Holding times for preparation or analysis exceeded	ND	Not Detected at the Reporting Limit
S	Spike/Surrogate outside of limits due to matrix interference		Results are wet unless otherwise specified
DO	Surrogate Diluted Out		

Advanced Technology Laboratories, Inc.

3151 W. Post Rd Las Vegas, NV 89118 Tel: 702-307-2659 Fax: 702-307-2691

ANALYTICAL RESULTS

Advanced Technology Laboratories, Inc.

Print Date: *09-Jul-13*

CLIENT:	Geocon Consultants, Inc.	**Client Sample ID:**	B2-6.0
Lab Order:	N010479	**Collection Date:**	6/27/2013 11:40:00 AM
Project:	Crissy Field Outfall, E8560-02-51	**Matrix:**	SOIL
Lab ID:	N010479-009		

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
VOLATILE ORGANIC COMPOUNDS BY GC/MS						
			EPA 8260B			
RunID: MS1_130702A	QC Batch: D13VS040			PrepDate:		Analyst: **QBM**
Dibromochloromethane	ND	5.0		µg/Kg	1	7/2/2013 08:25 PM
Dibromomethane	ND	5.0		µg/Kg	1	7/2/2013 08:25 PM
Dichlorodifluoromethane	ND	5.0		µg/Kg	1	7/2/2013 08:25 PM
Ethylbenzene	ND	5.0		µg/Kg	1	7/2/2013 08:25 PM
Hexachlorobutadiene	ND	5.0		µg/Kg	1	7/2/2013 08:25 PM
Isopropylbenzene	ND	5.0		µg/Kg	1	7/2/2013 08:25 PM
m,p-Xylene	ND	10		µg/Kg	1	7/2/2013 08:25 PM
Methylene chloride	ND	5.0		µg/Kg	1	7/2/2013 08:25 PM
n-Butylbenzene	ND	5.0		µg/Kg	1	7/2/2013 08:25 PM
n-Propylbenzene	ND	5.0		µg/Kg	1	7/2/2013 08:25 PM
Naphthalene	ND	5.0		µg/Kg	1	7/2/2013 08:25 PM
o-Xylene	ND	5.0		µg/Kg	1	7/2/2013 08:25 PM
sec-Butylbenzene	ND	5.0		µg/Kg	1	7/2/2013 08:25 PM
Styrene	ND	5.0		µg/Kg	1	7/2/2013 08:25 PM
tert-Butylbenzene	ND	5.0		µg/Kg	1	7/2/2013 08:25 PM
Tetrachloroethene	ND	5.0		µg/Kg	1	7/2/2013 08:25 PM
Toluene	ND	5.0		µg/Kg	1	7/2/2013 08:25 PM
trans-1,2-Dichloroethene	ND	5.0		µg/Kg	1	7/2/2013 08:25 PM
Trichloroethene	ND	5.0		µg/Kg	1	7/2/2013 08:25 PM
Trichlorofluoromethane	ND	5.0		µg/Kg	1	7/2/2013 08:25 PM
Vinyl chloride	ND	5.0		µg/Kg	1	7/2/2013 08:25 PM
Surr: 1,2-Dichloroethane-d4	105	63-139		%REC	1	7/2/2013 08:25 PM
Surr: 4-Bromofluorobenzene	70.4	75-124	S	%REC	1	7/2/2013 08:25 PM
Surr: Dibromofluoromethane	97.3	70-133		%REC	1	7/2/2013 08:25 PM
Surr: Toluene-d8	83.4	80-123		%REC	1	7/2/2013 08:25 PM
ICP METALS						
	EPA 3050B			**EPA 6010B**		
RunID: ICP2_130702B	QC Batch: 43321			PrepDate:	7/1/2013	Analyst: **WLS**
Lead	3.6	2.0		mg/Kg	1	7/2/2013 04:09 PM

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range
H	Holding times for preparation or analysis exceeded	ND	Not Detected at the Reporting Limit
S	Spike/Surrogate outside of limits due to matrix interference		Results are wet unless otherwise specified
DO	Surrogate Diluted Out		

Advanced Technology Laboratories, Inc.

3151 W. Post Rd Las Vegas, NV 89118 Tel: 702-307-2659 Fax: 702-307-2691

ANALYTICAL RESULTS

Advanced Technology Laboratories, Inc.

Print Date: *09-Jul-13*

CLIENT:	Geocon Consultants, Inc.	**Client Sample ID:**	B2-11.0
Lab Order:	N010479	**Collection Date:**	6/27/2013 11:50:00 AM
Project:	Crissy Field Outfall, E8560-02-51	**Matrix:**	SOIL
Lab ID:	N010479-010		

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
ICP METALS						
	EPA 3050B			**EPA 6010B**		
RunID: ICP2_130702B	QC Batch: 43321			PrepDate:	7/1/2013	Analyst: **WLS**
Lead	ND	2.0		mg/Kg	1	7/2/2013 04:13 PM

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range
H	Holding times for preparation or analysis exceeded	ND	Not Detected at the Reporting Limit
S	Spike/Surrogate outside of limits due to matrix interference		Results are wet unless otherwise specified
DO	Surrogate Diluted Out		

Advanced Technology Laboratories, Inc.

3151 W. Post Rd Las Vegas, NV 89118 Tel: 702-307-2659 Fax: 702-307-2691

ANALYTICAL RESULTS

Advanced Technology Laboratories, Inc.

Print Date: *09-Jul-13*

CLIENT:	Geocon Consultants, Inc.	**Client Sample ID:**	B3-0.5
Lab Order:	N010479	**Collection Date:**	6/27/2013 8:20:00 AM
Project:	Crissy Field Outfall, E8560-02-51	**Matrix:**	SOIL
Lab ID:	N010479-011		

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
ICP METALS						
	EPA 3050B			**EPA 6010B**		
RunID: ICP2_130702B	QC Batch: 43321			PrepDate:	7/1/2013	Analyst: **WLS**
Lead	11	2.0		mg/Kg	1	7/2/2013 04:18 PM

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range
H	Holding times for preparation or analysis exceeded	ND	Not Detected at the Reporting Limit
S	Spike/Surrogate outside of limits due to matrix interference		Results are wet unless otherwise specified
DO	Surrogate Diluted Out		

Advanced Technology Laboratories, Inc.

3151 W. Post Rd Las Vegas, NV 89118 Tel: 702-307-2659 Fax: 702-307-2691

CLIENT:	Geocon Consultants, Inc.	**Client Sample ID:**	B3-1.5
Lab Order:	N010479	**Collection Date:**	6/27/2013 8:25:00 AM
Project:	Crissy Field Outfall, E8560-02-51	**Matrix:**	SOIL
Lab ID:	N010479-012		

VOLATILE ORGANIC COMPOUNDS BY GC/MS

EPA 8260B

RunID: MS1_130702A QC Batch: D13VS040 PrepDate: Analyst: **QBM**

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
1,1,1,2-Tetrachloroethane	ND	5.0		µg/Kg	1	7/2/2013 05:28 PM
1,1,1-Trichloroethane	ND	5.0		µg/Kg	1	7/2/2013 05:28 PM
1,1,2,2-Tetrachloroethane	ND	5.0		µg/Kg	1	7/2/2013 05:28 PM
1,1,2-Trichloroethane	ND	5.0		µg/Kg	1	7/2/2013 05:28 PM
1,1-Dichloroethane	ND	5.0		µg/Kg	1	7/2/2013 05:28 PM
1,1-Dichloroethene	ND	5.0		µg/Kg	1	7/2/2013 05:28 PM
1,1-Dichloropropene	ND	5.0		µg/Kg	1	7/2/2013 05:28 PM
1,2,3-Trichlorobenzene	ND	5.0		µg/Kg	1	7/2/2013 05:28 PM
1,2,3-Trichloropropane	ND	5.0		µg/Kg	1	7/2/2013 05:28 PM
1,2,4-Trichlorobenzene	ND	5.0		µg/Kg	1	7/2/2013 05:28 PM
1,2,4-Trimethylbenzene	ND	5.0		µg/Kg	1	7/2/2013 05:28 PM
1,2-Dibromo-3-chloropropane	ND	10		µg/Kg	1	7/2/2013 05:28 PM
1,2-Dibromoethane	ND	5.0		µg/Kg	1	7/2/2013 05:28 PM
1,2-Dichlorobenzene	ND	5.0		µg/Kg	1	7/2/2013 05:28 PM
1,2-Dichloroethane	ND	5.0		µg/Kg	1	7/2/2013 05:28 PM
1,2-Dichloropropane	ND	5.0		µg/Kg	1	7/2/2013 05:28 PM
1,3,5-Trimethylbenzene	ND	5.0		µg/Kg	1	7/2/2013 05:28 PM
1,3-Dichlorobenzene	ND	5.0		µg/Kg	1	7/2/2013 05:28 PM
1,3-Dichloropropane	ND	5.0		µg/Kg	1	7/2/2013 05:28 PM
1,4-Dichlorobenzene	ND	5.0		µg/Kg	1	7/2/2013 05:28 PM
2,2-Dichloropropane	ND	5.0		µg/Kg	1	7/2/2013 05:28 PM
2-Chlorotoluene	ND	5.0		µg/Kg	1	7/2/2013 05:28 PM
4-Chlorotoluene	ND	5.0		µg/Kg	1	7/2/2013 05:28 PM
4-Isopropyltoluene	ND	5.0		µg/Kg	1	7/2/2013 05:28 PM
Benzene	ND	5.0		µg/Kg	1	7/2/2013 05:28 PM
Bromobenzene	ND	5.0		µg/Kg	1	7/2/2013 05:28 PM
Bromodichloromethane	ND	5.0		µg/Kg	1	7/2/2013 05:28 PM
Bromoform	ND	5.0		µg/Kg	1	7/2/2013 05:28 PM
Bromomethane	ND	5.0		µg/Kg	1	7/2/2013 05:28 PM
Carbon tetrachloride	ND	5.0		µg/Kg	1	7/2/2013 05:28 PM
Chlorobenzene	ND	5.0		µg/Kg	1	7/2/2013 05:28 PM
Chloroethane	ND	5.0		µg/Kg	1	7/2/2013 05:28 PM
Chloroform	ND	5.0		µg/Kg	1	7/2/2013 05:28 PM
Chloromethane	ND	5.0		µg/Kg	1	7/2/2013 05:28 PM
cis-1,2-Dichloroethene	ND	5.0		µg/Kg	1	7/2/2013 05:28 PM
cis-1,3-Dichloropropene	ND	5.0		µg/Kg	1	7/2/2013 05:28 PM

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range
H	Holding times for preparation or analysis exceeded	ND	Not Detected at the Reporting Limit
S	Spike/Surrogate outside of limits due to matrix interference		Results are wet unless otherwise specified
DO	Surrogate Diluted Out		

CLIENT: Geocon Consultants, Inc.
Lab Order: N010479
Project: Crissy Field Outfall, E8560-02-51
Lab ID: N010479-012

Client Sample ID: B3-1.5
Collection Date: 6/27/2013 8:25:00 AM
Matrix: SOIL

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
VOLATILE ORGANIC COMPOUNDS BY GC/MS						
			EPA 8260B			
RunID: MS1_130702A	QC Batch: D13VS040			PrepDate:		Analyst: **QBM**
Dibromochloromethane	ND	5.0		µg/Kg	1	7/2/2013 05:28 PM
Dibromomethane	ND	5.0		µg/Kg	1	7/2/2013 05:28 PM
Dichlorodifluoromethane	ND	5.0		µg/Kg	1	7/2/2013 05:28 PM
Ethylbenzene	ND	5.0		µg/Kg	1	7/2/2013 05:28 PM
Hexachlorobutadiene	ND	5.0		µg/Kg	1	7/2/2013 05:28 PM
Isopropylbenzene	ND	5.0		µg/Kg	1	7/2/2013 05:28 PM
m,p-Xylene	ND	10		µg/Kg	1	7/2/2013 05:28 PM
Methylene chloride	ND	5.0		µg/Kg	1	7/2/2013 05:28 PM
n-Butylbenzene	ND	5.0		µg/Kg	1	7/2/2013 05:28 PM
n-Propylbenzene	ND	5.0		µg/Kg	1	7/2/2013 05:28 PM
Naphthalene	ND	5.0		µg/Kg	1	7/2/2013 05:28 PM
o-Xylene	ND	5.0		µg/Kg	1	7/2/2013 05:28 PM
sec-Butylbenzene	ND	5.0		µg/Kg	1	7/2/2013 05:28 PM
Styrene	ND	5.0		µg/Kg	1	7/2/2013 05:28 PM
tert-Butylbenzene	ND	5.0		µg/Kg	1	7/2/2013 05:28 PM
Tetrachloroethene	ND	5.0		µg/Kg	1	7/2/2013 05:28 PM
Toluene	ND	5.0		µg/Kg	1	7/2/2013 05:28 PM
trans-1,2-Dichloroethene	ND	5.0		µg/Kg	1	7/2/2013 05:28 PM
Trichloroethene	ND	5.0		µg/Kg	1	7/2/2013 05:28 PM
Trichlorofluoromethane	ND	5.0		µg/Kg	1	7/2/2013 05:28 PM
Vinyl chloride	ND	5.0		µg/Kg	1	7/2/2013 05:28 PM
Surr: 1,2-Dichloroethane-d4	107	63-139		%REC	1	7/2/2013 05:28 PM
Surr: 4-Bromofluorobenzene	94.4	75-124		%REC	1	7/2/2013 05:28 PM
Surr: Dibromofluoromethane	102	70-133		%REC	1	7/2/2013 05:28 PM
Surr: Toluene-d8	96.9	80-123		%REC	1	7/2/2013 05:28 PM
PCBS BY GC/ECD						
	EPA 3550B			**EPA 8082**		
RunID: GC7_130702B	QC Batch: 43333			PrepDate:	7/2/2013	Analyst: **MDM**
Aroclor 1016	ND	16		µg/Kg	1	7/3/2013 04:38 AM
Aroclor 1221	ND	33		µg/Kg	1	7/3/2013 04:38 AM
Aroclor 1232	ND	16		µg/Kg	1	7/3/2013 04:38 AM
Aroclor 1242	ND	16		µg/Kg	1	7/3/2013 04:38 AM
Aroclor 1248	ND	16		µg/Kg	1	7/3/2013 04:38 AM
Aroclor 1254	ND	16		µg/Kg	1	7/3/2013 04:38 AM
Aroclor 1260	ND	16		µg/Kg	1	7/3/2013 04:38 AM
Surr: Decachlorobiphenyl	93.6	40-146		%REC	1	7/3/2013 04:38 AM

Qualifiers:
- B Analyte detected in the associated Method Blank
- H Holding times for preparation or analysis exceeded
- S Spike/Surrogate outside of limits due to matrix interference
- DO Surrogate Diluted Out
- E Value above quantitation range
- ND Not Detected at the Reporting Limit

Results are wet unless otherwise specified

Advanced Technology Laboratories, Inc.

ANALYTICAL RESULTS

Print Date: *09-Jul-13*

CLIENT: Geocon Consultants, Inc.
Lab Order: N010479
Project: Crissy Field Outfall, E8560-02-51
Lab ID: N010479-012

Client Sample ID: B3-1.5
Collection Date: 6/27/2013 8:25:00 AM
Matrix: SOIL

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
PCBS BY GC/ECD						
	EPA 3550B			**EPA 8082**		
RunID: GC7_130702B	QC Batch: 43333			PrepDate:	7/2/2013	Analyst: **MDM**
Surr: Tetrachloro-m-xylene	69.2	32-109		%REC	1	7/3/2013 04:38 AM
GASOLINE RANGE ORGANICS BY GC/FID						
				EPA 8015B		
RunID: GC4_130702A	QC Batch: E13VS071			PrepDate:		Analyst: **QBM**
GRO	ND	1.0		mg/Kg	1	7/2/2013 12:35 PM
Surr: Chlorobenzene - d5	107	51-136		%REC	1	7/2/2013 12:35 PM
MERCURY BY COLD VAPOR TECHNIQUE						
	EPA 7471			**EPA 7471A**		
RunID: AA1_130701B	QC Batch: 43313			PrepDate:	6/28/2013	Analyst: **LCC**
Mercury	ND	0.10		mg/Kg	1	7/1/2013
ICP METALS						
	EPA 3050B			**EPA 6010B**		
RunID: ICP2_130708A	QC Batch: 43320			PrepDate:	7/1/2013	Analyst: **WLS**
Antimony	ND	2.0		mg/Kg	1	7/8/2013 12:50 PM
Arsenic	3.7	1.0		mg/Kg	1	7/8/2013 12:50 PM
Barium	32	1.0		mg/Kg	1	7/8/2013 12:50 PM
Beryllium	ND	1.0		mg/Kg	1	7/8/2013 12:50 PM
Cadmium	ND	1.0		mg/Kg	1	7/8/2013 12:50 PM
Chromium	37	1.0		mg/Kg	1	7/8/2013 12:50 PM
Cobalt	5.3	1.0		mg/Kg	1	7/8/2013 12:50 PM
Copper	6.9	2.0		mg/Kg	1	7/8/2013 12:50 PM
Lead	4.4	1.0		mg/Kg	1	7/8/2013 12:50 PM
Molybdenum	ND	1.0		mg/Kg	1	7/8/2013 12:50 PM
Nickel	25	1.0		mg/Kg	1	7/8/2013 12:50 PM
Selenium	ND	1.0		mg/Kg	1	7/8/2013 12:50 PM
Silver	ND	1.0		mg/Kg	1	7/8/2013 12:50 PM
Thallium	ND	1.0		mg/Kg	1	7/8/2013 12:50 PM
Vanadium	21	1.0		mg/Kg	1	7/8/2013 12:50 PM
Zinc	17	1.0		mg/Kg	1	7/8/2013 12:50 PM

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range
H	Holding times for preparation or analysis exceeded	ND	Not Detected at the Reporting Limit
S	Spike/Surrogate outside of limits due to matrix interference		Results are wet unless otherwise specified
DO	Surrogate Diluted Out		

Advanced Technology Laboratories, Inc.
3151 W. Post Rd Las Vegas, NV 89118 Tel: 702-307-2659 Fax: 702-307-2691

CLIENT: Geocon Consultants, Inc.
Lab Order: N010479
Project: Crissy Field Outfall, E8560-02-51
Lab ID: N010479-013

Client Sample ID: B3-3.0
Collection Date: 6/27/2013 8:35:00 AM
Matrix: SOIL

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
PH						
				EPA 9045C		
RunID: WETCHEM_130628A	QC Batch: R89413			PrepDate:		Analyst: **LCC**
pH	8.9	0.10		pH Units	1	6/28/2013
Temp. at time of pH Analysis	25	0		pH Units	1	6/28/2013
VOLATILE ORGANIC COMPOUNDS BY GC/MS						
				EPA 8260B		
RunID: MS1_130702A	QC Batch: D13VS040			PrepDate:		Analyst: **QBM**
1,1,1,2-Tetrachloroethane	ND	5.0		µg/Kg	1	7/2/2013 05:50 PM
1,1,1-Trichloroethane	ND	5.0		µg/Kg	1	7/2/2013 05:50 PM
1,1,2,2-Tetrachloroethane	ND	5.0		µg/Kg	1	7/2/2013 05:50 PM
1,1,2-Trichloroethane	ND	5.0		µg/Kg	1	7/2/2013 05:50 PM
1,1-Dichloroethane	ND	5.0		µg/Kg	1	7/2/2013 05:50 PM
1,1-Dichloroethene	ND	5.0		µg/Kg	1	7/2/2013 05:50 PM
1,1-Dichloropropene	ND	5.0		µg/Kg	1	7/2/2013 05:50 PM
1,2,3-Trichlorobenzene	ND	5.0		µg/Kg	1	7/2/2013 05:50 PM
1,2,3-Trichloropropane	ND	5.0		µg/Kg	1	7/2/2013 05:50 PM
1,2,4-Trichlorobenzene	ND	5.0		µg/Kg	1	7/2/2013 05:50 PM
1,2,4-Trimethylbenzene	ND	5.0		µg/Kg	1	7/2/2013 05:50 PM
1,2-Dibromo-3-chloropropane	ND	10		µg/Kg	1	7/2/2013 05:50 PM
1,2-Dibromoethane	ND	5.0		µg/Kg	1	7/2/2013 05:50 PM
1,2-Dichlorobenzene	ND	5.0		µg/Kg	1	7/2/2013 05:50 PM
1,2-Dichloroethane	ND	5.0		µg/Kg	1	7/2/2013 05:50 PM
1,2-Dichloropropane	ND	5.0		µg/Kg	1	7/2/2013 05:50 PM
1,3,5-Trimethylbenzene	ND	5.0		µg/Kg	1	7/2/2013 05:50 PM
1,3-Dichlorobenzene	ND	5.0		µg/Kg	1	7/2/2013 05:50 PM
1,3-Dichloropropane	ND	5.0		µg/Kg	1	7/2/2013 05:50 PM
1,4-Dichlorobenzene	ND	5.0		µg/Kg	1	7/2/2013 05:50 PM
2,2-Dichloropropane	ND	5.0		µg/Kg	1	7/2/2013 05:50 PM
2-Chlorotoluene	ND	5.0		µg/Kg	1	7/2/2013 05:50 PM
4-Chlorotoluene	ND	5.0		µg/Kg	1	7/2/2013 05:50 PM
4-Isopropyltoluene	ND	5.0		µg/Kg	1	7/2/2013 05:50 PM
Benzene	ND	5.0		µg/Kg	1	7/2/2013 05:50 PM
Bromobenzene	ND	5.0		µg/Kg	1	7/2/2013 05:50 PM
Bromodichloromethane	ND	5.0		µg/Kg	1	7/2/2013 05:50 PM
Bromoform	ND	5.0		µg/Kg	1	7/2/2013 05:50 PM
Bromomethane	ND	5.0		µg/Kg	1	7/2/2013 05:50 PM
Carbon tetrachloride	ND	5.0		µg/Kg	1	7/2/2013 05:50 PM
Chlorobenzene	ND	5.0		µg/Kg	1	7/2/2013 05:50 PM

Qualifiers:
B Analyte detected in the associated Method Blank
H Holding times for preparation or analysis exceeded
S Spike/Surrogate outside of limits due to matrix interference
DO Surrogate Diluted Out
E Value above quantitation range
ND Not Detected at the Reporting Limit
Results are wet unless otherwise specified

CLIENT: Geocon Consultants, Inc.
Lab Order: N010479
Project: Crissy Field Outfall, E8560-02-51
Lab ID: N010479-013

Client Sample ID: B3-3.0
Collection Date: 6/27/2013 8:35:00 AM
Matrix: SOIL

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
VOLATILE ORGANIC COMPOUNDS BY GC/MS						
			EPA 8260B			
RunID: MS1_130702A	QC Batch: D13VS040			PrepDate:		Analyst: **QBM**
Chloroethane	ND	5.0		µg/Kg	1	7/2/2013 05:50 PM
Chloroform	ND	5.0		µg/Kg	1	7/2/2013 05:50 PM
Chloromethane	ND	5.0		µg/Kg	1	7/2/2013 05:50 PM
cis-1,2-Dichloroethene	ND	5.0		µg/Kg	1	7/2/2013 05:50 PM
cis-1,3-Dichloropropene	ND	5.0		µg/Kg	1	7/2/2013 05:50 PM
Dibromochloromethane	ND	5.0		µg/Kg	1	7/2/2013 05:50 PM
Dibromomethane	ND	5.0		µg/Kg	1	7/2/2013 05:50 PM
Dichlorodifluoromethane	ND	5.0		µg/Kg	1	7/2/2013 05:50 PM
Ethylbenzene	ND	5.0		µg/Kg	1	7/2/2013 05:50 PM
Hexachlorobutadiene	ND	5.0		µg/Kg	1	7/2/2013 05:50 PM
Isopropylbenzene	ND	5.0		µg/Kg	1	7/2/2013 05:50 PM
m,p-Xylene	ND	10		µg/Kg	1	7/2/2013 05:50 PM
Methylene chloride	ND	5.0		µg/Kg	1	7/2/2013 05:50 PM
n-Butylbenzene	ND	5.0		µg/Kg	1	7/2/2013 05:50 PM
n-Propylbenzene	ND	5.0		µg/Kg	1	7/2/2013 05:50 PM
Naphthalene	ND	5.0		µg/Kg	1	7/2/2013 05:50 PM
o-Xylene	ND	5.0		µg/Kg	1	7/2/2013 05:50 PM
sec-Butylbenzene	ND	5.0		µg/Kg	1	7/2/2013 05:50 PM
Styrene	ND	5.0		µg/Kg	1	7/2/2013 05:50 PM
tert-Butylbenzene	ND	5.0		µg/Kg	1	7/2/2013 05:50 PM
Tetrachloroethene	ND	5.0		µg/Kg	1	7/2/2013 05:50 PM
Toluene	ND	5.0		µg/Kg	1	7/2/2013 05:50 PM
trans-1,2-Dichloroethene	ND	5.0		µg/Kg	1	7/2/2013 05:50 PM
Trichloroethene	ND	5.0		µg/Kg	1	7/2/2013 05:50 PM
Trichlorofluoromethane	ND	5.0		µg/Kg	1	7/2/2013 05:50 PM
Vinyl chloride	ND	5.0		µg/Kg	1	7/2/2013 05:50 PM
Surr: 1,2-Dichloroethane-d4	104	63-139		%REC	1	7/2/2013 05:50 PM
Surr: 4-Bromofluorobenzene	93.6	75-124		%REC	1	7/2/2013 05:50 PM
Surr: Dibromofluoromethane	101	70-133		%REC	1	7/2/2013 05:50 PM
Surr: Toluene-d8	97.8	80-123		%REC	1	7/2/2013 05:50 PM
DIESEL & MOTOR OIL RANGE ORGANICS BY GC/FID						
	EPA 3550B			**EPA 8015B**		
RunID: GC3_130701A	QC Batch: 43322			PrepDate:	7/1/2013	Analyst: **MDM**
DRO	1.7	1.0		mg/Kg	1	7/1/2013 07:54 PM
ORO	2.1	1.0		mg/Kg	1	7/1/2013 07:54 PM
Surr: p-Terphenyl	104	59-127		%REC	1	7/1/2013 07:54 PM

Qualifiers:
- B Analyte detected in the associated Method Blank
- H Holding times for preparation or analysis exceeded
- S Spike/Surrogate outside of limits due to matrix interference
- DO Surrogate Diluted Out
- E Value above quantitation range
- ND Not Detected at the Reporting Limit

Results are wet unless otherwise specified

ANALYTICAL RESULTS

Advanced Technology Laboratories, Inc.

Print Date: *09-Jul-13*

CLIENT:	Geocon Consultants, Inc.	**Client Sample ID:**	B3-3.0
Lab Order:	N010479	**Collection Date:**	6/27/2013 8:35:00 AM
Project:	Crissy Field Outfall, E8560-02-51	**Matrix:**	SOIL
Lab ID:	N010479-013		

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
PCBS BY GC/ECD						
	EPA 3550B			**EPA 8082**		
RunID: GC7_130702B	QC Batch: 43333			PrepDate:	7/2/2013	Analyst: **MDM**
Aroclor 1016	ND	17		µg/Kg	1	7/3/2013 05:07 AM
Aroclor 1221	ND	33		µg/Kg	1	7/3/2013 05:07 AM
Aroclor 1232	ND	17		µg/Kg	1	7/3/2013 05:07 AM
Aroclor 1242	ND	17		µg/Kg	1	7/3/2013 05:07 AM
Aroclor 1248	ND	17		µg/Kg	1	7/3/2013 05:07 AM
Aroclor 1254	ND	17		µg/Kg	1	7/3/2013 05:07 AM
Aroclor 1260	ND	17		µg/Kg	1	7/3/2013 05:07 AM
Surr: Decachlorobiphenyl	91.3	40-146		%REC	1	7/3/2013 05:07 AM
Surr: Tetrachloro-m-xylene	54.8	32-109		%REC	1	7/3/2013 05:07 AM
ICP METALS						
	EPA 3050B			**EPA 6010B**		
RunID: ICP2_130702B	QC Batch: 43321			PrepDate:	7/1/2013	Analyst: **WLS**
Lead	3.0	2.0		mg/Kg	1	7/2/2013 04:22 PM

Qualifiers:

B	Analyte detected in the associated Method Blank
H	Holding times for preparation or analysis exceeded
S	Spike/Surrogate outside of limits due to matrix interference
DO	Surrogate Diluted Out
E	Value above quantitation range
ND	Not Detected at the Reporting Limit
	Results are wet unless otherwise specified

Advanced Technology Laboratories, Inc.

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CLIENT:	Geocon Consultants, Inc.	**Client Sample ID:**	B3-6.0
Lab Order:	N010479	**Collection Date:**	6/27/2013 8:40:00 AM
Project:	Crissy Field Outfall, E8560-02-51	**Matrix:**	SOIL
Lab ID:	N010479-014		

VOLATILE ORGANIC COMPOUNDS BY GC/MS

EPA 8260B

RunID: MS1_130702A QC Batch: D13VS040 PrepDate: Analyst: **QBM**

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
1,1,1,2-Tetrachloroethane	ND	5.0		µg/Kg	1	7/2/2013 06:57 PM
1,1,1-Trichloroethane	ND	5.0		µg/Kg	1	7/2/2013 06:57 PM
1,1,2,2-Tetrachloroethane	ND	5.0		µg/Kg	1	7/2/2013 06:57 PM
1,1,2-Trichloroethane	ND	5.0		µg/Kg	1	7/2/2013 06:57 PM
1,1-Dichloroethane	ND	5.0		µg/Kg	1	7/2/2013 06:57 PM
1,1-Dichloroethene	ND	5.0		µg/Kg	1	7/2/2013 06:57 PM
1,1-Dichloropropene	ND	5.0		µg/Kg	1	7/2/2013 06:57 PM
1,2,3-Trichlorobenzene	ND	5.0		µg/Kg	1	7/2/2013 06:57 PM
1,2,3-Trichloropropane	ND	5.0		µg/Kg	1	7/2/2013 06:57 PM
1,2,4-Trichlorobenzene	ND	5.0		µg/Kg	1	7/2/2013 06:57 PM
1,2,4-Trimethylbenzene	ND	5.0		µg/Kg	1	7/2/2013 06:57 PM
1,2-Dibromo-3-chloropropane	ND	10		µg/Kg	1	7/2/2013 06:57 PM
1,2-Dibromoethane	ND	5.0		µg/Kg	1	7/2/2013 06:57 PM
1,2-Dichlorobenzene	ND	5.0		µg/Kg	1	7/2/2013 06:57 PM
1,2-Dichloroethane	ND	5.0		µg/Kg	1	7/2/2013 06:57 PM
1,2-Dichloropropane	ND	5.0		µg/Kg	1	7/2/2013 06:57 PM
1,3,5-Trimethylbenzene	ND	5.0		µg/Kg	1	7/2/2013 06:57 PM
1,3-Dichlorobenzene	ND	5.0		µg/Kg	1	7/2/2013 06:57 PM
1,3-Dichloropropane	ND	5.0		µg/Kg	1	7/2/2013 06:57 PM
1,4-Dichlorobenzene	ND	5.0		µg/Kg	1	7/2/2013 06:57 PM
2,2-Dichloropropane	ND	5.0		µg/Kg	1	7/2/2013 06:57 PM
2-Chlorotoluene	ND	5.0		µg/Kg	1	7/2/2013 06:57 PM
4-Chlorotoluene	ND	5.0		µg/Kg	1	7/2/2013 06:57 PM
4-Isopropyltoluene	ND	5.0		µg/Kg	1	7/2/2013 06:57 PM
Benzene	ND	5.0		µg/Kg	1	7/2/2013 06:57 PM
Bromobenzene	ND	5.0		µg/Kg	1	7/2/2013 06:57 PM
Bromodichloromethane	ND	5.0		µg/Kg	1	7/2/2013 06:57 PM
Bromoform	ND	5.0		µg/Kg	1	7/2/2013 06:57 PM
Bromomethane	ND	5.0		µg/Kg	1	7/2/2013 06:57 PM
Carbon tetrachloride	ND	5.0		µg/Kg	1	7/2/2013 06:57 PM
Chlorobenzene	ND	5.0		µg/Kg	1	7/2/2013 06:57 PM
Chloroethane	ND	5.0		µg/Kg	1	7/2/2013 06:57 PM
Chloroform	ND	5.0		µg/Kg	1	7/2/2013 06:57 PM
Chloromethane	ND	5.0		µg/Kg	1	7/2/2013 06:57 PM
cis-1,2-Dichloroethene	ND	5.0		µg/Kg	1	7/2/2013 06:57 PM
cis-1,3-Dichloropropene	ND	5.0		µg/Kg	1	7/2/2013 06:57 PM

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range
H	Holding times for preparation or analysis exceeded	ND	Not Detected at the Reporting Limit
S	Spike/Surrogate outside of limits due to matrix interference		Results are wet unless otherwise specified
DO	Surrogate Diluted Out		

ANALYTICAL RESULTS

Advanced Technology Laboratories, Inc.

Print Date: *09-Jul-13*

CLIENT:	Geocon Consultants, Inc.	**Client Sample ID:**	B3-6.0
Lab Order:	N010479	**Collection Date:**	6/27/2013 8:40:00 AM
Project:	Crissy Field Outfall, E8560-02-51	**Matrix:**	SOIL
Lab ID:	N010479-014		

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
VOLATILE ORGANIC COMPOUNDS BY GC/MS						
			EPA 8260B			
RunID: MS1_130702A	QC Batch: D13VS040			PrepDate:		Analyst: **QBM**
Dibromochloromethane	ND	5.0		µg/Kg	1	7/2/2013 06:57 PM
Dibromomethane	ND	5.0		µg/Kg	1	7/2/2013 06:57 PM
Dichlorodifluoromethane	ND	5.0		µg/Kg	1	7/2/2013 06:57 PM
Ethylbenzene	ND	5.0		µg/Kg	1	7/2/2013 06:57 PM
Hexachlorobutadiene	ND	5.0		µg/Kg	1	7/2/2013 06:57 PM
Isopropylbenzene	ND	5.0		µg/Kg	1	7/2/2013 06:57 PM
m,p-Xylene	ND	10		µg/Kg	1	7/2/2013 06:57 PM
Methylene chloride	ND	5.0		µg/Kg	1	7/2/2013 06:57 PM
n-Butylbenzene	ND	5.0		µg/Kg	1	7/2/2013 06:57 PM
n-Propylbenzene	ND	5.0		µg/Kg	1	7/2/2013 06:57 PM
Naphthalene	ND	5.0		µg/Kg	1	7/2/2013 06:57 PM
o-Xylene	ND	5.0		µg/Kg	1	7/2/2013 06:57 PM
sec-Butylbenzene	ND	5.0		µg/Kg	1	7/2/2013 06:57 PM
Styrene	ND	5.0		µg/Kg	1	7/2/2013 06:57 PM
tert-Butylbenzene	ND	5.0		µg/Kg	1	7/2/2013 06:57 PM
Tetrachloroethene	ND	5.0		µg/Kg	1	7/2/2013 06:57 PM
Toluene	ND	5.0		µg/Kg	1	7/2/2013 06:57 PM
trans-1,2-Dichloroethene	ND	5.0		µg/Kg	1	7/2/2013 06:57 PM
Trichloroethene	ND	5.0		µg/Kg	1	7/2/2013 06:57 PM
Trichlorofluoromethane	ND	5.0		µg/Kg	1	7/2/2013 06:57 PM
Vinyl chloride	ND	5.0		µg/Kg	1	7/2/2013 06:57 PM
Surr: 1,2-Dichloroethane-d4	104	63-139		%REC	1	7/2/2013 06:57 PM
Surr: 4-Bromofluorobenzene	95.6	75-124		%REC	1	7/2/2013 06:57 PM
Surr: Dibromofluoromethane	105	70-133		%REC	1	7/2/2013 06:57 PM
Surr: Toluene-d8	98.4	80-123		%REC	1	7/2/2013 06:57 PM
ICP METALS						
	EPA 3050B			**EPA 6010B**		
RunID: ICP2_130702B	QC Batch: 43321			PrepDate:	7/1/2013	Analyst: **WLS**
Lead	2.8	2.0		mg/Kg	1	7/2/2013 04:31 PM

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range
H	Holding times for preparation or analysis exceeded	ND	Not Detected at the Reporting Limit
S	Spike/Surrogate outside of limits due to matrix interference		Results are wet unless otherwise specified
DO	Surrogate Diluted Out		

Advanced Technology Laboratories, Inc.

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ANALYTICAL RESULTS

Advanced Technology Laboratories, Inc.

Print Date: *09-Jul-13*

CLIENT:	Geocon Consultants, Inc.	**Client Sample ID:**	B3-9.0
Lab Order:	N010479	**Collection Date:**	6/27/2013 8:40:00 AM
Project:	Crissy Field Outfall, E8560-02-51	**Matrix:**	SOIL
Lab ID:	N010479-015		

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
ICP METALS						
	EPA 3050B			**EPA 6010B**		
RunID: ICP2_130702B	QC Batch: 43321			PrepDate:	7/1/2013	Analyst: **WLS**
Lead	3.1	2.0		mg/Kg	1	7/2/2013 04:52 PM

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range
H	Holding times for preparation or analysis exceeded	ND	Not Detected at the Reporting Limit
S	Spike/Surrogate outside of limits due to matrix interference		Results are wet unless otherwise specified
DO	Surrogate Diluted Out		

Advanced Technology Laboratories, Inc.

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ANALYTICAL RESULTS

Advanced Technology Laboratories, Inc.

Print Date: *09-Jul-13*

CLIENT:	Geocon Consultants, Inc.	**Client Sample ID:**	B4-0.5
Lab Order:	N010479	**Collection Date:**	6/27/2013 8:55:00 AM
Project:	Crissy Field Outfall, E8560-02-51	**Matrix:**	SOIL
Lab ID:	N010479-016		

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
ICP METALS						
	EPA 3050B			**EPA 6010B**		
RunID: ICP2_130702B	QC Batch: 43321			PrepDate:	7/1/2013	Analyst: **WLS**
Lead	3.4	2.0		mg/Kg	1	7/2/2013 05:21 PM

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range
H	Holding times for preparation or analysis exceeded	ND	Not Detected at the Reporting Limit
S	Spike/Surrogate outside of limits due to matrix interference		Results are wet unless otherwise specified
DO	Surrogate Diluted Out		

Advanced Technology Laboratories, Inc.

3151 W. Post Rd Las Vegas, NV 89118 Tel: 702-307-2659 Fax: 702-307-2691

ANALYTICAL RESULTS

Advanced Technology Laboratories, Inc.

Print Date: *09-Jul-13*

CLIENT:	Geocon Consultants, Inc.	**Client Sample ID:**	B4-1.5
Lab Order:	N010479	**Collection Date:**	6/27/2013 8:55:00 AM
Project:	Crissy Field Outfall, E8560-02-51	**Matrix:**	SOIL
Lab ID:	N010479-017		

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
VOLATILE ORGANIC COMPOUNDS BY GC/MS						
			EPA 8260B			
RunID: MS1_130702A	QC Batch: D13VS040			PrepDate:		Analyst: **QBM**
1,1,1,2-Tetrachloroethane	ND	5.0		µg/Kg	1	7/2/2013 01:01 PM
1,1,1-Trichloroethane	ND	5.0		µg/Kg	1	7/2/2013 01:01 PM
1,1,2,2-Tetrachloroethane	ND	5.0		µg/Kg	1	7/2/2013 01:01 PM
1,1,2-Trichloroethane	ND	5.0		µg/Kg	1	7/2/2013 01:01 PM
1,1-Dichloroethane	ND	5.0		µg/Kg	1	7/2/2013 01:01 PM
1,1-Dichloroethene	ND	5.0		µg/Kg	1	7/2/2013 01:01 PM
1,1-Dichloropropene	ND	5.0		µg/Kg	1	7/2/2013 01:01 PM
1,2,3-Trichlorobenzene	ND	5.0		µg/Kg	1	7/2/2013 01:01 PM
1,2,3-Trichloropropane	ND	5.0		µg/Kg	1	7/2/2013 01:01 PM
1,2,4-Trichlorobenzene	ND	5.0		µg/Kg	1	7/2/2013 01:01 PM
1,2,4-Trimethylbenzene	ND	5.0		µg/Kg	1	7/2/2013 01:01 PM
1,2-Dibromo-3-chloropropane	ND	10		µg/Kg	1	7/2/2013 01:01 PM
1,2-Dibromoethane	ND	5.0		µg/Kg	1	7/2/2013 01:01 PM
1,2-Dichlorobenzene	ND	5.0		µg/Kg	1	7/2/2013 01:01 PM
1,2-Dichloroethane	ND	5.0		µg/Kg	1	7/2/2013 01:01 PM
1,2-Dichloropropane	ND	5.0		µg/Kg	1	7/2/2013 01:01 PM
1,3,5-Trimethylbenzene	ND	5.0		µg/Kg	1	7/2/2013 01:01 PM
1,3-Dichlorobenzene	ND	5.0		µg/Kg	1	7/2/2013 01:01 PM
1,3-Dichloropropane	ND	5.0		µg/Kg	1	7/2/2013 01:01 PM
1,4-Dichlorobenzene	ND	5.0		µg/Kg	1	7/2/2013 01:01 PM
2,2-Dichloropropane	ND	5.0		µg/Kg	1	7/2/2013 01:01 PM
2-Chlorotoluene	ND	5.0		µg/Kg	1	7/2/2013 01:01 PM
4-Chlorotoluene	ND	5.0		µg/Kg	1	7/2/2013 01:01 PM
4-Isopropyltoluene	ND	5.0		µg/Kg	1	7/2/2013 01:01 PM
Benzene	ND	5.0		µg/Kg	1	7/2/2013 01:01 PM
Bromobenzene	ND	5.0		µg/Kg	1	7/2/2013 01:01 PM
Bromodichloromethane	ND	5.0		µg/Kg	1	7/2/2013 01:01 PM
Bromoform	ND	5.0		µg/Kg	1	7/2/2013 01:01 PM
Bromomethane	ND	5.0		µg/Kg	1	7/2/2013 01:01 PM
Carbon tetrachloride	ND	5.0		µg/Kg	1	7/2/2013 01:01 PM
Chlorobenzene	ND	5.0		µg/Kg	1	7/2/2013 01:01 PM
Chloroethane	ND	5.0		µg/Kg	1	7/2/2013 01:01 PM
Chloroform	ND	5.0		µg/Kg	1	7/2/2013 01:01 PM
Chloromethane	ND	5.0		µg/Kg	1	7/2/2013 01:01 PM
cis-1,2-Dichloroethene	ND	5.0		µg/Kg	1	7/2/2013 01:01 PM
cis-1,3-Dichloropropene	ND	5.0		µg/Kg	1	7/2/2013 01:01 PM

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range
H	Holding times for preparation or analysis exceeded	ND	Not Detected at the Reporting Limit
S	Spike/Surrogate outside of limits due to matrix interference		Results are wet unless otherwise specified
DO	Surrogate Diluted Out		

Advanced Technology Laboratories, Inc.

3151 W. Post Rd Las Vegas, NV 89118 Tel: 702-307-2659 Fax: 702-307-2691

CLIENT: Geocon Consultants, Inc.
Lab Order: N010479
Project: Crissy Field Outfall, E8560-02-51
Lab ID: N010479-017

Client Sample ID: B4-1.5
Collection Date: 6/27/2013 8:55:00 AM
Matrix: SOIL

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
VOLATILE ORGANIC COMPOUNDS BY GC/MS						
			EPA 8260B			
RunID: MS1_130702A	QC Batch: D13VS040			PrepDate:		Analyst: **QBM**
Dibromochloromethane	ND	5.0		µg/Kg	1	7/2/2013 01:01 PM
Dibromomethane	ND	5.0		µg/Kg	1	7/2/2013 01:01 PM
Dichlorodifluoromethane	ND	5.0		µg/Kg	1	7/2/2013 01:01 PM
Ethylbenzene	ND	5.0		µg/Kg	1	7/2/2013 01:01 PM
Hexachlorobutadiene	ND	5.0		µg/Kg	1	7/2/2013 01:01 PM
Isopropylbenzene	ND	5.0		µg/Kg	1	7/2/2013 01:01 PM
m,p-Xylene	ND	10		µg/Kg	1	7/2/2013 01:01 PM
Methylene chloride	ND	5.0		µg/Kg	1	7/2/2013 01:01 PM
n-Butylbenzene	ND	5.0		µg/Kg	1	7/2/2013 01:01 PM
n-Propylbenzene	ND	5.0		µg/Kg	1	7/2/2013 01:01 PM
Naphthalene	ND	5.0		µg/Kg	1	7/2/2013 01:01 PM
o-Xylene	ND	5.0		µg/Kg	1	7/2/2013 01:01 PM
sec-Butylbenzene	ND	5.0		µg/Kg	1	7/2/2013 01:01 PM
Styrene	ND	5.0		µg/Kg	1	7/2/2013 01:01 PM
tert-Butylbenzene	ND	5.0		µg/Kg	1	7/2/2013 01:01 PM
Tetrachloroethene	ND	5.0		µg/Kg	1	7/2/2013 01:01 PM
Toluene	ND	5.0		µg/Kg	1	7/2/2013 01:01 PM
trans-1,2-Dichloroethene	ND	5.0		µg/Kg	1	7/2/2013 01:01 PM
Trichloroethene	ND	5.0		µg/Kg	1	7/2/2013 01:01 PM
Trichlorofluoromethane	ND	5.0		µg/Kg	1	7/2/2013 01:01 PM
Vinyl chloride	ND	5.0		µg/Kg	1	7/2/2013 01:01 PM
Surr: 1,2-Dichloroethane-d4	93.6	63-139		%REC	1	7/2/2013 01:01 PM
Surr: 4-Bromofluorobenzene	92.6	75-124		%REC	1	7/2/2013 01:01 PM
Surr: Dibromofluoromethane	94.7	70-133		%REC	1	7/2/2013 01:01 PM
Surr: Toluene-d8	98.9	80-123		%REC	1	7/2/2013 01:01 PM
PCBS BY GC/ECD						
	EPA 3550B			**EPA 8082**		
RunID: GC7_130702B	QC Batch: 43333			PrepDate:	7/2/2013	Analyst: **MDM**
Aroclor 1016	ND	16		µg/Kg	1	7/3/2013 05:37 AM
Aroclor 1221	ND	33		µg/Kg	1	7/3/2013 05:37 AM
Aroclor 1232	ND	16		µg/Kg	1	7/3/2013 05:37 AM
Aroclor 1242	ND	16		µg/Kg	1	7/3/2013 05:37 AM
Aroclor 1248	ND	16		µg/Kg	1	7/3/2013 05:37 AM
Aroclor 1254	ND	16		µg/Kg	1	7/3/2013 05:37 AM
Aroclor 1260	ND	16		µg/Kg	1	7/3/2013 05:37 AM
Surr: Decachlorobiphenyl	89.4	40-146		%REC	1	7/3/2013 05:37 AM

Qualifiers:
- B Analyte detected in the associated Method Blank
- H Holding times for preparation or analysis exceeded
- S Spike/Surrogate outside of limits due to matrix interference
- DO Surrogate Diluted Out
- E Value above quantitation range
- ND Not Detected at the Reporting Limit

Results are wet unless otherwise specified

ANALYTICAL RESULTS

Advanced Technology Laboratories, Inc.

Print Date: *09-Jul-13*

CLIENT:	Geocon Consultants, Inc.	**Client Sample ID:**	B4-1.5
Lab Order:	N010479	**Collection Date:**	6/27/2013 8:55:00 AM
Project:	Crissy Field Outfall, E8560-02-51	**Matrix:**	SOIL
Lab ID:	N010479-017		

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
PCBS BY GC/ECD						
	EPA 3550B			**EPA 8082**		
RunID: GC7_130702B	QC Batch: 43333			PrepDate:	7/2/2013	Analyst: **MDM**
Surr: Tetrachloro-m-xylene	62.0	32-109		%REC	1	7/3/2013 05:37 AM
GASOLINE RANGE ORGANICS BY GC/FID						
				EPA 8015B		
RunID: GC4_130702A	QC Batch: E13VS071			PrepDate:		Analyst: **QBM**
GRO	ND	1.0		mg/Kg	1	7/2/2013 01:06 PM
Surr: Chlorobenzene - d5	105	51-136		%REC	1	7/2/2013 01:06 PM
MERCURY BY COLD VAPOR TECHNIQUE						
	EPA 7471			**EPA 7471A**		
RunID: AA1_130701B	QC Batch: 43313			PrepDate:	6/28/2013	Analyst: **LCC**
Mercury	ND	0.10		mg/Kg	1	7/1/2013
ICP METALS						
	EPA 3050B			**EPA 6010B**		
RunID: ICP2_130708A	QC Batch: 43320			PrepDate:	7/1/2013	Analyst: **WLS**
Antimony	ND	2.0		mg/Kg	1	7/8/2013 12:57 PM
Arsenic	2.8	1.0		mg/Kg	1	7/8/2013 12:57 PM
Barium	9.2	1.0		mg/Kg	1	7/8/2013 12:57 PM
Beryllium	ND	1.0		mg/Kg	1	7/8/2013 12:57 PM
Cadmium	ND	1.0		mg/Kg	1	7/8/2013 12:57 PM
Chromium	21	1.0		mg/Kg	1	7/8/2013 12:57 PM
Cobalt	3.9	1.0		mg/Kg	1	7/8/2013 12:57 PM
Copper	2.4	2.0		mg/Kg	1	7/8/2013 12:57 PM
Lead	3.2	1.0		mg/Kg	1	7/8/2013 12:57 PM
Molybdenum	ND	1.0		mg/Kg	1	7/8/2013 12:57 PM
Nickel	19	1.0		mg/Kg	1	7/8/2013 12:57 PM
Selenium	ND	1.0		mg/Kg	1	7/8/2013 12:57 PM
Silver	ND	1.0		mg/Kg	1	7/8/2013 12:57 PM
Thallium	ND	1.0		mg/Kg	1	7/8/2013 12:57 PM
Vanadium	18	1.0		mg/Kg	1	7/8/2013 12:57 PM
Zinc	13	1.0		mg/Kg	1	7/8/2013 12:57 PM

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range
H	Holding times for preparation or analysis exceeded	ND	Not Detected at the Reporting Limit
S	Spike/Surrogate outside of limits due to matrix interference		Results are wet unless otherwise specified
DO	Surrogate Diluted Out		

Advanced Technology Laboratories, Inc.

3151 W. Post Rd Las Vegas, NV 89118 Tel: 702-307-2659 Fax: 702-307-2691

ANALYTICAL RESULTS

Advanced Technology Laboratories, Inc.

Print Date: *09-Jul-13*

CLIENT:	Geocon Consultants, Inc.	**Client Sample ID:**	B4-3.0
Lab Order:	N010479	**Collection Date:**	6/27/2013 9:00:00 AM
Project:	Crissy Field Outfall, E8560-02-51	**Matrix:**	SOIL
Lab ID:	N010479-018		

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
PH						
				EPA 9045C		
RunID: WETCHEM_130628A	QC Batch: R89413			PrepDate:		Analyst: **LCC**
pH	9.3	0.10		pH Units	1	6/28/2013
Temp. at time of pH Analysis	25	0		pH Units	1	6/28/2013
VOLATILE ORGANIC COMPOUNDS BY GC/MS						
				EPA 8260B		
RunID: MS1_130702A	QC Batch: D13VS040			PrepDate:		Analyst: **QBM**
1,1,1,2-Tetrachloroethane	ND	5.0		µg/Kg	1	7/2/2013 07:19 PM
1,1,1-Trichloroethane	ND	5.0		µg/Kg	1	7/2/2013 07:19 PM
1,1,2,2-Tetrachloroethane	ND	5.0		µg/Kg	1	7/2/2013 07:19 PM
1,1,2-Trichloroethane	ND	5.0		µg/Kg	1	7/2/2013 07:19 PM
1,1-Dichloroethane	ND	5.0		µg/Kg	1	7/2/2013 07:19 PM
1,1-Dichloroethene	ND	5.0		µg/Kg	1	7/2/2013 07:19 PM
1,1-Dichloropropene	ND	5.0		µg/Kg	1	7/2/2013 07:19 PM
1,2,3-Trichlorobenzene	ND	5.0		µg/Kg	1	7/2/2013 07:19 PM
1,2,3-Trichloropropane	ND	5.0		µg/Kg	1	7/2/2013 07:19 PM
1,2,4-Trichlorobenzene	ND	5.0		µg/Kg	1	7/2/2013 07:19 PM
1,2,4-Trimethylbenzene	ND	5.0		µg/Kg	1	7/2/2013 07:19 PM
1,2-Dibromo-3-chloropropane	ND	10		µg/Kg	1	7/2/2013 07:19 PM
1,2-Dibromoethane	ND	5.0		µg/Kg	1	7/2/2013 07:19 PM
1,2-Dichlorobenzene	ND	5.0		µg/Kg	1	7/2/2013 07:19 PM
1,2-Dichloroethane	ND	5.0		µg/Kg	1	7/2/2013 07:19 PM
1,2-Dichloropropane	ND	5.0		µg/Kg	1	7/2/2013 07:19 PM
1,3,5-Trimethylbenzene	ND	5.0		µg/Kg	1	7/2/2013 07:19 PM
1,3-Dichlorobenzene	ND	5.0		µg/Kg	1	7/2/2013 07:19 PM
1,3-Dichloropropane	ND	5.0		µg/Kg	1	7/2/2013 07:19 PM
1,4-Dichlorobenzene	ND	5.0		µg/Kg	1	7/2/2013 07:19 PM
2,2-Dichloropropane	ND	5.0		µg/Kg	1	7/2/2013 07:19 PM
2-Chlorotoluene	ND	5.0		µg/Kg	1	7/2/2013 07:19 PM
4-Chlorotoluene	ND	5.0		µg/Kg	1	7/2/2013 07:19 PM
4-Isopropyltoluene	ND	5.0		µg/Kg	1	7/2/2013 07:19 PM
Benzene	ND	5.0		µg/Kg	1	7/2/2013 07:19 PM
Bromobenzene	ND	5.0		µg/Kg	1	7/2/2013 07:19 PM
Bromodichloromethane	ND	5.0		µg/Kg	1	7/2/2013 07:19 PM
Bromoform	ND	5.0		µg/Kg	1	7/2/2013 07:19 PM
Bromomethane	ND	5.0		µg/Kg	1	7/2/2013 07:19 PM
Carbon tetrachloride	ND	5.0		µg/Kg	1	7/2/2013 07:19 PM
Chlorobenzene	ND	5.0		µg/Kg	1	7/2/2013 07:19 PM

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range
H	Holding times for preparation or analysis exceeded	ND	Not Detected at the Reporting Limit
S	Spike/Surrogate outside of limits due to matrix interference		Results are wet unless otherwise specified
DO	Surrogate Diluted Out		

Advanced Technology Laboratories, Inc.

3151 W. Post Rd Las Vegas, NV 89118 Tel: 702-307-2659 Fax: 702-307-2691

Advanced Technology Laboratories, Inc.

ANALYTICAL RESULTS

Print Date: *09-Jul-13*

CLIENT:	Geocon Consultants, Inc.	**Client Sample ID:**	B4-3.0
Lab Order:	N010479	**Collection Date:**	6/27/2013 9:00:00 AM
Project:	Crissy Field Outfall, E8560-02-51	**Matrix:**	SOIL
Lab ID:	N010479-018		

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
VOLATILE ORGANIC COMPOUNDS BY GC/MS						
				EPA 8260B		
RunID: MS1_130702A	QC Batch: D13VS040			PrepDate:		Analyst: **QBM**
Chloroethane	ND	5.0		µg/Kg	1	7/2/2013 07:19 PM
Chloroform	ND	5.0		µg/Kg	1	7/2/2013 07:19 PM
Chloromethane	ND	5.0		µg/Kg	1	7/2/2013 07:19 PM
cis-1,2-Dichloroethene	ND	5.0		µg/Kg	1	7/2/2013 07:19 PM
cis-1,3-Dichloropropene	ND	5.0		µg/Kg	1	7/2/2013 07:19 PM
Dibromochloromethane	ND	5.0		µg/Kg	1	7/2/2013 07:19 PM
Dibromomethane	ND	5.0		µg/Kg	1	7/2/2013 07:19 PM
Dichlorodifluoromethane	ND	5.0		µg/Kg	1	7/2/2013 07:19 PM
Ethylbenzene	ND	5.0		µg/Kg	1	7/2/2013 07:19 PM
Hexachlorobutadiene	ND	5.0		µg/Kg	1	7/2/2013 07:19 PM
Isopropylbenzene	ND	5.0		µg/Kg	1	7/2/2013 07:19 PM
m,p-Xylene	ND	10		µg/Kg	1	7/2/2013 07:19 PM
Methylene chloride	ND	5.0		µg/Kg	1	7/2/2013 07:19 PM
n-Butylbenzene	ND	5.0		µg/Kg	1	7/2/2013 07:19 PM
n-Propylbenzene	ND	5.0		µg/Kg	1	7/2/2013 07:19 PM
Naphthalene	ND	5.0		µg/Kg	1	7/2/2013 07:19 PM
o-Xylene	ND	5.0		µg/Kg	1	7/2/2013 07:19 PM
sec-Butylbenzene	ND	5.0		µg/Kg	1	7/2/2013 07:19 PM
Styrene	ND	5.0		µg/Kg	1	7/2/2013 07:19 PM
tert-Butylbenzene	ND	5.0		µg/Kg	1	7/2/2013 07:19 PM
Tetrachloroethene	ND	5.0		µg/Kg	1	7/2/2013 07:19 PM
Toluene	ND	5.0		µg/Kg	1	7/2/2013 07:19 PM
trans-1,2-Dichloroethene	ND	5.0		µg/Kg	1	7/2/2013 07:19 PM
Trichloroethene	ND	5.0		µg/Kg	1	7/2/2013 07:19 PM
Trichlorofluoromethane	ND	5.0		µg/Kg	1	7/2/2013 07:19 PM
Vinyl chloride	ND	5.0		µg/Kg	1	7/2/2013 07:19 PM
Surr: 1,2-Dichloroethane-d4	111	63-139		%REC	1	7/2/2013 07:19 PM
Surr: 4-Bromofluorobenzene	96.3	75-124		%REC	1	7/2/2013 07:19 PM
Surr: Dibromofluoromethane	102	70-133		%REC	1	7/2/2013 07:19 PM
Surr: Toluene-d8	101	80-123		%REC	1	7/2/2013 07:19 PM
DIESEL & MOTOR OIL RANGE ORGANICS BY GC/FID						
EPA 3550B				**EPA 8015B**		
RunID: GC3_130701A	QC Batch: 43322			PrepDate:	7/1/2013	Analyst: **MDM**
DRO	1.1	1.0		mg/Kg	1	7/1/2013 08:21 PM
ORO	1.2	1.0		mg/Kg	1	7/1/2013 08:21 PM
Surr: p-Terphenyl	89.4	59-127		%REC	1	7/1/2013 08:21 PM

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range
H	Holding times for preparation or analysis exceeded	ND	Not Detected at the Reporting Limit
S	Spike/Surrogate outside of limits due to matrix interference		Results are wet unless otherwise specified
DO	Surrogate Diluted Out		

Advanced Technology Laboratories, Inc.
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ANALYTICAL RESULTS

Advanced Technology Laboratories, Inc.

Print Date: *09-Jul-13*

CLIENT:	Geocon Consultants, Inc.	**Client Sample ID:**	B4-3.0
Lab Order:	N010479	**Collection Date:**	6/27/2013 9:00:00 AM
Project:	Crissy Field Outfall, E8560-02-51	**Matrix:**	SOIL
Lab ID:	N010479-018		

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
PCBS BY GC/ECD						
	EPA 3550B			**EPA 8082**		
RunID: GC7_130702B	QC Batch: 43333			PrepDate:	7/2/2013	Analyst: **MDM**
Aroclor 1016	ND	16		µg/Kg	1	7/3/2013 06:06 AM
Aroclor 1221	ND	33		µg/Kg	1	7/3/2013 06:06 AM
Aroclor 1232	ND	16		µg/Kg	1	7/3/2013 06:06 AM
Aroclor 1242	ND	16		µg/Kg	1	7/3/2013 06:06 AM
Aroclor 1248	ND	16		µg/Kg	1	7/3/2013 06:06 AM
Aroclor 1254	ND	16		µg/Kg	1	7/3/2013 06:06 AM
Aroclor 1260	ND	16		µg/Kg	1	7/3/2013 06:06 AM
Surr: Decachlorobiphenyl	86.4	40-146		%REC	1	7/3/2013 06:06 AM
Surr: Tetrachloro-m-xylene	60.0	32-109		%REC	1	7/3/2013 06:06 AM
ICP METALS						
	EPA 3050B			**EPA 6010B**		
RunID: ICP2_130702B	QC Batch: 43321			PrepDate:	7/1/2013	Analyst: **WLS**
Lead	2.0	2.0		mg/Kg	1	7/2/2013 05:01 PM

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range
H	Holding times for preparation or analysis exceeded	ND	Not Detected at the Reporting Limit
S	Spike/Surrogate outside of limits due to matrix interference		Results are wet unless otherwise specified
DO	Surrogate Diluted Out		

Advanced Technology Laboratories, Inc.

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Advanced Technology Laboratories, Inc.

ANALYTICAL RESULTS

Print Date: *09-Jul-13*

CLIENT:	Geocon Consultants, Inc.	**Client Sample ID:**	B4-6.0
Lab Order:	N010479	**Collection Date:**	6/27/2013 9:05:00 AM
Project:	Crissy Field Outfall, E8560-02-51	**Matrix:**	SOIL
Lab ID:	N010479-019		

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
VOLATILE ORGANIC COMPOUNDS BY GC/MS						
			EPA 8260B			
RunID: MS1_130702A	QC Batch: D13VS040			PrepDate:		Analyst: **QBM**
1,1,1,2-Tetrachloroethane	ND	5.0		µg/Kg	1	7/2/2013 07:41 PM
1,1,1-Trichloroethane	ND	5.0		µg/Kg	1	7/2/2013 07:41 PM
1,1,2,2-Tetrachloroethane	ND	5.0		µg/Kg	1	7/2/2013 07:41 PM
1,1,2-Trichloroethane	ND	5.0		µg/Kg	1	7/2/2013 07:41 PM
1,1-Dichloroethane	ND	5.0		µg/Kg	1	7/2/2013 07:41 PM
1,1-Dichloroethene	ND	5.0		µg/Kg	1	7/2/2013 07:41 PM
1,1-Dichloropropene	ND	5.0		µg/Kg	1	7/2/2013 07:41 PM
1,2,3-Trichlorobenzene	ND	5.0		µg/Kg	1	7/2/2013 07:41 PM
1,2,3-Trichloropropane	ND	5.0		µg/Kg	1	7/2/2013 07:41 PM
1,2,4-Trichlorobenzene	ND	5.0		µg/Kg	1	7/2/2013 07:41 PM
1,2,4-Trimethylbenzene	ND	5.0		µg/Kg	1	7/2/2013 07:41 PM
1,2-Dibromo-3-chloropropane	ND	10		µg/Kg	1	7/2/2013 07:41 PM
1,2-Dibromoethane	ND	5.0		µg/Kg	1	7/2/2013 07:41 PM
1,2-Dichlorobenzene	ND	5.0		µg/Kg	1	7/2/2013 07:41 PM
1,2-Dichloroethane	ND	5.0		µg/Kg	1	7/2/2013 07:41 PM
1,2-Dichloropropane	ND	5.0		µg/Kg	1	7/2/2013 07:41 PM
1,3,5-Trimethylbenzene	ND	5.0		µg/Kg	1	7/2/2013 07:41 PM
1,3-Dichlorobenzene	ND	5.0		µg/Kg	1	7/2/2013 07:41 PM
1,3-Dichloropropane	ND	5.0		µg/Kg	1	7/2/2013 07:41 PM
1,4-Dichlorobenzene	ND	5.0		µg/Kg	1	7/2/2013 07:41 PM
2,2-Dichloropropane	ND	5.0		µg/Kg	1	7/2/2013 07:41 PM
2-Chlorotoluene	ND	5.0		µg/Kg	1	7/2/2013 07:41 PM
4-Chlorotoluene	ND	5.0		µg/Kg	1	7/2/2013 07:41 PM
4-Isopropyltoluene	ND	5.0		µg/Kg	1	7/2/2013 07:41 PM
Benzene	ND	5.0		µg/Kg	1	7/2/2013 07:41 PM
Bromobenzene	ND	5.0		µg/Kg	1	7/2/2013 07:41 PM
Bromodichloromethane	ND	5.0		µg/Kg	1	7/2/2013 07:41 PM
Bromoform	ND	5.0		µg/Kg	1	7/2/2013 07:41 PM
Bromomethane	ND	5.0		µg/Kg	1	7/2/2013 07:41 PM
Carbon tetrachloride	ND	5.0		µg/Kg	1	7/2/2013 07:41 PM
Chlorobenzene	ND	5.0		µg/Kg	1	7/2/2013 07:41 PM
Chloroethane	ND	5.0		µg/Kg	1	7/2/2013 07:41 PM
Chloroform	ND	5.0		µg/Kg	1	7/2/2013 07:41 PM
Chloromethane	ND	5.0		µg/Kg	1	7/2/2013 07:41 PM
cis-1,2-Dichloroethene	ND	5.0		µg/Kg	1	7/2/2013 07:41 PM
cis-1,3-Dichloropropene	ND	5.0		µg/Kg	1	7/2/2013 07:41 PM

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range
H	Holding times for preparation or analysis exceeded	ND	Not Detected at the Reporting Limit
S	Spike/Surrogate outside of limits due to matrix interference		Results are wet unless otherwise specified
DO	Surrogate Diluted Out		

Advanced Technology Laboratories, Inc.

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ANALYTICAL RESULTS

Advanced Technology Laboratories, Inc.

Print Date: *09-Jul-13*

CLIENT:	Geocon Consultants, Inc.	**Client Sample ID:**	B4-6.0
Lab Order:	N010479	**Collection Date:**	6/27/2013 9:05:00 AM
Project:	Crissy Field Outfall, E8560-02-51	**Matrix:**	SOIL
Lab ID:	N010479-019		

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
VOLATILE ORGANIC COMPOUNDS BY GC/MS						
			EPA 8260B			
RunID: MS1_130702A	QC Batch: D13VS040			PrepDate:		Analyst: **QBM**
Dibromochloromethane	ND	5.0		µg/Kg	1	7/2/2013 07:41 PM
Dibromomethane	ND	5.0		µg/Kg	1	7/2/2013 07:41 PM
Dichlorodifluoromethane	ND	5.0		µg/Kg	1	7/2/2013 07:41 PM
Ethylbenzene	ND	5.0		µg/Kg	1	7/2/2013 07:41 PM
Hexachlorobutadiene	ND	5.0		µg/Kg	1	7/2/2013 07:41 PM
Isopropylbenzene	ND	5.0		µg/Kg	1	7/2/2013 07:41 PM
m,p-Xylene	ND	10		µg/Kg	1	7/2/2013 07:41 PM
Methylene chloride	ND	5.0		µg/Kg	1	7/2/2013 07:41 PM
n-Butylbenzene	ND	5.0		µg/Kg	1	7/2/2013 07:41 PM
n-Propylbenzene	ND	5.0		µg/Kg	1	7/2/2013 07:41 PM
Naphthalene	ND	5.0		µg/Kg	1	7/2/2013 07:41 PM
o-Xylene	ND	5.0		µg/Kg	1	7/2/2013 07:41 PM
sec-Butylbenzene	ND	5.0		µg/Kg	1	7/2/2013 07:41 PM
Styrene	ND	5.0		µg/Kg	1	7/2/2013 07:41 PM
tert-Butylbenzene	ND	5.0		µg/Kg	1	7/2/2013 07:41 PM
Tetrachloroethene	ND	5.0		µg/Kg	1	7/2/2013 07:41 PM
Toluene	ND	5.0		µg/Kg	1	7/2/2013 07:41 PM
trans-1,2-Dichloroethene	ND	5.0		µg/Kg	1	7/2/2013 07:41 PM
Trichloroethene	ND	5.0		µg/Kg	1	7/2/2013 07:41 PM
Trichlorofluoromethane	ND	5.0		µg/Kg	1	7/2/2013 07:41 PM
Vinyl chloride	ND	5.0		µg/Kg	1	7/2/2013 07:41 PM
Surr: 1,2-Dichloroethane-d4	106	63-139		%REC	1	7/2/2013 07:41 PM
Surr: 4-Bromofluorobenzene	93.7	75-124		%REC	1	7/2/2013 07:41 PM
Surr: Dibromofluoromethane	100	70-133		%REC	1	7/2/2013 07:41 PM
Surr: Toluene-d8	97.8	80-123		%REC	1	7/2/2013 07:41 PM
ICP METALS						
	EPA 3050B			**EPA 6010B**		
RunID: ICP2_130702B	QC Batch: 43321			PrepDate:	7/1/2013	Analyst: **WLS**
Lead	2.3	2.0		mg/Kg	1	7/2/2013 05:26 PM

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range
H	Holding times for preparation or analysis exceeded	ND	Not Detected at the Reporting Limit
S	Spike/Surrogate outside of limits due to matrix interference		Results are wet unless otherwise specified
DO	Surrogate Diluted Out		

Advanced Technology Laboratories, Inc.

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ANALYTICAL RESULTS

Advanced Technology Laboratories, Inc.

Print Date: *09-Jul-13*

CLIENT:	Geocon Consultants, Inc.	**Client Sample ID:**	B4-7.5
Lab Order:	N010479	**Collection Date:**	6/27/2013 9:05:00 AM
Project:	Crissy Field Outfall, E8560-02-51	**Matrix:**	SOIL
Lab ID:	N010479-020		

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
ICP METALS						
	EPA 3050B			**EPA 6010B**		
RunID: ICP2_130702B	QC Batch: 43321			PrepDate:	7/1/2013	Analyst: **WLS**
Lead	2.7	2.0		mg/Kg	1	7/2/2013 05:10 PM

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range
H	Holding times for preparation or analysis exceeded	ND	Not Detected at the Reporting Limit
S	Spike/Surrogate outside of limits due to matrix interference		Results are wet unless otherwise specified
DO	Surrogate Diluted Out		

Advanced Technology Laboratories, Inc.

3151 W. Post Rd Las Vegas, NV 89118 Tel: 702-307-2659 Fax: 702-307-2691

Advanced Technology Laboratories, Inc.

ANALYTICAL RESULTS

Print Date: *09-Jul-13*

CLIENT:	Geocon Consultants, Inc.	**Client Sample ID:**	B3-GW
Lab Order:	N010479	**Collection Date:**	6/27/2013 9:10:00 AM
Project:	Crissy Field Outfall, E8560-02-51	**Matrix:**	GROUNDWATER
Lab ID:	N010479-021		

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
VOLATILE ORGANIC COMPOUNDS BY GC/MS						
			EPA 8260B			
RunID: MS5_130705A	QC Batch: P13VW105			PrepDate:		Analyst: **QBM**
1,1,1,2-Tetrachloroethane	ND	0.50		µg/L	1	7/5/2013 11:42 AM
1,1,1-Trichloroethane	ND	0.50		µg/L	1	7/5/2013 11:42 AM
1,1,2,2-Tetrachloroethane	ND	0.50		µg/L	1	7/5/2013 11:42 AM
1,1,2-Trichloroethane	ND	0.50		µg/L	1	7/5/2013 11:42 AM
1,1-Dichloroethane	ND	0.50		µg/L	1	7/5/2013 11:42 AM
1,1-Dichloroethene	ND	0.50		µg/L	1	7/5/2013 11:42 AM
1,1-Dichloropropene	ND	0.50		µg/L	1	7/5/2013 11:42 AM
1,2,3-Trichlorobenzene	ND	0.50		µg/L	1	7/5/2013 11:42 AM
1,2,3-Trichloropropane	ND	0.50		µg/L	1	7/5/2013 11:42 AM
1,2,4-Trichlorobenzene	ND	0.50		µg/L	1	7/5/2013 11:42 AM
1,2,4-Trimethylbenzene	ND	0.50		µg/L	1	7/5/2013 11:42 AM
1,2-Dibromo-3-chloropropane	ND	1.0		µg/L	1	7/5/2013 11:42 AM
1,2-Dibromoethane	ND	0.50		µg/L	1	7/5/2013 11:42 AM
1,2-Dichlorobenzene	ND	0.50		µg/L	1	7/5/2013 11:42 AM
1,2-Dichloroethane	ND	0.50		µg/L	1	7/5/2013 11:42 AM
1,2-Dichloropropane	ND	0.50		µg/L	1	7/5/2013 11:42 AM
1,3,5-Trimethylbenzene	ND	0.50		µg/L	1	7/5/2013 11:42 AM
1,3-Dichlorobenzene	ND	0.50		µg/L	1	7/5/2013 11:42 AM
1,3-Dichloropropane	ND	0.50		µg/L	1	7/5/2013 11:42 AM
1,4-Dichlorobenzene	ND	0.50		µg/L	1	7/5/2013 11:42 AM
2,2-Dichloropropane	ND	0.50		µg/L	1	7/5/2013 11:42 AM
2-Chlorotoluene	ND	0.50		µg/L	1	7/5/2013 11:42 AM
4-Chlorotoluene	ND	0.50		µg/L	1	7/5/2013 11:42 AM
4-Isopropyltoluene	ND	0.50		µg/L	1	7/5/2013 11:42 AM
Benzene	ND	0.50		µg/L	1	7/5/2013 11:42 AM
Bromobenzene	ND	0.50		µg/L	1	7/5/2013 11:42 AM
Bromodichloromethane	ND	0.50		µg/L	1	7/5/2013 11:42 AM
Bromoform	ND	0.50		µg/L	1	7/5/2013 11:42 AM
Bromomethane	ND	1.0		µg/L	1	7/5/2013 11:42 AM
Carbon tetrachloride	ND	0.50		µg/L	1	7/5/2013 11:42 AM
Chlorobenzene	ND	0.50		µg/L	1	7/5/2013 11:42 AM
Chloroethane	ND	1.0		µg/L	1	7/5/2013 11:42 AM
Chloroform	ND	0.50		µg/L	1	7/5/2013 11:42 AM
Chloromethane	ND	0.50		µg/L	1	7/5/2013 11:42 AM
cis-1,2-Dichloroethene	ND	0.50		µg/L	1	7/5/2013 11:42 AM
cis-1,3-Dichloropropene	ND	0.50		µg/L	1	7/5/2013 11:42 AM

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range
H	Holding times for preparation or analysis exceeded	ND	Not Detected at the Reporting Limit
S	Spike/Surrogate outside of limits due to matrix interference		Results are wet unless otherwise specified
DO	Surrogate Diluted Out		

Advanced Technology Laboratories, Inc.

3151 W. Post Rd Las Vegas, NV 89118 Tel: 702-307-2659 Fax: 702-307-2691

CLIENT: Geocon Consultants, Inc.
Lab Order: N010479
Project: Crissy Field Outfall, E8560-02-51
Lab ID: N010479-021

Client Sample ID: B3-GW
Collection Date: 6/27/2013 9:10:00 AM
Matrix: GROUNDWATER

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
VOLATILE ORGANIC COMPOUNDS BY GC/MS						
				EPA 8260B		
RunID: MS5_130705A	QC Batch: P13VW105			PrepDate:		Analyst: **QBM**
Dibromochloromethane	ND	0.50		µg/L	1	7/5/2013 11:42 AM
Dibromomethane	ND	0.50		µg/L	1	7/5/2013 11:42 AM
Dichlorodifluoromethane	ND	0.50		µg/L	1	7/5/2013 11:42 AM
Ethylbenzene	ND	0.50		µg/L	1	7/5/2013 11:42 AM
Hexachlorobutadiene	ND	0.50		µg/L	1	7/5/2013 11:42 AM
Isopropylbenzene	ND	0.50		µg/L	1	7/5/2013 11:42 AM
m,p-Xylene	ND	1.0		µg/L	1	7/5/2013 11:42 AM
Methylene chloride	ND	2.0		µg/L	1	7/5/2013 11:42 AM
n-Butylbenzene	ND	0.50		µg/L	1	7/5/2013 11:42 AM
n-Propylbenzene	ND	0.50		µg/L	1	7/5/2013 11:42 AM
Naphthalene	ND	0.50		µg/L	1	7/5/2013 11:42 AM
o-Xylene	ND	0.50		µg/L	1	7/5/2013 11:42 AM
sec-Butylbenzene	ND	0.50		µg/L	1	7/5/2013 11:42 AM
Styrene	ND	0.50		µg/L	1	7/5/2013 11:42 AM
tert-Butylbenzene	ND	0.50		µg/L	1	7/5/2013 11:42 AM
Tetrachloroethene	ND	0.50		µg/L	1	7/5/2013 11:42 AM
Toluene	ND	0.50		µg/L	1	7/5/2013 11:42 AM
trans-1,2-Dichloroethene	ND	0.50		µg/L	1	7/5/2013 11:42 AM
Trichloroethene	ND	0.50		µg/L	1	7/5/2013 11:42 AM
Trichlorofluoromethane	ND	0.50		µg/L	1	7/5/2013 11:42 AM
Vinyl chloride	ND	0.50		µg/L	1	7/5/2013 11:42 AM
Surr: 1,2-Dichloroethane-d4	100	70-127		%REC	1	7/5/2013 11:42 AM
Surr: 4-Bromofluorobenzene	102	80-120		%REC	1	7/5/2013 11:42 AM
Surr: Dibromofluoromethane	102	73-128		%REC	1	7/5/2013 11:42 AM
Surr: Toluene-d8	101	80-120		%REC	1	7/5/2013 11:42 AM
GASOLINE RANGE ORGANICS BY GC/FID						
				EPA 8015B		
RunID: GC4_130703A	QC Batch: E13VW038			PrepDate:		Analyst: **QBM**
GRO	ND	0.050		mg/L	1	7/3/2013 11:38 AM
Surr: Chlorobenzene - d5	110	74-126		%REC	1	7/3/2013 11:38 AM

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range
H	Holding times for preparation or analysis exceeded	ND	Not Detected at the Reporting Limit
S	Spike/Surrogate outside of limits due to matrix interference		Results are wet unless otherwise specified
DO	Surrogate Diluted Out		

Advanced Technology Laboratories, Inc.

ANALYTICAL RESULTS

Print Date: *09-Jul-13*

CLIENT:	Geocon Consultants, Inc.	**Client Sample ID:**	B2-GW
Lab Order:	N010479	**Collection Date:**	6/27/2013 12:00:00 PM
Project:	Crissy Field Outfall, E8560-02-51	**Matrix:**	GROUNDWATER
Lab ID:	N010479-022		

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
VOLATILE ORGANIC COMPOUNDS BY GC/MS						
			EPA 8260B			
RunID: MS5_130705A	QC Batch: P13VW105			PrepDate:		Analyst: **QBM**
1,1,1,2-Tetrachloroethane	ND	0.50		µg/L	1	7/5/2013 12:10 PM
1,1,1-Trichloroethane	ND	0.50		µg/L	1	7/5/2013 12:10 PM
1,1,2,2-Tetrachloroethane	ND	0.50		µg/L	1	7/5/2013 12:10 PM
1,1,2-Trichloroethane	ND	0.50		µg/L	1	7/5/2013 12:10 PM
1,1-Dichloroethane	ND	0.50		µg/L	1	7/5/2013 12:10 PM
1,1-Dichloroethene	ND	0.50		µg/L	1	7/5/2013 12:10 PM
1,1-Dichloropropene	ND	0.50		µg/L	1	7/5/2013 12:10 PM
1,2,3-Trichlorobenzene	ND	0.50		µg/L	1	7/5/2013 12:10 PM
1,2,3-Trichloropropane	ND	0.50		µg/L	1	7/5/2013 12:10 PM
1,2,4-Trichlorobenzene	ND	0.50		µg/L	1	7/5/2013 12:10 PM
1,2,4-Trimethylbenzene	ND	0.50		µg/L	1	7/5/2013 12:10 PM
1,2-Dibromo-3-chloropropane	ND	1.0		µg/L	1	7/5/2013 12:10 PM
1,2-Dibromoethane	ND	0.50		µg/L	1	7/5/2013 12:10 PM
1,2-Dichlorobenzene	ND	0.50		µg/L	1	7/5/2013 12:10 PM
1,2-Dichloroethane	ND	0.50		µg/L	1	7/5/2013 12:10 PM
1,2-Dichloropropane	ND	0.50		µg/L	1	7/5/2013 12:10 PM
1,3,5-Trimethylbenzene	ND	0.50		µg/L	1	7/5/2013 12:10 PM
1,3-Dichlorobenzene	ND	0.50		µg/L	1	7/5/2013 12:10 PM
1,3-Dichloropropane	ND	0.50		µg/L	1	7/5/2013 12:10 PM
1,4-Dichlorobenzene	ND	0.50		µg/L	1	7/5/2013 12:10 PM
2,2-Dichloropropane	ND	0.50		µg/L	1	7/5/2013 12:10 PM
2-Chlorotoluene	ND	0.50		µg/L	1	7/5/2013 12:10 PM
4-Chlorotoluene	ND	0.50		µg/L	1	7/5/2013 12:10 PM
4-Isopropyltoluene	ND	0.50		µg/L	1	7/5/2013 12:10 PM
Benzene	ND	0.50		µg/L	1	7/5/2013 12:10 PM
Bromobenzene	ND	0.50		µg/L	1	7/5/2013 12:10 PM
Bromodichloromethane	ND	0.50		µg/L	1	7/5/2013 12:10 PM
Bromoform	ND	0.50		µg/L	1	7/5/2013 12:10 PM
Bromomethane	ND	1.0		µg/L	1	7/5/2013 12:10 PM
Carbon tetrachloride	ND	0.50		µg/L	1	7/5/2013 12:10 PM
Chlorobenzene	ND	0.50		µg/L	1	7/5/2013 12:10 PM
Chloroethane	ND	1.0		µg/L	1	7/5/2013 12:10 PM
Chloroform	ND	0.50		µg/L	1	7/5/2013 12:10 PM
Chloromethane	ND	0.50		µg/L	1	7/5/2013 12:10 PM
cis-1,2-Dichloroethene	ND	0.50		µg/L	1	7/5/2013 12:10 PM
cis-1,3-Dichloropropene	ND	0.50		µg/L	1	7/5/2013 12:10 PM

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range
H	Holding times for preparation or analysis exceeded	ND	Not Detected at the Reporting Limit
S	Spike/Surrogate outside of limits due to matrix interference		Results are wet unless otherwise specified
DO	Surrogate Diluted Out		

Advanced Technology Laboratories, Inc.

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CLIENT: Geocon Consultants, Inc.
Lab Order: N010479
Project: Crissy Field Outfall, E8560-02-51
Lab ID: N010479-022

Client Sample ID: B2-GW
Collection Date: 6/27/2013 12:00:00 PM
Matrix: GROUNDWATER

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
VOLATILE ORGANIC COMPOUNDS BY GC/MS						
				EPA 8260B		
RunID: MS5_130705A	QC Batch: P13VW105			PrepDate:		Analyst: **QBM**
Dibromochloromethane	ND	0.50		µg/L	1	7/5/2013 12:10 PM
Dibromomethane	ND	0.50		µg/L	1	7/5/2013 12:10 PM
Dichlorodifluoromethane	ND	0.50		µg/L	1	7/5/2013 12:10 PM
Ethylbenzene	ND	0.50		µg/L	1	7/5/2013 12:10 PM
Hexachlorobutadiene	ND	0.50		µg/L	1	7/5/2013 12:10 PM
Isopropylbenzene	ND	0.50		µg/L	1	7/5/2013 12:10 PM
m,p-Xylene	ND	1.0		µg/L	1	7/5/2013 12:10 PM
Methylene chloride	ND	2.0		µg/L	1	7/5/2013 12:10 PM
n-Butylbenzene	ND	0.50		µg/L	1	7/5/2013 12:10 PM
n-Propylbenzene	ND	0.50		µg/L	1	7/5/2013 12:10 PM
Naphthalene	ND	0.50		µg/L	1	7/5/2013 12:10 PM
o-Xylene	ND	0.50		µg/L	1	7/5/2013 12:10 PM
sec-Butylbenzene	ND	0.50		µg/L	1	7/5/2013 12:10 PM
Styrene	ND	0.50		µg/L	1	7/5/2013 12:10 PM
tert-Butylbenzene	ND	0.50		µg/L	1	7/5/2013 12:10 PM
Tetrachloroethene	ND	0.50		µg/L	1	7/5/2013 12:10 PM
Toluene	ND	0.50		µg/L	1	7/5/2013 12:10 PM
trans-1,2-Dichloroethene	ND	0.50		µg/L	1	7/5/2013 12:10 PM
Trichloroethene	ND	0.50		µg/L	1	7/5/2013 12:10 PM
Trichlorofluoromethane	ND	0.50		µg/L	1	7/5/2013 12:10 PM
Vinyl chloride	ND	0.50		µg/L	1	7/5/2013 12:10 PM
Surr: 1,2-Dichloroethane-d4	102	70-127		%REC	1	7/5/2013 12:10 PM
Surr: 4-Bromofluorobenzene	103	80-120		%REC	1	7/5/2013 12:10 PM
Surr: Dibromofluoromethane	101	73-128		%REC	1	7/5/2013 12:10 PM
Surr: Toluene-d8	101	80-120		%REC	1	7/5/2013 12:10 PM
GASOLINE RANGE ORGANICS BY GC/FID						
				EPA 8015B		
RunID: GC4_130703A	QC Batch: E13VW038			PrepDate:		Analyst: **QBM**
GRO	ND	0.050		mg/L	1	7/3/2013 12:39 PM
Surr: Chlorobenzene - d5	98.4	74-126		%REC	1	7/3/2013 12:39 PM

Qualifiers:

B	Analyte detected in the associated Method Blank
H	Holding times for preparation or analysis exceeded
S	Spike/Surrogate outside of limits due to matrix interference
DO	Surrogate Diluted Out
E	Value above quantitation range
ND	Not Detected at the Reporting Limit

Results are wet unless otherwise specified

ANALYTICAL RESULTS

Advanced Technology Laboratories, Inc.

Print Date: *09-Jul-13*

CLIENT:	Geocon Consultants, Inc.	**Client Sample ID:**	B4-10
Lab Order:	N010479	**Collection Date:**	6/27/2013 12:00:00 PM
Project:	Crissy Field Outfall, E8560-02-51	**Matrix:**	SOIL
Lab ID:	N010479-023		

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
MERCURY BY COLD VAPOR TECHNIQUE						
EPA 7471				**EPA 7471A**		
RunID: AA1_130701B	QC Batch: 43313			PrepDate:	6/28/2013	Analyst: **LCC**
Mercury	ND	0.10		mg/Kg	1	7/1/2013
ICP METALS						
EPA 3050B				**EPA 6010B**		
RunID: ICP2_130708A	QC Batch: 43320			PrepDate:	7/1/2013	Analyst: **WLS**
Antimony	ND	2.0		mg/Kg	1	7/8/2013 01:03 PM
Arsenic	3.2	1.0		mg/Kg	1	7/8/2013 01:03 PM
Barium	8.3	1.0		mg/Kg	1	7/8/2013 01:03 PM
Beryllium	ND	1.0		mg/Kg	1	7/8/2013 01:03 PM
Cadmium	ND	1.0		mg/Kg	1	7/8/2013 01:03 PM
Chromium	37	1.0		mg/Kg	1	7/8/2013 01:03 PM
Cobalt	4.7	1.0		mg/Kg	1	7/8/2013 01:03 PM
Copper	4.2	2.0		mg/Kg	1	7/8/2013 01:03 PM
Lead	6.6	1.0		mg/Kg	1	7/8/2013 01:03 PM
Molybdenum	ND	1.0		mg/Kg	1	7/8/2013 01:03 PM
Nickel	32	1.0		mg/Kg	1	7/8/2013 01:03 PM
Selenium	ND	1.0		mg/Kg	1	7/8/2013 01:03 PM
Silver	ND	1.0		mg/Kg	1	7/8/2013 01:03 PM
Thallium	ND	1.0		mg/Kg	1	7/8/2013 01:03 PM
Vanadium	17	1.0		mg/Kg	1	7/8/2013 01:03 PM
Zinc	16	1.0		mg/Kg	1	7/8/2013 01:03 PM

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range
H	Holding times for preparation or analysis exceeded	ND	Not Detected at the Reporting Limit
S	Spike/Surrogate outside of limits due to matrix interference		Results are wet unless otherwise specified
DO	Surrogate Diluted Out		

Advanced Technology Laboratories, Inc.

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ANALYTICAL RESULTS

Advanced Technology Laboratories, Inc.

Print Date: *09-Jul-13*

CLIENT:	Geocon Consultants, Inc.	**Client Sample ID:**	Trip Blank
Lab Order:	N010479	**Collection Date:**	6/27/2013
Project:	Crissy Field Outfall, E8560-02-51	**Matrix:**	WATER
Lab ID:	N010479-024		

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
GASOLINE RANGE ORGANICS BY GC/FID						
				EPA 8015B		
RunID: GC4_130703A	QC Batch: E13VW038			PrepDate:		Analyst: **QBM**
GRO	ND	0.050		mg/L	1	7/3/2013 01:10 PM
Surr: Chlorobenzene - d5	98.3	74-126		%REC	1	7/3/2013 01:10 PM

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range
H	Holding times for preparation or analysis exceeded	ND	Not Detected at the Reporting Limit
S	Spike/Surrogate outside of limits due to matrix interference		Results are wet unless otherwise specified
DO	Surrogate Diluted Out		

Advanced Technology Laboratories, Inc.

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ANALYTICAL RESULTS

Advanced Technology Laboratories, Inc.

Print Date: *09-Jul-13*

CLIENT:	Geocon Consultants, Inc.	**Client Sample ID:**	Equipment Blank
Lab Order:	N010479	**Collection Date:**	6/27/2013 4:00:00 PM
Project:	Crissy Field Outfall, E8560-02-51	**Matrix:**	WATER
Lab ID:	N010479-025		

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
ICP METALS						
	EPA 3010A			**EPA 6010B**		
RunID: ICP2_130703C	QC Batch: 43325				PrepDate: 7/1/2013	Analyst: **WLS**
Lead	ND	0.0050		mg/L	1	7/3/2013 02:33 PM

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range
H	Holding times for preparation or analysis exceeded	ND	Not Detected at the Reporting Limit
S	Spike/Surrogate outside of limits due to matrix interference		Results are wet unless otherwise specified
DO	Surrogate Diluted Out		

Advanced Technology Laboratories, Inc.

3151 W. Post Rd Las Vegas, NV 89118 Tel: 702-307-2659 Fax: 702-307-2691

CLIENT: Geocon Consultants, Inc.
Work Order: N010479
Project: Crissy Field Outfall, E8560-02-51

ANALYTICAL QC SUMMARY REPORT

TestCode: 6010_S

Sample ID: **LCS-43320** SampType: **LCS** TestCode: **6010_S** Units: **mg/Kg** Prep Date: **7/1/2013** RunNo: **89481**
Client ID: **LCSS** Batch ID: **43320** TestNo: **EPA 6010B** **EPA 3050B** Analysis Date: **7/8/2013** SeqNo: **1606097**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Antimony	49.064	2.0	50.08	0	98.0	80	120				
Arsenic	48.088	1.0	50.08	0	96.0	80	120				
Barium	48.973	1.0	50.08	0	97.8	80	120				
Beryllium	47.754	1.0	50.08	0	95.4	80	120				
Cadmium	47.851	1.0	50.08	0	95.6	80	120				
Chromium	48.055	1.0	50.08	0	96.0	80	120				
Cobalt	47.024	1.0	50.08	0	93.9	80	120				
Copper	48.754	2.0	50.08	0	97.4	80	120				
Lead	49.212	1.0	50.08	0	98.3	80	120				
Molybdenum	49.812	1.0	50.08	0	99.5	80	120				
Nickel	46.314	1.0	50.08	0	92.5	80	120				
Selenium	43.543	1.0	50.08	0	87.0	80	120				
Silver	47.387	1.0	50.08	0	94.6	80	120				
Thallium	47.657	1.0	50.08	0	95.2	80	120				
Vanadium	49.162	1.0	50.08	0	98.2	80	120				
Zinc	47.124	1.0	50.08	0	94.1	80	120				

Sample ID: **N010478-001B-DUP** SampType: **DUP** TestCode: **6010_S** Units: **mg/Kg** Prep Date: **7/1/2013** RunNo: **89481**
Client ID: **ZZZZZZ** Batch ID: **43320** TestNo: **EPA 6010B** **EPA 3050B** Analysis Date: **7/8/2013** SeqNo: **1606099**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Antimony	ND	2.0						0	0	20	
Arsenic	3.371	1.0						3.293	2.35	20	
Barium	116.125	1.0						113.2	2.57	20	
Beryllium	0.179	1.0						0.1775	0	20	
Cadmium	ND	1.0						0	0	20	
Chromium	13.153	1.0						12.81	2.62	20	
Cobalt	5.009	1.0						4.778	4.73	20	

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range	H	Holding times for preparation or analysis exceeded
ND	Not Detected at the Reporting Limit	R	RPD outside accepted recovery limits	S	Spike/Surrogate outside of limits due to matrix interference
DO	Surrogate Diluted Out		Calculations are based on raw values		

CLIENT: Geocon Consultants, Inc.
Work Order: N010479
Project: Crissy Field Outfall, E8560-02-51

ANALYTICAL QC SUMMARY REPORT

TestCode: 6010_S

Sample ID: **N010478-001B-DUP** SampType: **DUP** TestCode: **6010_S** Units: **mg/Kg** Prep Date: **7/1/2013** RunNo: **89481**
Client ID: **ZZZZZZ** Batch ID: **43320** TestNo: **EPA 6010B** **EPA 3050B** Analysis Date: **7/8/2013** SeqNo: **1606099**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Copper	8.084	2.0						7.762	4.06	20	
Lead	4.539	1.0						5.019	10.0	20	
Molybdenum	0.234	1.0						0.2296	0	20	
Nickel	10.852	1.0						10.67	1.68	20	
Selenium	ND	1.0						0	0	20	
Silver	ND	1.0						0	0	20	
Thallium	ND	1.0						0	0	20	
Vanadium	20.752	1.0						20.46	1.40	20	
Zinc	25.402	1.0						25.39	0.0635	20	

Sample ID: **N010478-001B-MS** SampType: **MS** TestCode: **6010_S** Units: **mg/Kg** Prep Date: **7/1/2013** RunNo: **89481**
Client ID: **ZZZZZZ** Batch ID: **43320** TestNo: **EPA 6010B** **EPA 3050B** Analysis Date: **7/8/2013** SeqNo: **1606102**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Antimony	34.978	2.0	50.05	0	69.9	75	125				S
Arsenic	47.485	1.0	50.05	3.293	88.3	75	125				
Barium	169.219	1.0	50.05	113.2	112	75	125				
Beryllium	43.128	1.0	50.05	0.1775	85.8	75	125				
Cadmium	40.882	1.0	50.05	0	81.7	75	125				
Chromium	56.081	1.0	50.05	12.81	86.4	75	125				
Cobalt	46.630	1.0	50.05	4.778	83.6	75	125				
Copper	53.647	2.0	50.05	7.762	91.7	75	125				
Lead	47.841	1.0	50.05	5.019	85.6	75	125				
Molybdenum	41.534	1.0	50.05	0.2296	82.5	75	125				
Nickel	51.169	1.0	50.05	10.67	80.9	75	125				
Selenium	39.535	1.0	50.05	0	79.0	75	125				
Silver	42.601	1.0	50.05	0	85.1	75	125				
Thallium	38.792	1.0	50.05	0	77.5	75	125				
Vanadium	67.829	1.0	50.05	20.46	94.6	75	125				
Zinc	69.990	1.0	50.05	25.39	89.1	75	125				

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range	H	Holding times for preparation or analysis exceeded
ND	Not Detected at the Reporting Limit	R	RPD outside accepted recovery limits	S	Spike/Surrogate outside of limits due to matrix interference
DO	Surrogate Diluted Out		Calculations are based on raw values		

Advanced Technology Laboratories, Inc.
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CLIENT: Geocon Consultants, Inc.
Work Order: N010479
Project: Crissy Field Outfall, E8560-02-51

ANALYTICAL QC SUMMARY REPORT

TestCode: 6010_S

Sample ID: **N010478-001B-MSD** SampType: **MSD** TestCode: **6010_S** Units: **mg/Kg** Prep Date: **7/1/2013** RunNo: **89481**
Client ID: **ZZZZZZ** Batch ID: **43320** TestNo: **EPA 6010B** **EPA 3050B** Analysis Date: **7/8/2013** SeqNo: **1606103**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Antimony	34.502	2.0	50.23	0	68.7	75	125	34.98	1.37	20	S
Arsenic	48.194	1.0	50.23	3.293	89.4	75	125	47.48	1.48	20	
Barium	161.199	1.0	50.23	113.2	95.6	75	125	169.2	4.85	20	
Beryllium	43.337	1.0	50.23	0.1775	85.9	75	125	43.13	0.485	20	
Cadmium	41.072	1.0	50.23	0	81.8	75	125	40.88	0.466	20	
Chromium	56.244	1.0	50.23	12.81	86.5	75	125	56.08	0.290	20	
Cobalt	47.012	1.0	50.23	4.778	84.1	75	125	46.63	0.816	20	
Copper	53.893	2.0	50.23	7.762	91.8	75	125	53.65	0.458	20	
Lead	46.043	1.0	50.23	5.019	81.7	75	125	47.84	3.83	20	
Molybdenum	41.630	1.0	50.23	0.2296	82.4	75	125	41.53	0.231	20	
Nickel	51.924	1.0	50.23	10.67	82.1	75	125	51.17	1.47	20	
Selenium	40.055	1.0	50.23	0	79.7	75	125	39.54	1.30	20	
Silver	42.676	1.0	50.23	0	85.0	75	125	42.60	0.177	20	
Thallium	38.947	1.0	50.23	0	77.5	75	125	38.79	0.399	20	
Vanadium	68.699	1.0	50.23	20.46	96.0	75	125	67.83	1.28	20	
Zinc	70.931	1.0	50.23	25.39	90.7	75	125	69.99	1.33	20	

Sample ID: **MB2-43320** SampType: **MBLK** TestCode: **6010_S** Units: **mg/Kg** Prep Date: RunNo: **89481**
Client ID: **PBS** Batch ID: **43320** TestNo: **EPA 6010B** **EPA 3050B** Analysis Date: **7/8/2013** SeqNo: **1606113**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Antimony	ND	2.0									
Arsenic	ND	1.0									
Barium	ND	1.0									
Beryllium	ND	1.0									
Cadmium	ND	1.0									
Chromium	ND	1.0									
Cobalt	ND	1.0									
Copper	ND	2.0									
Lead	ND	1.0									

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range	H	Holding times for preparation or analysis exceeded
ND	Not Detected at the Reporting Limit	R	RPD outside accepted recovery limits	S	Spike/Surrogate outside of limits due to matrix interference
DO	Surrogate Diluted Out		Calculations are based on raw values		

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Work Order: N010479
Project: Crissy Field Outfall, E8560-02-51

ANALYTICAL QC SUMMARY REPORT

TestCode: 6010_S

Sample ID: **MB2-43320** SampType: **MBLK** TestCode: **6010_S** Units: **mg/Kg** Prep Date: RunNo: **89481**
Client ID: **PBS** Batch ID: **43320** TestNo: **EPA 6010B** **EPA 3050B** Analysis Date: **7/8/2013** SeqNo: **1606113**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Molybdenum	ND	1.0									
Nickel	ND	1.0									
Selenium	ND	1.0									
Silver	ND	1.0									
Thallium	ND	1.0									
Vanadium	ND	1.0									
Zinc	ND	1.0									

Sample ID: **N010467-003B-DUP** SampType: **DUP** TestCode: **6010_S** Units: **mg/Kg** Prep Date: **7/1/2013** RunNo: **89481**
Client ID: **ZZZZZZ** Batch ID: **43320** TestNo: **EPA 6010B** **EPA 3050B** Analysis Date: **7/8/2013** SeqNo: **1606116**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Antimony	ND	2.0						0	0	20	
Arsenic	2.112	1.0						2.453	14.9	20	
Barium	9.594	1.0						9.006	6.32	20	
Beryllium	ND	1.0						0	0	20	
Cadmium	ND	1.0						0	0	20	
Chromium	22.816	1.0						24.86	8.59	20	
Cobalt	4.134	1.0						4.605	10.8	20	
Copper	3.532	2.0						3.755	6.12	20	
Lead	3.505	1.0						3.805	8.19	20	
Molybdenum	ND	1.0						0	0	20	
Nickel	23.860	1.0						24.49	2.60	20	
Selenium	ND	1.0						0	0	20	
Silver	ND	1.0						0	0	20	
Thallium	ND	1.0						0	0	20	
Vanadium	14.944	1.0						16.27	8.46	20	
Zinc	18.103	1.0						18.52	2.27	20	

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range	H	Holding times for preparation or analysis exceeded
ND	Not Detected at the Reporting Limit	R	RPD outside accepted recovery limits	S	Spike/Surrogate outside of limits due to matrix interference
DO	Surrogate Diluted Out		Calculations are based on raw values		

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Project: Crissy Field Outfall, E8560-02-51

ANALYTICAL QC SUMMARY REPORT

TestCode: 6010_S

Sample ID: **N010467-003B-MS** SampType: **MS** TestCode: **6010_S** Units: **mg/Kg** Prep Date: **7/1/2013** RunNo: **89481**
Client ID: **ZZZZZZ** Batch ID: **43320** TestNo: **EPA 6010B** **EPA 3050B** Analysis Date: **7/8/2013** SeqNo: **1606117**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Antimony	40.172	2.0	49.98	0	80.4	75	125				
Arsenic	49.194	1.0	49.98	2.453	93.5	75	125				
Barium	58.341	1.0	49.98	9.006	98.7	75	125				
Beryllium	44.862	1.0	49.98	0	89.8	75	125				
Cadmium	44.145	1.0	49.98	0	88.3	75	125				
Chromium	76.660	1.0	49.98	24.86	104	75	125				
Cobalt	48.256	1.0	49.98	4.605	87.3	75	125				
Copper	51.751	2.0	49.98	3.755	96.0	75	125				
Lead	48.536	1.0	49.98	3.805	89.5	75	125				
Molybdenum	44.772	1.0	49.98	0	89.6	75	125				
Nickel	70.568	1.0	49.98	24.49	92.2	75	125				
Selenium	41.402	1.0	49.98	0	82.8	75	125				
Silver	44.445	1.0	49.98	0	88.9	75	125				
Thallium	42.005	1.0	49.98	0	84.1	75	125				
Vanadium	66.136	1.0	49.98	16.27	99.8	75	125				
Zinc	61.930	1.0	49.98	18.52	86.9	75	125				

Qualifiers:

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ND	Not Detected at the Reporting Limit	R	RPD outside accepted recovery limits	S	Spike/Surrogate outside of limits due to matrix interference
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ANALYTICAL QC SUMMARY REPORT

TestCode: 6010_S

Sample ID: **LCS-43321** SampType: **LCS** TestCode: **6010_S** Units: **mg/Kg** Prep Date: **7/1/2013** RunNo: **89444**
Client ID: **LCSS** Batch ID: **43321** TestNo: **EPA 6010B** **EPA 3050B** Analysis Date: **7/2/2013** SeqNo: **1606862**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Lead	42.677	2.0	50.20	0	85.0	80	120				

Sample ID: **N010479-002A-DUP** SampType: **DUP** TestCode: **6010_S** Units: **mg/Kg** Prep Date: **7/1/2013** RunNo: **89444**
Client ID: **ZZZZZZ** Batch ID: **43321** TestNo: **EPA 6010B** **EPA 3050B** Analysis Date: **7/2/2013** SeqNo: **1606864**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Lead	28.838	2.0						36.73	24.1	20	R

Sample ID: **N010479-002A-MS** SampType: **MS** TestCode: **6010_S** Units: **mg/Kg** Prep Date: **7/1/2013** RunNo: **89444**
Client ID: **ZZZZZZ** Batch ID: **43321** TestNo: **EPA 6010B** **EPA 3050B** Analysis Date: **7/2/2013** SeqNo: **1606867**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Lead	76.486	2.0	50.25	36.73	79.1	75	125				

Sample ID: **N010479-002A-MSD** SampType: **MSD** TestCode: **6010_S** Units: **mg/Kg** Prep Date: **7/1/2013** RunNo: **89444**
Client ID: **ZZZZZZ** Batch ID: **43321** TestNo: **EPA 6010B** **EPA 3050B** Analysis Date: **7/2/2013** SeqNo: **1606868**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Lead	88.935	2.0	50.10	36.73	104	75	125	76.49	15.1	20	

Sample ID: **MB2-43321** SampType: **MBLK** TestCode: **6010_S** Units: **mg/Kg** Prep Date: RunNo: **89444**
Client ID: **PBS** Batch ID: **43321** TestNo: **EPA 6010B** **EPA 3050B** Analysis Date: **7/2/2013** SeqNo: **1606880**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Lead	ND	1.0									

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range	H	Holding times for preparation or analysis exceeded
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ANALYTICAL QC SUMMARY REPORT

TestCode: 6010_S

Sample ID: **N010479-014A-DUP** SampType: **DUP** TestCode: **6010_S** Units: **mg/Kg** Prep Date: **7/1/2013** RunNo: **89444**
Client ID: **ZZZZZZ** Batch ID: **43321** TestNo: **EPA 6010B** **EPA 3050B** Analysis Date: **7/2/2013** SeqNo: **1606882**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Lead	2.216	2.0						2.786	22.8	20	R

Sample ID: **N010479-014A-MS** SampType: **MS** TestCode: **6010_S** Units: **mg/Kg** Prep Date: **7/1/2013** RunNo: **89444**
Client ID: **ZZZZZZ** Batch ID: **43321** TestNo: **EPA 6010B** **EPA 3050B** Analysis Date: **7/2/2013** SeqNo: **1606885**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Lead	39.991	2.0	49.70	2.786	74.9	75	125				S

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range	H	Holding times for preparation or analysis exceeded
ND	Not Detected at the Reporting Limit	R	RPD outside accepted recovery limits	S	Spike/Surrogate outside of limits due to matrix interference
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ANALYTICAL QC SUMMARY REPORT

TestCode: 6010_W

Sample ID: **MB-43325** SampType: **MBLK** TestCode: **6010_W** Units: **mg/L** Prep Date: **7/1/2013** RunNo: **89462**
Client ID: **PBW** Batch ID: **43325** TestNo: **EPA 6010B** **EPA 3010A** Analysis Date: **7/3/2013** SeqNo: **1605051**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Lead	ND	0.0050									

Sample ID: **LCS-43325** SampType: **LCS** TestCode: **6010_W** Units: **mg/L** Prep Date: **7/1/2013** RunNo: **89462**
Client ID: **LCSW** Batch ID: **43325** TestNo: **EPA 6010B** **EPA 3010A** Analysis Date: **7/3/2013** SeqNo: **1605052**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Lead	0.493	0.0050	0.5000	0	98.6	85	115				

Sample ID: **N010467-004A-MS** SampType: **MS** TestCode: **6010_W** Units: **mg/L** Prep Date: **7/1/2013** RunNo: **89462**
Client ID: **ZZZZZZ** Batch ID: **43325** TestNo: **EPA 6010B** **EPA 3010A** Analysis Date: **7/3/2013** SeqNo: **1605056**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Lead	0.488	0.0050	0.5000	0.003660	96.9	75	125				

Sample ID: **N010467-004A-MSD** SampType: **MSD** TestCode: **6010_W** Units: **mg/L** Prep Date: **7/1/2013** RunNo: **89462**
Client ID: **ZZZZZZ** Batch ID: **43325** TestNo: **EPA 6010B** **EPA 3010A** Analysis Date: **7/3/2013** SeqNo: **1605057**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Lead	0.488	0.0050	0.5000	0.003660	96.9	75	125	0.4880	0.00560	20	

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range	H	Holding times for preparation or analysis exceeded
ND	Not Detected at the Reporting Limit	R	RPD outside accepted recovery limits	S	Spike/Surrogate outside of limits due to matrix interference
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ANALYTICAL QC SUMMARY REPORT

TestCode: 7471_S

Sample ID: **LCS-43313** SampType: **LCS** TestCode: **7471_S** Units: **mg/Kg** Prep Date: **6/28/2013** RunNo: **89420**
Client ID: **LCSS** Batch ID: **43313** TestNo: **EPA 7471A** **EPA 7471** Analysis Date: **7/1/2013** SeqNo: **1602676**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Mercury	0.466	0.099	0.4139	0	113	80	120				

Sample ID: **MB-43313** SampType: **MBLK** TestCode: **7471_S** Units: **mg/Kg** Prep Date: **6/28/2013** RunNo: **89420**
Client ID: **PBS** Batch ID: **43313** TestNo: **EPA 7471A** **EPA 7471** Analysis Date: **7/1/2013** SeqNo: **1602677**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Mercury	ND	0.099									

Sample ID: **N010479-001A-DUP** SampType: **DUP** TestCode: **7471_S** Units: **mg/Kg** Prep Date: **6/28/2013** RunNo: **89420**
Client ID: **ZZZZZZ** Batch ID: **43313** TestNo: **EPA 7471A** **EPA 7471** Analysis Date: **7/1/2013** SeqNo: **1602687**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Mercury	0.078	0.099						0.09357	0	20	

Sample ID: **N010479-001A-MS** SampType: **MS** TestCode: **7471_S** Units: **mg/Kg** Prep Date: **6/28/2013** RunNo: **89420**
Client ID: **ZZZZZZ** Batch ID: **43313** TestNo: **EPA 7471A** **EPA 7471** Analysis Date: **7/1/2013** SeqNo: **1602688**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Mercury	0.514	0.099	0.4112	0.09357	102	75	125				

Sample ID: **N010479-001A-MSD** SampType: **MSD** TestCode: **7471_S** Units: **mg/Kg** Prep Date: **6/28/2013** RunNo: **89420**
Client ID: **ZZZZZZ** Batch ID: **43313** TestNo: **EPA 7471A** **EPA 7471** Analysis Date: **7/1/2013** SeqNo: **1602689**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Mercury	0.531	0.10	0.4167	0.09357	105	75	125	0.5144	3.19	20	

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range	H	Holding times for preparation or analysis exceeded
ND	Not Detected at the Reporting Limit	R	RPD outside accepted recovery limits	S	Spike/Surrogate outside of limits due to matrix interference
DO	Surrogate Diluted Out		Calculations are based on raw values		

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ANALYTICAL QC SUMMARY REPORT

TestCode: 8015_S_DM LL

Sample ID: **LCS-43322** SampType: **LCS** TestCode: **8015_S_DM L** Units: **mg/Kg** Prep Date: **7/1/2013** RunNo: **89430**
Client ID: **LCSS** Batch ID: **43322** TestNo: **EPA 8015B EPA 3550B** Analysis Date: **7/1/2013** SeqNo: **1602896**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
DRO	63.133	1.0	83.30	0	75.8	52	126				
Surr: p-Terphenyl	6.780		6.670		102	59	127				

Sample ID: **N010479-003A-DUP** SampType: **DUP** TestCode: **8015_S_DM L** Units: **mg/Kg** Prep Date: **7/1/2013** RunNo: **89430**
Client ID: **ZZZZZZ** Batch ID: **43322** TestNo: **EPA 8015B EPA 3550B** Analysis Date: **7/1/2013** SeqNo: **1602901**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
DRO	1.851	1.0						2.585	33.1	20	R
ORO	3.776	1.0						5.067	29.2	20	R
Surr: p-Terphenyl	6.224		6.672		93.3	59	127		0		

Sample ID: **N010467-003A-MS** SampType: **MS** TestCode: **8015_S_DM L** Units: **mg/Kg** Prep Date: **7/1/2013** RunNo: **89430**
Client ID: **ZZZZZZ** Batch ID: **43322** TestNo: **EPA 8015B EPA 3550B** Analysis Date: **7/1/2013** SeqNo: **1602905**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
DRO	69.433	1.0	83.11	5.620	76.8	13	129				
Surr: p-Terphenyl	7.405		6.654		111	59	127				

Sample ID: **N010467-003A-MSD** SampType: **MSD** TestCode: **8015_S_DM L** Units: **mg/Kg** Prep Date: **7/1/2013** RunNo: **89430**
Client ID: **ZZZZZZ** Batch ID: **43322** TestNo: **EPA 8015B EPA 3550B** Analysis Date: **7/1/2013** SeqNo: **1602906**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
DRO	67.352	1.0	83.44	5.620	74.0	13	129	69.43	3.04	20	
Surr: p-Terphenyl	7.668		6.681		115	59	127		0		

Sample ID: **MB-43322** SampType: **MBLK** TestCode: **8015_S_DM L** Units: **mg/Kg** Prep Date: **7/1/2013** RunNo: **89430**
Client ID: **PBS** Batch ID: **43322** TestNo: **EPA 8015B EPA 3550B** Analysis Date: **7/1/2013** SeqNo: **1602907**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range	H	Holding times for preparation or analysis exceeded
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ANALYTICAL QC SUMMARY REPORT

TestCode: 8015_S_DM LL

Sample ID: **MB-43322** SampType: **MBLK** TestCode: **8015_S_DM L** Units: **mg/Kg** Prep Date: **7/1/2013** RunNo: **89430**
Client ID: **PBS** Batch ID: **43322** TestNo: **EPA 8015B** **EPA 3550B** Analysis Date: **7/1/2013** SeqNo: **1602907**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
DRO	ND	1.0									
ORO	ND	1.0									
Surr: p-Terphenyl	7.320		6.670		110	59	127				

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range	H	Holding times for preparation or analysis exceeded
ND	Not Detected at the Reporting Limit	R	RPD outside accepted recovery limits	S	Spike/Surrogate outside of limits due to matrix interference
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ANALYTICAL QC SUMMARY REPORT

TestCode: 8015GAS_S

Sample ID: **E130702LCS** SampType: **LCS** TestCode: **8015GAS_S** Units: **mg/Kg** Prep Date: RunNo: **89435**
Client ID: **LCSS** Batch ID: **E13VS071** TestNo: **EPA 8015B** Analysis Date: **7/2/2013** SeqNo: **1603039**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
GRO	4.904	1.0	5.000	0	98.1	77	122				
Surr: Chlorobenzene - d5	98.606		100.0		98.6	51	136				

Sample ID: **E130702MBLK** SampType: **MBLK** TestCode: **8015GAS_S** Units: **mg/Kg** Prep Date: RunNo: **89435**
Client ID: **PBS** Batch ID: **E13VS071** TestNo: **EPA 8015B** Analysis Date: **7/2/2013** SeqNo: **1603040**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
GRO	0.061	1.0									
Surr: Chlorobenzene - d5	99.931		100.0		99.9	51	136				

Sample ID: **N010479-007ADUP** SampType: **DUP** TestCode: **8015GAS_S** Units: **mg/Kg** Prep Date: RunNo: **89435**
Client ID: **ZZZZZZ** Batch ID: **E13VS071** TestNo: **EPA 8015B** Analysis Date: **7/2/2013** SeqNo: **1603043**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
GRO	0.048	1.0						0.04900	0	20	
Surr: Chlorobenzene - d5	106.236		100.0		106	51	136		0		

Sample ID: **N010479-002AMS** SampType: **MS** TestCode: **8015GAS_S** Units: **mg/Kg** Prep Date: RunNo: **89435**
Client ID: **ZZZZZZ** Batch ID: **E13VS071** TestNo: **EPA 8015B** Analysis Date: **7/2/2013** SeqNo: **1603069**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
GRO	4.563	1.0	5.000	0.04700	90.3	41	132				
Surr: Chlorobenzene - d5	95.203		100.0		95.2	51	136				

Sample ID: **N010479-002AMSD** SampType: **MSD** TestCode: **8015GAS_S** Units: **mg/Kg** Prep Date: RunNo: **89435**
Client ID: **ZZZZZZ** Batch ID: **E13VS071** TestNo: **EPA 8015B** Analysis Date: **7/2/2013** SeqNo: **1603070**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
GRO	4.328	1.0	5.000	0.04700	85.6	41	132	4.563	5.29	20	

Qualifiers:

B Analyte detected in the associated Method Blank
ND Not Detected at the Reporting Limit
DO Surrogate Diluted Out
E Value above quantitation range
R RPD outside accepted recovery limits
Calculations are based on raw values
H Holding times for preparation or analysis exceeded
S Spike/Surrogate outside of limits due to matrix interference

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Work Order: N010479
Project: Crissy Field Outfall, E8560-02-51

ANALYTICAL QC SUMMARY REPORT

TestCode: 8015GAS_S

Sample ID: **N010479-002AMSD** SampType: **MSD** TestCode: **8015GAS_S** Units: **mg/Kg** Prep Date: RunNo: **89435**
Client ID: **ZZZZZZ** Batch ID: **E13VS071** TestNo: **EPA 8015B** Analysis Date: **7/2/2013** SeqNo: **1603070**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Surr: Chlorobenzene - d5	95.784		100.0		95.8	51	136		0		

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range	H	Holding times for preparation or analysis exceeded
ND	Not Detected at the Reporting Limit	R	RPD outside accepted recovery limits	S	Spike/Surrogate outside of limits due to matrix interference
DO	Surrogate Diluted Out		Calculations are based on raw values		

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Project: Crissy Field Outfall, E8560-02-51

ANALYTICAL QC SUMMARY REPORT

TestCode: 8015GAS_WP

Sample ID: **E130703LCS** SampType: **LCS** TestCode: **8015GAS_WP** Units: **mg/L** Prep Date: RunNo: **89450**
Client ID: **LCSW** Batch ID: **E13VW038** TestNo: **EPA 8015B** Analysis Date: **7/3/2013** SeqNo: **1603568**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
GRO	0.947	0.050	1.000	0	94.7	70	130				
Surr: Chlorobenzene - d5	47.964		50.00		95.9	74	126				

Sample ID: **E130703MB1** SampType: **MBLK** TestCode: **8015GAS_WP** Units: **mg/L** Prep Date: RunNo: **89450**
Client ID: **PBW** Batch ID: **E13VW038** TestNo: **EPA 8015B** Analysis Date: **7/3/2013** SeqNo: **1603569**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
GRO	ND	0.050									
Surr: Chlorobenzene - d5	51.213		50.00		102	74	126				

Sample ID: **N010479-021ADUP** SampType: **DUP** TestCode: **8015GAS_WP** Units: **mg/L** Prep Date: RunNo: **89450**
Client ID: **ZZZZZZ** Batch ID: **E13VW038** TestNo: **EPA 8015B** Analysis Date: **7/3/2013** SeqNo: **1603571**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
GRO	ND	0.050						0	0	20	
Surr: Chlorobenzene - d5	56.020		50.00		112	74	126		0		

Sample ID: **N010510-001BMS** SampType: **MS** TestCode: **8015GAS_WP** Units: **mg/L** Prep Date: RunNo: **89450**
Client ID: **ZZZZZZ** Batch ID: **E13VW038** TestNo: **EPA 8015B** Analysis Date: **7/3/2013** SeqNo: **1603575**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
GRO	0.918	0.050	1.000	0	91.8	39	153				
Surr: Chlorobenzene - d5	51.966		50.00		104	74	126				

Sample ID: **N010510-001BMSD** SampType: **MSD** TestCode: **8015GAS_WP** Units: **mg/L** Prep Date: RunNo: **89450**
Client ID: **ZZZZZZ** Batch ID: **E13VW038** TestNo: **EPA 8015B** Analysis Date: **7/3/2013** SeqNo: **1603576**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
GRO	0.770	0.050	1.000	0	77.0	39	153	0.9180	17.5	30	

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range	H	Holding times for preparation or analysis exceeded
ND	Not Detected at the Reporting Limit	R	RPD outside accepted recovery limits	S	Spike/Surrogate outside of limits due to matrix interference
DO	Surrogate Diluted Out		Calculations are based on raw values		

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ANALYTICAL QC SUMMARY REPORT

TestCode: 8015GAS_WP

Sample ID: **N010510-001BMSD** SampType: **MSD** TestCode: **8015GAS_WP** Units: **mg/L** Prep Date: RunNo: **89450**
Client ID: **ZZZZZZ** Batch ID: **E13VW038** TestNo: **EPA 8015B** Analysis Date: **7/3/2013** SeqNo: **1603576**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Surr: Chlorobenzene - d5	50.433		50.00		101	74	126		0		

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range	H	Holding times for preparation or analysis exceeded
ND	Not Detected at the Reporting Limit	R	RPD outside accepted recovery limits	S	Spike/Surrogate outside of limits due to matrix interference
DO	Surrogate Diluted Out		Calculations are based on raw values		

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ANALYTICAL QC SUMMARY REPORT

TestCode: 8082_S

Sample ID: **LCS-43333** SampType: **LCS** TestCode: **8082_S** Units: **µg/Kg** Prep Date: **7/2/2013** RunNo: **89466**
Client ID: **LCSS** Batch ID: **43333** TestNo: **EPA 8082** **EPA 3550B** Analysis Date: **7/2/2013** SeqNo: **1604416**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Aroclor 1016	127.814	16	166.7	0	76.7	56	121				
Aroclor 1260	135.554	16	166.7	0	81.3	62	121				
Surr: Decachlorobiphenyl	14.430		16.67		86.6	40	146				
Surr: Tetrachloro-m-xylene	9.860		16.67		59.1	32	109				

Sample ID: **MB-43333** SampType: **MBLK** TestCode: **8082_S** Units: **µg/Kg** Prep Date: **7/2/2013** RunNo: **89466**
Client ID: **PBS** Batch ID: **43333** TestNo: **EPA 8082** **EPA 3550B** Analysis Date: **7/2/2013** SeqNo: **1604417**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Aroclor 1016	ND	16									
Aroclor 1221	ND	33									
Aroclor 1232	ND	16									
Aroclor 1242	ND	16									
Aroclor 1248	ND	16									
Aroclor 1254	ND	16									
Aroclor 1260	ND	16									
Surr: Decachlorobiphenyl	14.804		16.67		88.8	40	146				
Surr: Tetrachloro-m-xylene	8.968		16.67		53.8	32	109				

Sample ID: **N010479-002A-DUP** SampType: **DUP** TestCode: **8082_S** Units: **µg/Kg** Prep Date: **7/2/2013** RunNo: **89466**
Client ID: **ZZZZZZ** Batch ID: **43333** TestNo: **EPA 8082** **EPA 3550B** Analysis Date: **7/3/2013** SeqNo: **1604419**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Aroclor 1016	ND	17						0	0	20	
Aroclor 1221	ND	33						0	0	20	
Aroclor 1232	ND	17						0	0	20	
Aroclor 1242	ND	17						0	0	20	
Aroclor 1248	ND	17						0	0	20	
Aroclor 1254	ND	17						0	0	20	
Aroclor 1260	ND	17						0	0	20	

Qualifiers:

B Analyte detected in the associated Method Blank
ND Not Detected at the Reporting Limit
DO Surrogate Diluted Out
E Value above quantitation range
R RPD outside accepted recovery limits
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H Holding times for preparation or analysis exceeded
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CLIENT: Geocon Consultants, Inc.
Work Order: N010479
Project: Crissy Field Outfall, E8560-02-51

ANALYTICAL QC SUMMARY REPORT

TestCode: 8082_S

Sample ID: **N010479-002A-DUP** SampType: **DUP** TestCode: **8082_S** Units: **µg/Kg** Prep Date: **7/2/2013** RunNo: **89466**
Client ID: **ZZZZZZ** Batch ID: **43333** TestNo: **EPA 8082** **EPA 3550B** Analysis Date: **7/3/2013** SeqNo: **1604419**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Surr: Decachlorobiphenyl	13.520		16.70		81.0	40	146		0		
Surr: Tetrachloro-m-xylene	12.964		16.70		77.6	32	109		0		

Sample ID: **N010479-008A-MS** SampType: **MS** TestCode: **8082_S** Units: **µg/Kg** Prep Date: **7/2/2013** RunNo: **89466**
Client ID: **ZZZZZZ** Batch ID: **43333** TestNo: **EPA 8082** **EPA 3550B** Analysis Date: **7/3/2013** SeqNo: **1604427**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Aroclor 1016	146.073	16	166.5	0	87.7	43	142				
Aroclor 1260	153.894	16	166.5	0	92.4	34	146				
Surr: Decachlorobiphenyl	16.065		16.65		96.5	40	146				
Surr: Tetrachloro-m-xylene	11.169		16.65		67.1	32	109				

Sample ID: **N010479-008A-MSD** SampType: **MSD** TestCode: **8082_S** Units: **µg/Kg** Prep Date: **7/2/2013** RunNo: **89466**
Client ID: **ZZZZZZ** Batch ID: **43333** TestNo: **EPA 8082** **EPA 3550B** Analysis Date: **7/3/2013** SeqNo: **1604428**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Aroclor 1016	148.865	16	166.7	0	89.3	43	142	146.1	1.89	20	
Aroclor 1260	153.988	16	166.7	0	92.4	34	146	153.9	0.0608	20	
Surr: Decachlorobiphenyl	16.056		16.67		96.3	40	146		0		
Surr: Tetrachloro-m-xylene	11.875		16.67		71.2	32	109		0		

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range	H	Holding times for preparation or analysis exceeded
ND	Not Detected at the Reporting Limit	R	RPD outside accepted recovery limits	S	Spike/Surrogate outside of limits due to matrix interference
DO	Surrogate Diluted Out		Calculations are based on raw values		

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Work Order: N010479
Project: Crissy Field Outfall, E8560-02-51

ANALYTICAL QC SUMMARY REPORT

TestCode: 8260SOIL

Sample ID: **D130702LCS** SampType: **LCS** TestCode: **8260SOIL** Units: **µg/Kg** Prep Date: RunNo: **89437**
Client ID: **LCSS** Batch ID: **D13VS040** TestNo: **EPA 8260B** Analysis Date: **7/2/2013** SeqNo: **1603374**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
1,1,1,2-Tetrachloroethane	39.320	5.0	40.00	0	98.3	80	123				
1,1,1-Trichloroethane	37.920	5.0	40.00	0	94.8	71	127				
1,1,2,2-Tetrachloroethane	38.160	5.0	40.00	0	95.4	80	120				
1,1,2-Trichloroethane	37.740	5.0	40.00	0	94.4	80	120				
1,1-Dichloroethane	37.860	5.0	40.00	0	94.6	80	120				
1,1-Dichloroethene	39.550	5.0	40.00	0	98.9	80	121				
1,1-Dichloropropene	38.100	5.0	40.00	0	95.2	74	131				
1,2,3-Trichlorobenzene	40.130	5.0	40.00	0	100	64	137				
1,2,3-Trichloropropane	38.450	5.0	40.00	0	96.1	75	120				
1,2,4-Trichlorobenzene	41.290	5.0	40.00	0	103	75	128				
1,2,4-Trimethylbenzene	41.190	5.0	40.00	0	103	73	128				
1,2-Dibromo-3-chloropropane	32.720	10	40.00	0	81.8	53	143				
1,2-Dibromoethane	38.240	5.0	40.00	0	95.6	74	124				
1,2-Dichlorobenzene	39.080	5.0	40.00	0	97.7	80	120				
1,2-Dichloroethane	36.150	5.0	40.00	0	90.4	70	139				
1,2-Dichloropropane	40.040	5.0	40.00	0	100	80	120				
1,3,5-Trimethylbenzene	41.600	5.0	40.00	0	104	76	126				
1,3-Dichlorobenzene	40.410	5.0	40.00	0	101	80	120				
1,3-Dichloropropane	38.720	5.0	40.00	0	96.8	80	120				
1,4-Dichlorobenzene	38.850	5.0	40.00	0	97.1	80	120				
2,2-Dichloropropane	41.670	5.0	40.00	0	104	72	135				
2-Chlorotoluene	40.030	5.0	40.00	0	100	79	120				
4-Chlorotoluene	40.140	5.0	40.00	0	100	80	120				
4-Isopropyltoluene	42.730	5.0	40.00	0	107	76	126				
Benzene	39.110	5.0	40.00	0	97.8	80	120				
Bromobenzene	39.510	5.0	40.00	0	98.8	80	120				
Bromodichloromethane	37.540	5.0	40.00	0	93.8	79	131				
Bromoform	37.660	5.0	40.00	0	94.2	80	120				
Bromomethane	37.370	5.0	40.00	0	93.4	43	179				
Carbon tetrachloride	39.170	5.0	40.00	0	97.9	80	125				

Qualifiers:

B Analyte detected in the associated Method Blank
ND Not Detected at the Reporting Limit
DO Surrogate Diluted Out
E Value above quantitation range
R RPD outside accepted recovery limits
Calculations are based on raw values
H Holding times for preparation or analysis exceeded
S Spike/Surrogate outside of limits due to matrix interference

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Work Order: N010479
Project: Crissy Field Outfall, E8560-02-51

ANALYTICAL QC SUMMARY REPORT

TestCode: 8260SOIL

Sample ID: **D130702LCS** SampType: **LCS** TestCode: **8260SOIL** Units: **µg/Kg** Prep Date: RunNo: **89437**
Client ID: **LCSS** Batch ID: **D13VS040** TestNo: **EPA 8260B** Analysis Date: **7/2/2013** SeqNo: **1603374**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Chlorobenzene	38.130	5.0	40.00	0	95.3	80	120				
Chloroethane	40.300	5.0	40.00	0	101	32	181				
Chloroform	37.860	5.0	40.00	0	94.6	77	129				
Chloromethane	36.810	5.0	40.00	0	92.0	80	120				
cis-1,2-Dichloroethene	39.180	5.0	40.00	0	98.0	80	120				
cis-1,3-Dichloropropene	40.320	5.0	40.00	0	101	80	120				
Dibromochloromethane	41.290	5.0	40.00	0	103	80	122				
Dibromomethane	36.690	5.0	40.00	0	91.7	80	120				
Dichlorodifluoromethane	36.940	5.0	40.00	0	92.4	64	135				
Ethylbenzene	38.400	5.0	40.00	0	96.0	80	120				
Hexachlorobutadiene	39.900	5.0	40.00	0	99.8	69	132				
Isopropylbenzene	42.100	5.0	40.00	0	105	79	121				
m,p-Xylene	80.030	10	80.00	0	100	80	121				
Methylene chloride	38.250	5.0	40.00	0	95.6	74	123				
n-Butylbenzene	42.840	5.0	40.00	0	107	72	131				
n-Propylbenzene	41.680	5.0	40.00	0	104	79	122				
Naphthalene	41.970	5.0	40.00	0	105	69	126				
o-Xylene	39.290	5.0	40.00	0	98.2	80	120				
sec-Butylbenzene	41.440	5.0	40.00	0	104	74	127				
Styrene	40.790	5.0	40.00	0	102	80	120				
tert-Butylbenzene	41.920	5.0	40.00	0	105	75	125				
Tetrachloroethene	39.280	5.0	40.00	0	98.2	80	120				
Toluene	37.900	5.0	40.00	0	94.8	80	120				
trans-1,2-Dichloroethene	38.480	5.0	40.00	0	96.2	80	125				
Trichloroethene	38.200	5.0	40.00	0	95.5	80	120				
Trichlorofluoromethane	38.190	5.0	40.00	0	95.5	67	152				
Vinyl chloride	38.060	5.0	40.00	0	95.2	69	135				
Surr: 1,2-Dichloroethane-d4	46.230		50.00		92.5	63	139				
Surr: 4-Bromofluorobenzene	47.510		50.00		95.0	75	124				
Surr: Dibromofluoromethane	48.810		50.00		97.6	70	133				

Qualifiers:

B Analyte detected in the associated Method Blank
ND Not Detected at the Reporting Limit
DO Surrogate Diluted Out
E Value above quantitation range
R RPD outside accepted recovery limits
Calculations are based on raw values
H Holding times for preparation or analysis exceeded
S Spike/Surrogate outside of limits due to matrix interference

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Project: Crissy Field Outfall, E8560-02-51

ANALYTICAL QC SUMMARY REPORT

TestCode: 8260SOIL

Sample ID: **D130702LCS** SampType: **LCS** TestCode: **8260SOIL** Units: **µg/Kg** Prep Date: RunNo: **89437**
Client ID: **LCSS** Batch ID: **D13VS040** TestNo: **EPA 8260B** Analysis Date: **7/2/2013** SeqNo: **1603374**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Surr: Toluene-d8	48.920		50.00		97.8	80	123				

Sample ID: **N010479-008AMS** SampType: **MS** TestCode: **8260SOIL** Units: **µg/Kg** Prep Date: RunNo: **89437**
Client ID: **ZZZZZZ** Batch ID: **D13VS040** TestNo: **EPA 8260B** Analysis Date: **7/2/2013** SeqNo: **1603375**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
1,1,1,2-Tetrachloroethane	39.900	5.0	40.00	0	99.8	58	149				
1,1,1-Trichloroethane	38.020	5.0	40.00	0	95.1	67	126				
1,1,2,2-Tetrachloroethane	38.420	5.0	40.00	0	96.0	18	193				
1,1,2-Trichloroethane	41.200	5.0	40.00	0	103	70	136				
1,1-Dichloroethane	40.060	5.0	40.00	0	100	65	134				
1,1-Dichloroethene	39.200	5.0	40.00	0	98.0	61	135				
1,1-Dichloropropene	37.490	5.0	40.00	0	93.7	68	125				
1,2,3-Trichlorobenzene	35.050	5.0	40.00	0	87.6	40	134				
1,2,3-Trichloropropane	37.490	5.0	40.00	0	93.7	38	167				
1,2,4-Trichlorobenzene	36.300	5.0	40.00	0	90.8	40	132				
1,2,4-Trimethylbenzene	39.250	5.0	40.00	0	98.1	58	123				
1,2-Dibromo-3-chloropropane	33.430	10	40.00	0	83.6	30	181				
1,2-Dibromoethane	39.890	5.0	40.00	0	99.7	67	139				
1,2-Dichlorobenzene	37.920	5.0	40.00	0	94.8	65	122				
1,2-Dichloroethane	37.590	5.0	40.00	0	94.0	63	149				
1,2-Dichloropropane	40.100	5.0	40.00	0	100	69	127				
1,3,5-Trimethylbenzene	39.470	5.0	40.00	0	98.7	58	122				
1,3-Dichlorobenzene	38.340	5.0	40.00	0	95.9	64	120				
1,3-Dichloropropane	39.260	5.0	40.00	0	98.2	64	141				
1,4-Dichlorobenzene	37.240	5.0	40.00	0	93.1	62	122				
2,2-Dichloropropane	42.340	5.0	40.00	0	106	62	138				
2-Chlorotoluene	38.250	5.0	40.00	0	95.6	59	124				
4-Chlorotoluene	38.760	5.0	40.00	0	96.9	60	123				
4-Isopropyltoluene	38.980	5.0	40.00	0	97.5	50	124				

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range	H	Holding times for preparation or analysis exceeded
ND	Not Detected at the Reporting Limit	R	RPD outside accepted recovery limits	S	Spike/Surrogate outside of limits due to matrix interference
DO	Surrogate Diluted Out		Calculations are based on raw values		

Advanced Technology Laboratories, Inc.
3151 W. Post Rd Las Vegas, NV 89118 Tel: 702-307-2659 Fax: 702-307-2691

CLIENT: Geocon Consultants, Inc.
Work Order: N010479
Project: Crissy Field Outfall, E8560-02-51

ANALYTICAL QC SUMMARY REPORT

TestCode: 8260SOIL

Sample ID: **N010479-008AMS** SampType: **MS** TestCode: **8260SOIL** Units: **µg/Kg** Prep Date: RunNo: **89437**
Client ID: **ZZZZZZ** Batch ID: **D13VS040** TestNo: **EPA 8260B** Analysis Date: **7/2/2013** SeqNo: **1603375**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Benzene	39.420	5.0	40.00	0	98.6	72	122				
Bromobenzene	38.970	5.0	40.00	0	97.4	64	129				
Bromodichloromethane	39.710	5.0	40.00	0	99.3	67	142				
Bromoform	38.940	5.0	40.00	0	97.4	35	192				
Bromomethane	37.930	5.0	40.00	0	94.8	62	150				
Carbon tetrachloride	38.960	5.0	40.00	0	97.4	56	142				
Chlorobenzene	37.860	5.0	40.00	0	94.6	71	120				
Chloroethane	39.770	5.0	40.00	0	99.4	55	149				
Chloroform	38.650	5.0	40.00	0	96.6	70	135				
Chloromethane	37.800	5.0	40.00	0	94.5	37	151				
cis-1,2-Dichloroethene	40.820	5.0	40.00	0	102	69	131				
cis-1,3-Dichloropropene	42.260	5.0	40.00	0	106	71	129				
Dibromochloromethane	40.880	5.0	40.00	0	102	53	161				
Dibromomethane	37.760	5.0	40.00	0	94.4	66	145				
Dichlorodifluoromethane	37.300	5.0	40.00	0	93.3	52	135				
Ethylbenzene	37.510	5.0	40.00	0	93.8	65	120				
Hexachlorobutadiene	31.510	5.0	40.00	0	78.8	22	135				
Isopropylbenzene	39.890	5.0	40.00	0	99.7	60	121				
m,p-Xylene	77.480	10	80.00	0	96.9	65	120				
Methylene chloride	39.820	5.0	40.00	1.760	95.2	55	138				
n-Butylbenzene	39.000	5.0	40.00	0	97.5	43	126				
n-Propylbenzene	39.170	5.0	40.00	0	97.9	56	122				
Naphthalene	37.310	5.0	40.00	0	93.3	48	139				
o-Xylene	39.570	5.0	40.00	0	98.9	67	118				
sec-Butylbenzene	38.450	5.0	40.00	0	96.1	50	123				
Styrene	40.520	5.0	40.00	0	101	57	129				
tert-Butylbenzene	39.690	5.0	40.00	0	99.2	54	121				
Tetrachloroethene	38.370	5.0	40.00	0	95.9	35	149				
Toluene	38.180	5.0	40.00	0	95.4	68	120				
trans-1,2-Dichloroethene	39.690	5.0	40.00	0	99.2	62	139				

Qualifiers:

B Analyte detected in the associated Method Blank
ND Not Detected at the Reporting Limit
DO Surrogate Diluted Out
E Value above quantitation range
R RPD outside accepted recovery limits
Calculations are based on raw values
H Holding times for preparation or analysis exceeded
S Spike/Surrogate outside of limits due to matrix interference

Advanced Technology Laboratories, Inc.
3151 W. Post Rd Las Vegas, NV 89118 Tel: 702-307-2659 Fax: 702-307-2691

CLIENT: Geocon Consultants, Inc.
Work Order: N010479
Project: Crissy Field Outfall, E8560-02-51

ANALYTICAL QC SUMMARY REPORT

TestCode: 8260SOIL

Sample ID: **N010479-008AMS** SampType: **MS** TestCode: **8260SOIL** Units: **µg/Kg** Prep Date: RunNo: **89437**
Client ID: **ZZZZZZ** Batch ID: **D13VS040** TestNo: **EPA 8260B** Analysis Date: **7/2/2013** SeqNo: **1603375**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Trichloroethene	37.790	5.0	40.00	0	94.5	63	134				
Trichlorofluoromethane	37.860	5.0	40.00	0	94.6	34	179				
Vinyl chloride	38.600	5.0	40.00	0	96.5	57	136				
Surr: 1,2-Dichloroethane-d4	50.430		50.00		101	63	139				
Surr: 4-Bromofluorobenzene	49.180		50.00		98.4	75	124				
Surr: Dibromofluoromethane	53.390		50.00		107	70	133				
Surr: Toluene-d8	49.370		50.00		98.7	80	123				

Sample ID: **N010479-008AMSD** SampType: **MSD** TestCode: **8260SOIL** Units: **µg/Kg** Prep Date: RunNo: **89437**
Client ID: **ZZZZZZ** Batch ID: **D13VS040** TestNo: **EPA 8260B** Analysis Date: **7/2/2013** SeqNo: **1603376**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
1,1,1,2-Tetrachloroethane	39.940	5.0	40.00	0	99.8	58	149	39.90	0.100	20	
1,1,1-Trichloroethane	37.870	5.0	40.00	0	94.7	67	126	38.02	0.395	20	
1,1,2,2-Tetrachloroethane	38.750	5.0	40.00	0	96.9	18	193	38.42	0.855	20	
1,1,2-Trichloroethane	41.510	5.0	40.00	0	104	70	136	41.20	0.750	20	
1,1-Dichloroethane	40.360	5.0	40.00	0	101	65	134	40.06	0.746	20	
1,1-Dichloroethene	39.600	5.0	40.00	0	99.0	61	135	39.20	1.02	20	
1,1-Dichloropropene	38.300	5.0	40.00	0	95.8	68	125	37.49	2.14	20	
1,2,3-Trichlorobenzene	35.600	5.0	40.00	0	89.0	40	134	35.05	1.56	20	
1,2,3-Trichloropropane	36.960	5.0	40.00	0	92.4	38	167	37.49	1.42	20	
1,2,4-Trichlorobenzene	37.200	5.0	40.00	0	93.0	40	132	36.30	2.45	20	
1,2,4-Trimethylbenzene	39.830	5.0	40.00	0	99.6	58	123	39.25	1.47	20	
1,2-Dibromo-3-chloropropane	35.050	10	40.00	0	87.6	30	181	33.43	4.73	20	
1,2-Dibromoethane	41.290	5.0	40.00	0	103	67	139	39.89	3.45	20	
1,2-Dichlorobenzene	38.280	5.0	40.00	0	95.7	65	122	37.92	0.945	20	
1,2-Dichloroethane	38.980	5.0	40.00	0	97.5	63	149	37.59	3.63	20	
1,2-Dichloropropane	42.060	5.0	40.00	0	105	69	127	40.10	4.77	20	
1,3,5-Trimethylbenzene	38.910	5.0	40.00	0	97.3	58	122	39.47	1.43	20	
1,3-Dichlorobenzene	38.270	5.0	40.00	0	95.7	64	120	38.34	0.183	20	

Qualifiers:

B Analyte detected in the associated Method Blank
ND Not Detected at the Reporting Limit
DO Surrogate Diluted Out
E Value above quantitation range
R RPD outside accepted recovery limits
Calculations are based on raw values
H Holding times for preparation or analysis exceeded
S Spike/Surrogate outside of limits due to matrix interference

Advanced Technology Laboratories, Inc.
3151 W. Post Rd Las Vegas, NV 89118 Tel: 702-307-2659 Fax: 702-307-2691

CLIENT: Geocon Consultants, Inc.
Work Order: N010479
Project: Crissy Field Outfall, E8560-02-51

ANALYTICAL QC SUMMARY REPORT

TestCode: 8260SOIL

Sample ID: **N010479-008AMSD** SampType: **MSD** TestCode: **8260SOIL** Units: **µg/Kg** Prep Date: RunNo: **89437**
Client ID: **ZZZZZZ** Batch ID: **D13VS040** TestNo: **EPA 8260B** Analysis Date: **7/2/2013** SeqNo: **1603376**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
1,3-Dichloropropane	40.200	5.0	40.00	0	101	64	141	39.26	2.37	20	
1,4-Dichlorobenzene	37.400	5.0	40.00	0	93.5	62	122	37.24	0.429	20	
2,2-Dichloropropane	42.070	5.0	40.00	0	105	62	138	42.34	0.640	20	
2-Chlorotoluene	38.500	5.0	40.00	0	96.2	59	124	38.25	0.651	20	
4-Chlorotoluene	38.540	5.0	40.00	0	96.4	60	123	38.76	0.569	20	
4-Isopropyltoluene	39.030	5.0	40.00	0	97.6	50	124	38.98	0.128	20	
Benzene	41.030	5.0	40.00	0	103	72	122	39.42	4.00	20	
Bromobenzene	39.550	5.0	40.00	0	98.9	64	129	38.97	1.48	20	
Bromodichloromethane	40.250	5.0	40.00	0	101	67	142	39.71	1.35	20	
Bromoform	39.140	5.0	40.00	0	97.9	35	192	38.94	0.512	20	
Bromomethane	40.060	5.0	40.00	0	100	62	150	37.93	5.46	20	
Carbon tetrachloride	38.710	5.0	40.00	0	96.8	56	142	38.96	0.644	20	
Chlorobenzene	38.500	5.0	40.00	0	96.2	71	120	37.86	1.68	20	
Chloroethane	40.630	5.0	40.00	0	102	55	149	39.77	2.14	20	
Chloroform	39.650	5.0	40.00	0	99.1	70	135	38.65	2.55	20	
Chloromethane	38.030	5.0	40.00	0	95.1	37	151	37.80	0.607	20	
cis-1,2-Dichloroethene	41.070	5.0	40.00	0	103	69	131	40.82	0.611	20	
cis-1,3-Dichloropropene	42.850	5.0	40.00	0	107	71	129	42.26	1.39	20	
Dibromochloromethane	42.070	5.0	40.00	0	105	53	161	40.88	2.87	20	
Dibromomethane	40.700	5.0	40.00	0	102	66	145	37.76	7.49	20	
Dichlorodifluoromethane	36.830	5.0	40.00	0	92.1	52	135	37.30	1.27	20	
Ethylbenzene	37.780	5.0	40.00	0	94.4	65	120	37.51	0.717	20	
Hexachlorobutadiene	32.490	5.0	40.00	0	81.2	22	135	31.51	3.06	20	
Isopropylbenzene	39.570	5.0	40.00	0	98.9	60	121	39.89	0.805	20	
m,p-Xylene	78.900	10	80.00	0	98.6	65	120	77.48	1.82	20	
Methylene chloride	41.540	5.0	40.00	1.760	99.4	55	138	39.82	4.23	20	
n-Butylbenzene	38.470	5.0	40.00	0	96.2	43	126	39.00	1.37	20	
n-Propylbenzene	38.700	5.0	40.00	0	96.8	56	122	39.17	1.21	20	
Naphthalene	36.760	5.0	40.00	0	91.9	48	139	37.31	1.49	20	
o-Xylene	40.390	5.0	40.00	0	101	67	118	39.57	2.05	20	

Qualifiers:

B Analyte detected in the associated Method Blank
ND Not Detected at the Reporting Limit
DO Surrogate Diluted Out
E Value above quantitation range
R RPD outside accepted recovery limits
Calculations are based on raw values
H Holding times for preparation or analysis exceeded
S Spike/Surrogate outside of limits due to matrix interference

Advanced Technology Laboratories, Inc.
3151 W. Post Rd Las Vegas, NV 89118 Tel: 702-307-2659 Fax: 702-307-2691

CLIENT: Geocon Consultants, Inc.
Work Order: N010479
Project: Crissy Field Outfall, E8560-02-51

ANALYTICAL QC SUMMARY REPORT

TestCode: 8260SOIL

Sample ID: **N010479-008AMSD** SampType: **MSD** TestCode: **8260SOIL** Units: **µg/Kg** Prep Date: RunNo: **89437**
Client ID: **ZZZZZZ** Batch ID: **D13VS040** TestNo: **EPA 8260B** Analysis Date: **7/2/2013** SeqNo: **1603376**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
sec-Butylbenzene	38.610	5.0	40.00	0	96.5	50	123	38.45	0.415	20	
Styrene	40.750	5.0	40.00	0	102	57	129	40.52	0.566	20	
tert-Butylbenzene	39.790	5.0	40.00	0	99.5	54	121	39.69	0.252	20	
Tetrachloroethene	38.330	5.0	40.00	0	95.8	35	149	38.37	0.104	20	
Toluene	39.260	5.0	40.00	0	98.2	68	120	38.18	2.79	20	
trans-1,2-Dichloroethene	39.940	5.0	40.00	0	99.8	62	139	39.69	0.628	20	
Trichloroethene	39.040	5.0	40.00	0	97.6	63	134	37.79	3.25	20	
Trichlorofluoromethane	37.980	5.0	40.00	0	95.0	34	179	37.86	0.316	20	
Vinyl chloride	38.960	5.0	40.00	0	97.4	57	136	38.60	0.928	20	
Surr: 1,2-Dichloroethane-d4	49.020		50.00		98.0	63	139		0		
Surr: 4-Bromofluorobenzene	48.930		50.00		97.9	75	124		0		
Surr: Dibromofluoromethane	51.640		50.00		103	70	133		0		
Surr: Toluene-d8	49.710		50.00		99.4	80	123		0		

Sample ID: **N010479-017AMS** SampType: **MS** TestCode: **8260SOIL** Units: **µg/Kg** Prep Date: RunNo: **89437**
Client ID: **ZZZZZZ** Batch ID: **D13VS040** TestNo: **EPA 8260B** Analysis Date: **7/2/2013** SeqNo: **1603377**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
1,1,1,2-Tetrachloroethane	39.060	5.0	40.00	0	97.6	58	149				
1,1,1-Trichloroethane	38.310	5.0	40.00	0	95.8	67	126				
1,1,2,2-Tetrachloroethane	33.520	5.0	40.00	0	83.8	18	193				
1,1,2-Trichloroethane	38.340	5.0	40.00	0	95.9	70	136				
1,1-Dichloroethane	39.910	5.0	40.00	0	99.8	65	134				
1,1-Dichloroethene	39.630	5.0	40.00	0	99.1	61	135				
1,1-Dichloropropene	37.910	5.0	40.00	0	94.8	68	125				
1,2,3-Trichlorobenzene	38.390	5.0	40.00	0	96.0	40	134				
1,2,3-Trichloropropane	36.400	5.0	40.00	0	91.0	38	167				
1,2,4-Trichlorobenzene	39.870	5.0	40.00	0	99.7	40	132				
1,2,4-Trimethylbenzene	41.140	5.0	40.00	0	103	58	123				
1,2-Dibromo-3-chloropropane	32.440	10	40.00	0	81.1	30	181				

Qualifiers:

B Analyte detected in the associated Method Blank
ND Not Detected at the Reporting Limit
DO Surrogate Diluted Out
E Value above quantitation range
R RPD outside accepted recovery limits
Calculations are based on raw values
H Holding times for preparation or analysis exceeded
S Spike/Surrogate outside of limits due to matrix interference

Advanced Technology Laboratories, Inc.
3151 W. Post Rd Las Vegas, NV 89118 Tel: 702-307-2659 Fax: 702-307-2691

CLIENT: Geocon Consultants, Inc.
Work Order: N010479
Project: Crissy Field Outfall, E8560-02-51

ANALYTICAL QC SUMMARY REPORT

TestCode: 8260SOIL

Sample ID: **N010479-017AMS** SampType: **MS** TestCode: **8260SOIL** Units: **µg/Kg** Prep Date: RunNo: **89437**
Client ID: **ZZZZZZ** Batch ID: **D13VS040** TestNo: **EPA 8260B** Analysis Date: **7/2/2013** SeqNo: **1603377**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
1,2-Dibromoethane	38.710	5.0	40.00	0	96.8	67	139				
1,2-Dichlorobenzene	39.540	5.0	40.00	0	98.8	65	122				
1,2-Dichloroethane	37.240	5.0	40.00	0	93.1	63	149				
1,2-Dichloropropane	41.560	5.0	40.00	0	104	69	127				
1,3,5-Trimethylbenzene	40.530	5.0	40.00	0	101	58	122				
1,3-Dichlorobenzene	40.050	5.0	40.00	0	100	64	120				
1,3-Dichloropropane	39.480	5.0	40.00	0	98.7	64	141				
1,4-Dichlorobenzene	38.690	5.0	40.00	0	96.7	62	122				
2,2-Dichloropropane	41.920	5.0	40.00	0	105	62	138				
2-Chlorotoluene	39.420	5.0	40.00	0	98.6	59	124				
4-Chlorotoluene	39.840	5.0	40.00	0	99.6	60	123				
4-Isopropyltoluene	40.590	5.0	40.00	0	101	50	124				
Benzene	40.340	5.0	40.00	0	101	72	122				
Bromobenzene	40.300	5.0	40.00	0	101	64	129				
Bromodichloromethane	39.080	5.0	40.00	0	97.7	67	142				
Bromoform	37.000	5.0	40.00	0	92.5	35	192				
Bromomethane	38.200	5.0	40.00	0	95.5	62	150				
Carbon tetrachloride	38.300	5.0	40.00	0	95.8	56	142				
Chlorobenzene	38.700	5.0	40.00	0	96.8	71	120				
Chloroethane	41.400	5.0	40.00	0	104	55	149				
Chloroform	38.700	5.0	40.00	0	96.8	70	135				
Chloromethane	37.370	5.0	40.00	0	93.4	37	151				
cis-1,2-Dichloroethene	40.720	5.0	40.00	0	102	69	131				
cis-1,3-Dichloropropene	42.060	5.0	40.00	0	105	71	129				
Dibromochloromethane	40.320	5.0	40.00	0	101	53	161				
Dibromomethane	39.030	5.0	40.00	0	97.6	66	145				
Dichlorodifluoromethane	36.370	5.0	40.00	0	90.9	52	135				
Ethylbenzene	38.660	5.0	40.00	0	96.7	65	120				
Hexachlorobutadiene	36.550	5.0	40.00	0	91.4	22	135				
Isopropylbenzene	41.610	5.0	40.00	0	104	60	121				

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range	H	Holding times for preparation or analysis exceeded
ND	Not Detected at the Reporting Limit	R	RPD outside accepted recovery limits	S	Spike/Surrogate outside of limits due to matrix interference
DO	Surrogate Diluted Out		Calculations are based on raw values		

Advanced Technology Laboratories, Inc.
3151 W. Post Rd Las Vegas, NV 89118 Tel: 702-307-2659 Fax: 702-307-2691

CLIENT: Geocon Consultants, Inc.
Work Order: N010479
Project: Crissy Field Outfall, E8560-02-51

ANALYTICAL QC SUMMARY REPORT

TestCode: 8260SOIL

Sample ID: **N010479-017AMS** SampType: **MS** TestCode: **8260SOIL** Units: **µg/Kg** Prep Date: RunNo: **89437**
Client ID: **ZZZZZZ** Batch ID: **D13VS040** TestNo: **EPA 8260B** Analysis Date: **7/2/2013** SeqNo: **1603377**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
m,p-Xylene	79.990	10	80.00	0	100	65	120				
Methylene chloride	38.000	5.0	40.00	0	95.0	55	138				
n-Butylbenzene	40.620	5.0	40.00	0	102	43	126				
n-Propylbenzene	40.840	5.0	40.00	0	102	56	122				
Naphthalene	36.840	5.0	40.00	0	92.1	48	139				
o-Xylene	39.940	5.0	40.00	0	99.8	67	118				
sec-Butylbenzene	39.910	5.0	40.00	0	99.8	50	123				
Styrene	40.830	5.0	40.00	0	102	57	129				
tert-Butylbenzene	40.670	5.0	40.00	0	102	54	121				
Tetrachloroethene	39.260	5.0	40.00	0	98.2	35	149				
Toluene	38.790	5.0	40.00	0	97.0	68	120				
trans-1,2-Dichloroethene	39.600	5.0	40.00	0	99.0	62	139				
Trichloroethene	42.570	5.0	40.00	0	106	63	134				
Trichlorofluoromethane	39.070	5.0	40.00	0	97.7	34	179				
Vinyl chloride	38.670	5.0	40.00	0	96.7	57	136				
Surr: 1,2-Dichloroethane-d4	48.610		50.00		97.2	63	139				
Surr: 4-Bromofluorobenzene	49.340		50.00		98.7	75	124				
Surr: Dibromofluoromethane	50.430		50.00		101	70	133				
Surr: Toluene-d8	50.760		50.00		102	80	123				

Sample ID: **D130702MB3** SampType: **MBLK** TestCode: **8260SOIL** Units: **µg/Kg** Prep Date: RunNo: **89437**
Client ID: **PBS** Batch ID: **D13VS040** TestNo: **EPA 8260B** Analysis Date: **7/2/2013** SeqNo: **1603378**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
1,1,1,2-Tetrachloroethane	ND	5.0									
1,1,1-Trichloroethane	ND	5.0									
1,1,2,2-Tetrachloroethane	ND	5.0									
1,1,2-Trichloroethane	ND	5.0									
1,1-Dichloroethane	ND	5.0									
1,1-Dichloroethene	ND	5.0									

Qualifiers:

B Analyte detected in the associated Method Blank
ND Not Detected at the Reporting Limit
DO Surrogate Diluted Out
E Value above quantitation range
R RPD outside accepted recovery limits
Calculations are based on raw values
H Holding times for preparation or analysis exceeded
S Spike/Surrogate outside of limits due to matrix interference

Advanced Technology Laboratories, Inc.
3151 W. Post Rd Las Vegas, NV 89118 Tel: 702-307-2659 Fax: 702-307-2691

CLIENT: Geocon Consultants, Inc.
Work Order: N010479
Project: Crissy Field Outfall, E8560-02-51

ANALYTICAL QC SUMMARY REPORT

TestCode: 8260SOIL

Sample ID: **D130702MB3** SampType: **MBLK** TestCode: **8260SOIL** Units: **µg/Kg** Prep Date: RunNo: **89437**
Client ID: **PBS** Batch ID: **D13VS040** TestNo: **EPA 8260B** Analysis Date: **7/2/2013** SeqNo: **1603378**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
1,1-Dichloropropene	ND	5.0									
1,2,3-Trichlorobenzene	ND	5.0									
1,2,3-Trichloropropane	ND	5.0									
1,2,4-Trichlorobenzene	ND	5.0									
1,2,4-Trimethylbenzene	ND	5.0									
1,2-Dibromo-3-chloropropane	ND	10									
1,2-Dibromoethane	ND	5.0									
1,2-Dichlorobenzene	ND	5.0									
1,2-Dichloroethane	ND	5.0									
1,2-Dichloropropane	ND	5.0									
1,3,5-Trimethylbenzene	ND	5.0									
1,3-Dichlorobenzene	ND	5.0									
1,3-Dichloropropane	ND	5.0									
1,4-Dichlorobenzene	ND	5.0									
2,2-Dichloropropane	ND	5.0									
2-Chlorotoluene	ND	5.0									
4-Chlorotoluene	ND	5.0									
4-Isopropyltoluene	ND	5.0									
Benzene	ND	5.0									
Bromobenzene	ND	5.0									
Bromodichloromethane	ND	5.0									
Bromoform	ND	5.0									
Bromomethane	ND	5.0									
Carbon tetrachloride	ND	5.0									
Chlorobenzene	ND	5.0									
Chloroethane	ND	5.0									
Chloroform	ND	5.0									
Chloromethane	ND	5.0									
cis-1,2-Dichloroethene	ND	5.0									
cis-1,3-Dichloropropene	ND	5.0									

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range	H	Holding times for preparation or analysis exceeded
ND	Not Detected at the Reporting Limit	R	RPD outside accepted recovery limits	S	Spike/Surrogate outside of limits due to matrix interference
DO	Surrogate Diluted Out		Calculations are based on raw values		

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CLIENT: Geocon Consultants, Inc.
Work Order: N010479
Project: Crissy Field Outfall, E8560-02-51

ANALYTICAL QC SUMMARY REPORT

TestCode: 8260SOIL

Sample ID: **D130702MB3** SampType: **MBLK** TestCode: **8260SOIL** Units: **µg/Kg** Prep Date: RunNo: **89437**
Client ID: **PBS** Batch ID: **D13VS040** TestNo: **EPA 8260B** Analysis Date: **7/2/2013** SeqNo: **1603378**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Dibromochloromethane	ND	5.0									
Dibromomethane	ND	5.0									
Dichlorodifluoromethane	ND	5.0									
Ethylbenzene	ND	5.0									
Hexachlorobutadiene	ND	5.0									
Isopropylbenzene	ND	5.0									
m,p-Xylene	ND	10									
Methylene chloride	ND	5.0									
n-Butylbenzene	ND	5.0									
n-Propylbenzene	ND	5.0									
Naphthalene	ND	5.0									
o-Xylene	ND	5.0									
sec-Butylbenzene	ND	5.0									
Styrene	ND	5.0									
tert-Butylbenzene	ND	5.0									
Tetrachloroethene	ND	5.0									
Toluene	ND	5.0									
trans-1,2-Dichloroethene	ND	5.0									
Trichloroethene	ND	5.0									
Trichlorofluoromethane	ND	5.0									
Vinyl chloride	ND	5.0									
Surr: 1,2-Dichloroethane-d4	44.710		50.00		89.4	63	139				
Surr: 4-Bromofluorobenzene	46.340		50.00		92.7	75	124				
Surr: Dibromofluoromethane	46.470		50.00		92.9	70	133				
Surr: Toluene-d8	50.050		50.00		100	80	123				

Sample ID: **N010479-002ADUP** SampType: **DUP** TestCode: **8260SOIL** Units: **µg/Kg** Prep Date: RunNo: **89437**
Client ID: **ZZZZZZ** Batch ID: **D13VS040** TestNo: **EPA 8260B** Analysis Date: **7/2/2013** SeqNo: **1603386**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range	H	Holding times for preparation or analysis exceeded
ND	Not Detected at the Reporting Limit	R	RPD outside accepted recovery limits	S	Spike/Surrogate outside of limits due to matrix interference
DO	Surrogate Diluted Out		Calculations are based on raw values		

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CLIENT: Geocon Consultants, Inc.
Work Order: N010479
Project: Crissy Field Outfall, E8560-02-51

ANALYTICAL QC SUMMARY REPORT

TestCode: 8260SOIL

Sample ID: **N010479-002ADUP** SampType: **DUP** TestCode: **8260SOIL** Units: **µg/Kg** Prep Date: RunNo: **89437**
Client ID: **ZZZZZZ** Batch ID: **D13VS040** TestNo: **EPA 8260B** Analysis Date: **7/2/2013** SeqNo: **1603386**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
1,1,1,2-Tetrachloroethane	ND	5.0						0	0	20	
1,1,1-Trichloroethane	ND	5.0						0	0	20	
1,1,2,2-Tetrachloroethane	ND	5.0						0	0	20	
1,1,2-Trichloroethane	ND	5.0						0	0	20	
1,1-Dichloroethane	ND	5.0						0	0	20	
1,1-Dichloroethene	ND	5.0						0	0	20	
1,1-Dichloropropene	ND	5.0						0	0	20	
1,2,3-Trichlorobenzene	ND	5.0						0	0	20	
1,2,3-Trichloropropane	ND	5.0						0	0	20	
1,2,4-Trichlorobenzene	ND	5.0						0	0	20	
1,2,4-Trimethylbenzene	ND	5.0						0	0	20	
1,2-Dibromo-3-chloropropane	ND	10						0	0	20	
1,2-Dibromoethane	ND	5.0						0	0	20	
1,2-Dichlorobenzene	ND	5.0						0	0	20	
1,2-Dichloroethane	ND	5.0						0	0	20	
1,2-Dichloropropane	ND	5.0						0	0	20	
1,3,5-Trimethylbenzene	ND	5.0						0	0	20	
1,3-Dichlorobenzene	ND	5.0						0	0	20	
1,3-Dichloropropane	ND	5.0						0	0	20	
1,4-Dichlorobenzene	ND	5.0						0	0	20	
2,2-Dichloropropane	ND	5.0						0	0	20	
2-Chlorotoluene	ND	5.0						0	0	20	
4-Chlorotoluene	ND	5.0						0	0	20	
4-Isopropyltoluene	ND	5.0						0	0	20	
Benzene	ND	5.0						0	0	20	
Bromobenzene	ND	5.0						0	0	20	
Bromodichloromethane	ND	5.0						0	0	20	
Bromoform	ND	5.0						0	0	20	
Bromomethane	ND	5.0						0	0	20	
Carbon tetrachloride	ND	5.0						0	0	20	

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range	H	Holding times for preparation or analysis exceeded
ND	Not Detected at the Reporting Limit	R	RPD outside accepted recovery limits	S	Spike/Surrogate outside of limits due to matrix interference
DO	Surrogate Diluted Out		Calculations are based on raw values		

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CLIENT: Geocon Consultants, Inc.
Work Order: N010479
Project: Crissy Field Outfall, E8560-02-51

ANALYTICAL QC SUMMARY REPORT

TestCode: 8260SOIL

Sample ID: **N010479-002ADUP** SampType: **DUP** TestCode: **8260SOIL** Units: **µg/Kg** Prep Date: RunNo: **89437**
Client ID: **ZZZZZZ** Batch ID: **D13VS040** TestNo: **EPA 8260B** Analysis Date: **7/2/2013** SeqNo: **1603386**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Chlorobenzene	ND	5.0						0	0	20	
Chloroethane	ND	5.0						0	0	20	
Chloroform	ND	5.0						0	0	20	
Chloromethane	ND	5.0						0	0	20	
cis-1,2-Dichloroethene	ND	5.0						0	0	20	
cis-1,3-Dichloropropene	ND	5.0						0	0	20	
Dibromochloromethane	ND	5.0						0	0	20	
Dibromomethane	ND	5.0						0	0	20	
Dichlorodifluoromethane	ND	5.0						0	0	20	
Ethylbenzene	ND	5.0						0	0	20	
Hexachlorobutadiene	ND	5.0						0	0	20	
Isopropylbenzene	ND	5.0						0	0	20	
m,p-Xylene	ND	10						0	0	20	
Methylene chloride	ND	5.0						0	0	20	
n-Butylbenzene	ND	5.0						0	0	20	
n-Propylbenzene	ND	5.0						0	0	20	
Naphthalene	ND	5.0						0	0	20	
o-Xylene	ND	5.0						0	0	20	
sec-Butylbenzene	ND	5.0						0	0	20	
Styrene	ND	5.0						0	0	20	
tert-Butylbenzene	ND	5.0						0	0	20	
Tetrachloroethene	ND	5.0						0	0	20	
Toluene	ND	5.0						0	0	20	
trans-1,2-Dichloroethene	ND	5.0						0	0	20	
Trichloroethene	ND	5.0						0	0	20	
Trichlorofluoromethane	ND	5.0						0	0	20	
Vinyl chloride	ND	5.0						0	0	20	
Surr: 1,2-Dichloroethane-d4	55.170		50.00		110	63	139		0		
Surr: 4-Bromofluorobenzene	46.670		50.00		93.3	75	124		0		
Surr: Dibromofluoromethane	52.460		50.00		105	70	133		0		

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range	H	Holding times for preparation or analysis exceeded
ND	Not Detected at the Reporting Limit	R	RPD outside accepted recovery limits	S	Spike/Surrogate outside of limits due to matrix interference
DO	Surrogate Diluted Out		Calculations are based on raw values		

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CLIENT: Geocon Consultants, Inc.
Work Order: N010479
Project: Crissy Field Outfall, E8560-02-51

ANALYTICAL QC SUMMARY REPORT

TestCode: 8260SOIL

Sample ID: **N010479-002ADUP** SampType: **DUP** TestCode: **8260SOIL** Units: **µg/Kg** Prep Date: RunNo: **89437**
Client ID: **ZZZZZZ** Batch ID: **D13VS040** TestNo: **EPA 8260B** Analysis Date: **7/2/2013** SeqNo: **1603386**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Surr: Toluene-d8	48.930		50.00		97.9	80	123		0		

Sample ID: **N010479-004ADUP** SampType: **DUP** TestCode: **8260SOIL** Units: **µg/Kg** Prep Date: RunNo: **89437**
Client ID: **ZZZZZZ** Batch ID: **D13VS040** TestNo: **EPA 8260B** Analysis Date: **7/2/2013** SeqNo: **1603387**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
1,1,1,2-Tetrachloroethane	ND	5.0						0	0	20	
1,1,1-Trichloroethane	ND	5.0						0	0	20	
1,1,2,2-Tetrachloroethane	ND	5.0						0	0	20	
1,1,2-Trichloroethane	ND	5.0						0	0	20	
1,1-Dichloroethane	ND	5.0						0	0	20	
1,1-Dichloroethene	ND	5.0						0	0	20	
1,1-Dichloropropene	ND	5.0						0	0	20	
1,2,3-Trichlorobenzene	ND	5.0						0	0	20	
1,2,3-Trichloropropane	ND	5.0						0	0	20	
1,2,4-Trichlorobenzene	ND	5.0						0	0	20	
1,2,4-Trimethylbenzene	ND	5.0						0	0	20	
1,2-Dibromo-3-chloropropane	ND	10						0	0	20	
1,2-Dibromoethane	ND	5.0						0	0	20	
1,2-Dichlorobenzene	ND	5.0						0	0	20	
1,2-Dichloroethane	ND	5.0						0	0	20	
1,2-Dichloropropane	ND	5.0						0	0	20	
1,3,5-Trimethylbenzene	ND	5.0						0	0	20	
1,3-Dichlorobenzene	ND	5.0						0	0	20	
1,3-Dichloropropane	ND	5.0						0	0	20	
1,4-Dichlorobenzene	ND	5.0						0	0	20	
2,2-Dichloropropane	ND	5.0						0	0	20	
2-Chlorotoluene	ND	5.0						0	0	20	
4-Chlorotoluene	ND	5.0						0	0	20	
4-Isopropyltoluene	ND	5.0						0	0	20	

Qualifiers:

B Analyte detected in the associated Method Blank
ND Not Detected at the Reporting Limit
DO Surrogate Diluted Out
E Value above quantitation range
R RPD outside accepted recovery limits
Calculations are based on raw values
H Holding times for preparation or analysis exceeded
S Spike/Surrogate outside of limits due to matrix interference

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CLIENT: Geocon Consultants, Inc.
Work Order: N010479
Project: Crissy Field Outfall, E8560-02-51

ANALYTICAL QC SUMMARY REPORT

TestCode: 8260SOIL

Sample ID: **N010479-004ADUP** SampType: **DUP** TestCode: **8260SOIL** Units: **µg/Kg** Prep Date: RunNo: **89437**
Client ID: **ZZZZZZ** Batch ID: **D13VS040** TestNo: **EPA 8260B** Analysis Date: **7/2/2013** SeqNo: **1603387**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Benzene	ND	5.0						0	0	20	
Bromobenzene	ND	5.0						0	0	20	
Bromodichloromethane	ND	5.0						0	0	20	
Bromoform	ND	5.0						0	0	20	
Bromomethane	ND	5.0						0	0	20	
Carbon tetrachloride	ND	5.0						0	0	20	
Chlorobenzene	ND	5.0						0	0	20	
Chloroethane	ND	5.0						0	0	20	
Chloroform	ND	5.0						0	0	20	
Chloromethane	ND	5.0						0	0	20	
cis-1,2-Dichloroethene	ND	5.0						0	0	20	
cis-1,3-Dichloropropene	ND	5.0						0	0	20	
Dibromochloromethane	ND	5.0						0	0	20	
Dibromomethane	ND	5.0						0	0	20	
Dichlorodifluoromethane	ND	5.0						0	0	20	
Ethylbenzene	ND	5.0						0	0	20	
Hexachlorobutadiene	ND	5.0						0	0	20	
Isopropylbenzene	ND	5.0						0	0	20	
m,p-Xylene	ND	10						0	0	20	
Methylene chloride	ND	5.0						1.420	0	20	
n-Butylbenzene	ND	5.0						0	0	20	
n-Propylbenzene	ND	5.0						0	0	20	
Naphthalene	ND	5.0						0	0	20	
o-Xylene	ND	5.0						0	0	20	
sec-Butylbenzene	ND	5.0						0	0	20	
Styrene	ND	5.0						0	0	20	
tert-Butylbenzene	ND	5.0						0	0	20	
Tetrachloroethene	ND	5.0						0	0	20	
Toluene	ND	5.0						0	0	20	
trans-1,2-Dichloroethene	ND	5.0						0	0	20	

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range	H	Holding times for preparation or analysis exceeded
ND	Not Detected at the Reporting Limit	R	RPD outside accepted recovery limits	S	Spike/Surrogate outside of limits due to matrix interference
DO	Surrogate Diluted Out		Calculations are based on raw values		

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CLIENT: Geocon Consultants, Inc.
Work Order: N010479
Project: Crissy Field Outfall, E8560-02-51

ANALYTICAL QC SUMMARY REPORT

TestCode: 8260SOIL

Sample ID: **N010479-004ADUP** SampType: **DUP** TestCode: **8260SOIL** Units: **µg/Kg** Prep Date: RunNo: **89437**
Client ID: **ZZZZZZ** Batch ID: **D13VS040** TestNo: **EPA 8260B** Analysis Date: **7/2/2013** SeqNo: **1603387**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Trichloroethene	ND	5.0						0	0	20	
Trichlorofluoromethane	ND	5.0						0	0	20	
Vinyl chloride	ND	5.0						0	0	20	
Surr: 1,2-Dichloroethane-d4	49.980		50.00		100	63	139		0		
Surr: 4-Bromofluorobenzene	44.200		50.00		88.4	75	124		0		
Surr: Dibromofluoromethane	49.550		50.00		99.1	70	133		0		
Surr: Toluene-d8	47.950		50.00		95.9	80	123		0		

Qualifiers:

B Analyte detected in the associated Method Blank
ND Not Detected at the Reporting Limit
DO Surrogate Diluted Out
E Value above quantitation range
R RPD outside accepted recovery limits
Calculations are based on raw values
H Holding times for preparation or analysis exceeded
S Spike/Surrogate outside of limits due to matrix interference

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CLIENT: Geocon Consultants, Inc.
Work Order: N010479
Project: Crissy Field Outfall, E8560-02-51

ANALYTICAL QC SUMMARY REPORT

TestCode: 8260WATERP

Sample ID: **P130705LCS** SampType: **LCS** TestCode: **8260WATERP** Units: **µg/L** Prep Date: RunNo: **89470**
Client ID: **LCSW** Batch ID: **P13VW105** TestNo: **EPA 8260B** Analysis Date: **7/5/2013** SeqNo: **1604695**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
1,1,1,2-Tetrachloroethane	20.340	0.50	20.00	0	102	77	127				
1,1,1-Trichloroethane	19.430	0.50	20.00	0	97.2	74	122				
1,1,2,2-Tetrachloroethane	20.570	0.50	20.00	0	103	70	128				
1,1,2-Trichloroethane	19.560	0.50	20.00	0	97.8	73	120				
1,1-Dichloroethane	19.740	0.50	20.00	0	98.7	72	120				
1,1-Dichloroethene	19.840	0.50	20.00	0	99.2	69	125				
1,1-Dichloropropene	19.440	0.50	20.00	0	97.2	80	120				
1,2,3-Trichlorobenzene	20.400	0.50	20.00	0	102	80	126				
1,2,3-Trichloropropane	19.950	0.50	20.00	0	99.8	68	126				
1,2,4-Trichlorobenzene	20.870	0.50	20.00	0	104	80	125				
1,2,4-Trimethylbenzene	20.180	0.50	20.00	0	101	80	124				
1,2-Dibromo-3-chloropropane	21.740	1.0	20.00	0	109	66	129				
1,2-Dibromoethane	19.670	0.50	20.00	0	98.4	78	120				
1,2-Dichlorobenzene	20.170	0.50	20.00	0	101	80	120				
1,2-Dichloroethane	19.290	0.50	20.00	0	96.5	79	120				
1,2-Dichloropropane	19.440	0.50	20.00	0	97.2	75	120				
1,3,5-Trimethylbenzene	20.160	0.50	20.00	0	101	80	122				
1,3-Dichlorobenzene	20.270	0.50	20.00	0	101	80	120				
1,3-Dichloropropane	20.080	0.50	20.00	0	100	80	120				
1,4-Dichlorobenzene	20.020	0.50	20.00	0	100	80	120				
2,2-Dichloropropane	21.410	0.50	20.00	0	107	61	151				
2-Chlorotoluene	19.900	0.50	20.00	0	99.5	80	120				
4-Chlorotoluene	20.100	0.50	20.00	0	101	80	120				
4-Isopropyltoluene	20.340	0.50	20.00	0	102	80	122				
Benzene	19.550	0.50	20.00	0	97.8	80	120				
Bromobenzene	20.220	0.50	20.00	0	101	80	120				
Bromodichloromethane	20.460	0.50	20.00	0	102	79	123				
Bromoform	21.560	0.50	20.00	0	108	65	141				
Bromomethane	19.010	1.0	20.00	0	95.1	13	175				
Carbon tetrachloride	20.570	0.50	20.00	0	103	71	136				

Qualifiers:

B Analyte detected in the associated Method Blank
ND Not Detected at the Reporting Limit
DO Surrogate Diluted Out
E Value above quantitation range
R RPD outside accepted recovery limits
Calculations are based on raw values
H Holding times for preparation or analysis exceeded
S Spike/Surrogate outside of limits due to matrix interference

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CLIENT: Geocon Consultants, Inc.
Work Order: N010479
Project: Crissy Field Outfall, E8560-02-51

ANALYTICAL QC SUMMARY REPORT

TestCode: 8260WATERP

Sample ID: **P130705LCS** SampType: **LCS** TestCode: **8260WATERP** Units: **µg/L** Prep Date: RunNo: **89470**
Client ID: **LCSW** Batch ID: **P13VW105** TestNo: **EPA 8260B** Analysis Date: **7/5/2013** SeqNo: **1604695**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Chlorobenzene	19.710	0.50	20.00	0	98.6	80	120				
Chloroethane	20.960	1.0	20.00	0	105	63	137				
Chloroform	19.040	0.50	20.00	0	95.2	71	120				
Chloromethane	20.310	0.50	20.00	0	102	35	145				
cis-1,2-Dichloroethene	19.420	0.50	20.00	0	97.1	74	120				
cis-1,3-Dichloropropene	20.520	0.50	20.00	0	103	80	120				
Dibromochloromethane	21.340	0.50	20.00	0	107	74	127				
Dibromomethane	20.310	0.50	20.00	0	102	80	120				
Dichlorodifluoromethane	20.580	0.50	20.00	0	103	67	123				
Ethylbenzene	19.510	0.50	20.00	0	97.6	80	120				
Hexachlorobutadiene	20.260	0.50	20.00	0	101	80	120				
Isopropylbenzene	20.190	0.50	20.00	0	101	80	120				
m,p-Xylene	39.310	1.0	40.00	0	98.3	80	120				
Methylene chloride	19.530	2.0	20.00	0	97.6	63	126				
n-Butylbenzene	20.520	0.50	20.00	0	103	80	121				
n-Propylbenzene	20.300	0.50	20.00	0	102	80	120				
Naphthalene	20.470	0.50	20.00	0	102	74	131				
o-Xylene	19.620	0.50	20.00	0	98.1	80	120				
sec-Butylbenzene	20.090	0.50	20.00	0	100	80	120				
Styrene	19.960	0.50	20.00	0	99.8	80	120				
tert-Butylbenzene	19.990	0.50	20.00	0	100	80	120				
Tetrachloroethene	19.150	0.50	20.00	0	95.8	80	120				
Toluene	19.510	0.50	20.00	0	97.6	80	120				
trans-1,2-Dichloroethene	19.030	0.50	20.00	0	95.2	74	120				
Trichloroethene	19.420	0.50	20.00	0	97.1	80	120				
Trichlorofluoromethane	20.290	0.50	20.00	0	101	67	135				
Vinyl chloride	19.580	0.50	20.00	0	97.9	72	120				
Surr: 1,2-Dichloroethane-d4	24.930		25.00		99.7	70	127				
Surr: 4-Bromofluorobenzene	25.870		25.00		103	80	120				
Surr: Dibromofluoromethane	25.460		25.00		102	73	128				

Qualifiers:

B Analyte detected in the associated Method Blank
ND Not Detected at the Reporting Limit
DO Surrogate Diluted Out
E Value above quantitation range
R RPD outside accepted recovery limits
Calculations are based on raw values
H Holding times for preparation or analysis exceeded
S Spike/Surrogate outside of limits due to matrix interference

Advanced Technology Laboratories, Inc.
3151 W. Post Rd Las Vegas, NV 89118 Tel: 702-307-2659 Fax: 702-307-2691

CLIENT: Geocon Consultants, Inc.
Work Order: N010479
Project: Crissy Field Outfall, E8560-02-51

ANALYTICAL QC SUMMARY REPORT

TestCode: 8260WATERP

Sample ID: **P130705LCS** SampType: **LCS** TestCode: **8260WATERP** Units: **µg/L** Prep Date: RunNo: **89470**
Client ID: **LCSW** Batch ID: **P13VW105** TestNo: **EPA 8260B** Analysis Date: **7/5/2013** SeqNo: **1604695**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Surr: Toluene-d8	25.600		25.00		102	80	120				

Sample ID: **P130705MB2** SampType: **MBLK** TestCode: **8260WATERP** Units: **µg/L** Prep Date: RunNo: **89470**
Client ID: **PBW** Batch ID: **P13VW105** TestNo: **EPA 8260B** Analysis Date: **7/5/2013** SeqNo: **1604697**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
1,1,1,2-Tetrachloroethane	ND	0.50									
1,1,1-Trichloroethane	ND	0.50									
1,1,2,2-Tetrachloroethane	ND	0.50									
1,1,2-Trichloroethane	ND	0.50									
1,1-Dichloroethane	ND	0.50									
1,1-Dichloroethene	ND	0.50									
1,1-Dichloropropene	ND	0.50									
1,2,3-Trichlorobenzene	ND	0.50									
1,2,3-Trichloropropane	ND	0.50									
1,2,4-Trichlorobenzene	ND	0.50									
1,2,4-Trimethylbenzene	ND	0.50									
1,2-Dibromo-3-chloropropane	ND	1.0									
1,2-Dibromoethane	ND	0.50									
1,2-Dichlorobenzene	ND	0.50									
1,2-Dichloroethane	ND	0.50									
1,2-Dichloropropane	ND	0.50									
1,3,5-Trimethylbenzene	ND	0.50									
1,3-Dichlorobenzene	ND	0.50									
1,3-Dichloropropane	ND	0.50									
1,4-Dichlorobenzene	ND	0.50									
2,2-Dichloropropane	ND	0.50									
2-Chlorotoluene	ND	0.50									
4-Chlorotoluene	ND	0.50									
4-Isopropyltoluene	ND	0.50									

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range	H	Holding times for preparation or analysis exceeded
ND	Not Detected at the Reporting Limit	R	RPD outside accepted recovery limits	S	Spike/Surrogate outside of limits due to matrix interference
DO	Surrogate Diluted Out		Calculations are based on raw values		

Advanced Technology Laboratories, Inc.
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CLIENT: Geocon Consultants, Inc.
Work Order: N010479
Project: Crissy Field Outfall, E8560-02-51

ANALYTICAL QC SUMMARY REPORT

TestCode: 8260WATERP

Sample ID: **P130705MB2** SampType: **MBLK** TestCode: **8260WATERP** Units: **µg/L** Prep Date: RunNo: **89470**
Client ID: **PBW** Batch ID: **P13VW105** TestNo: **EPA 8260B** Analysis Date: **7/5/2013** SeqNo: **1604697**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Benzene	ND	0.50									
Bromobenzene	ND	0.50									
Bromodichloromethane	ND	0.50									
Bromoform	ND	0.50									
Bromomethane	ND	1.0									
Carbon tetrachloride	ND	0.50									
Chlorobenzene	ND	0.50									
Chloroethane	ND	1.0									
Chloroform	ND	0.50									
Chloromethane	ND	0.50									
cis-1,2-Dichloroethene	ND	0.50									
cis-1,3-Dichloropropene	ND	0.50									
Dibromochloromethane	ND	0.50									
Dibromomethane	ND	0.50									
Dichlorodifluoromethane	ND	0.50									
Ethylbenzene	ND	0.50									
Hexachlorobutadiene	ND	0.50									
Isopropylbenzene	ND	0.50									
m,p-Xylene	ND	1.0									
Methylene chloride	ND	2.0									
n-Butylbenzene	ND	0.50									
n-Propylbenzene	ND	0.50									
Naphthalene	ND	0.50									
o-Xylene	ND	0.50									
sec-Butylbenzene	ND	0.50									
Styrene	ND	0.50									
tert-Butylbenzene	ND	0.50									
Tetrachloroethene	ND	0.50									
Toluene	ND	0.50									
trans-1,2-Dichloroethene	ND	0.50									

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range	H	Holding times for preparation or analysis exceeded
ND	Not Detected at the Reporting Limit	R	RPD outside accepted recovery limits	S	Spike/Surrogate outside of limits due to matrix interference
DO	Surrogate Diluted Out		Calculations are based on raw values		

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CLIENT: Geocon Consultants, Inc.
Work Order: N010479
Project: Crissy Field Outfall, E8560-02-51

ANALYTICAL QC SUMMARY REPORT

TestCode: 8260WATERP

Sample ID: **P130705MB2** SampType: **MBLK** TestCode: **8260WATERP** Units: **µg/L** Prep Date: RunNo: **89470**
Client ID: **PBW** Batch ID: **P13VW105** TestNo: **EPA 8260B** Analysis Date: **7/5/2013** SeqNo: **1604697**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Trichloroethene	ND	0.50									
Trichlorofluoromethane	ND	0.50									
Vinyl chloride	ND	0.50									
Surr: 1,2-Dichloroethane-d4	25.070		25.00		100	70	127				
Surr: 4-Bromofluorobenzene	25.230		25.00		101	80	120				
Surr: Dibromofluoromethane	25.240		25.00		101	73	128				
Surr: Toluene-d8	25.000		25.00		100	80	120				

Sample ID: **N010479-022ADUP** SampType: **DUP** TestCode: **8260WATERP** Units: **µg/L** Prep Date: RunNo: **89470**
Client ID: **ZZZZZZ** Batch ID: **P13VW105** TestNo: **EPA 8260B** Analysis Date: **7/5/2013** SeqNo: **1604700**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
1,1,1,2-Tetrachloroethane	ND	0.50						0	0	20	
1,1,1-Trichloroethane	ND	0.50						0	0	20	
1,1,2,2-Tetrachloroethane	ND	0.50						0	0	20	
1,1,2-Trichloroethane	ND	0.50						0	0	20	
1,1-Dichloroethane	ND	0.50						0	0	20	
1,1-Dichloroethene	ND	0.50						0	0	20	
1,1-Dichloropropene	ND	0.50						0	0	20	
1,2,3-Trichlorobenzene	ND	0.50						0	0	20	
1,2,3-Trichloropropane	ND	0.50						0	0	20	
1,2,4-Trichlorobenzene	ND	0.50						0	0	20	
1,2,4-Trimethylbenzene	ND	0.50						0	0	20	
1,2-Dibromo-3-chloropropane	ND	1.0						0	0	20	
1,2-Dibromoethane	ND	0.50						0	0	20	
1,2-Dichlorobenzene	ND	0.50						0	0	20	
1,2-Dichloroethane	ND	0.50						0	0	20	
1,2-Dichloropropane	ND	0.50						0	0	20	
1,3,5-Trimethylbenzene	ND	0.50						0	0	20	
1,3-Dichlorobenzene	ND	0.50						0	0	20	

Qualifiers:

B Analyte detected in the associated Method Blank
ND Not Detected at the Reporting Limit
DO Surrogate Diluted Out
E Value above quantitation range
R RPD outside accepted recovery limits
Calculations are based on raw values
H Holding times for preparation or analysis exceeded
S Spike/Surrogate outside of limits due to matrix interference

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CLIENT: Geocon Consultants, Inc.
Work Order: N010479
Project: Crissy Field Outfall, E8560-02-51

ANALYTICAL QC SUMMARY REPORT

TestCode: 8260WATERP

Sample ID: **N010479-022ADUP** SampType: **DUP** TestCode: **8260WATERP** Units: **µg/L** Prep Date: RunNo: **89470**
Client ID: **ZZZZZZ** Batch ID: **P13VW105** TestNo: **EPA 8260B** Analysis Date: **7/5/2013** SeqNo: **1604700**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
1,3-Dichloropropane	ND	0.50						0	0	20	
1,4-Dichlorobenzene	ND	0.50						0	0	20	
2,2-Dichloropropane	ND	0.50						0	0	20	
2-Chlorotoluene	ND	0.50						0	0	20	
4-Chlorotoluene	ND	0.50						0	0	20	
4-Isopropyltoluene	ND	0.50						0	0	20	
Benzene	ND	0.50						0	0	20	
Bromobenzene	ND	0.50						0	0	20	
Bromodichloromethane	ND	0.50						0	0	20	
Bromoform	ND	0.50						0	0	20	
Bromomethane	ND	1.0						0	0	20	
Carbon tetrachloride	ND	0.50						0	0	20	
Chlorobenzene	ND	0.50						0	0	20	
Chloroethane	ND	1.0						0	0	20	
Chloroform	ND	0.50						0	0	20	
Chloromethane	ND	0.50						0	0	20	
cis-1,2-Dichloroethene	ND	0.50						0	0	20	
cis-1,3-Dichloropropene	ND	0.50						0	0	20	
Dibromochloromethane	ND	0.50						0	0	20	
Dibromomethane	ND	0.50						0	0	20	
Dichlorodifluoromethane	ND	0.50						0	0	20	
Ethylbenzene	ND	0.50						0	0	20	
Hexachlorobutadiene	ND	0.50						0	0	20	
Isopropylbenzene	ND	0.50						0	0	20	
m,p-Xylene	ND	1.0						0	0	20	
Methylene chloride	ND	2.0						0	0	20	
n-Butylbenzene	ND	0.50						0	0	20	
n-Propylbenzene	ND	0.50						0	0	20	
Naphthalene	ND	0.50						0	0	20	
o-Xylene	ND	0.50						0	0	20	

Qualifiers:

B Analyte detected in the associated Method Blank
ND Not Detected at the Reporting Limit
DO Surrogate Diluted Out
E Value above quantitation range
R RPD outside accepted recovery limits
Calculations are based on raw values
H Holding times for preparation or analysis exceeded
S Spike/Surrogate outside of limits due to matrix interference

Advanced Technology Laboratories, Inc.
3151 W. Post Rd Las Vegas, NV 89118 Tel: 702-307-2659 Fax: 702-307-2691

CLIENT: Geocon Consultants, Inc.
Work Order: N010479
Project: Crissy Field Outfall, E8560-02-51

ANALYTICAL QC SUMMARY REPORT

TestCode: 8260WATERP

Sample ID: **N010479-022ADUP** SampType: **DUP** TestCode: **8260WATERP** Units: **µg/L** Prep Date: RunNo: **89470**
Client ID: **ZZZZZZ** Batch ID: **P13VW105** TestNo: **EPA 8260B** Analysis Date: **7/5/2013** SeqNo: **1604700**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
sec-Butylbenzene	ND	0.50						0	0	20	
Styrene	ND	0.50						0	0	20	
tert-Butylbenzene	ND	0.50						0	0	20	
Tetrachloroethene	ND	0.50						0	0	20	
Toluene	ND	0.50						0	0	20	
trans-1,2-Dichloroethene	ND	0.50						0	0	20	
Trichloroethene	ND	0.50						0	0	20	
Trichlorofluoromethane	ND	0.50						0	0	20	
Vinyl chloride	ND	0.50						0	0	20	
Surr: 1,2-Dichloroethane-d4	25.270		25.00		101	70	127		0		
Surr: 4-Bromofluorobenzene	25.410		25.00		102	80	120		0		
Surr: Dibromofluoromethane	25.220		25.00		101	73	128		0		
Surr: Toluene-d8	25.080		25.00		100	80	120		0		

Sample ID: **N010483-001AMS** SampType: **MS** TestCode: **8260WATERP** Units: **µg/L** Prep Date: RunNo: **89470**
Client ID: **ZZZZZZ** Batch ID: **P13VW105** TestNo: **EPA 8260B** Analysis Date: **7/5/2013** SeqNo: **1604704**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
1,1,1,2-Tetrachloroethane	20.460	0.50	20.00	0	102	67	135				
1,1,1-Trichloroethane	19.890	0.50	20.00	0	99.4	67	131				
1,1,2,2-Tetrachloroethane	21.470	0.50	20.00	0	107	67	131				
1,1,2-Trichloroethane	20.250	0.50	20.00	0	101	73	120				
1,1-Dichloroethane	19.940	0.50	20.00	0	99.7	69	124				
1,1-Dichloroethene	20.510	0.50	20.00	0	103	65	128				
1,1-Dichloropropene	19.850	0.50	20.00	0	99.2	79	120				
1,2,3-Trichlorobenzene	19.980	0.50	20.00	0	99.9	79	124				
1,2,3-Trichloropropane	20.760	0.50	20.00	0	104	64	123				
1,2,4-Trichlorobenzene	20.170	0.50	20.00	0	101	79	124				
1,2,4-Trimethylbenzene	20.020	0.50	20.00	0	100	61	135				
1,2-Dibromo-3-chloropropane	21.550	1.0	20.00	0	108	52	140				

Qualifiers:

B Analyte detected in the associated Method Blank
ND Not Detected at the Reporting Limit
DO Surrogate Diluted Out
E Value above quantitation range
R RPD outside accepted recovery limits
Calculations are based on raw values
H Holding times for preparation or analysis exceeded
S Spike/Surrogate outside of limits due to matrix interference

Advanced Technology Laboratories, Inc.
3151 W. Post Rd Las Vegas, NV 89118 Tel: 702-307-2659 Fax: 702-307-2691

CLIENT: Geocon Consultants, Inc.
Work Order: N010479
Project: Crissy Field Outfall, E8560-02-51

ANALYTICAL QC SUMMARY REPORT

TestCode: 8260WATERP

Sample ID: **N010483-001AMS** SampType: **MS** TestCode: **8260WATERP** Units: **µg/L** Prep Date: RunNo: **89470**
Client ID: **ZZZZZZ** Batch ID: **P13VW105** TestNo: **EPA 8260B** Analysis Date: **7/5/2013** SeqNo: **1604704**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
1,2-Dibromoethane	20.210	0.50	20.00	0	101	70	122				
1,2-Dichlorobenzene	20.390	0.50	20.00	0	102	80	120				
1,2-Dichloroethane	20.240	0.50	20.00	0	101	75	122				
1,2-Dichloropropane	20.200	0.50	20.00	0	101	73	120				
1,3,5-Trimethylbenzene	19.990	0.50	20.00	0	100	74	124				
1,3-Dichlorobenzene	20.070	0.50	20.00	0	100	80	120				
1,3-Dichloropropane	20.480	0.50	20.00	0	102	78	120				
1,4-Dichlorobenzene	19.860	0.50	20.00	0	99.3	80	120				
2,2-Dichloropropane	22.420	0.50	20.00	0	112	51	154				
2-Chlorotoluene	20.250	0.50	20.00	0	101	79	120				
4-Chlorotoluene	19.970	0.50	20.00	0	99.8	80	120				
4-Isopropyltoluene	20.010	0.50	20.00	0	100	80	120				
Benzene	19.960	0.50	20.00	0	99.8	72	122				
Bromobenzene	20.240	0.50	20.00	0	101	80	120				
Bromodichloromethane	20.490	0.50	20.00	0	102	72	130				
Bromoform	20.770	0.50	20.00	0	104	49	155				
Bromomethane	17.810	1.0	20.00	0	89.0	11	165				
Carbon tetrachloride	20.360	0.50	20.00	0	102	60	145				
Chlorobenzene	20.120	0.50	20.00	0	101	80	120				
Chloroethane	21.720	1.0	20.00	0	109	53	145				
Chloroform	19.970	0.50	20.00	0	99.8	66	130				
Chloromethane	22.110	0.50	20.00	0	111	40	137				
cis-1,2-Dichloroethene	19.750	0.50	20.00	0	98.8	73	120				
cis-1,3-Dichloropropene	20.590	0.50	20.00	0	103	75	121				
Dibromochloromethane	20.740	0.50	20.00	0	104	60	137				
Dibromomethane	20.340	0.50	20.00	0	102	78	120				
Dichlorodifluoromethane	20.480	0.50	20.00	0	102	57	128				
Ethylbenzene	19.780	0.50	20.00	0	98.9	80	120				
Hexachlorobutadiene	19.770	0.50	20.00	0	98.8	74	120				
Isopropylbenzene	20.380	0.50	20.00	0	102	80	120				

Qualifiers:

B Analyte detected in the associated Method Blank
ND Not Detected at the Reporting Limit
DO Surrogate Diluted Out
E Value above quantitation range
R RPD outside accepted recovery limits
Calculations are based on raw values
H Holding times for preparation or analysis exceeded
S Spike/Surrogate outside of limits due to matrix interference

Advanced Technology Laboratories, Inc.
3151 W. Post Rd Las Vegas, NV 89118 Tel: 702-307-2659 Fax: 702-307-2691

CLIENT: Geocon Consultants, Inc.
Work Order: N010479
Project: Crissy Field Outfall, E8560-02-51

ANALYTICAL QC SUMMARY REPORT

TestCode: 8260WATERP

Sample ID: **N010483-001AMS** SampType: **MS** TestCode: **8260WATERP** Units: **µg/L** Prep Date: RunNo: **89470**
Client ID: **ZZZZZZ** Batch ID: **P13VW105** TestNo: **EPA 8260B** Analysis Date: **7/5/2013** SeqNo: **1604704**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
m,p-Xylene	39.910	1.0	40.00	0	99.8	80	120				
Methylene chloride	19.310	2.0	20.00	0	96.6	59	125				
n-Butylbenzene	20.350	0.50	20.00	0	102	80	122				
n-Propylbenzene	20.290	0.50	20.00	0	101	79	120				
Naphthalene	20.870	0.50	20.00	0	104	65	130				
o-Xylene	19.820	0.50	20.00	0	99.1	80	120				
sec-Butylbenzene	19.930	0.50	20.00	0	99.7	80	120				
Styrene	20.200	0.50	20.00	0	101	50	138				
tert-Butylbenzene	19.730	0.50	20.00	0	98.6	80	120				
Tetrachloroethene	21.080	0.50	20.00	1.860	96.1	76	120				
Toluene	20.000	0.50	20.00	0	100	78	120				
trans-1,2-Dichloroethene	19.780	0.50	20.00	0	98.9	72	122				
Trichloroethene	19.620	0.50	20.00	0	98.1	76	120				
Trichlorofluoromethane	21.250	0.50	20.00	0	106	53	148				
Vinyl chloride	19.960	0.50	20.00	0	99.8	67	120				
Surr: 1,2-Dichloroethane-d4	26.000		25.00		104	70	127				
Surr: 4-Bromofluorobenzene	25.920		25.00		104	80	120				
Surr: Dibromofluoromethane	25.710		25.00		103	73	128				
Surr: Toluene-d8	25.790		25.00		103	80	120				

Sample ID: **N010483-001AMSD** SampType: **MSD** TestCode: **8260WATERP** Units: **µg/L** Prep Date: RunNo: **89470**
Client ID: **ZZZZZZ** Batch ID: **P13VW105** TestNo: **EPA 8260B** Analysis Date: **7/5/2013** SeqNo: **1604705**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
1,1,1,2-Tetrachloroethane	19.960	0.50	20.00	0	99.8	67	135	20.46	2.47	20	
1,1,1-Trichloroethane	19.210	0.50	20.00	0	96.0	67	131	19.89	3.48	20	
1,1,2,2-Tetrachloroethane	21.190	0.50	20.00	0	106	67	131	21.47	1.31	20	
1,1,2-Trichloroethane	19.600	0.50	20.00	0	98.0	73	120	20.25	3.26	20	
1,1-Dichloroethane	19.610	0.50	20.00	0	98.0	69	124	19.94	1.67	20	
1,1-Dichloroethene	19.460	0.50	20.00	0	97.3	65	128	20.51	5.25	20	

Qualifiers:

B Analyte detected in the associated Method Blank
ND Not Detected at the Reporting Limit
DO Surrogate Diluted Out
E Value above quantitation range
R RPD outside accepted recovery limits
Calculations are based on raw values
H Holding times for preparation or analysis exceeded
S Spike/Surrogate outside of limits due to matrix interference

Advanced Technology Laboratories, Inc.
3151 W. Post Rd Las Vegas, NV 89118 Tel: 702-307-2659 Fax: 702-307-2691

CLIENT: Geocon Consultants, Inc.
Work Order: N010479
Project: Crissy Field Outfall, E8560-02-51

ANALYTICAL QC SUMMARY REPORT

TestCode: 8260WATERP

Sample ID: **N010483-001AMSD** SampType: **MSD** TestCode: **8260WATERP** Units: **µg/L** Prep Date: RunNo: **89470**
Client ID: **ZZZZZZ** Batch ID: **P13VW105** TestNo: **EPA 8260B** Analysis Date: **7/5/2013** SeqNo: **1604705**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
1,1-Dichloropropene	19.020	0.50	20.00	0	95.1	79	120	19.85	4.27	20	
1,2,3-Trichlorobenzene	19.910	0.50	20.00	0	99.6	79	124	19.98	0.351	20	
1,2,3-Trichloropropane	20.240	0.50	20.00	0	101	64	123	20.76	2.54	20	
1,2,4-Trichlorobenzene	20.310	0.50	20.00	0	102	79	124	20.17	0.692	20	
1,2,4-Trimethylbenzene	19.500	0.50	20.00	0	97.5	61	135	20.02	2.63	20	
1,2-Dibromo-3-chloropropane	21.520	1.0	20.00	0	108	52	140	21.55	0.139	20	
1,2-Dibromoethane	19.730	0.50	20.00	0	98.6	70	122	20.21	2.40	20	
1,2-Dichlorobenzene	19.990	0.50	20.00	0	100	80	120	20.39	1.98	20	
1,2-Dichloroethane	19.390	0.50	20.00	0	97.0	75	122	20.24	4.29	20	
1,2-Dichloropropane	19.530	0.50	20.00	0	97.6	73	120	20.20	3.37	20	
1,3,5-Trimethylbenzene	19.530	0.50	20.00	0	97.6	74	124	19.99	2.33	20	
1,3-Dichlorobenzene	19.730	0.50	20.00	0	98.6	80	120	20.07	1.71	20	
1,3-Dichloropropane	19.900	0.50	20.00	0	99.5	78	120	20.48	2.87	20	
1,4-Dichlorobenzene	19.460	0.50	20.00	0	97.3	80	120	19.86	2.03	20	
2,2-Dichloropropane	21.470	0.50	20.00	0	107	51	154	22.42	4.33	20	
2-Chlorotoluene	19.640	0.50	20.00	0	98.2	79	120	20.25	3.06	20	
4-Chlorotoluene	19.450	0.50	20.00	0	97.3	80	120	19.97	2.64	20	
4-Isopropyltoluene	19.860	0.50	20.00	0	99.3	80	120	20.01	0.752	20	
Benzene	19.430	0.50	20.00	0	97.2	72	122	19.96	2.69	20	
Bromobenzene	19.830	0.50	20.00	0	99.2	80	120	20.24	2.05	20	
Bromodichloromethane	19.900	0.50	20.00	0	99.5	72	130	20.49	2.92	20	
Bromoform	20.940	0.50	20.00	0	105	49	155	20.77	0.815	20	
Bromomethane	19.120	1.0	20.00	0	95.6	11	165	17.81	7.09	20	
Carbon tetrachloride	19.930	0.50	20.00	0	99.7	60	145	20.36	2.13	20	
Chlorobenzene	19.460	0.50	20.00	0	97.3	80	120	20.12	3.34	20	
Chloroethane	21.050	1.0	20.00	0	105	53	145	21.72	3.13	20	
Chloroform	19.330	0.50	20.00	0	96.7	66	130	19.97	3.26	20	
Chloromethane	21.330	0.50	20.00	0	107	40	137	22.11	3.59	20	
cis-1,2-Dichloroethene	19.320	0.50	20.00	0	96.6	73	120	19.75	2.20	20	
cis-1,3-Dichloropropene	20.100	0.50	20.00	0	101	75	121	20.59	2.41	20	

Qualifiers:

B Analyte detected in the associated Method Blank
ND Not Detected at the Reporting Limit
DO Surrogate Diluted Out
E Value above quantitation range
R RPD outside accepted recovery limits
Calculations are based on raw values
H Holding times for preparation or analysis exceeded
S Spike/Surrogate outside of limits due to matrix interference

Advanced Technology Laboratories, Inc.
3151 W. Post Rd Las Vegas, NV 89118 Tel: 702-307-2659 Fax: 702-307-2691

CLIENT: Geocon Consultants, Inc.
Work Order: N010479
Project: Crissy Field Outfall, E8560-02-51

ANALYTICAL QC SUMMARY REPORT

TestCode: 8260WATERP

Sample ID: **N010483-001AMSD** SampType: **MSD** TestCode: **8260WATERP** Units: **µg/L** Prep Date: RunNo: **89470**
Client ID: **ZZZZZZ** Batch ID: **P13VW105** TestNo: **EPA 8260B** Analysis Date: **7/5/2013** SeqNo: **1604705**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Dibromochloromethane	20.550	0.50	20.00	0	103	60	137	20.74	0.920	20	
Dibromomethane	20.310	0.50	20.00	0	102	78	120	20.34	0.148	20	
Dichlorodifluoromethane	19.600	0.50	20.00	0	98.0	57	128	20.48	4.39	20	
Ethylbenzene	19.190	0.50	20.00	0	96.0	80	120	19.78	3.03	20	
Hexachlorobutadiene	19.900	0.50	20.00	0	99.5	74	120	19.77	0.655	20	
Isopropylbenzene	19.860	0.50	20.00	0	99.3	80	120	20.38	2.58	20	
m,p-Xylene	38.420	1.0	40.00	0	96.0	80	120	39.91	3.80	20	
Methylene chloride	18.850	2.0	20.00	0	94.3	59	125	19.31	2.41	20	
n-Butylbenzene	20.050	0.50	20.00	0	100	80	122	20.35	1.49	20	
n-Propylbenzene	19.820	0.50	20.00	0	99.1	79	120	20.29	2.34	20	
Naphthalene	20.930	0.50	20.00	0	105	65	130	20.87	0.287	20	
o-Xylene	19.120	0.50	20.00	0	95.6	80	120	19.82	3.60	20	
sec-Butylbenzene	19.640	0.50	20.00	0	98.2	80	120	19.93	1.47	20	
Styrene	19.680	0.50	20.00	0	98.4	50	138	20.20	2.61	20	
tert-Butylbenzene	19.610	0.50	20.00	0	98.0	80	120	19.73	0.610	20	
Tetrachloroethene	20.460	0.50	20.00	1.860	93.0	76	120	21.08	2.99	20	
Toluene	19.400	0.50	20.00	0	97.0	78	120	20.00	3.05	20	
trans-1,2-Dichloroethene	19.060	0.50	20.00	0	95.3	72	122	19.78	3.71	20	
Trichloroethene	19.140	0.50	20.00	0	95.7	76	120	19.62	2.48	20	
Trichlorofluoromethane	20.380	0.50	20.00	0	102	53	148	21.25	4.18	20	
Vinyl chloride	19.150	0.50	20.00	0	95.8	67	120	19.96	4.14	20	
Surr: 1,2-Dichloroethane-d4	24.760		25.00		99.0	70	127		0		
Surr: 4-Bromofluorobenzene	24.890		25.00		99.6	80	120		0		
Surr: Dibromofluoromethane	25.090		25.00		100	73	128		0		
Surr: Toluene-d8	25.250		25.00		101	80	120		0		

Sample ID: **N010479-021AMS** SampType: **MS** TestCode: **8260WATERP** Units: **µg/L** Prep Date: RunNo: **89470**
Client ID: **ZZZZZZ** Batch ID: **P13VW105** TestNo: **EPA 8260B** Analysis Date: **7/5/2013** SeqNo: **1604706**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range	H	Holding times for preparation or analysis exceeded
ND	Not Detected at the Reporting Limit	R	RPD outside accepted recovery limits	S	Spike/Surrogate outside of limits due to matrix interference
DO	Surrogate Diluted Out		Calculations are based on raw values		

Advanced Technology Laboratories, Inc.
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CLIENT: Geocon Consultants, Inc.
Work Order: N010479
Project: Crissy Field Outfall, E8560-02-51

ANALYTICAL QC SUMMARY REPORT

TestCode: 8260WATERP

Sample ID: **N010479-021AMS** SampType: **MS** TestCode: **8260WATERP** Units: **µg/L** Prep Date: RunNo: **89470**
Client ID: **ZZZZZZ** Batch ID: **P13VW105** TestNo: **EPA 8260B** Analysis Date: **7/5/2013** SeqNo: **1604706**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
1,1,1,2-Tetrachloroethane	20.390	0.50	20.00	0	102	67	135				
1,1,1-Trichloroethane	19.130	0.50	20.00	0	95.7	67	131				
1,1,2,2-Tetrachloroethane	20.950	0.50	20.00	0	105	67	131				
1,1,2-Trichloroethane	20.090	0.50	20.00	0	100	73	120				
1,1-Dichloroethane	19.740	0.50	20.00	0	98.7	69	124				
1,1-Dichloroethene	19.580	0.50	20.00	0	97.9	65	128				
1,1-Dichloropropene	19.420	0.50	20.00	0	97.1	79	120				
1,2,3-Trichlorobenzene	16.030	0.50	20.00	0	80.2	79	124				
1,2,3-Trichloropropane	20.000	0.50	20.00	0	100	64	123				
1,2,4-Trichlorobenzene	16.340	0.50	20.00	0	81.7	79	124				
1,2,4-Trimethylbenzene	18.180	0.50	20.00	0	90.9	61	135				
1,2-Dibromo-3-chloropropane	21.840	1.0	20.00	0	109	52	140				
1,2-Dibromoethane	19.770	0.50	20.00	0	98.8	70	122				
1,2-Dichlorobenzene	18.650	0.50	20.00	0	93.3	80	120				
1,2-Dichloroethane	19.780	0.50	20.00	0	98.9	75	122				
1,2-Dichloropropane	19.930	0.50	20.00	0	99.7	73	120				
1,3,5-Trimethylbenzene	17.880	0.50	20.00	0	89.4	74	124				
1,3-Dichlorobenzene	18.220	0.50	20.00	0	91.1	80	120				
1,3-Dichloropropane	20.150	0.50	20.00	0	101	78	120				
1,4-Dichlorobenzene	18.190	0.50	20.00	0	91.0	80	120				
2,2-Dichloropropane	21.080	0.50	20.00	0	105	51	154				
2-Chlorotoluene	18.530	0.50	20.00	0	92.6	79	120				
4-Chlorotoluene	18.460	0.50	20.00	0	92.3	80	120				
4-Isopropyltoluene	16.400	0.50	20.00	0	82.0	80	120				
Benzene	19.810	0.50	20.00	0	99.0	72	122				
Bromobenzene	19.330	0.50	20.00	0	96.7	80	120				
Bromodichloromethane	20.550	0.50	20.00	0	103	72	130				
Bromoform	21.000	0.50	20.00	0	105	49	155				
Bromomethane	20.810	1.0	20.00	0	104	11	165				
Carbon tetrachloride	20.370	0.50	20.00	0	102	60	145				

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range	H	Holding times for preparation or analysis exceeded
ND	Not Detected at the Reporting Limit	R	RPD outside accepted recovery limits	S	Spike/Surrogate outside of limits due to matrix interference
DO	Surrogate Diluted Out		Calculations are based on raw values		

Advanced Technology Laboratories, Inc.
3151 W. Post Rd Las Vegas, NV 89118 Tel: 702-307-2659 Fax: 702-307-2691

CLIENT: Geocon Consultants, Inc.
Work Order: N010479
Project: Crissy Field Outfall, E8560-02-51

ANALYTICAL QC SUMMARY REPORT

TestCode: 8260WATERP

Sample ID: **N010479-021AMS** SampType: **MS** TestCode: **8260WATERP** Units: **µg/L** Prep Date: RunNo: **89470**
Client ID: **ZZZZZZ** Batch ID: **P13VW105** TestNo: **EPA 8260B** Analysis Date: **7/5/2013** SeqNo: **1604706**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Chlorobenzene	19.460	0.50	20.00	0	97.3	80	120				
Chloroethane	21.070	1.0	20.00	0	105	53	145				
Chloroform	19.280	0.50	20.00	0	96.4	66	130				
Chloromethane	21.560	0.50	20.00	0	108	40	137				
cis-1,2-Dichloroethene	19.260	0.50	20.00	0	96.3	73	120				
cis-1,3-Dichloropropene	20.450	0.50	20.00	0	102	75	121				
Dibromochloromethane	20.650	0.50	20.00	0	103	60	137				
Dibromomethane	20.340	0.50	20.00	0	102	78	120				
Dichlorodifluoromethane	19.080	0.50	20.00	0	95.4	57	128				
Ethylbenzene	19.160	0.50	20.00	0	95.8	80	120				
Hexachlorobutadiene	9.750	0.50	20.00	0	48.8	74	120				S
Isopropylbenzene	18.480	0.50	20.00	0	92.4	80	120				
m,p-Xylene	37.960	1.0	40.00	0	94.9	80	120				
Methylene chloride	18.850	2.0	20.00	0	94.3	59	125				
n-Butylbenzene	15.210	0.50	20.00	0	76.1	80	122				S
n-Propylbenzene	17.970	0.50	20.00	0	89.8	79	120				
Naphthalene	19.520	0.50	20.00	0	97.6	65	130				
o-Xylene	19.070	0.50	20.00	0	95.4	80	120				
sec-Butylbenzene	15.990	0.50	20.00	0	80.0	80	120				S
Styrene	19.560	0.50	20.00	0	97.8	50	138				
tert-Butylbenzene	17.100	0.50	20.00	0	85.5	80	120				
Tetrachloroethene	18.150	0.50	20.00	0	90.8	76	120				
Toluene	19.730	0.50	20.00	0	98.6	78	120				
trans-1,2-Dichloroethene	19.130	0.50	20.00	0	95.7	72	122				
Trichloroethene	19.120	0.50	20.00	0	95.6	76	120				
Trichlorofluoromethane	20.370	0.50	20.00	0	102	53	148				
Vinyl chloride	19.050	0.50	20.00	0	95.2	67	120				
Surr: 1,2-Dichloroethane-d4	24.640		25.00		98.6	70	127				
Surr: 4-Bromofluorobenzene	24.880		25.00		99.5	80	120				
Surr: Dibromofluoromethane	24.940		25.00		99.8	73	128				

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range	H	Holding times for preparation or analysis exceeded
ND	Not Detected at the Reporting Limit	R	RPD outside accepted recovery limits	S	Spike/Surrogate outside of limits due to matrix interference
DO	Surrogate Diluted Out		Calculations are based on raw values		

Advanced Technology Laboratories, Inc.
3151 W. Post Rd Las Vegas, NV 89118 Tel: 702-307-2659 Fax: 702-307-2691

CLIENT: Geocon Consultants, Inc.
Work Order: N010479
Project: Crissy Field Outfall, E8560-02-51

ANALYTICAL QC SUMMARY REPORT

TestCode: 8260WATERP

Sample ID: **N010479-021AMS** SampType: **MS** TestCode: **8260WATERP** Units: **µg/L** Prep Date: RunNo: **89470**
Client ID: **ZZZZZZ** Batch ID: **P13VW105** TestNo: **EPA 8260B** Analysis Date: **7/5/2013** SeqNo: **1604706**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Surr: Toluene-d8	25.330		25.00		101	80	120				

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range	H	Holding times for preparation or analysis exceeded
ND	Not Detected at the Reporting Limit	R	RPD outside accepted recovery limits	S	Spike/Surrogate outside of limits due to matrix interference
DO	Surrogate Diluted Out		Calculations are based on raw values		

Advanced Technology Laboratories, Inc.
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CLIENT: Geocon Consultants, Inc.
Work Order: N010479
Project: Crissy Field Outfall, E8560-02-51

ANALYTICAL QC SUMMARY REPORT

TestCode: 9045_S

Sample ID: **N010478-001B-DUP** SampType: **DUP** TestCode: **9045_S** Units: **pH Units** Prep Date: RunNo: **89413**
Client ID: **ZZZZZZ** Batch ID: **R89413** TestNo: **EPA 9045C** Analysis Date: **6/28/2013** SeqNo: **1602419**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
pH	8.650	0.10						8.560	1.05	20	
Temp. at time of pH Analysis	25.000	0						25.00	0	0	

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range	H	Holding times for preparation or analysis exceeded
ND	Not Detected at the Reporting Limit	R	RPD outside accepted recovery limits	S	Spike/Surrogate outside of limits due to matrix interference
DO	Surrogate Diluted Out		Calculations are based on raw values		

Advanced Technology Laboratories, Inc.
3151 W. Post Rd Las Vegas, NV 89118 Tel: 702-307-2659 Fax: 702-307-2691

CHAIN OF CUSTODY RECORD

Advanced Technology Laboratories INC.
3151-3153 W. Post Rd.
Las Vegas, NV 89118
Tel: (702) 307-2659 • Fax: (702) 307-2691

FOR LABORATORY USE ONLY

P.O. #: _____
Logged By: HSG Date: 6/28/13

Method of Transport: Client ☐ ATL ☐ CA OverN ☐ FedEx ☐ Other: GSO

Sample Condition Upon Receipt:
1. CHILLED 4.4°C IR#1 Y ☑ N ☐
2. HEADSPACE (VOA) Y ☐ N ☐
3. CONTAINER INTACT Y ☐ N ☐
4. SEALED Y ☐ N ☐
5. # OF SPLS MATCH COC Y ☐ N ☐
6. PRESERVED Y ☐ N ☐

Client: Geocon Consultants, Inc.
Attention: Luann Beadle / Rick Day
Address: 6671 Brisa St.
City: Livermore State: CA Zip Code: 94550
Tel: 925-961-5272
Fax:

Project Name: Crissy Field Outfall
Project #: E8560-02-51
Sampler: *I attest to the validity and authenticity of this sample. I am aware that tampering with or intentionally mislabeling the sample location, date or time of collection is considered fraud and may be grounds for legal action.*
(Printed Name) Luann Beadle
(Signature) Luann Beadle

Relinquished by: (Signature and Printed Name)	Date:	Time:	Received by: (Signature and Printed Name)	Date:	Time:
Luann Beadle	6-27-13	1700	GSO		
				6/28/13	8:35

I hereby authorize ATL to perform the work indicated below:
Project Mgr /Submitter: Luann Beadle 6-27-13
Print Name Date
Signature: Luann Beadle

Send Report To:
Attn: Luann Beadle / Rick Day
Co: Geocon Consultants
Addr: beadle@geoconinc.com
City: State: Zip:

Bill To:
Attn: Same
Co:
Addr:
City: State: Zip:

Special Instructions/Comments:

Sample/Records - Archival & Disposal
Unless otherwise requested by client, all samples will be disposed 45 days after receipt and records will be disposed 1 year after submittal of final report.

Storage Fees (applies when storage is requested):
- Sample :$2.00 / sample /mo (after 45 days)
- Records: $1 /ATL workorder /mo (after 1 year)

Circle or Add Analysis(es) Requested

ITEM	LAB USE ONLY: Lab No.	Sample Description: Sample ID / Location	Date	Time	8260B (Volatiles)	8015M - GRO / BTEX	8015B - DRO/ORO	6010 CAM 17	Total lead (low)	PCBs - 8082A	5 VOC - 8260C	4-4'-DDE - 8270C	8045	SOIL	WATER	GROUND WATER	WASTEWATER	TAT	Container(s) #	Container(s) Type	PRESERVATION	REMARKS
	N010479-1	B1-0.5	6-27-13	10:10				X						X				E	1	S T		
	2	B1-1.5		10:15	X	X		X	X													
	3	B1-3.0		10:20	X		X	X	X		X									N		
	4	B1-6.0		10:25	X			X												P		
	5	B1-9.0		10:25				X												P		
	6	B2-0.5		11:05				X												S T		
	7	B2-1.5		11:10	X	X	X	X														
	8	B2-3.0		11:20	X		X	X	X		X									N		
	9	B2-6.0		11:40	X			X												P		
	10	B2-11.0		11:50				X														

QA/QC: RTNE ☐ CT ☒ SWRCB ☐ Logcode_____ OTHER _____

- TAT starts 8AM the following day if samples received after 3 PM

TAT: ☐ A = Overnight ≤ 24 hrs ☐ B = Emergency Next Workday ☐ C = Critical 2 Workdays ☐ D = Urgent 3 Workdays ☒ E = Routine 7 Workdays

Container Types: T=Tube V=VOA L=Liter P=Pint J=Jar B=Tedlar G=Glass P=Plastic M=Metal

Preservatives: H=HCl N=HNO_3 S=H_2SO_4 C=4°C Z=$Zn(AC)_2$ O=NaOH T=$Na_2S_2O_3$

CHAIN OF CUSTODY RECORD

Advanced Technology Laboratories INC.
3151-3153 W. Post Rd.
Las Vegas, NV 89118
Tel: (702) 307-2659 • Fax: (702) 307-2691

FOR LABORATORY USE ONLY

P.O. #:
Logged By: HSG Date: 6/28/13

Method of Transport: Client ☐ ATL ☐ CA OverN ☐ FedEx ☐ Other:

Sample Condition Upon Receipt: 1. CHILLED Y ☐ N ☐ 2. HEADSPACE (VOA) Y ☐ N ☐ 3. CONTAINER INTACT Y ☐ N ☐ 4. SEALED Y ☐ N ☐ 5. # OF SPLS MATCH COC Y ☐ N ☐ 6. PRESERVED Y ☐ N ☐

Client: Geocon Consultants, Inc.
Attention: Luann Beadle
Address: 6671 Brisa St.
City: Livermore State: CA Zip Code: 94550
Tel: 925-961-5272
Fax:

Project Name: Crissy Field outfall
Project #: E8560-02-51
Sampler: *I attest to the validity and authenticity of this sample. I am aware that tampering with or intentionally mislabeling the sample location, date or time of collection is considered fraud and may be grounds for legal action.*
(Printed Name) Luann Beadle
(Signature) Luann Be

Relinquished by: (Signature and Printed Name)	Date:	Time:	Received by: (Signature and Printed Name)	Date:	Time:
Luann Be	6-27-13	1700	G-50		
			HSG	6/28/13	8:35

I hereby authorize ATL to perform the work indicated below:
Project Mgr /Submitter:
Luann Beadle 6-27-13
Print Name Date
Luann Be
Signature

Send Report To:
Attn: Luann Beadle / Rich Day
Co: Geocon Consultants
Addr: beadle@geoconinc.com
City: State: Zip:

Bill To:
Attn: Same
Co:
Addr:
City: State: Zip:

Special Instructions/Comments:

Sample/Records - Archival & Disposal
Unless otherwise requested by client, all samples will be disposed 45 days after receipt and records will be disposed 1 year after submittal of final report.

Storage Fees (applies when storage is requested):
- Sample :$2.00 / sample /mo (after 45 days)
- Records: $1 /ATL workorder /mo (after 1 year)

Circle or Add Analysis(es) Requested

SPECIFY APPROPRIATE MATRIX

QA/QC: RTNE ☐ CT ☒ SWRCB ☐ Logcode ____ OTHER ____

ITEM	LAB USE ONLY: Lab No.	Sample Description: Sample ID / Location	Date	Time	8260B (Volatiles)	8015M - GRO	8015B - DRO/ORO	6010 CAM 17	TOTAL LEAD - 6010	PCB - 8082A	SVOCs - 8270C	VOC - 8045	SOIL	WATER	GROUND WATER	WASTEWATER	TAT	Container(s) #	Container(s) Type	PRESERVATION	REMARKS
	N010479-11	B3-0.5	6/27/13	0820				X	X				1				E	1	P	C	
	12	B3-1.5		0825		X		X	X												
	13	B3-3.0		0835	X		X		X	X	X										
	14	B3-6.0		0840	X				X												
	15	B3-9.0		0840					X												
	16	B4-0.5		0855					X												
	17	B4-1.5		0855	X	X		X		X											
	18	B4-3.0		0900	X		X		X	X	X										
	19	B4-6.0		0905	X				X												
	20	B4-7.5		0905					X												

■ TAT starts 8AM the following day if samples received after 3 PM

TAT: ☐ A = Overnight ≤ 24 hrs ☐ B = Emergency Next Workday ☐ C = Critical 2 Workdays ☐ D = Urgent 3 Workdays ☒ E = Routine 7 Workdays

Container Types: T=Tube V=VOA L=Liter P=Pint J=Jar B=Tedlar G=Glass P=Plastic M=Metal

Preservatives:
H=HCl N=HNO_3 S=H_2SO_4 C=4°C
Z=$Zn(AC)_2$ O=NaOH T=$Na_2S_2O_3$

CHAIN OF CUSTODY RECORD

Advanced Technology Laboratories INC.
3151-3153 W. Post Rd.
Las Vegas, NV 89118
Tel: (702) 307-2659 • Fax: (702) 307-2691

FOR LABORATORY USE ONLY

P.O. #:
Logged By: HSG Date: 6/28/13

Method of Transport: Client ☐ ATL ☐ CA OverN ☐ FedEx ☐ Other:

Sample Condition Upon Receipt:
1. CHILLED Y ☐ N ☐
2. HEADSPACE (VOA) Y ☐ N ☐
3. CONTAINER INTACT Y ☐ N ☐
4. SEALED Y ☐ N ☐
5. # OF SPLS MATCH COC Y ☐ N ☐
6. PRESERVED Y ☐ N ☐

Client: Geocon Consultants, Inc.
Attention: Luann Beadle
Address: 6671 Brisa St.
City: Livermore State: CA Zip Code: 94550
Tel: 925 961 5272
Fax:

Project Name: Crissy Field outfall
Project #: E 8560-02-51
Sampler: *I attest to the validity and authenticity of this sample. I am aware that tampering with or intentionally mislabeling the sample location, date or time of collection is considered fraud and may be grounds for legal action.*
(Printed Name) Luann Beadle/Merritt
(Signature) Luann Beadle

Relinquished by: (Signature and Printed Name)	Date	Time	Received by: (Signature and Printed Name)	Date	Time
Luann Beadle	6-27-13	1700	GSO		
			T Stoddard	6/28/13	8:35

I hereby authorize ATL to perform the work indicated below:
Project Mgr /Submitter: Luann Beadle 6-27-13
Print Name Date
Signature: Luann Beadle

Send Report To:
Attn: Luann Beadle (Rick Day)
Co: Geocon Consultants
Addr: beadle@geoconinc.com
City: State: Zip:

Bill To:
Attn: Same
Co:
Addr:
City: State: Zip:

Special Instructions/Comments:

Sample/Records - Archival & Disposal
Unless otherwise requested by client, all samples will be disposed 45 days after receipt and records will be disposed 1 year after submittal of final report.

Storage Fees (applies when storage is requested):
- Sample :$2.00 / sample /mo (after 45 days)
- Records: $1 /ATL workorder /mo (after 1 year)

Circle or Add Analysis(es) Requested

SPECIFY APPROPRIATE MATRIX

QA/QC: RTNE ☐ CT ☑ SWRCB ☐ Logcode ____ OTHER ____

ITEM	LAB USE ONLY: Lab No.	Sample Description: Sample ID / Location	Date	Time	8260B (Volatiles)	8015M - GRO/BTEX	8015B - DRO/ORO	6010 CAM 17	6010 - Total lead	TPH-gas	SOIL	WATER	GROUND WATER	WASTEWATER	TAT	Container(s) #	Type	PRESERVATION	REMARKS
	N010479-21	B3-GW	6-27-13	910	X	X							X		E	4	V	H	
	22	B2-GW		1200	X	X							X			5	V	H	
	23	B4-10		1200			X				X					1	P	C	
	24	Trip Blank		—				X				X				4	V	H	
	25	Equipment Blank	6-27-13	1600				X				X				1	G	C	

- TAT starts 8AM the following day if samples received after 3 PM

TAT: ☐ A = Overnight ≤ 24 hrs ☐ B = Emergency Next Workday ☐ C = Critical 2 Workdays ☐ D = Urgent 3 Workdays ☒ E = Routine 7 Workdays

Container Types: T=Tube V=VOA L=Liter P=Pint J=Jar B=Tedlar G=Glass P=Plastic M=Metal

Preservatives: H=HCl N=HNO_3 S=H_2SO_4 C=4°C Z=$Zn(AC)_2$ O=NaOH T=$Na_2S_2O_3$

Advanced Technology Laboratories, Inc.

Please review the checklist below. Any NO signifies non-compliance. Any non-compliance will be noted and must be understood as having an impact on the quality of the data. All tests will be performed as requested regardless of any compliance issues.

If you have any questions or further instruction, please contact our Project Coordinator at (702) 307-2659.

Cooler Received/Opened On:	6/28/2013	Workorder:	N010479
Rep sample Temp (Deg C):	4.4	IR Gun ID:	1
Temp Blank:	☐ Yes ☑ No		
Carrier name:	GSO		
Last 4 digits of Tracking No.:	5104	Packing Material Used:	None
Cooling process:	☑ Ice ☐ Ice Pack ☐ Dry Ice ☐ Other ☐ None		

Sample Receipt Checklist

1. Shipping container/cooler in good condition?	Yes ☑	No ☐	Not Present ☐
2. Custody seals intact, signed, dated on shippping container/cooler?	Yes ☐	No ☐	Not Present ☑
3. Custody seals intact on sample bottles?	Yes ☐	No ☐	Not Present ☑
4. Chain of custody present?	Yes ☑	No ☐	
5. Sampler's name present in COC?	Yes ☑	No ☐	
6. Chain of custody signed when relinquished and received?	Yes ☑	No ☐	
7. Chain of custody agrees with sample labels?	Yes ☑	No ☐	
8. Samples in proper container/bottle?	Yes ☑	No ☐	
9. Sample containers intact?	Yes ☑	No ☐	
10. Sufficient sample volume for indicated test?	Yes ☑	No ☐	
11. All samples received within holding time?	Yes ☑	No ☐	
12. Temperature of rep sample or Temp Blank within acceptable limit?	Yes ☑	No ☐	NA ☐
13. Water - VOA vials have zero headspace?	Yes ☐	No ☑	NA ☐
14. Water - pH acceptable upon receipt? Example: pH > 12 for (CN,S); pH<2 for Metals	Yes ☐	No ☐	NA ☑
15. Did the bottle labels indicate correct preservatives used?	Yes ☑	No ☐	NA ☐
16. Were there Non-Conformance issues at login?	Yes ☐	No ☐	NA ☑
Was Client notified?	Yes ☐	No ☐	NA ☑

Comments: 2 of 5 VOA of B2-GW has headspace greater than 5mm while 3 of 5 has less than 5mm headspace. 2 of 4 VOA of B3-GW has headspace less han 5mm.

Checklist Completed B HG HSG 7/1/13

Reviewed By: jgb

GSO GOLDEN STATE OVERNIGHT

< WebShip > > > > >

800-322-5555 www.gso.com

Ship From:
GEOCON - LIVERMORE OFFICE
GEOCON, INC.
6671 BRISA STREET
LIVERMORE, CA 94550

Ship To:
SAMPLE RECEIVING
ADVANCED TECHNOLOGY LABS - LAS VEGAS
3151 W. POST ROAD
LAS VEGAS, NV 89118

COD:
$0.00

Reference:
E8560-02-51

Delivery Instructions:

Signature Type:
SIGNATURE REQUIRED

Tracking #: 522155104

PDS

LVS

LAS VEGAS

D89103A

13549148

Print Date : 06/27/13 16:30 PM

Package 1 of 1

Send Label To Printer | ☑ Print All | Edit Shipment | Finish

LABEL INSTRUCTIONS:

Do not copy or reprint this label for additional shipments - each package must have a unique barcode.

STEP 1 - Use the "Send Label to Printer" button on this page to print the shipping label on a laser or inkjet printer.
STEP 2 - Fold this page in half.
STEP 3 - Securely attach this label to your package, do not cover the barcode.
STEP 4 - Request an on-call pickup for your package, if you do not have scheduled daily pickup service or Drop-off your package at the nearest GSO drop box. Locate nearest GSO dropbox locations using this link.

ADDITIONAL OPTIONS:

Send Label Via Email | Create Return Label

TERMS AND CONDITIONS:

By giving us your shipment to deliver, you agree to all the service terms and conditions described in this section.
Our liability for loss or damage to any package is limited to your actual damages or $100 whichever is less, unless you pay for and declare a higher authorized value. If you declare a higher value and pay the additional charge, our liability will be the lesser of your declared value or the actual value of your loss or damage. In any event, we will not be liable for any damage, whether direct, incidental, special or consequential, in excess of the declared value of a shipment whether or not we had knowledge that such damage might be incurred including but not limited to loss of income or profit. We will not be liable for your acts or omissions, including but not limited to improper or insufficient packaging, securing, marking or addressing. Also, we will not be liable if you or the recipient violates any of the terms of our agreement. We will not be liable for loss, damage or delay caused by events we cannot control, including but not limited to acts of God, perils of the air, weather conditions, act of public enemies, war, strikes, or civil commotion. The highest declared value for our GSO Priority Letter or GSO Priority Package is $500. For other shipments the highest declared value is $10,000 unless your package contains items of "extraordinary value", in which case the highest declared value we allow is $500. Items of "extraordinary value" include, but or not limited to, artwork, jewelry, furs, precious metals, tickets, negotiable instruments and other items with intrinsic value.

July 15, 2013

Luann Beadle
Geocon Consultants, Inc.
6671 Brisa Street
Livermore, CA 94550

TEL: 925-371-5900 Ext 403
FAX: (925) 371-5915

CA-ELAP No.: 2676
NV Cert. No.: NV-009222007A

Workorder No.: N010479

RE: Crissy Field Outfall, E8560-02-51

Attention: Luann Beadle

Enclosed are the results for sample(s) received on June 28, 2013 by Advanced Technology Laboratories, Inc. . The sample(s) are tested for the parameters as indicated in the enclosed chain of custody in accordance with the applicable laboratory certifications.

This is an addendum report. Please incorporate with documentation previously submitted.

Thank you for the opportunity to service the needs of your company.

Please feel free to call me at (702) 307-2659 if I can be of further assistance to your company.

Sincerely,

Jose Tenorio Jr.
Laboratory Director

The cover letter is an integral part of this analytical report. This Laboratory Report cannot be reproduced in part or in its entirety without written permission from the client and Advanced Technology Laboratories - Las Vegas.

Advanced Technology Laboratories, Inc.

ANALYTICAL RESULTS

Print Date: *15-Jul-13*

CLIENT:	Geocon Consultants, Inc.	**Client Sample ID:**	B2-0.5
Lab Order:	N010479	**Collection Date:**	6/27/2013 11:05:00 AM
Project:	Crissy Field Outfall, E8560-02-51	**Matrix:**	SOIL
Lab ID:	N010479-006A		

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
ICP METALS BY STLC						
			WET/ EPA 6010B			
RunID: ICP2_130715A	QC Batch: R89566			PrepDate:		Analyst: **CEI**
Lead	3.5	0.050		mg/L	5	7/15/2013 11:56 AM

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range
H	Holding times for preparation or analysis exceeded	ND	Not Detected at the Reporting Limit
S	Spike/Surrogate outside of limits due to matrix interference		Results are wet unless otherwise specified
DO	Surrogate Diluted Out		

Advanced Technology Laboratories, Inc.

3151 W. Post Rd Las Vegas, NV 89118 Tel: 702-307-2659 Fax: 702-307-2691

CLIENT: Geocon Consultants, Inc.
Work Order: N010479
Project: Crissy Field Outfall, E8560-02-51

ANALYTICAL QC SUMMARY REPORT

TestCode: 6010_ST

Sample ID: **MB-R89566** SampType: **MBLK** TestCode: **6010_ST** Units: **mg/L** Prep Date: RunNo: **89566**
Client ID: **PBS** Batch ID: **R89566** TestNo: **WET/ EPA 60** Analysis Date: **7/15/2013** SeqNo: **1612188**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Lead	ND	0.010									

Sample ID: **LCS-R89566** SampType: **LCS** TestCode: **6010_ST** Units: **mg/L** Prep Date: RunNo: **89566**
Client ID: **LCSS** Batch ID: **R89566** TestNo: **WET/ EPA 60** Analysis Date: **7/15/2013** SeqNo: **1612189**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Lead	1.035	0.010	1.000	0	103	85	115				

Sample ID: **MB-43382 STLC** SampType: **MBLK** TestCode: **6010_ST** Units: **mg/L** Prep Date: RunNo: **89566**
Client ID: **PBS** Batch ID: **R89566** TestNo: **WET/ EPA 60** Analysis Date: **7/15/2013** SeqNo: **1612190**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Lead	ND	0.050									

Sample ID: **N010479-006A-MS** SampType: **MS** TestCode: **6010_ST** Units: **mg/L** Prep Date: RunNo: **89566**
Client ID: **ZZZZZZ** Batch ID: **R89566** TestNo: **WET/ EPA 60** Analysis Date: **7/15/2013** SeqNo: **1612193**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Lead	5.777	0.050	2.500	3.473	92.1	75	125				

Sample ID: **N010479-006A-MSD** SampType: **MSD** TestCode: **6010_ST** Units: **mg/L** Prep Date: RunNo: **89566**
Client ID: **ZZZZZZ** Batch ID: **R89566** TestNo: **WET/ EPA 60** Analysis Date: **7/15/2013** SeqNo: **1612194**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Lead	5.790	0.050	2.500	3.473	92.7	75	125	5.777	0.227	20	

Qualifiers:

B	Analyte detected in the associated Method Blank	E	Value above quantitation range	H	Holding times for preparation or analysis exceeded
ND	Not Detected at the Reporting Limit	R	RPD outside accepted recovery limits	S	Spike/Surrogate outside of limits due to matrix interference
DO	Surrogate Diluted Out		Calculations are based on raw values		

Advanced Technology Laboratories, Inc.
3151 W. Post Rd Las Vegas, NV 89118 Tel: 702-307-2659 Fax: 702-307-2691

Glen S. Gesmundo

From: Rick Day [day@geoconinc.com]
Sent: Tuesday, July 09, 2013 11:12 AM
To: Glen S. Gesmundo; Marlon Cartin
Cc: Luann Beadle
Subject: RE: Crissy Field Outfall, E8560-02-51 (ATL No.N010479)

Please run sample N010479-006 (B2-0.5) for STLC Lead on 72-hr TAT.

Thanks,
Rick.

Please note new office extension and direct dial number.

Richard Day, CEG, CHG | *Principal / Senior Geologist*
Geocon Consultants, Inc.
6671 Brisa Street, Livermore, California 94550
Office 925.371.5900, ext. 401 Direct 925.961.5270 Mobile 925.872.5860
Visit our NEW website at www.geoconinc.com

From: ATLInc Reports [mailto:reports@atl-labs.com]
Sent: Tuesday, July 09, 2013 10:59 AM
To: beadle@geoconinc.com; 'Rick Day'
Cc: livermore@geoconinc.com
Subject: Crissy Field Outfall, E8560-02-51 (ATL No.N010479)

Enclosed is the final report for the above project.

Thanks.

Glen Gesmundo

Advanced Technology Laboratories, Inc.
Your Partner for Quality Environmental Testing

Advanced Technology Laboratories, Inc. *3151 W. Post Rd Las Vegas, NV 89118 Tel: 702-307-2659 Fax: 702-307-2691*

EMSL Analytical, Inc
2235 Polvorosa Ave , Suite 230, San Leandro, CA 94577
Phone/Fax: (510) 895-3675 / (510) 895-3680
http://www.emsl.com sanleandrolab@emsl.com

EMSL Order:	091310221
CustomerID:	GECN21
CustomerPO:	E8560-02-51
ProjectID:	E8560-06-**

Attn: **Rick Day**
Geocon Consultants, Inc.
6671 Brisa Street

Livermore, CA 94550

Phone:	(925) 371-5900
Fax:	(925) 371-5915
Received:	06/28/13 12:15 PM
Analysis Date:	7/5/2013
Collected:	6/27/2013

Project: **CRISSY FIELO OUTFALL (CALTRANS) / E8560-02-51**

Test Report: PLM Analysis of Bulk Samples for Asbestos via EPA 600/R-93/116 Method with CARB 435 Prep (Milling) Level A for 0.25% Target Analytical Sensitivity

Sample	Description	Appearance	Non-Asbestos % Fibrous	Non-Asbestos % Non-Fibrous	Asbestos % Type
B1-1.5 *091310221-0001*		Gray Non-Fibrous Homogeneous		98.75% Non-fibrous (other)	**1.25% Chrysotile**
B1-3.0 *091310221-0002*		Brown Non-Fibrous Homogeneous		100.00% Non-fibrous (other)	**<0.25% Chrysotile**
B1-6.0 *091310221-0003*		Brown Non-Fibrous Homogeneous		100.00% Non-fibrous (other)	**None Detected**
B2-0.5 *091310221-0004*		Brown Non-Fibrous Homogeneous		100.00% Non-fibrous (other)	**None Detected**
B2-1.5 *091310221-0005*		Brown Non-Fibrous Homogeneous		100.00% Non-fibrous (other)	**None Detected**
B2-11.0 *091310221-0006*		Brown Non-Fibrous Homogeneous		100.00% Non-fibrous (other)	**None Detected**
B3-1.5 *091310221-0007*		Brown Non-Fibrous Homogeneous		100.00% Non-fibrous (other)	**None Detected**

Analyst(s)

Jorge Leon (12)

Baojia Ke, Laboratory Manager
or other approved signatory

This report relates only to the samples listed above and may not be reproduced except in full, without EMSL's written approval. This report must not be used by the client to claim product certification, approval, or endorsement by NVLAP, NIST, or any agency of the federal government. EMSL is not responsible for sample collection activities or method limitations. Some samples may contain asbestos fibers below the resolution limit of PLM. EMSL recommends that samples reported as none detected or less than the limit of detection undergo additional analysis via TEM.Samples received in good condition unless otherwise noted.

Samples analyzed by EMSL Analytical, Inc San Leandro, CA

Initial report from 07/05/2013 15:30:59

EMSL Analytical, Inc
2235 Polvorosa Ave , Suite 230, San Leandro, CA 94577
Phone/Fax: (510) 895-3675 / (510) 895-3680
http://www.emsl.com sanleandrolab@emsl.com

EMSL Order:	091310221
CustomerID:	GECN21
CustomerPO:	E8560-02-51
ProjectID:	E8560-06-**

Attn: **Rick Day**
Geocon Consultants, Inc.
6671 Brisa Street

Livermore, CA 94550

Phone:	(925) 371-5900
Fax:	(925) 371-5915
Received:	06/28/13 12:15 PM
Analysis Date:	7/5/2013
Collected:	6/27/2013

Project: **CRISSY FIELO OUTFALL (CALTRANS) / E8560-02-51**

Test Report: PLM Analysis of Bulk Samples for Asbestos via EPA 600/R-93/116 Method with CARB 435 Prep (Milling) Level A for 0.25% Target Analytical Sensitivity

			Non-Asbestos		Asbestos
Sample	**Description**	**Appearance**	**% Fibrous**	**% Non-Fibrous**	**% Type**
B3-3.0 *091310221-0008*		Brown Non-Fibrous Homogeneous		100.00% Non-fibrous (other)	**None Detected**
B3-6.0 *091310221-0009*		Brown Non-Fibrous Homogeneous		100.00% Non-fibrous (other)	**None Detected**
B4-1.5 *091310221-0010*		Brown Non-Fibrous Homogeneous		100.00% Non-fibrous (other)	**None Detected**
B4-6.0 *091310221-0011*		Brown Non-Fibrous Homogeneous		100.00% Non-fibrous (other)	**<0.25% Chrysotile**
B4-7.5 *091310221-0012*		Brown Non-Fibrous Homogeneous		100.00% Non-fibrous (other)	**<0.25% Chrysotile**

Analyst(s)

Jorge Leon (12)

Baojia Ke, Laboratory Manager
or other approved signatory

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Samples analyzed by EMSL Analytical, Inc San Leandro, CA

Initial report from 07/05/2013 15:30:59

091310221

EMSL ANALYTICAL, INC.
LABORATORY • PRODUCTS • TRAINING

Asbestos Chain of Custody

EMSL Order Number (*Lab Use Only*):

#091310221

EMSL ANALYTICAL, INC.
2235 POLVOROSA DR., STE. 230
SAN LEANDRO, CA 94577
PHONE: (510) 895-3675
FAX: (510) 895-3680

Company : GEOCON	EMSL-Bill to: ☐ Same ☐ Different If Bill to is Different note instructions in Comments** *Third Party Billing requires written authorization from third party*
Street: 6671 BRISA ST	
City: LIVERMORE State/Province: CA	Zip/Postal Code: 94550 Country: US
Report To (Name): R DAY, L. BEADLE	Fax #: 925-371-5915
Telephone #: 925-371-5900	Email Address: ON FILE
Project Name/Number: CRISSY FIELD OUTFALL (CALTRANS) E8560-02-51	
Please Provide Results: ☐ Fax ☐ Email Purchase Order:	U.S. State Samples Taken:

Turnaround Time (TAT) Options* – Please Check

☐ 3 Hour ☐ 6 Hour ☐ 24 Hour ☐ 48 Hour ☐ 72 Hour ☐ 96 Hour ■ 1 Week ☐ 2 Week

**For TEM Air 3 hours/6 hours, please call ahead to schedule.*There is a premium charge for 3 Hour TEM AHERA or EPA Level II TAT. You will be asked to sign an authorization form for this service. Analysis completed in accordance with EMSL's Terms and Conditions located in the Analytical Price Guide.*

PCM - Air
- ☐ NIOSH 7400
- ☐ w/ OSHA 8hr. TWA

PLM - Bulk (reporting limit)
- ☐ PLM EPA 600/R-93/116 (<1%)
- ☐ PLM EPA NOB (<1%)

Point Count
- ☐ 400 (<0.25%) ☐ 1000 (<0.1%)

Point Count w/Gravimetric
- ☐ 400 (<0.25%) ☐ 1000 (<0.1%)
- ☐ NYS 198.1 (friable in NY)
- ☐ NYS 198.6 NOB (non-friable-NY)
- ☐ NIOSH 9002 (<1%)

TEM – Air ☐ **4-4.5hr TAT (AHERA only)**
- ☐ AHERA 40 CFR, Part 763
- ☐ NIOSH 7402
- ☐ EPA Level II
- ☐ ISO 10312

TEM - Bulk
- ☐ TEM EPA NOB
- ☐ NYS NOB 198.4 (non-friable-NY)
- ☐ Chatfield SOP
- ☐ TEM Mass Analysis-EPA 600 sec. 2.5

TEM – Water: EPA 100.2
- Fibers >10µm ☐ Waste ☐ Drinking
- All Fiber Sizes ☐ Waste ☐ Drinking

TEM- Dust
- ☐ Microvac - ASTM D 5755
- ☐ Wipe - ASTM D6480
- ☐ Carpet Sonication (EPA 600/J-93/167)

Soil/Rock/Vermiculite
- ■ PLM CARB 435 - A (0.25% sensitivity)
- ☐ PLM CARB 435 - B (0.1% sensitivity)
- ☐ TEM CARB 435 - B (0.1% sensitivity)
- ☐ TEM CARB 435 - C (0.01% sensitivity)
- ☐ EPA Protocol (Semi-Quantitative)
- ☐ EPA Protocol (Quantitative)

Other:
- ☐

☐ **Check For Positive Stop – Clearly Identify Homogenous Group**

Samplers Name: **Samplers Signature:**

Sample #	Sample Description	Volume/Area (Air) HA # (Bulk)	Date/Time Sampled
B1-1.5	SOIL		6-27-13 VARIOUS
-3.0			
-6.0			
B2-0.5			
-1.5			
-11.0			
B3-1.5			
" " -3.0			

Client Sample # (s): B1 (3 TOTAL) THROUGH B4 (3 TOTAL) **Total # of Samples:** 12

Relinquished (Client): CHRIS MERRITT **Date:** 6-27-13 **Time:** 1700

Received (Lab): [signature] **Date:** 6-27-13 6-28-13 **Time:** 1600 1220

Comments/Special Instructions:

RECEIVED JUN 28 2013

12:15 pm

WI Angel

091310221

EMSL ANALYTICAL, INC.
LABORATORY • PRODUCTS • TRAINING

Asbestos Chain of Custody

EMSL Order Number *(Lab Use Only)*:

EMSL ANALYTICAL, INC.
2235 POLVOROSA DR., STE 230
SAN LEANDRO, CA 94577
PHONE: (510) 895-3675
FAX: (510) 895-3680

Additional Pages of the Chain of Custody are only necessary if needed for additional sample information

Sample #	Sample Description	Volume/Area (Air) HA # (Bulk)	Date/Time Sampled
B3-6.0	SOIL		6-27-13 VARIOUS
B4-1.5			
B4-6.0			
B4-7.5			

***Comments/Special Instructions:**

APPENDIX B

As - Soil

Number of Valid Observations	5
Number of Distinct Observations	5
Minimum	2.1
Maximum	3.7
Mean	2.86
Median	2.8
SD	0.619
Variance	0.383
Coefficient of Variation	0.216
Skewness	0.257
Mean of log data	1.032
SD of log data	0.219
95% Standard Bootstrap UCL	3.27

As - Sediment

Number of Valid Observations	3
Number of Distinct Observations	2
Minimum	2.4
Maximum	2.5
Mean	2.43

State of California
DEPARTMENT OF TRANSPORTATION

California State Transportation Agency

M e m o r a n d u m

Flex your power!
Be energy efficient!

To: MR. PETER AGUILERA
Project Development
Special Project

Date: July 18 2014

Attention: Susana Onate

File: 04-SF-101- PM 9.0
EA 04-1637N1
Efis # 0400020923
Doyle Drive Outfall IJKL

From: CAROLINE CHEN
Transportation Engineer
Office of Geotechnical Design – West
Geotechnical Services
Division of Engineering Services

MAHMOOD MOMENZADEH
Chief, Branch C
Office of Geotechnical Design – West
Geotechnical Services
Division of Engineering Services

Subject: **FOUNDATION RECOMMENDATIONS**

This memorandum provides foundation recommendations for the modification of Doyle Drive Storm Drain Outfall, located at and near Crissy Field, beach area, and extend into San Francisco Bay. The site location is shown on Figure 1.

The beach in the area has been accreting and the outfall has subsequently been covered and blocked with sand, causing flooding of the drainage system upstream along Mason Street. The proposed project will replace approximately 175 feet of the existing 42” outside diameter High Density Polyethylene (HDPE) pipe from the manhole on the beach to the current outfall outlet, and extend the outfall by approximately 291 feet into San Francisco Bay with a 54" outside diameter HDPE pipe for a total project length of 466 feet.

GEOLOGY AND SUBSURFACE CONDITIONS

A Geology Report dated May 30, 2013 was prepared by Matthew Gaffney from Office of Geotechnical Design West for the same project. The following sections depicting regional geology, site geology, faulting and seismicity, and hazardous waste are part of the referenced report.

Regional Geology

The project site is located within the California Coast Ranges geomorphic province. Extensive folding has created a series of northwest trending ranges and valleys. One of which is the San Francisco Bay. San Francisco Bay drains 40% of California via the Sacramento and the San Joaquin Rivers through the Golden Gate to the Pacific Ocean. The San Andreas Fault forms the boundary between the Pacific Plate and the North American Plate, and was formed following the cessation of the subduction of the Farllon Plate. Once the plate was subducted, the San Andreas fault was the new contact and was between the Pacific Plate and the North American Plate. This fault is a right lateral strike slip fault and is part of a larger system including the Hayward, San Gregorio, and Calaveras faults, which accommodate the stresses formed by the migrating plates.

Site Geology

San Francisco is mostly covered by Quaternary deposits with outcrops of the Jurassic Franciscan Complex dotted across the city. This project is underlain by Quaternary alluvium at the west end of the project, and artificial fill and Quaternary beach and dune sand under the remaining line to the bay. (Geology is presented on Figure 2) The soils directly beneath the surface are sands and then clay layers (young bay mud and possible old bay mud at depth).

Faulting and Seismicity

The project site is located within a seismically active region dominated by the northwest trending San Andreas Fault. Several other faults that parallel the San Andreas make up the larger San Andreas Fault system and separate the Pacific Plate on the west from the North American Plate to the east. The San Andreas Fault system can be thought of as a diffuse plate boundary at which strain is spread across a wide region. There are larger, well-known faults within the system that tend to be the most active, however, there are other unnamed faults that are not mapped that may produce moderate earthquakes.

There are numerous active faults within the San Francisco Bay Area that have the potential to produce large earthquakes, such as: the San Andreas (Peninsula), San Andreas (North Coast) and San Gregorio fault (San Gregorio section). The closest of these faults is the San Andreas (Peninsula) Fault, which is within six miles of the project site. The San Andreas Fault is a right-lateral strike-slip fault that dips 90 degrees relative to horizontal. Table 1 presents the seismic data for the closest faults to the project.

Tsunami

According to the Association of Bay Area Governments website the project site is in a “Tsunami Inundation Area.”

Hazardous Waste Potential

This site has been remediated in the past, so to our knowledge there is no hazardous waste in the project limits.

Table 1 Seismic Data

FAULT	Fault No.	Distance (Miles)	Fault Type	Maximum Magnitude (M_{Max})
San Andreas (Peninsula)	134	5.9	Right Lateral Strike Slip	8.0
San Andreas (North Coast)	80	7.2	Right Lateral Strike Slip	8.0
San Gregorio fault (San Gregorio section)	127	8.8	Right Lateral Strike Slip	7.4

SUBSURFACE CONDITIONS

Field investigation was conducted by the Office of Geotechnical Design West in June 2013 and Earth Mechanics, Inc. in July 2013 for the proposed project. A list of the Cone Penetration Tests (CPTs) and rotary wash borings (SPTs) is summarized and presented in Table 2.

Borings RW-13-001 and RW-13-002, and CPTs CPT-13-003 through CPT-13-005 were conducted on the beach. Borings R-13-003 through R-13-006 were conducted off shore. The boring locations are shown on the Log of Test Borings (LOTBs). LOTBs are attached to this report in Appendix A.

Based on these borings, loose to dense sand, sand with silt, and silty sand were encountered up to elevation -35 ft. The underlying soil is consisted of soft to stiff clay interbedded with medium dense to dense sand and silty sand to the exploration depth. Two very dense sand layers were encountered at approximate elevations -30 ft and -60 ft in both Borings R-13-004 and R-13-005. Thickness of each layer ranges from 5 to 10 ft. Presence of dense sand layers is anticipated throughout of the site area.

Groundwater was not measured during drilling. Considering the project starts at beach and extends into San Francisco Bay, the Mean Higher High Water (MHHW) elevation at 5.9 ft should be considered for design and construction purpose. The Mean Lower Low Water (MLLW) elevation at this site is 0.06 ft.

Table 2 Summary of CPTs and SPTs conducted for the project

Boring No.	CPT/Boring Depth (ft)	Top of CPT/Boring Elevation (ft)	Bottom Elevation (ft)
CPT-13-003	25.3	7.5	-17.8
CPT-13-004	101.5	7.3	-94.2
CPT-13-005	33.8	8.3	-25.5
RW-13-001	71.5	8.3	-63.2
RW-13-002	81.5	8.5	-73.0
R-13-003	-2.4	68.4	-70.8
R-13-004	-10.4	76.6	-87.0
R-13-005	-10.3	86.7	-97.0
R-13-006	-2.2	78.8	-81.0

CORROSIVITY

No corrosion test was performed for the proposed project. The site is considered corrosive due to the nature of the site being located at marine environment. But corrosivity of the site is a non-issue for the outfall pipe, piles, and the other plastic components.

SCOUR

There is no hydraulic study available to conclude the scour issue. A scour depth was assumed for the pile design described in the Foundation Recommendation below.

SEISMIC DATA/LIQUEFACTION POTENTIAL

The peak ground acceleration obtained using Caltrans ARS online tool (v2.3.06) is 0.67g. Based on the field investigation mentioned above, the layers of loose to medium dense poorly graded sand/silty sand encountered blow the water table, up to elevation -25.0 ft, poses a moderate to

high liquefaction potential during a strong seismic event.

FOUNDATION RECOMMENDATIONS

SeaPile with section of 13SP8F08 is proposed by structure designer to support the proposed drainage pipe. The proposed piles are 13 inch in diameter, consisted of recycled HDPE reinforced by 8 1-inch diameter fiberglass rebars. They are products of Bedford Technology. Properties of the proposed piles are shown on Table 3. Plans showing layout and longitudinal cross section of the proposed piles, pipe, and the shoring are shown in Figure 3 and 4. These plans were provided to us by District 4 Special Design in December 2013 and June 2014, respectively.

Table 3 Performance Data of the Proposed SeaPile (Manufacturer: Bedford Technology)

Seapile Section	Diameter (inch)	Rebar Quantity	Rebar Size (inch)	Yield Strength (psi)	Modulus of Elasticity (psi)	Stiffness (psi)	Weight (lb/ft)
13 SP 8F08	13	8	1	5170	345000	4.84E+08	43-50

The existing pipe is supported by 13 inch plastic piles. These piles will be driven 6 ft down from current tip elevation -19.25 ft to the new tip elevation at -25.25 ft after the existing pipe and crossties are removed. If some of the piles can not be driven to the specified tip elevations before loads demands are satisfied, they will need to be extracted and re-installed. We recommend including contingency to account for this uncertainty in cost estimate.

Based on the input from consultant Moffatt&Nichol, there is no compression demand on the piles. The tension design load is 500 lb per pile and lateral force 500 lb equal to the entire applied wave force. Pile tip elevation is controlled by lateral demand. Pile tip elevations specified by Moffatt&Nichol ranges from -34.07 to -34.62 ft (See Figure 5). The length of each pile is 35 ft. Calculations by Moffatt&Nichol shows deflection at pile top is 4.1 inch, without taking scour and liquefaction into consideration. We conducted the pile lateral analyses using LPile 5 Plus Program for the same load demand using subsurface soil conditions of boring RW-13-001, which is generally the weakest among boring drilled. The analyses were conducted for the maximum free standing pile length, which corresponds to the lowest existing ground surface. Pile top deflection considering liquefaction of loose to medium dense sand layer is in the order of 1.4 inch. And the pile top deflection considering 5 ft deep scour is in the order of 4.1 inch. Structure designer should evaluate if this amount of pile deflection is acceptable. If the pile deflection is not meeting requirement, use of a stronger class of the Sea Pile is needed since making piles deeper does not reduce the deflection for this case.

PILE DRIVING

Due to environmental concerns, diesel hammer driving system is not allowed.

All piles shall be equipped with a suitable driving shoe to drive the pile in denser soil layers and to reduce the sound pressure caused by pile driving. If other obstructions are encountered during driving, special driving tips or take other measures to prevent damage to the pile during driving should be provided.

Isolation casing of 40 inch inside diameter shall be used for all piles. The casings shall be provided with a suitable base support or a sufficient embedment in the sea floor soils at the discretion of the contractor to be sufficiently stable during the pile driving. The isolation casing shall be equipped with a suitable Air Bubble system. The Air Bubble System shall be turned on during all pile driving operations.

The sound pressure shall not exceed 170 db (Peak) and 160 db (RMS) at 33 ft distance from the pile driven. Only the Peak or RMS value can exceed by 5 db. If sound pressure criteria mentioned above is exceeded due to tidal water effects, the piling shall be conducted during the slack tide.

Contractor may perform a test pile in deeper section of alignment before the actual pile driving to calibrate the driving energy and other hammer setting needed to satisfy the pile installation to the specified pile tip and the sound pressure criteria. The criteria of the sound pressure limits can also be checked during conducting the test pile.

PILE DRIVABILITY STUDY

Pile drivability is analyzed by Caltrans Foundation Testing Branch using software GRLWEAP. Since there is no option available for plastic composite pile in GRLWEAP, timber pile and concrete pile are analyzed to find out the possible bound of driving stress. Two driving system was used in the analyses, hydraulic hammers MHF 5-5 and MHF 5-6. Base on the results, the maximum compressive stress during driving is less than 2.0 ksi. Thus, the proposed piles should be able to be driven to the specified tip elevations without being overstressed. In our opinion, timber pile is a closer simulation of the proposed piles, but is not an accurate match. Contractor is responsible for selecting appropriate driving system and is required to submit related documents. Table 4 presents the parameters used in the drivability analysis.

We recommend Pile Dynamic Analysis (PDA) conducted on one pile between Station 23+50 and 25+00 where dense subsurface layers are more frequent. The test pile will need to have 15 ft extra length to allow PDA assuming water depth is 10 ft. The exact location will be determined by the Engineer and approved by the Office of Geotechnical Design West.

Table 4 Properties used in the drivability analysis

Smith Damping		**Soil Quakes**		**Note**	**Static Elastic Modulus (ksi)**	**Dynamic Elastic Modulus (ksi)**
Shaft (s/ft)	Toe, s/ft	Shaft (inch)	Toe (inch)			
0.2	0.24	0.09	0.61	End of initial driving	490	1125
0.3	0.38	0.1	0.11	Beginning of re-strike		

CONSTRUCTION CONSIDERATIONS

- Dewatering and shoring are anticipated throughout the project limits particularly for the onshore excavation. Shoring may be designed based on the LOTBs prepared for this project and/or subsurface soils data obtained by the contractor by drilling additional boreholes, if needed. Contactor should submit shoring design and plan for our review. The excavation and shoring in general shall conform to Cal-Osha requirements and any other design and safety requirements deemed necessary for a project in marine environments. There are some specific measurements required due to environmental concerns, such as turbidity curtain for the section from station 21+80 to approximate station 23+40, and 48 inch steel casings to be replaced at the pile location during driving for the section from station 23+40 to the end of the pipe. Contractor should consider all these requirements when designing shoring.

- Difficulties with pile driving in marine environments and hard driving in dense sand layer is anticipated.

If you have any questions or need additional information, please contact Caroline Chen at 916-227-5386 or Mahmood Momenzadeh at 510-286-5732.

Attachments:

c: TPokrywka -Email
MMomenzadeh -Email

MMacaranas -Email
APang – Email
Geodog

CChen/MMomenzadeh/mm

Figure 1 Location Map

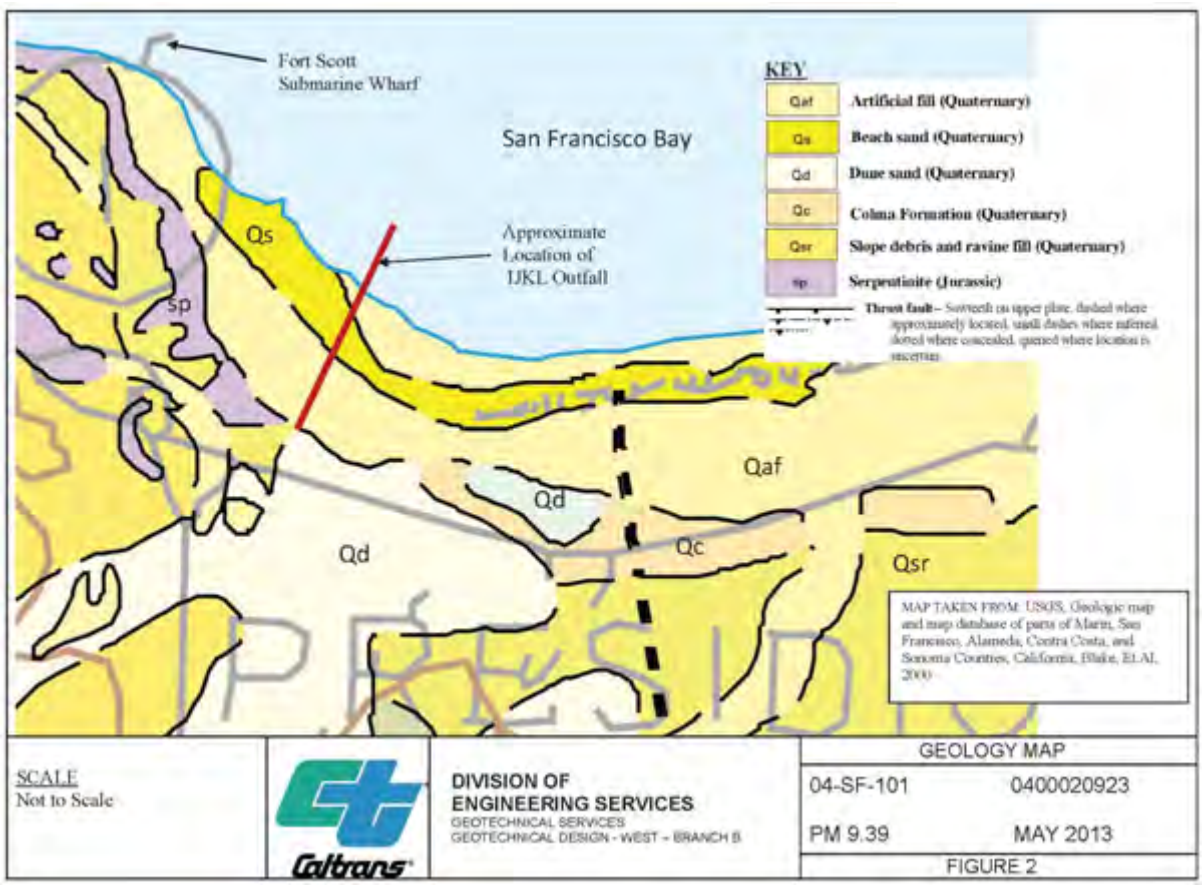

Figure 2 Geology Map

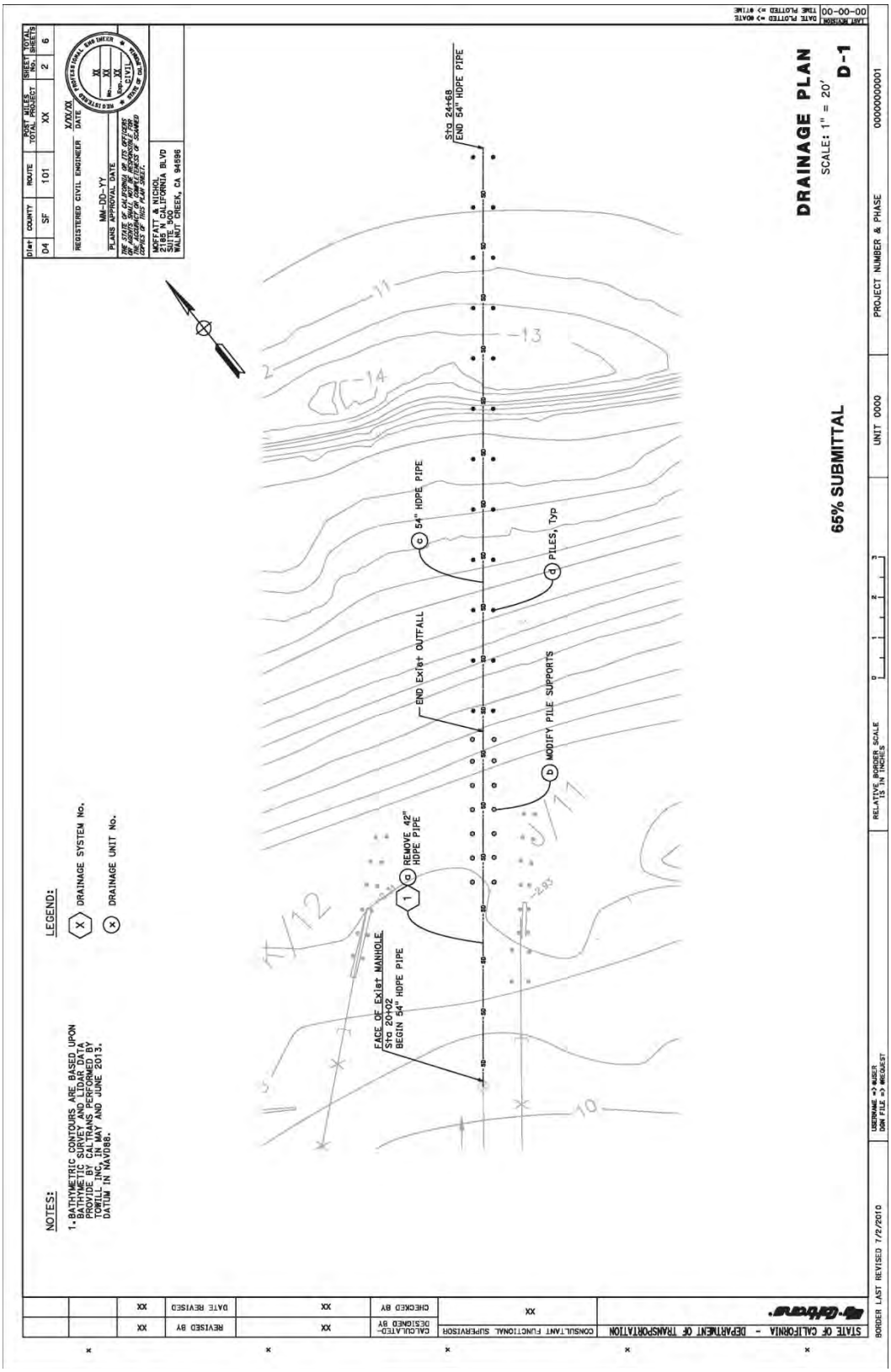

Figure 3 Layout of Drainage Pipe and Piles

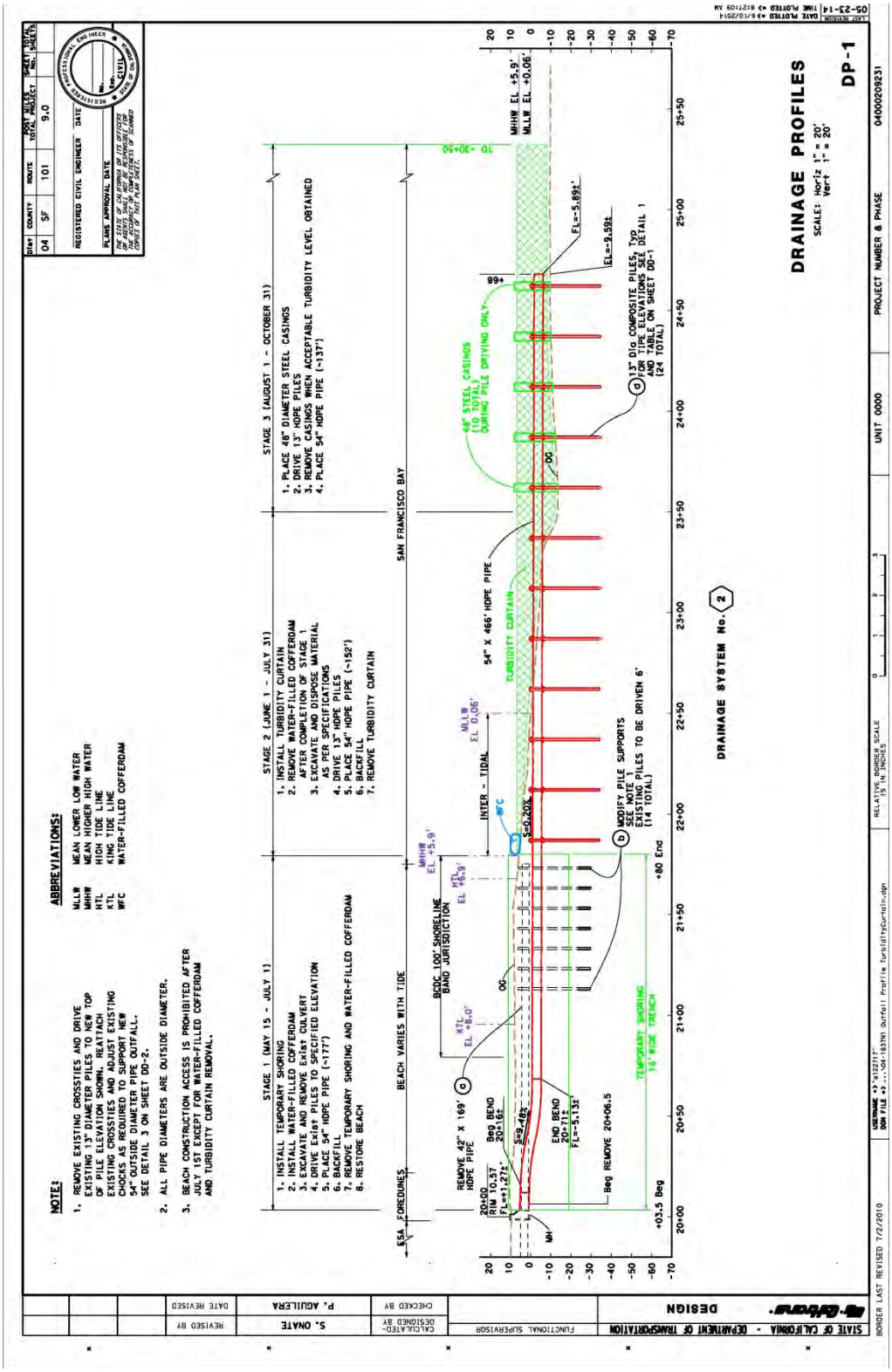

Figure 4 Drainage Profile

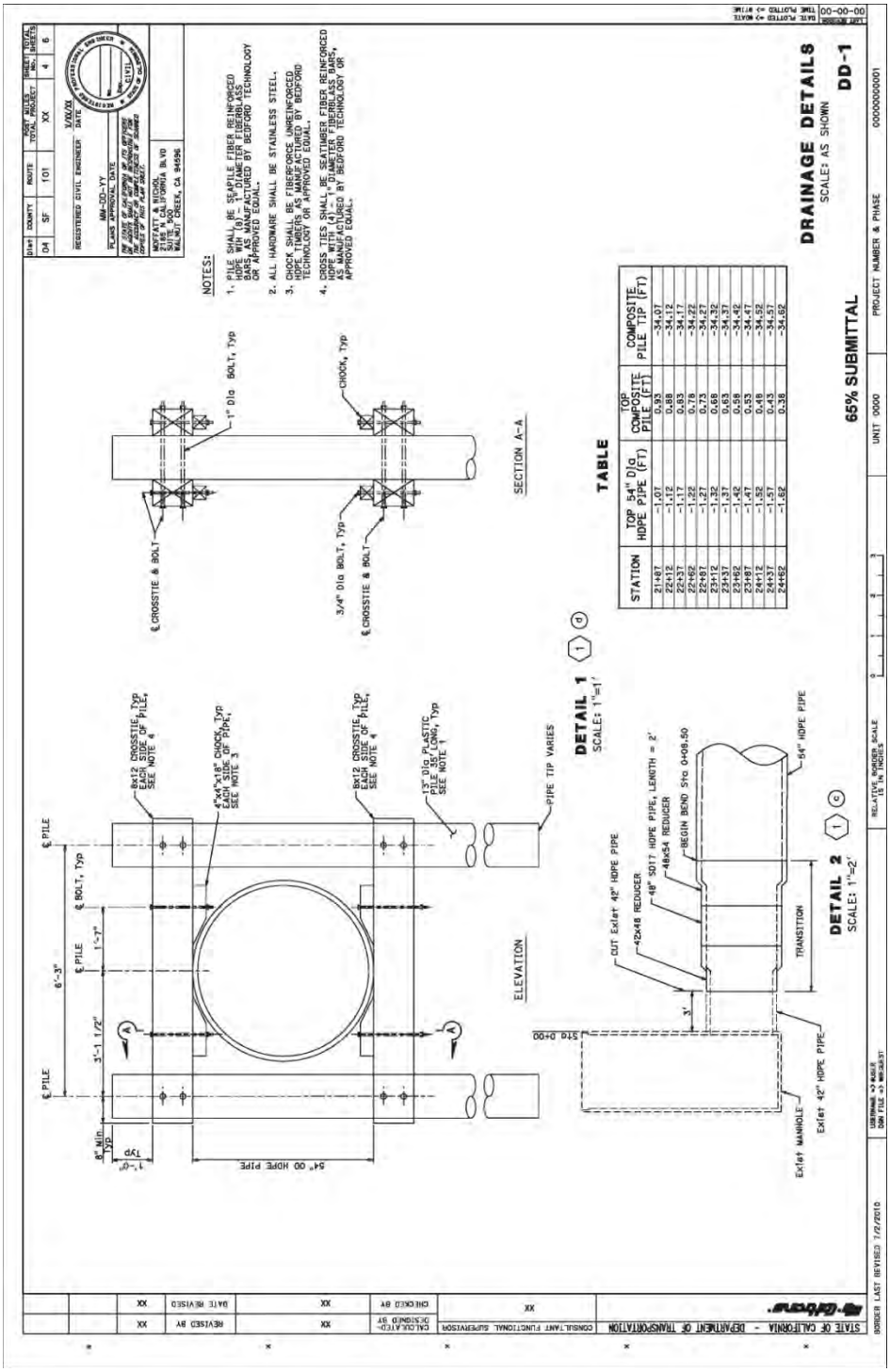

Figure 5 Plans Showing Pile Data