ANTIOCH BRIDGE SEISMIC RETROFIT

INFORMATION HANDOUT

Master CD Index

Contract No. 04-1A5214
04-CC/SAC-160-0.8/1.3,L0.0/L1.3

If you have any questions, please contact:

The Toll Bridge Program Duty Senior
District 04 Office
111 Grand Avenue
Oakland CA 94612
Telephone Number: (510) 286-5209

e-mail address
duty_senior_district04@dot.ca.gov

Master CD Index

File Name	File Size	Description
04-1A5214Info Handout CD Index.pdf	71 KB	**Index of Information Handout**
WATER QUALITY		
04-1A5214IH_CRWQCB Permit.pdf	3.08 MB	**California Regional Water Quality Control Board (CRWQCB)** Water Quality Certification, dated October 26, 2009
PERMITS		
04-1A5214IH_CDFG_1602.pdf	2.55 MB	**State of California Department of Fish and Game(F&G) 1602 Lake and Streambed Alteration Agreement,** Permit No. 1600-2009-0248-3, dated November 19, 2001
04-1A5214IH_CDFG_2081 ITP.pdf	41.62 MB	**State of California Department of Fish and Game(F&G) 2081 Incidental Take Permit** 2081-2009-022-03, dated November 16, 2009
04-1A5214IH_NMFS_Permit.pdf	5.19 MB	**National Marine Fisheries Service (NMFS) Biological Opinion** 151422SWR2009SA00060, dated June 23, 2009
04-1A5214IH_NMFS_Errata.pdf	396 KB	**National Marine Fisheries Service (NMFS),** Errata, dated August 5, 2009
04-1A5214IH_USACE_Permit.pdf	293 KB	**United States Army Corps of Engineer (ACOE),** Permit No. SPK-2008-01340, dated August 20, 2009
04-1A5214IH_USFWS_Permit.pdf	3.93 MB	**United States Fish and Wildlife (USFWS) Biological Opinion** File No. 81420-2008-F-1537-3, dated August 14, 2009
MATERIALS INFORMATION		
04-1A5214IH_FR_Antioch_Founda-tionRpt.pdf	2.48 MB	**Foundation Analysis Report**, dated September 26, 2009 submitted by Earth Mechanics

File Name	File Size	Description
04-1A5214IH_FR_Appendix_A.pdf	6.38 MB	**Foundation Analysis Report Appendix A, Idealized Soil Conditions And Foundation Data,** dated September 26, 2009 submitted by Earth Mechanics
04-1A5214IH_FR_Appendix_B.pdf	371 KB	**Foundation Analysis Report Appendix B, T-Z And Q-U Curves,** dated September 26, 2009 submitted by Earth Mechanics
04-1A5214IH_FR_Appendix_C.pdf	235 KB	**Foundation Analysis Report Appendix C, Q-δ Curves,** dated September 26, 2009 submitted by Earth Mechanics
04-1A5214IH_FR_Appendix_D.pdf	301 KB	**Foundation Analysis Report Appendix D, P-Y Curves,** dated September 26, 2009 submitted by Earth Mechanics
04-1A5214IH_FR_Appendix_E.pdf	4.58 MB	**Foundation Analysis Report Appendix E, Lateral Push-Over Curves,** dated September 26, 2009 submitted by Earth Mechanics
04-1A5214IH_FR_Appendix_F.pdf	54 KB	**Foundation Analysis Report Appendix F, Q-δ Curves At Liquefied State,** dated September 26, 2009 submitted by Earth Mechanics
04-1A5214IH_FR_Appendix_G.pdf	260 KB	**Foundation Analysis Report Appendix G, 6x6 Matrices,** dated September 26, 2009 submitted by Earth Mechanics
04-1A5214IH_FR_Appendix_H.pdf	847 KB	**Foundation Analysis Report Appendix H, Pushover Analysis And Evaluation Pile Group Stiffness,** dated October 23, 2008 submitted by Earth Mechanics
04-1A5214IH_SC_Antioch_SiteCharRpt.pdf	191 KB	**Geotechnical Site Characterization Report,** dated October 2, 2008 submitted by Earth Mechanics
04-1A5214IH_SC_Appendix_A.pdf	978 KB	**Geotechnical Site Characterization Report Appendix A, Logs Of Previous Explorations,** dated October 2, 2008 submitted by Earth Mechanics
04-1A5214IH_SC_Appendix_B.pdf	3.16 MB	**Geotechnical Site Characterization Report Appendix B, Logs Of Test Borings,** dated October 2, 2008 submitted by Earth Mechanics

File Name	File Size	Description
04-1A5214IH_SC_Appendix_C.pdf	4.87 MB	**Geotechnical Site Characterization Report Appendix C, Suspension Logging Results,** dated October 2, 2008 submitted by Earth Mechanics
04-1A5214IH_SC_Appendix_D.pdf	10.84 MB	**Geotechnical Site Characterization Report Appendix D, Cone Penetration Results,** dated October 2, 2008 submitted by Earth Mechanics
04-1A5214IH_SC_Appendix_E1.pdf	5.06 MB	**Geotechnical Site Characterization Report Appendix E1, Geophysical Survey And Bathymetry Map,** dated October 2, 2008 submitted by Earth Mechanics
04-1A5214IH_SC_Appendix_E2.pdf	22.53 MB	**Geotechnical Site Characterization Report Appendix E2, Geophysical Survey And Bathymetry Map,** dated October 2, 2008 submitted by Earth Mechanics
04-1A5214IH_SC_Appendix_F.pdf	20.40 MB	**Geotechnical Site Characterization Report Appendix F, Laboratory Test Results,** dated October 2, 2008 submitted by Earth Mechanics
04-1A5214IH_SC_Appendix_G.pdf	2.96 MB	**Geotechnical Site Characterization Report Appendix G, Site Exploration Photos,** dated October 2, 2008 submitted by Earth Mechanics
04-1A5214IH_SC_Appendix_H.pdf	19.79 MB	**Geotechnical Site Characterization Report Appendix H, Seismicity Report,** dated October 2, 2008 submitted by Earth Mechanics
04-1A5214IH_SC_Appendix_I.pdf	3.24 MB	**Geotechnical Site Characterization Report Appendix I, Antioch Fault Review,** dated October 2, 2008 submitted by Earth Mechanics
04-1A5214IH_SC_Figures.pdf	19.39 MB	**Geotechnical Site Characterization Report, Figures,** dated October 2, 2008 submitted by Earth Mechanics
04-1A5214IH_Site_Investigation.pdf	4.85 MB	**Site Investigation Report, Evaluation Of Mining And Agricultural Contaminants In Surface Soil On Sherman Island Near The Antioch Bridge,** dated August 2009 submitted by Geocon Consultants

File Name	File Size	Description
04-1A5214IH_Soil_Logging_ Manual.pdf	10.70 MB	**Soil and Rock Logging, Classification, and Presentation Manual (June 2007)**
04-1A5214IH_Soil_Logging_ Manual_Errata.pdf	200 KB	**Soil and Rock Logging, Classification, and Presentation Manual (June 2007) Errata (May 2009)**

Linda S. Adams
Secretary for Environmental Protection

California Regional Water Quality Control Board
Central Valley Region
Karl E. Longley, ScD, P.E., Chair

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Arnold Schwarzenegger
Governor

26 October 2009

Mo Pazooki
California Dept. of Transportation (Caltrans) District 4
111 Grand Ave/P.O. Box 23660
Oakland, CA 94623-0660

CLEAN WATER ACT §401 TECHNICALLY CONDITIONED WATER QUALITY CERTIFICATION FOR DISCHARGE OF DREDGED AND/OR FILL MATERIALS FOR THE ANTIOCH BRIDGE SEISMIC RETROFIT PROJECT, (WDID#5B07CR00103) CONTRA COSTA AND SACRAMENTO COUNTIES

WATER QUALITY CERTIFICATION STANDARD CONDITIONS:

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

2. This certification action is not intended and shall not be construed to 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 23 CCR subsection 3855(b) and the application specifically identified that a FERC license or amendment to a FERC license for a hydroelectric facility was being sought.

3. The validity of any non-denial certification action shall be conditioned upon total payment of the full fee required under 23 CCR §3833, unless otherwise stated in writing by the certifying agency.

4. Certification is valid for the duration of the described project. This certification is no longer valid if the project (as described) is modified, or coverage under Section 404 of the Clean Water Act has expired. Caltrans shall notify the Central Valley Water Board in writing within 7 days of project completion.

ADDITIONAL TECHNICALLY CONDITIONED CERTIFICATION CONDITIONS:

In addition to the four standard conditions, Caltrans shall satisfy the following:

1. Caltrans shall notify the Central Valley Water Board in writing 7 days in advance of the start of any in-water activities.

2. Except for activities permitted by the U.S. Army Corps under §404 of the Clean Water Act, soil, silt, or other organic materials shall not be placed where such materials could pass

into surface water or surface water drainage courses.

3. All areas disturbed by project activities shall be protected from washout or erosion.

4. An effective combination of erosion and sediment control Best Management Practices (BMPs) must be implemented and adequately working during all phases of construction.

5. All temporarily affected areas will be restored to pre-construction contours and conditions upon completion of construction activities.

6. Caltrans shall perform surface water sampling: 1) When performing any in-water work; 2) In the event that project activities result in any materials reaching surface waters or; 3) When any activities result in the creation of a visible plume in surface waters. The following monitoring shall be conducted immediately upstream out of the influence of the project and 300 feet downstream of the active work area. Sampling results shall be submitted to this office within two weeks of initiation of sampling and every two weeks thereafter. The sampling frequency may be modified for certain projects with written permission from the Central Valley Water Board.

Parameter	Unit	Type of Sample	Frequency of Sample
Turbidity	NTU	Grab	Every 4 hours during in water work
Settleable Material	ml/l	Grab	Same as above.
Visible construction related pollutants	Observations	Visible Inspections	Continuous throughout the construction period

7. Activities shall not cause turbidity increases in surface water to exceed:

   (a) where natural turbidity is less than 1 Nephelometric Turbidity Units (NTUs), controllable factors shall not cause downstream turbidity to exceed 2 NTU;
   (b) where natural turbidity is between 1 and 5 NTUs, increases shall not exceed 1 NTU;
   (c) where natural turbidity is between 5 and 50 NTUs, increases shall not exceed 20 percent;
   (d) where natural turbidity is between 50 and 100 NTUs, increases shall not exceed 10 NTUs;
   (e) where natural turbidity is greater than 100 NTUs, increases shall not exceed 10 percent.

   Except that these limits will be eased during in-water working periods to allow a turbidity increase of 15 NTU over background turbidity as measured in surface waters 300 feet downstream from the working area. In determining compliance with the above limits, appropriate averaging periods may be applied provided that beneficial uses will be fully protected. Averaging periods may only be assessed by prior permission of the Central Valley Water Board.

8. Activities shall not cause settleable matter to exceed 0.1 ml/l in surface waters as measured in surface waters 300 feet downstream from the project.

9. The discharge of petroleum products or other excavated materials to surface water is prohibited. Activities shall not cause visible oil, grease, or foam in the work area or downstream. Caltrans shall notify the Central Valley Water Board immediately of any spill of petroleum products or other organic or earthen materials.

10. Caltrans shall notify the Central Valley Water Board immediately if the above criteria for turbidity, settleable matter, oil/grease, or foam are exceeded.

11. Caltrans shall comply with all Department of Fish and Game 1600 requirements for the project.

12. Caltrans must obtain coverage under the NPDES General Permit for Storm Water Discharges Associated with Construction Activities issued by the State Water Resources Control Board for any project disturbing an area of 1 acre or greater.

13. Daily visual inspections for waste releases of all vehicles and equipment parked or operating on temporary access roads and staging areas adjacent to state waters must be conducted before the vehicles or equipment begin conducting work for the day. Spillage and leaks must also be noted during any point that they occur during the day. Presence of any spillage from leaks must be noted and contaminated soils must be immediately removed from the area for disposal at a permitted facility.

14. A daily log shall be maintained to note the presence and absence of waste releases from vehicles and equipment and how waste release clean-ups were resolved. Copies of the daily log must be maintained on site for inspection and submitted to this office on a monthly basis. Any major waste releases (greater than 1 gallon) must be reported to Water Board staff within 24 hours with an explanation of how the problem was resolved.

15. Caltrans shall submit copies of its re-establishment monitoring reports for the U.S. Army Corps to Central Valley Water Board staff.

16. The temporary marine trestle that will be placed into the San Joaquin River will be constructed of materials that will be determined by the Caltrans contractor. The materials that will be used to construct the temporary marine trestle must be approved by Central Valley Water Board staff before the trestle is installed in the San Joaquin River.

17. The Conditions in this water quality certification are based on the information in the attached "Project Information." If the information in the attached Project Information is modified or the project changes, this water quality certification is no longer valid until amended by the Central Valley Water Board.

18. In the event of any violation or threatened violation of the conditions of this Order, the violation or threatened violation shall be subject to any remedies, penalties, process, or sanctions as provided for under State law and section 401 (d) of the federal Clean Water Act. The applicability of any State law authorizing remedies, penalties, process, or sanctions for the violation or threatened violation constitutes a limitation necessary to ensure compliance into this Order.

    a. If Caltrans or a duly authorized representative of the project fails or refuses to furnish technical or monitoring reports, as required under this Order, or falsifies any information provided in the monitoring reports, the applicant is subject to civil liability for each day of violation.

b. In response to a suspected violation of any condition of this Order, the Central Valley Water Board may require Caltrans to furnish, under penalty of perjury, any technical or monitoring reports the Central Valley Water Board deems appropriate, provided that the burden, including cost of the reports, shall be in reasonable relationship to the need for the reports and the benefits to be obtained from the reports.

c. Caltrans shall allow the staff(s) of the Central Valley Water Board, or an authorized representative(s), upon the presentation of credentials and other documents, as may be required by law, to enter the project premises for inspection, including taking photographs and securing copies of project-related records, for the purpose of assuring compliance with this certification and determining the ecological success of the project.

REGIONAL WATER QUALITY CONTROL BOARD CONTACT PERSON:

Robert J. Solecki, Environmental Scientist
11020 Sun Center Drive #200
Rancho Cordova, California 95670-6114
rsolecki@waterboards.ca.gov
(916) 464-4684

WATER QUALITY CERTIFICATION:

I hereby issue an order certifying that any discharge from Caltrans, Antioch Bridge Seismic Retrofit Project (WDID#5B07CR00103) will comply with the applicable provisions of §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. This discharge is also regulated under State Water Resources Control Board Water Quality Order No. 2008-0182 DWQ "Statewide General Waste Discharge Requirements For Dredged Or Fill Discharges That Have Received State Water Quality Certification (General WDRs)".

Except insofar as may be modified by any preceding conditions, all certification actions are contingent on (a) the discharge being limited and all proposed mitigation being completed in strict compliance with Caltrans's project description and the attached Project Information Sheet, and (b) compliance with all applicable requirements of the Regional Water Quality Control Board's Water Quality Control Plan (Basin Plan).

for Kenneth Landau
Pamela C. Creedon
Executive Officer

Enclosure: Project Information

cc: See Distribution List (page 10)

PROJECT INFORMATION

Application Date: 7 May 2009

Applicant: Mo Pazooki, Project Manager
California Dept. of Transportation (Caltrans) District 4
111 Grand Ave/P.O. Box 23660
Oakland, CA 94623-0660

Applicant Representatives: Hardeep Takhar, Water Quality Program Manager
California Dept. of Transportation (Caltrans) District 4
111 Grand Ave / P.O. Box 23660
Oakland, CA 94623-0660

Project Name: Antioch Bridge Seismic Retrofit Project

Application Number: WDID#5B07CR00103

U.S. Army Corps File Number: SPK-2008-01340

Type of Project: Bridge maintenance: seismic retrofit

Project Location: Sections 3, 4, 9, 10, 15, 16, Township 2 North, Range 2 East, MDB&M. Latitude: 38°02'41.2" and Longitude: -121°45'5.9" (North boundary)

County: Contra Costa and Sacramento Counties

Receiving Water(s) (hydrologic unit): Unnamed tributary of the San Joaquin River and Mayberry Slough, San Joaquin Hydrologic Basin, San Joaquin Delta Hydrologic Unit #544.00

Water Body Type: Wetlands, Streambed

Designated Beneficial Uses: The Basin Plan for the Central Valley Water Board has designated beneficial uses for surface and ground waters within the region. Beneficial uses that could be impacted by the project include: Municipal and Domestic Water Supply (MUN); Agricultural Supply (AGR); Industrial Supply (IND), Hydropower Generation (POW); Groundwater Recharge, Water Contact Recreation (REC-1); Non-Contact Water Recreation (REC-2); Warm Freshwater Habitat (WARM); Cold Freshwater Habitat (COLD); and Wildlife Habitat (WILD).

Project Description (purpose/goal): This certification is for Antioch Bridge Seismic Retrofit Project Phase 2 of the Sacramento Area Flood Control Agency's (SAFCA's) Natomas Levee Improvement Program (NLIP) Landside Improvement Project. The project description is based on information contained in the following documents:

a) Applications for water quality certification, U.S. Army Corps (Corps) Section 404 Permit, and Department of Fish and Game (DFG) Stream Alteration Agreement.

b) Letter from the Corps to Caltrans authorizing the Antioch Bridge Seismic Retrofit Project to be covered under Section 404 Nationwide Permit #3 (Corps file number: SPK-2008-01340), 20 August 2009.

c) Antioch Bridge Seismic Retrofit Project Draft Initial Study with Proposed Mitigated Negative Declaration (CEQA) and Environmental Assessment (NEPA). May 2009.

d) National Oceanic and Atmospheric Administration (NOAA) National Marine Fisheries Service (NMFS) Biological Opinion for the Antioch Bridge Seismic Retrofit Project, Reference number: 2009/00173, 23 June 2009.

e) U.S. Fish and Wildlife Service (USFWS) Biological Opinion for the Antioch Bridge Seismic Retrofit Project in Contra Costa and Sacramento Counties, California on the Threatened Delta Smelt, the Threatened Giant Garter Snake, and Critical Habitat for the Delta Smelt, Reference number: 81420-2008-F-1537-3, 14 August 2009.

The Antioch Bridge Seismic Retrofit Project involves a seismic safety retrofit to the Antioch Bridge. The seismic retrofit is necessary to meet current design standards. The bridge connects the City of Antioch on the south bank of the San Joaquin River to Sherman Island on the north. It spans the 3600-foot width of the river and over 4000 ft of Sherman Island before touching down just north of Mayberry Slough. The proposed project includes: 1) retrofitting the existing bridge through installation of steel cross bracings between columns, 2) replacement of the existing elastometric bearings with isolation bearings, 3) removal of the existing curtain walls, and 4) retrofitting of all the columns in the slab span structure. As part of this work a temporary marine trestle is proposed to be constructed on the south shore of the San Joaquin River and four temporary access roads are proposed to be constructed (three on Sherman Island and one on the south shore). Two small trestles are proposed to span wetland areas on Sherman Island. No construction staging areas are proposed within waters of the U.S. There will be no permanent impacts to waters of the U.S., but the project will result in a total of 4.501 acres of temporary impacts to waters of the U.S.

A temporary marine trestle with an approximate length of 310 feet and a width of 25 feet will be constructed from the south bank of the San Joaquin River to Pier 8 to allow construction access to the piers in the shallow water area. The temporary trestle will have a temporary impact on 0.011 acre of the San Joaquin River. The trestle platform is expected to be approximately 5 feet above the Mean Higher-High Water (MHHW). Caltrans biologists and engineers worked closely to define the parameters of constructing the temporary marine trestle. These parameters include constructing the trestle using approximately 160 24-inch steel hollow shell piles that will be installed with a vibratory hammer. Caltrans will proof test one pile per day using an impact hammer with an attenuation system. The "proofing" of one pile per day with an impact hammer is a necessary engineering/construction step that is required to ensure that the trestle can handle the load (weight) of equipment. As a result, the contractor will vibrate in the other piles to the appropriate depth, but one pile per bent (section) must be impacted (proofed) in order to confirm structural soundness, in accordance with standard engineering/construction practices. The sound attenuation system that will be placed around the pile during impact driving is a requirement of the DFG Incidental Take Permit, USFWS Biological Opinion, and the NMFS Biological Opinion. The attenuation system reduces the noise impacts on fish that may be in the action area during pile driving. The materials that the temporary marine trestle deck will be constructed of will be determined by the contractor. As indicated in Condition 16 of this certification, the materials that will be used to construct the temporary marine trestle must be approved by Central Valley Water Board staff prior to the trestle's installation in the San Joaquin River. At the completion of the Project, the trestle and the piles will be removed.

Temporary access roads are proposed in four locations. A description of those access roads and their locations is listed below.

Pier 22 to Pier 28: A temporary access road is proposed within the State ROW on Sherman Island to provide access for work to all bridge columns south of Mayberry Slough (Pier 22 to 38). The temporary access road will temporarily fill 2.745 acres of seasonal wetlands. The temporary access road will consist of placing geotextile fabric and a layer of crushed rock (approximately 4 feet in depth) over the existing ground. The temporary access road will be approximately 24 feet wide along the travel surface and will extend, with a 2:1 slope, to ground level. The base of the road will be approximately 40 feet wide at ground level and will extend 3,300 feet. Where the access road crosses the irrigation canal near Pier 32, a 24-ft wide temporary trestle will be installed to span the irrigation canal.

North of Mayberry Slough: Two additional temporary access roads, constructed of a 6-inch layer of crushed rock overlaying geotextile fabric, are proposed north of Mayberry Slough on both the west and east sides of the slab span structure. At the northern end of the bridge, on the west side of the slab span structure, a 24-ft wide temporary trestle will be installed to span an irrigation/drainage ditch. Therefore, there will no impacts to waters of the U.S.

Southern Access: On the south shore of the San Joaquin River, at the south end of the temporary marine trestle, existing access roads and the Caltrans ROW will be utilized to access the trestle. The existing roads will require widening, which will be accomplished using a 6-inch layer of crushed rock overlaying geotextile fabric. An "Environmentally Sensitive Area" fence will be placed along the west side of the access road to avoid impacts to the drainage ditch that borders the right-of-way. Therefore, there will be no impacts to waters of the U.S.

Silt fences will be installed at the base of the temporary access roads to provide sediment control for the roadway, to minimize the potential for inadvertent encroachment of equipment into the surrounding area, and to minimize the potential for wildlife to enter into the roadway. At the completion of the project, the silt fence, geotextile fabric, and crushed rock will be removed and the site will be restored to pre-existing conditions.

Preliminary Water Quality Concerns: Construction activities may impact surface waters with increased turbidity and settleable matter.

Proposed Mitigation to Address Concerns: Caltrans will implement Best Management Practices (BMPs) to control sedimentation and erosion. All temporary affected areas will be restored to pre-construction contours and conditions upon completion of construction activities. Caltrans will conduct turbidity and settleable matter testing during in-water work, stopping work if Basin Plan criteria are exceeded or are observed.

Fill/Excavation Area: The project will result in the temporary fill of 4.501 acres of waters of the U.S. with 22,625 cubic yards of geotextile fabric, crushed rock, and steel.

Dredge Volume: None

U.S. Army Corps of Engineers Permit Number: Nationwide Permit #3

Department of Fish and Game Streambed Alteration Agreement: Caltrans District 4 applied for a Streambed Alteration Agreement on June 2009

Possible Listed Species: Delta smelt, Sacramento winter-run Chinook salmon, Central Valley spring-run Chinook salmon, Central Valley Steelhead, and Southern DPS of the North American green sturgeon.

Status of CEQA Compliance: Caltrans District 4 approved the Mitigated Negative Declaration (CEQA) and Environmental Assessment (NEPA) for the Antioch Bridge Seismic Retrofit Project on 2 September 2009. The Final Mitigated Negative Declaration and Environmental Assessment were received by the State Clearing House (SCH# 2009062022) on 5 October 2009.

Compensatory Mitigation: The National Marine Fisheries Service (NMFS) and U.S. Fish and Wildlife Service (USFWS) issued Biological Opinions for the project. NMFS determined that the project is not likely to jeopardize of endangered Sacramento winter-run Chinook salmon, threatened Central Valley spring-run Chinook salmon, threatened Central Valley Steelhead, and threatened Southern DPS of the North American green sturgeon, and is not likely to destroy or adversely modify designated or proposed critical habitat for these species. NMFS anticipates incidental take of Central Valley steelhead and the Southern DPS of North American green sturgeon from project impacts directly related to pile driving and pile removal activities. Caltrans is required to follow the reasonable and prudent measures of the biological opinion and comply with the terms and conditions which implement the recommended measures. The reasonable and prudent measures of the biological opinion are:

1) Real time monitoring shall be conducted to ensure that underwater sound levels analyzed in the biological opinion are not exceeded.

2) Measures shall be taken to maintain, monitor, and adaptively manage all conservation measures in the biological opinion throughout the life of the project.

The USFWS biological opinion determined that the proposed project is not likely to jeopardize the continued existence of the delta smelt, or result in the destruction or adverse modification of its critical habitat, and it is not likely to jeopardize the continued existence of the giant garter snake. However, the USFWS anticipates take of delta smelt and giant garter snake from pile driving and pile removal activities. Caltrans is required to follow the reasonable and prudent measures of the biological opinion and comply with the terms and conditions which implement the recommended measures. The reasonable and prudent measures of the biological opinion are:

1) Caltrans shall implement the conservation measures in the project description as described in the January 2009, Biological Assessment and the biological opinion.

2) Caltrans shall minimize the adverse effects to the delta smelt and giant garter snake. Take in the form of harassment, harm, or mortality of delta smelt and harassment and/or harm of the giant garter snake during construction activities and associated with implementing the project shall be minimized.

3) Caltrans shall ensure their compliance with the biological opinion.

The Corps 404 Nationwide Permit for the project contains 15 special conditions that Caltrans must comply with. The following two special conditions apply to the compensatory mitigation requirements for the project:

1) To mitigate for the temporary loss of 4.501 acres of waters of the U.S. and abutting wetlands, Caltrans shall restore the 4.501 acres of waters of the U.S., including wetlands, back to their pre-existing condition. Upon completion of construction, Caltrans shall return the disturbed areas back to their preconstruction elevation and grade. The temporarily affected areas shall be re-vegetated according to the document entitled *Antioch Bridge Seismic Retrofit Project NWP PCN Package*, dated April 2009.

2) To ensure mitigation success, Caltrans shall monitor the on-site re-establishment areas for one year. This period shall commence upon completion of the authorized fill activity, but not later than one year after the initiation of fill activity. Caltrans shall submit a monitoring report to this office at the end of the first-year monitoring period.

Application Fee Provided: Total fees of $13,664.00 have been submitted as required by 23 CCR §3833b(3)(A) and by 23 CCR §2200(e).

DISTRIBUTION LIST

U.S. Army Corp of Engineers
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Regulatory Section, Room 1480
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Sacramento, CA 95814-2922

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NAPA CALIFORNIA 94558

October 15, 2009

Notification Number: 1600-2009-0248-3

Jeffrey Jensen
California Department of Transportation, District 4
111 Grand Avenue
Oakland, CA 94623

1602 LAKE AND STREAMBED ALTERATION AGREEMENT

This agreement is issued by the Department of Fish and Game pursuant to Division 2, Chapter 6 of the California Fish and Game Code:

WHEREAS, the Applicant Jeffrey Jensen/California Department of Transportation (Caltrans) submitted a signed NOTIFICATION proposing to substantially divert or obstruct the natural flow of, or substantially change the bed, channel, or bank of, or use material from the streambed or lake of the following water: San Joaquin River, located in Contra Costa and Sacramento counties, State of California; and

WHEREAS, the Department has determined that such operations may substantially adversely affect existing fish and wildlife resources including water quality, hydrology, aquatic or terrestrial plant or animal species; and

WHEREAS, the project has undergone the appropriate review under the California Environmental Quality Act; and

WHEREAS, the Applicant shall undertake the project as proposed in the signed PROJECT DESCRIPTION and PROJECT CONDITIONS (attached). If the Applicant changes the project from that described in the PROJECT DESCRIPTION and does not include the PROJECT CONDITIONS, this agreement is no longer valid; and

WHEREAS, the agreement shall expire on December 31, 2013; with the work to occur between August 1 and October 31; and

WHEREAS, nothing in this agreement authorizes the Applicant to trespass on any land or property, nor does it relieve the Applicant of the responsibility for compliance with applicable Federal, State, or local laws or ordinances. Placement, or removal, of any material below the level of ordinary high water may come under the jurisdiction of the U. S. Army Corps of Engineers pursuant to Section 404 of the Clean Water Act;

THEREFORE, the Applicant may proceed with the project as described in the PROJECT DESCRIPTION and PROJECT CONDITIONS. A copy of this agreement, with attached PROJECT DESCRIPTION and PROJECT CONDITIONS, shall be provided to contractors and subcontractors and shall be in their possession at the work site.

Failure to comply with all conditions of this agreement may result in legal action.

This agreement is approved by:

Cindy Catalano

Charles Armor
Regional Manager
Bay Delta Region

cc: Melissa Escaron
Warden Jacobsen
Lieutenant Christensen
Warden Mills
Lieutenant Mason

California Natural Resources Agency
DEPARTMENT OF FISH AND GAME
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YOUNTVILLE, CALIFORNIA 94599
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7329 SILVERADO TRAIL
NAPA, CALIFORNIA 94558

Fish & Game
OCT 14 2009
Yountville

Notification Number: 1600-2009-0248-3
San Joaquin River, Contra Costa and Sacramento Counties

Mr. Jeffrey Jensen
Caltrans District 4
111 Grand Ave.
Oakland, Ca
94623

PROJECT DESCRIPTION and PROJECT CONDITIONS

Description

The California Department of Transportation (Caltrans) proposes to seismically retrofit the Antioch Bridge (Project). The Project site is located on State Route (SR) 160 and spans approximately 2 miles from Post Mile (PM) .8 in Contra Costa county to PM 1.3 in Sacramento county. The bridge connects the City of Antioch on the south bank of the San Joaquin River to Sherman Island on the north, touching down just north of Mayberry Slough. The California Department of Fish and Game (Department) is issuing this Streambed Alteration Agreement #1600-2009-0248-3, for the project described herein.

Built in 1978, the bridge is 9,437 feet (ft) long, accommodates one lane of traffic in either direction, and includes narrow accommodation for bicyclists and pedestrians. The bridge features two structural elements: the main structure and the slab span structure. The main structure spans the south shore of the San Joaquin River, the San Joaquin River, and part of Sherman Island. The slab structure starts just north of Mayberry Slough and extends to the northern bridge abutment. The main structure is 8,650 ft long and consists of the roadway superstructure supported on 41 bridge piers with the distance between columns varying in length from 135 to 460 ft. The slab span structure is 787 ft long and is comprised of the roadway deck supported on 30 bents with four circular columns each. The entire slab structure is enclosed within concrete slab walls.

Proposed retrofit elements:

• Installation of steel cross bracing between columns to stiffen the superstructure cross frames (Pier 12 to Pier 31).

• Installation of bracing to existing cross frames at the pier caps (Pier 2 to Pier 40).

• Replacement of the existing elastometric bearings with isolation bearings (Abutment 1 to

Pier 41).

• Removal of the existing curtain walls and retrofit of all the columns within the slab span structure by installing composite fiber jackets (Bent 42 to Abutment 71).

Temporary Access and Staging:

• A temporary access road is proposed within state right-of-way (ROW) to provide access for work to all bridge columns south of Mayberry Slough (Pier 22 to Pier 38) on Sherman Island. The temporary access road will consist of placing geotextile fabric and a crushed rock layer, approximately 4 ft deep, over the existing ground. The temporary access road will be approximately 24 ft wide along the travel surface and will extend with 2:1 slopes to existing ground level. The base of the road will be approximately 40 ft wide at ground level and will extend 3,300 ft, covering an estimated 4.45 acres (ac). The temporary access road will stop at Mayberry Slough.

• Two additional temporary access roads, constructed of a 6 inch (in) layer of crushed rock overlaying geotextile fabric, are proposed north of Mayberry Slough on both the west and east sides of the slab span structure. The access road on the west side will occupy 0.6 ac and will measure 850 ft long by 36 ft wide. The access on the east side of the span will occupy 0.4 ac and will measure 850 ft long by 20 ft wide.

• Where the access road crosses the irrigation canal near Pier 32, a 24 ft wide temporary trestle will be installed to span the irrigation canal. The temporary trestle will prevent additional load on the existing culvert and will avoid the need for fill.

• At the northern end of the bridge, a 24 ft wide temporary trestle will be installed to the west to span an irrigation/drainage ditch. The temporary trestle will minimize disturbance to the existing irrigation ditch and wetland area.

• On the south shore of the San Joaquin River at the south end of the temporary marine trestle, existing access roads and the Caltrans ROW will be used to access the trestle. The existing road will require a widening from 9 ft to 24 ft along 650 ft, and a 24 ft wide extension along another 250 ft. This will be accomplished using a 6 in layer of crushed rock overlaying geotextile fabric. The total expanded/extended area will be 0.364 ac.

• A temporary staging and laydown area has been identified north of Mayberry Slough in a fallow upland field dominated by ruderal species. The staging area covers approximately 6 ac outside State ROW on the east side of the bridge. The area will be covered by a layer of crushed rock overlying geotextile fabric, approximately 6 in thick, for drivability. Silt fence, fiber rolls, and/or small earthen berms will be installed along the north and east side of the staging area to direct runoff away from the wetlands to the north and east.

• Two temporary contractor staging areas have been identified between bridge piers. One, located between Piers 29 and 30, will occupy approximately 0.17 ac and will measure 115 ft long by 65 ft wide. The other, on Sherman Island between Pier 31 and the permanently extended

access road, will occupy approximately 0.12 ac and will measure 81 ft long by 65 ft wide. These temporary staging areas will consist of placing geotextile fabric and a crushed rock layer, approximately 4 ft deep over the existing ground.

• On the south end of the bridge, the contractor will use existing paved areas for staging.

• The unpaved access road extending from the old Highway 84 to the staging area north of Mayberry Slough is currently 18 to 20 ft wide. This access road needs to be permanently widened to 24 ft over a distance of approximately 1,200 ft to accommodate large construction equipment and trucks. Widening of this access road will require minor grading of the approximately 0.218 ac area to be widened and placing 6 in of crushed rocks over the adjacent ground. The areas adjacent to this road currently consist of ruderal upland vegetation.

• All construction zones, access routes and staging areas will be delineated with high-visibility ESA fencing at a minimum, and sites that have potential for erosion will have silt fencing installed in addition to the ESA fencing. At completion of the Project, all ESA fence, silt fence, geotextile fabric, and crushed rock will be removed and the sites will be restored to their pre-construction conditions.

• A temporary marine trestle, approximately 310 ft long and 25 ft wide, will be constructed from the south bank of San Joaquin River to Pier 8 to allow construction access to the piers in the shallow water area. The trestle platform is expected to be approximately 5 feet above the Mean Higher High Water. The trestle will be constructed using approximately sixty 24 in steel hollow shell piles and will be installed with a vibratory hammer. Caltrans will proof test one pile per day using an impact hammer to confirm load bearing capacity. Sound attenuation will be used on the piles that are driven/proof tested with an impact hammer. At the completion of the Project, the trestle along with the piles will be removed.

• Barges will be used to retrofit Piers 9 to 21, and no aquatic impacts are anticipated beyond the potential installation of mooring lines.

• This Project will not require onsite borrow or disposal of excavated material. Gravel and rock will be imported for construction of the temporary access road and road widening. These materials will be removed upon completion of the Project.

Conditions

1. All in-water pile installation work shall be confined to the period of August 1 to October 31.

2. Caltrans shall submit for approval a plan for bird exclusion from the Antioch Bridge by December 31, 2009.

3. Caltrans shall submit for approval, a mitigation and monitoring plan for impacts to Mason's lilaeopsis and marsh aster at least 5 months prior to the installation of the marine trestle.

4. Caltrans shall purchase mitigation credits at a Department-approved site or preserve in perpetuity 3.1 acres of giant garter snake habitat within 18 months of start of construction.

5. Caltrans shall purchase mitigation credits at a Department-approved site or preserve in perpetuity 3.27 acres of delta smelt habitat within 18 months of start of construction.

6. At least 30 days before initiating in-water, ground- or vegetation-disturbing activities, Caltrans shall submit to the Department in writing the name, qualifications, business address, and contact information for a biological monitor (Designated Biologist).

7. The Designated Biologist shall have authority, through the Caltrans engineer, to immediately stop any activity to avoid the take of giant garter snake.

8. Caltrans shall initiate a trash abatement program during pre construction phases of the Project and continue the program throughout the duration of the Project. Trash and food items shall be contained in closed (raven proof) containers and removed regularly (at least once a week) to avoid attracting opportunistic predators such as ravens, coyotes, and feral dogs.

9. Caltrans shall implement dust control measures during Project activities to facilitate visibility for monitoring of the giant garter snake by the Designated Biologist.

10. Caltrans shall prohibit firearms and domestic dogs from the Project site and site access routes during construction of the Project, except those in the possession of authorized security personnel or local, State, or Federal law enforcement officials.

11. Caltrans shall clearly delineate potential habitat of the giant garter snake within the Project limits with high visibility Environmentally Sensitive Area (ESA) fencing to minimize the disturbance of habitat. ESA fencing shall be erected as directed by the designated biologist, 200 feet from the edge of potential aquatic habitat for the giant garter snake.

12. Signs identifying the ESAs to construction personnel shall be posted and maintained every 50 feet along the edge of the ESAs within 200 feet of giant garter snake aquatic habitat.

13. Project-related personnel shall access the Project site during construction and development activities using existing routes and shall not cross giant garter snake habitat outside of the Project site. Project-related vehicle traffic shall be restricted to established roads, staging, and parking areas. Vehicle speeds shall not exceed 20 miles per hour, except on county roads and state and federal highways, in order to avoid giant garter snake on or traversing the roads.

14. Caltrans shall confine all Project-related parking, storage areas, laydown sites, equipment storage, and any other surface-disturbing activities to the Project site using, to the extent possible, previously disturbed areas. Additionally, Caltrans shall not use or cross giant garter snake habitat outside of the marked Project boundaries.

15. Caltrans shall immediately stop/repair and clean up any fuel or hazardous waste leaks or spills on the Project site during construction and development activities at the time of occurrence. Caltrans shall exclude the storage and handling of hazardous materials from the construction zone and shall properly contain and dispose of any unused or leftover hazardous products off-site.

16. Use of erosion control materials potentially harmful to giant garter snake such as monofilament netting (used in erosion control matting or fiber rolls) or similar material shall not be used.

17. Upon Project completion, Caltrans shall remove from the Project site and properly dispose of all construction refuse, including, but not limited to, broken equipment parts, wrapping material, cords, cables, wire, rope, strapping, twine, buckets, metal or plastic containers, and boxes.

18. Trestle piles shall be installed with a vibratory pile driver. Maximum pile diameter shall be 24 inches.

19. Proofing of piles with an impact hammer shall be limited to one pile per day during the installation of the marine trestle.

20. Caltrans shall use a sound attenuation system during impact pile installation activities. The attenuation system may include but is not limited to one or more, or a combination of the following:
a. A confined bubble curtain
b. An unconfined bubble curtain
c. Isolation casings
d. Wooden pile cushions

21. It is anticipated sound pressure levels (SPLs) may reach 206 decibel (peak) and 183 decibel SEL (sound exposure level), within a 30 foot radius of each pile during installation with an impact hammer. Approximately 1.09 acres is the area surrounding the piles where these levels and potential take of delta smelt may occur. Caltrans shall conduct real time hydroacoustic monitoring during all trestle pile installation activities to measure efficacy of the sound attenuation system and to determine if the anticipated SPLs and associated distances from piles differ from the actual measurements. Should the hydroacoustic monitoring show the sound attenuation system is not sufficiently attenuating sound at, or below, the peak decibel level, Caltrans shall halt pile driving until the sound attenuation system is repaired or augmented to ensure peak levels are not exceeded. Should the hydroacoustic monitoring show that SPL values are exceeding, or have exceeded, the above levels and/or that the actual area of potential take extends beyond the anticipated 30-foot radius, then Caltrans shall either take measures to increase the effectiveness of the sound attenuation system, or obtain an ITP amendment from the Department.

22. If at any point turbidity levels exceed the acceptable criteria established by the Regional

Water Quality Control Board and permitted by the Storm Water Pollution Prevention Plan, construction activities shall halt until turbidity levels return to acceptable levels.

23. All vegetation- or ground-disturbing activities within giant garter snake habitat on Sherman Island will be conducted between May 1 and October 1 of any year. Once temporary access roads are in place, no further ground disturbing activity will take place.

24. If a giant garter snake is found on the Project site, the Designated Biologist shall be notified immediately. Giant garter snakes encountered in active construction areas shall be allowed to leave on their own volition. Caltrans shall immediately notify the Department of the incident, or no later than noon on the next business day if the incident occurs outside of normal business hours. Notification to the Department shall be via telephone or email, followed by a written incident report. Notification shall include the date, time, location and circumstances of the incident.

25. If a giant garter snake is injured as a result of Project-related activities, it shall be immediately taken to a Department-approved wildlife rehabilitation or veterinary facility. Caltrans shall identify the facility prior to the start of ground- or vegetation-disturbing activities. Caltrans shall bear any costs associated with the care or treatment of such injured giant garter snake. Caltrans shall notify the Department immediately unless the incident occurs outside of normal business hours. In that event the Department shall be notified no later than noon on the next business day. Notification to the Department shall be via telephone or email, followed by a written incident report. Notification shall include the date, time, location and circumstances of the incident, and the name of the facility where the animal was taken.

26. If a giant garter snake is killed by Project-related activities during construction, or if a giant garter snake is otherwise found dead, the Designated Biologist shall immediately notify the Department Regional Office at (707)339-0334 or (707) 944-5517 and provide information on the location, species, number of animals injured or killed. Following the initial notification, Caltrans shall send the Department a written report within two (2) calendar days. The report will include the date, time and location of the finding or incident, location of the carcass, and if possible provide a photograph, cause of death, and any other pertinent information

27. The Designated Biologist shall monitor for and clear the area of giant garter snakes during the installation of the ESA and silt fencing.

28. SWPPP measures shall be inspected and maintained to minimize sediment transport into sensitive habitat areas during construction. Caltrans shall provide a copy of the SWPPP to the Department upon request.

29. If earthwork, clearing and grubbing, or vegetation trimming is scheduled during bird nesting season, February 15 through August 15, pre-construction surveys shall be conducted by a qualified biologist for active bird nests. The surveys shall take place within 3 days prior to the commencement of work. If nesting birds are found a 50-foot radius buffer should be established around the nest, a 250-foot radius buffer in the case of raptors. If a lapse in project-related work

of 5 days or longer occurs, another survey will be required before project work can be reinitiated.

30. Department personnel or its agents may inspect the work site at any time.

To the extent that any provisions of this Agreement provide for activities that require the Caltrans to traverse another owner's property, such provisions are agreed to with the understanding that Caltrans possesses the legal right to so traverse. In the absence of such right, any such provision is void.

In the event that the project scope, nature, or environmental impact is altered by the imposition of subsequent permit conditions by any local, state or federal regulatory authority, Caltrans shall notify the Department of any imposed project modifications that interfere with compliance to Department conditions.

If Caltrans needs more time to complete the authorized activity, the work period may be extended on a day-to-day basis by Melissa Escaron at (707) 339-0334 or the Yountville office at (707) 944-5520.

A copy of this agreement must be provided to the contractor and all subcontractors who work within the stream zone and must be in their possession at the work site.

Caltrans is liable for compliance with the terms of this Agreement, including violations committed by the contractors and/or subcontractors. The Department reserves the right to suspend construction activity described in this Agreement if the Department determines any of the following has occurred:

A). Failure to comply with any of the conditions of this Agreement

B). Information provided in support of the Agreement is determined by the Department to be inaccurate.

C). Information becomes available to the Department that was not known when preparing the original conditions of this Agreement (including, but not limited to, the occurrence of State or federally listed species in the area or risk to resources not previously observed)

D).The project as described in the Agreement has changed or conditions affecting fish and wildlife resources change.

Any violation of the terms of this Agreement may result in the project being stopped, a citation being issued, or charges being filed with the District Attorney. Contractors and subcontractors may also be liable for violating the conditions of this agreement.

Amendments and Extensions

Caltrans shall notify the Department before any modifications are made in the project plans submitted to the Department. Project modifications may require an amendment or a new notification.

This Agreement is transferable to subsequent owners of the project property by requesting an amendment.

To extend the Agreement beyond the expiration date, a written request or completed "Request to Extend Lake or Streambed Alteration Agreement" form, with an appropriate fee, must be submitted to the Department (1600 Program, Post Office Box 47, Yountville, California 94599) for consideration at least 30 days before the Agreement expiration date. An extension requires a fee. The Fee Schedule and Extension form can be obtained at www.dfg.ca.gov/habcon/1600/Forms.html or by phone at (707) 944-5520. Extensions of the original Agreement are issued at the discretion of the Department.

To modify the project, a written request for an amendment or a completed "Request to Amend Lake or Streambed Alteration Agreement" form, with an appropriate fee, must be submitted to the Department (1600 Program, Post Office Box 47, Yountville, California 94599). An amendment requires a fee. The Fee Schedule and Amendment form can be obtained at www.dfg.ca.gov/habcon/1600/Forms.html or by phone at (707) 944-5520. Amendments to the original Agreement are issued at the discretion of the Department.

Please note that you may not proceed with construction until your proposed project has undergone CEQA review and the Department signs the Agreement.

I, the undersigned, state that the above is the final description of the project I am submitting to the Department for CEQA review, leading to an Agreement, and agree to implement the conditions above required by the Department as part of that project. I will not proceed with this project until the Department signs the Agreement. I also understand that the CEQA review may result in the addition of measures to the project to avoid, minimize, or compensate for significant environmental impacts:

Applicant's name (print): Amy Sparks for Jeffrey G. Jensen

Applicant's signature: Amy L. Sparks

Signed the 13th **day of** October **, 2009**

FOR DEPARTMENT USE ONLY				
Date Received	Amount Received	Amount Due	Date Complete	Notification No.
6/26/09	$4,000.00	$		1600-2009-0248-3

CK# 082-317818
CA Dept of Transportation

Escaron
Jacobsen
Christensen
Mills
Mason

STATE OF CALIFORNIA
DEPARTMENT OF FISH AND GAME

NOTIFICATION OF LAKE OR STREAMBED ALTERATION

Complete EACH field, unless otherwise indicated, following the enclosed instructions and submit ALL required enclosures. Attach additional pages, if necessary.

Fish & Game
JUN 26 2009
Yountville

1. APPLICANT PROPOSING PROJECT

Name	Jeffrey Jensen		
Business/Agency	Caltrans, District 4		
Street Address	111 Grand Avenue		
City, State, Zip	Oakland, CA 94612		
Telephone	(510) 622-8729	Fax	(510) 286-6301
Email	jeffrey_jensen@dot.ca.gov		

2. CONTACT PERSON (*Complete only if different from applicant*)

Name	Chris States		
Street Address	111 Grand Avenue		
City, State, Zip	Oakland, CA 94612		
Telephone	(510) 286-7185	Fax	(510) 286-6301
Email	christopher_states@dot.ca.gov		

3. PROPERTY OWNER (*Complete only if different from applicant*)

Name	Department of Water Resources (for areas outside of Caltrans Right-of-Way)		
Street Address	1416 Ninth Street, Room 425		
City, State, Zip	Sacramento, CA 95814		
Telephone	(916) 653-5620	Fax	
Email	jmercado@water.ca.gov (Juan Mercado, Senior Land Agent)		

4. PROJECT NAME AND AGREEMENT TERM

A. Project Name	Antioch Bridge Seismic Retrofit Project (EA 1A5210)
B. Agreement Term Requested	☑ Regular (*5 years or less*) ☐ Long-term (*greater than 5 years*)

C. Project Term		D. Seasonal Work Period		E. Number of Work Days
Beginning (*year*)	Ending (*year*)	Start Date (*month/day*)	End Date (*month/day*)	
2010	2015	04/15	10/15	614.00

5. AGREEMENT TYPE

Check the applicable box. If box B, C, D, or E is checked, complete the specified attachment.

A.	☑ Standard *(Most construction projects, excluding the categories listed below)*	
B.	☐ Gravel/Sand/Rock Extraction (*Attachment A*)	*Mine I.D. Number:* _____
C.	☐ Timber Harvesting (*Attachment B*)	THP *Number:* _____
D.	☐ Water Diversion/Extraction/Impoundment (*Attachment C*)	*SWRCB Number:* _____
E.	☐ Routine Maintenance (*Attachment D*)	
F.	☐ DFG Fisheries Restoration Grant Program (FRGP)	*FRGP Contract Number:* _____
G.	☐ Master	
H.	☐ Master Timber Harvesting	

6. FEES

Please see the current fee schedule to determine the appropriate notification fee. Itemize each project's estimated cost and corresponding fee. ***Note: The Department may not process this notification until the correct fee has been received.***

	A. Project	B. Project Cost	C. Project Fee
1	Antioch Bridge Seismic Retrofit Project	$279,000,000.00	$4,000.00
2			
3			
4			
5			
		D. Base Fee *(if applicable)*	
		E. TOTAL FEE ENCLOSED	$4,000.00

7. PRIOR NOTIFICATION OR ORDER

A. Has a notification previously been submitted to, or a Lake or Streambed Alteration Agreement previously been issued by, the Department for the project described in this notification?

☐ Yes (*Provide the information below*) ☑ No

Applicant: _____ Notification Number: _____ Date: _____

B. Is this notification being submitted in response to an order, notice, or other directive ("order") by a court or administrative agency (including the Department)?

☑ No ☐ Yes (*Enclose a copy of the order, notice, or other directive. If the directive is not in writing, identify the person who directed the applicant to submit this notification and the agency he or she represents, and describe the circumstances relating to the order.*)

☐ *Continued on additional page(s)*

8. PROJECT LOCATION

A. Address or description of project location.

(Include a map that marks the location of the project with a reference to the nearest city or town, and provide driving directions from a major road or highway)

The Antioch Bridge Seismic Retrofit Project (Project) spans roughly two miles of State Route (SR) 160, from the southern limit of the Project at post mile (PM) 0.8 in Contra Costa County to PM 1.3 at the Contra Costa/Sacramento County line, and from PM 0 to PM 1.3 in Sacramento County to the north, on Sherman Island. The bridge connects the City of Antioch on the south bank of the San Joaquin River to Sherman Island on the north. It spans the 3,600-ft width of the river and over 4,000-ft of Sherman Island, before touching down just north of Mayberry Slough. Vicinity and locality maps are included in Chapter 1 of the supplemental package.

☑ *Continued on additional page(s)*

B. River, stream, or lake affected by the project.	San Joaquin River
C. What water body is the river, stream, or lake tributary to?	San Francisco Bay
D. Is the river or stream segment affected by the project listed in the state or federal Wild and Scenic Rivers Acts?	☐ Yes ☑ No ☐ Unknown
E. County	Contra Costa and Sacramento

F. USGS 7.5 Minute Quad Map Name	G. Township	H. Range	I. Section	J. ¼ Section
Antioch North	2N	2E	4, 9, 16	
Jersey Island	2N	2E	3, 10, 15	

☐ *Continued on additional page(s)*

K. Meridian (*check one*) ☐ Humboldt ☑ Mt. Diablo ☐ San Bernardino

L. Assessor's Parcel Number(s)

15800700330000, 15800700290000, 15800900140000, 15800900150000

☐ *Continued on additional page(s)*

M. Coordinates (*If available, provide at least latitude/longitude or UTM coordinates and check appropriate boxes*)

Latitude/Longitude	*Latitude:* 38.0167-38.044 N		*Longitude:* 121.751-121.752 W	
	☐ Degrees/Minutes/Seconds	☑ Decimal Degrees	☐ Decimal Minutes	
UTM	*Easting:*	*Northing:*	☐ Zone 10	☐ Zone 11
Datum used for Latitude/Longitude or UTM	☐ NAD 27	☑ NAD 83 or WGS 84		

9. PROJECT CATEGORY AND WORK TYPE *(Check each box that applies)*

PROJECT CATEGORY	NEW CONSTRUCTION	REPLACE EXISTING STRUCTURE	REPAIR/MAINTAIN EXISTING STRUCTURE
Bank stabilization – bioengineering/recontouring	☐	☐	☐
Bank stabilization – rip-rap/retaining wall/gabion	☐	☐	☐
Boat dock/pier	☐	☐	☐
Boat ramp	☐	☐	☐
Bridge	☐	☐	☑
Channel clearing/vegetation management	☐	☐	☐
Culvert	☐	☐	☐
Debris basin	☐	☐	☐
Dam	☐	☐	☐
Diversion structure – weir or pump intake	☐	☐	☐
Filling of wetland, river, stream, or lake	☑	☐	☐
Geotechnical survey	☐	☐	☐
Habitat enhancement – revegetation/mitigation	☐	☐	☐
Levee	☐	☐	☐
Low water crossing	☐	☐	☐
Road/trail	☐	☐	☐
Sediment removal – pond, stream, or marina	☐	☐	☐
Storm drain outfall structure	☐	☐	☐
Temporary stream crossing	☐	☐	☐
Utility crossing : Horizontal Directional Drilling	☐	☐	☐
Jack/bore	☐	☐	☐
Open trench	☐	☐	☐
Other *(specify)*: Temporary Marine Trestle	☑	☐	☐

10. PROJECT DESCRIPTION

A. Describe the project in detail. Photographs of the project location and immediate surrounding area should be included.

- Include any structures (e.g., rip-rap, culverts, or channel clearing) that will be placed, built, or completed in or near the stream, river, or lake.
- Specify the type and volume of materials that will be used.
- If water will be diverted or drafted, specify the purpose or use.

Enclose diagrams, drawings, plans, and/or maps that provide all of the following: site specific construction details; the dimensions of each structure and/or extent of each activity in the bed, channel, bank or floodplain; an overview of the entire project area (i.e., "bird's-eye view") showing the location of each structure and/or activity, significant area features, and where the equipment/machinery will enter and exit the project area.

The seismic retrofit of the Antioch Bridge is necessary to meet current design standards. The proposed project includes retrofitting the existing bridge through installation of steel cross bracings, installing isolation bearings and removing the existing curtain walls. As part of this work a temporary marine trestle is proposed to be constructed on the south shore of the San Joaquin River, and construction of four temporary access roads (three on Sherman Island and one on the south shore) are proposed. In addition, two small trestles are proposed to span wetland areas, and staging areas are proposed in non-wetland areas. A complete project description with maps is included in Chapter 1 of the supplemental package. Construction Plans are included as Appendix A of the supplemental package.

A temporary marine trestle with an approximate length of 310-ft and a width of 25-ft will be constructed from the south bank of San Joaquin River to Pier 8 to allow construction access to the piers in the shallow water area. The trestle platform is expected to be approximately 5-ft above the Mean Higher-High Water (MHHW). Caltrans biologists and engineers worked closely to define the parameters of constructing the temporary marine trestle. These parameters include constructing the trestle using approximately 60 24-in steel hollow shell piles and will be installed with a vibratory hammer. Caltrans will proof test 1 pile per day using an impact hammer with an attenuation system. At the completion of the Project, the trestle along with the piles will be removed. Please refer to Chapter 2 of the attached supplemental information.

☑ *Continued on additional page(s)*

B. Specify the equipment and machinery that will be used to complete the project.

Barges, cranes, dump trucks, front loader, diesel hammer, 24-inch hollow steel piles

☐ *Continued on additional page(s)*

C. Will water be present during the proposed work period (specified in box 4.D) in the stream, river, or lake (specified in box 8.B).	☑ Yes ☐ No (*Skip to box 11*)
D. Will the proposed project require work in the wetted portion of the channel?	☑ Yes (*Enclose a plan to divert water around work site*) ☐ No

11. PROJECT IMPACTS

A. Describe impacts to the bed, channel, and bank of the river, stream, or lake, and the associated riparian habitat. Specify the dimensions of the modifications in length (linear feet) and area (square feet or acres) and the type and volume of material (cubic yards) that will be moved, displaced, or otherwise disturbed, if applicable.

The hollow steel shell piles will temporarily occupy 0.004 acres of the bank and bottom of the San Joaquin River. The bank is composed of very soft clay and peat while bottom materials range from medium dense sand to loose silty sand. Please refer to Chapter 3 of the attached supplemental information.

☑ *Continued on additional page(s)*

B. Will the project affect any vegetation? ☑ Yes (*Complete the tables below*) ☐ No

Vegetation Type	Temporary Impact	Permanent Impact
Coastal Brackish Marsh	Linear feet: _____ Total area: 0.0001 acres	Linear feet: _____ Total area: _____
Irrigated pasture & drainage	Linear feet: _____ Total area: 4.490 acres	Linear feet: _____ Total area: _____

Tree Species	Number of Trees to be Removed	Trunk Diameter (range)
Coast beefwood (Casuarina stricta)	10	3.5 - 7.3 inches
Catalina ironwood (Lyonothamnus floribundus)	5	2.5 - 4.8 inches
Fremont Cottonwood (Populus freemontii)	12	3 - 9.6 inches

☑ *Continued on additional page(s)*

C. Are any special status animal or plant species, or habitat that could support such species, known to be present on or near the project site?

☑ Yes *(List each species and/or describe the habitat below)* ☐ No ☐ Unknown

Giant garter snake, Delta smelt, longfin smelt, Chinook salmon, Central Valley steelhead, green sturgeon (see Chapter 3)

☑ *Continued on additional page(s)*

D. Identify the source(s) of information that supports a "yes" or "no" answer above in Box 11.C.

USFWS species list; CDFG CNDDB and Rarefind Databases, botanical surveys, giant garter snake habitat surveys, wetland delineation

☑ *Continued on additional page(s)*

E. Has a biological study been completed for the project site?

☑ Yes (*Enclose the biological study*) ☐ No

Note: A biological assessment or study may be required to evaluate potential project impacts on biological resources.

F. Has a hydrological study been completed for the project or project site?

☐ Yes (*Enclose the hydrological study*) ☑ No

Note: A hydrological study or other information on site hydraulics (e.g., flows, channel characteristics, and/or flood recurrence intervals) may be required to evaluate potential project impacts on hydrology.

12. MEASURES TO PROTECT FISH, WILDIFE, AND PLANT RESOURCES

A. Describe the techniques that will be used to prevent sediment from entering watercourses during and after construction.

Geotextile fabric will underlay all temporary roadway material.
Temporary Reinforced Silt Fence (Type 1) will be installed around all construction and staging areas.
Temporary Fiber Roll will be installed around the 5 acre staging area.
Erosion Control (Type D): revegetating after removal of temporary roads by applying seed mixture.

Refer to Chapter 4 of the supplemental package.

☑ *Continued on additional page(s)*

B. Describe project avoidance and/or minimization measures to protect fish, wildlife, and plant resources.

A description of proposed avoidance and minimization measures are listed in Chapter 4 of the supplemental package.

☑ *Continued on additional page(s)*

C. Describe any project mitigation and/or compensation measures to protect fish, wildlife, and plant resources.

The vegetation in areas of temporary impacts will be restored to preconstruction conditions, and is expected to take on the same vegetation community structure of the existing pastures adjacent to the areas of impact. Restoration will be accomplished by disking the top 4 to 6 inches of the soil and applying a seed mixture of native grasses.
Monitoring of the revegetation effort is not proposed. An in-water work window of August 1 - November 30 to minimize effects to listed fish species has been proposed. In addition, piles will be limited to a maximum of 24-inch diameter and installed with a vibratory hammer.
Mitigation for giant garter snake, Delta smelt, and longfin smelt are proposed to be conducted at USFWS and CDFG approved mitigation banks. Mitigation for Central Valley steelhead is proposed to conducted at a NMFS approved mitigation bank.
Refer to Chapter 4

☑ *Continued on additional page(s)*

13. PERMITS

List any local, state, and federal permits required for the project and check the corresponding box(es). Enclose a copy of each permit that has been issued.

A. USFWS Biological Opinion ☑ Applied ☐ Issued

B. NMFS Biological Opinion ☑ Applied ☐ Issued

C. USACE 404 Permit (NWP 3) ☑ Applied ☐ Issued

D. Unknown whether ☐ local, ☐ state, or ☐ federal permit is needed for the project. (*Check each box that applies*)

☑ *Continued on additional page(s)*

14. ENVIRONMENTAL REVIEW

A. Has a draft or final document been prepared for the project pursuant to the California Environmental Quality Act (CEQA), National Environmental Protection Act (NEPA), California Endangered Species Act (CESA) and/or federal Endangered Species Act (ESA)?

☑ Yes *(Check the box for each CEQA, NEPA, CESA, and ESA document that has been prepared and enclose a copy of each)*

☐ No *(Check the box for each CEQA, NEPA, CESA, and ESA document listed below that will be or is being prepared)*

☐ Notice of Exemption	☑ Mitigated Negative Declaration	☑ NEPA document (*type*): EA
☑ Initial Study	☐ Environmental Impact Report	☑ CESA document (*type*): Incidental Take
☐ Negative Declaration	☐ Notice of Determination *(Enclose)*	☑ ESA document (*type*): Biological Opinion
☐ THP/ NTMP	☐ Mitigation, Monitoring, Reporting Plan	

B. State Clearinghouse Number (*if applicable*)			
C. Has a CEQA lead agency been determined?	☑ Yes (*Complete boxes D, E, and F*)	☐ No (*Skip to box 14.G*)	
D. CEQA Lead Agency	Caltrans		
E. Contact Person	Howell Chan	F. Telephone Number	(510) 286-5623

G. If the project described in this notification is part of a larger project or plan, briefly describe that larger project or plan.

N/A

☐ *Continued on additional page(s)*

H. Has an environmental filing fee (Fish and Game Code section 711.4) been paid?

☑ Yes (*Enclose proof of payment*) ☐ No (*Briefly explain below the reason a filing fee has not been paid*)

Payment is included with the application.

Note: If a filing fee is required, the Department may not finalize a Lake or Streambed Alteration Agreement until the filing fee is paid.

15. SITE INSPECTION

Check one box only.

☐ In the event the Department determines that a site inspection is necessary, I hereby authorize a Department representative to enter the property where the project described in this notification will take place at any reasonable time, and hereby certify that I am authorized to grant the Department such entry.

☑ I request the Department to first contact (*insert name*) Stuart Kirkham at (*insert telephone number*) (510) 286-5602 to schedule a date and time to enter the property where the project described in this notification will take place. I understand that this may delay the Department's determination as to whether a Lake or Streambed Alteration Agreement is required and/or the Department's issuance of a draft agreement pursuant to this notification.

16. DIGITAL FORMAT

Is any of the information included as part of the notification available in digital format (i.e., CD, DVD, etc.)?

☑ Yes (Please enclose the information via digital media with the completed notification form)

☐ No

17. SIGNATURE

I hereby certify that to the best of my knowledge the information in this notification is true and correct and that I am authorized to sign this notification as, or on behalf of, the applicant. I understand that if any information in this notification is found to be untrue or incorrect, the Department may suspend processing this notification or suspend or revoke any draft or final Lake or Streambed Alteration Agreement issued pursuant to this notification. I understand also that if any information in this notification is found to be untrue or incorrect and the project described in this notification has already begun, I and/or the applicant may be subject to civil or criminal prosecution. I understand that this notification applies only to the project(s) described herein and that I and/or the applicant may be subject to civil or criminal prosecution for undertaking any project not described herein unless the Department has been separately notified of that project in accordance with Fish and Game Code section 1602 or 1611.

SIGNED FOR JEFFREY JENSEN

Signature of Applicant or Applicant's Authorized Representative

6.25.09

Date

CHRISTOPHER T. STATES

Print Name

California Department of Fish and Game
Bay Delta Region
PO Box 47
Yountville, Ca, 94599

California Endangered Species Act
Incidental Take Permit No. 2081-2009-022-03

California Department of Transportation
Antioch Bridge Seismic Retrofit Project

Authority: This California Endangered Species Act (CESA) Incidental Take Permit (ITP) is issued by the Department of Fish and Game (DFG) pursuant to Fish and Game Code section 2081, subdivisions (b) and (c), and California Code of Regulations, title 14, section 783.0 et seq. CESA prohibits the take[1] of any species of wildlife designated by the California Fish and Game Commission as an endangered, threatened, or candidate species.[2] DFG, however, may authorize the take of any such species by permit if the conditions set forth in Fish and Game Code section 2081, subdivisions (b) and (c) are met. (See also Cal. Code Regs., tit. 14, § 783.4.)

Permittee:	**California Department of Transportation**
Name and title of principal officer:	**Christopher States, Branch Chief**
Contact person:	**Stuart Kirkham, (510) 286-5602**
Mailing address:	**California Department of Transportation** **111 Grand Ave.** **Oakland, Ca 94623**

Effective Date and Expiration Date of the ITP:
This ITP shall be executed in duplicate original form and shall become effective once a duplicate original is acknowledged by signature of Permittee on the last page of the ITP and returned to DFG's Habitat Conservation Planning Branch at the address listed in the Notices section of this ITP. Unless renewed by DFG, this ITP's authorization to take the Covered Species shall expire on **December 31, 2013.**

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[1]Pursuant to Fish and Game Code section 86, "'Take' means hunt, pursue, catch, capture, or kill, or attempt to hunt, pursue, catch, capture or kill."

[2]"Candidate species" are species of wildlife that have not yet been placed on the list of endangered species or the list of threatened species, but which are under formal consideration for listing pursuant to Fish and Game Code section 2074.2.

Project Location:
The Project site is located on State Route (SR) 160 and spans approximately 2 miles from Post Mile (PM) 0.8 in Contra Costa County to PM 1.3 in Sacramento County. The bridge connects the City of Antioch on the south bank of the San Joaquin River to Sherman Island on the north, touching down just north of Mayberry Slough.

Project Description:
The California Department of Transportation (Caltrans or Permittee) proposes to seismically retrofit the Antioch Bridge (Project). Built in 1978, the bridge is 9,437 feet (ft) long, accommodates one lane of traffic in either direction, and includes narrow accommodation for bicyclists and pedestrians. The bridge features two structural elements: the main structure and the slab span structure. The main structure spans the south shore of the San Joaquin River, the San Joaquin River, and part of Sherman Island. The slab structure starts just north of Mayberry Slough and extends to the northern bridge abutment. The main structure is 8,650 ft long and consists of the roadway superstructure supported on 41 bridge piers with the distance between columns varying in length from 135 to 460 ft. The slab span structure is 787 ft long and is comprised of the roadway deck supported on 30 bents with four circular columns each. The entire slab structure is enclosed within concrete slab walls.

Proposed retrofit elements:

- Installation of steel cross bracing between columns to stiffen the superstructure cross frames (Pier 12 to Pier 31).

- Installation of bracing to existing cross frames at the pier caps (Pier 2 to Pier 40).

- Replacement of the existing elastometric bearings with isolation bearings (Abutment 1 to Pier 41).

- Removal of the existing curtain walls and retrofit of all the columns within the slab span structure by installing composite fiber jackets (Bent 42 to Abutment 71).

Temporary Access and Staging:

- A temporary access road is proposed within state right-of-way (ROW) to provide access for work to all bridge columns south of Mayberry Slough (Pier 22 to Pier 38) on Sherman Island. The temporary access road will consist of placing geotextile fabric and a crushed rock layer, approximately 4 ft deep, over the existing ground. The temporary access road will be approximately 24 ft wide along the travel surface and will extend with 2:1 slopes to existing ground level. The base of the road will be approximately 40 ft wide at ground level

and will extend 3,300 ft, covering an estimated 4.45 acres (ac). The temporary access road will stop at Mayberry Slough.

- Two additional temporary access roads, constructed of a 6 inch (in) layer of crushed rock overlaying geotextile fabric, are proposed north of Mayberry Slough on both the west and east sides of the slab span structure. The access road on the west side will occupy 0.6 ac and will measure 850 ft long by 36 ft wide. The access on the east side of the span will occupy 0.4 ac and will measure 850 ft long by 20 ft wide.

- Where the access road crosses the irrigation canal near Pier 32, a 24 ft wide temporary trestle will be installed to span the irrigation canal. The temporary trestle will prevent additional load on the existing culvert and will avoid the need for fill.

- At the northern end of the bridge, a 24 ft wide temporary trestle will be installed to the west to span an irrigation/drainage ditch. The temporary trestle will minimize disturbance to the existing irrigation ditch and wetland area.

- On the south shore of the San Joaquin River at the south end of the temporary marine trestle, existing access roads and the Caltrans ROW will be used to access the trestle. The existing road will require a widening from 9 ft to 24 ft along 650 ft, and a 24 ft wide extension along another 250 ft. This will be accomplished using a 6 in layer of crushed rock overlaying geotextile fabric. The total expanded/extended area will be 0.364 ac.

- A temporary staging and laydown area has been identified north of Mayberry Slough in a fallow upland field dominated by ruderal species. The staging area covers approximately 6 ac outside State ROW on the east side of the bridge. The area will be covered by a layer of crushed rock overlying geotextile fabric, approximately 6 in thick, for drivability. Silt fence, fiber rolls, and/or small earthen berms will be installed along the north and east side of the staging area to direct runoff away from the wetlands to the north and east.

- Two temporary contractor staging areas have been identified between bridge piers. One, located between Piers 29 and 30, will occupy approximately 0.17 ac and will measure 115 ft long by 65 ft wide. The other, on Sherman Island between Pier 31 and the permanently extended access road, will occupy approximately 0.12 ac and will measure 81 ft long by 65 ft wide. These temporary staging areas will consist of placing geotextile fabric and a crushed rock layer, approximately 4 ft deep over the existing ground.

- On the south end of the bridge, the contractor will use existing paved areas for staging.

- The unpaved access road extending from the old Highway 84 to the staging area north of Mayberry Slough is currently 18 to 20 ft wide. This access road needs to be permanently widened to 24 ft over a distance of approximately 1,200 ft to accommodate large construction equipment and trucks. Widening of this access road will require minor grading of the approximately 0.218 ac area to be widened and placing 6 in of crushed rocks over the adjacent ground. The areas adjacent to this road currently consist of ruderal upland vegetation.

- All construction zones, access routes and staging areas will be delineated with high-visibility Environmentally Sensitive Area (ESA) fencing at a minimum, and sites that have potential for erosion will have silt fencing installed in addition to the ESA fencing. At completion of the Project, all ESA fence, silt fence, geotextile fabric, and crushed rock will be removed and the sites will be restored to their pre-construction conditions.

- A temporary marine trestle, approximately 310 ft long and 25 ft wide, will be constructed from the south bank of San Joaquin River to Pier 8 to allow construction access to the piers in the shallow water area. The trestle platform is expected to be approximately 5 feet above the Mean Higher High Water. The trestle will be constructed using approximately sixty 24 in steel hollow shell piles and will be installed with a vibratory hammer. Caltrans will proof test one pile per day using an impact hammer to confirm load bearing capacity. Sound attenuation will be used on the piles that are driven/proof tested with an impact hammer. At the completion of the Project, the trestle along with the piles will be removed.

- Barges will be used to retrofit Piers 9 to 21, and no aquatic impacts are anticipated beyond the potential installation of mooring lines.

- This Project will not require onsite borrow or disposal of excavated material. Gravel and rock will be imported for construction of the temporary access road and road widening. These materials will be removed upon completion of the Project.

Covered Species Subject to Take Authorization Provided by this ITP:

This ITP covers the following species:

Name	CESA Status[3]
Reptiles	
1. Giant garter snake (*Thamnophis gigas*)	Threatened
Fish	
1. Delta smelt (*Hypomesus transpacificus)*	Threatened[4]

These species and only these species are hereinafter referred to as "Covered Species."

Impacts to Covered Species:

The Project activities described above and their resulting impacts are expected to result in the incidental take of individuals of the Covered Species. The impacts of the taking on each Covered Species are described in more detail below:

Giant Garter Snake

Of the 13.44 terrestrial acres affected by staging and site access, approximately 2.22 acres of giant garter snake (GGS) upland dispersal habitat will be temporarily impacted by staging and site access construction, and approximately 0.22 acre of GGS upland dispersal habitat will be permanently impacted by the permanent widening of the access road just north of Mayberry Slough (Attachment 4).

Individual GGS may be incidentally taken as a result of mortality due to ground- or vegetation-disturbing construction activities. Impacts of the proposed taking on GGS may

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[3]Under CESA, a species may be on the list of endangered species, the list of threatened species, or the list of candidate species. All other species are "unlisted."

[4] Delta smelt are currently protected under CESA as a threatened species. (Cal. Code Regs., tit. 14, § 670.5, subd. (b)(2)(A); see also Fish & G. Code, § 2080.) On June 7, 2007, the California Fish and Game Commission accepted a petition to uplist Delta smelt as an endangered species and on August 7, 2008, the Commission made a finding that uplisting from threatened to endangered is warranted. (Cal. Reg. Notice Register 2007, No. 25-Z, p. 1090, and 2009, No. 3-Z, p. 111.) The Commission is currently engaged in related rulemaking under the Administrative Procedure Act (APA) (Gov. Code, § 11340 et seq.) and, when complete, the legal status of Delta smelt under CESA will change from threatened to endangered. (Fish & G. Code, 2075.5(2); Cal. Reg. Notice Register 2009, No. 3-Z, p. 106; see also proposed Cal. Code Regs., tit. 14, § 670.5, subd. (a)(2)(O).) The species' change in legal status under CESA will not affect this ITP.

also include adverse impacts to GGS related to temporal habitat losses and the Project's incremental contribution to cumulative impacts by reducing available dispersal and foraging habitat for GGS.

Delta Smelt
The installation of the marine trestle will require "proofing" the steel piles with an impact hammer. Sound pressures levels (SPLs) up to 206 decibels, with a sound exposure level of 183 decibels, are expected within a 30-foot radius around each pile. There is potential for take of individual delta smelt within a 30-foot radius of each trestle pile, amounting to an affected area of 1.09 acres (Attachment 4).

Incidental Take Authorization of Covered Species:
This ITP authorizes incidental take of the Covered Species and only the Covered Species. With respect to incidental take of the Covered Species, DFG authorizes Permittee, its employees, contractors, and agents to take Covered Species incidentally in carrying out the Project, subject to the limitations described in this section and the Conditions of Approval identified below. This ITP does not authorize take of Covered Species from activities outside the scope of the Project as described above, take of Covered Species resulting from violation of this ITP, or intentional take of Covered Species, except for capture and relocation of Covered Species as authorized by this ITP.

Conditions of Approval:
Unless specified otherwise, the following measures shall pertain to all ground- or vegetation-disturbing activities within the Project construction boundaries, including areas used for ingress and egress routes during construction, and staging and parking areas. DFG's issuance of this ITP and Permittee's authorization to take the Covered Species are subject to Permittee's compliance with and implementation of the following Conditions of Approval:

1. Permittee shall comply with all applicable state, federal, and local laws in existence on the effective date of this ITP or adopted thereafter.

2. Permittee shall implement and adhere to the mitigation measures in the Biological Environment section of the Mitigated Negative Declaration adopted by the lead agency, California Department of Transportation, for the Antioch Bridge Seismic Retrofit Project on September 2, 2009 (SCH No. 2009062022).

3. Permittee shall fully implement and adhere to the conditions of this ITP within the time frames set forth below and in Attachment 1, the Mitigation Monitoring and Reporting Program (MMRP).

4. General Provisions:

4.1. Before initiating in-water, ground- or vegetation-disturbing Project activities, Permittee shall designate a representative (Designated Representative) responsible for communicating with DFG and overseeing compliance with this ITP. Permittee shall notify DFG, in writing, prior to commencement of in-water, ground- or vegetation-disturbing activities of the representative's name, business address, and contact information, and shall notify DFG in writing if a substitute representative is designated.

4.2. At least 30 days before initiating in-water, ground- or vegetation-disturbing activities, Permittee shall submit to DFG in writing the name, qualifications, business address, and contact information for a biological monitor (Designated Biologist). The Designated Biologist shall be knowledgeable and experienced in the biology and natural history of the Covered Species, and shall be responsible for monitoring construction and/or in-water, ground- or vegetation-disturbing activities in areas of Covered Species habitat to help avoid the unauthorized take of individual Covered Species and to minimize disturbance of Covered Species' habitat. Permittee must obtain DFG approval of the Designated Biologist prior to the commencement of Project activities.

4.3. To ensure compliance with the Conditions of Approval of this ITP, the Designated Biologist shall have authority, through the Engineer, to immediately stop any activity that is not in compliance with this ITP, and/or order any reasonable measure to avoid the take of an individual of the Covered Species.

4.4. Permittee shall conduct an education program for all persons employed on the Project prior to their performing work on-site. The program shall consist of a presentation from the Designated Biologist that includes a discussion of the biology and general behavior of the Covered Species, information about the distribution and habitat needs of the Covered Species, sensitivity of the Covered Species to human activities, its status under CESA including legal protection, recovery efforts, penalties for violations and Project-specific protective measures described in this ITP. Interpretation shall be provided for non-English speaking workers, and the same instruction shall be provided for any new workers prior to their performing work on-site. Copies of this ITP shall be maintained at the worksite. Permittee shall prepare and distribute wallet-sized cards or a fact sheet handout containing this information for workers to carry on-site. Upon completion of the program, employees shall sign a form stating they attended the program and understand all protection measures. These forms shall be filed at the worksite offices and be available to DFG upon request.

4.5. Permittee shall initiate a trash abatement program during pre construction phases of the Project and continue the program throughout the duration of the Project. Trash and food items shall be contained in closed (animal proof) containers and removed regularly (at least once a week) to avoid attracting opportunistic predators such as coyotes and feral dogs.

4.6. Permittee shall implement dust control measures during Project activities to facilitate visibility for monitoring of the GGS by the Designated Biologist.

4.7. Permittee shall prohibit firearms and domestic dogs from the Project site and site access routes during construction of the Project, except those in the possession of authorized security personnel or local, State, or Federal law enforcement officials.

4.8. Permittee shall clearly delineate potential habitat of the GGS within the Project limits with high visibility ESA fencing to minimize the disturbance of habitat. ESA fencing shall be erected as directed by the Designated Biologist, 200 ft from the edge of potential aquatic habitat for the GGS.

4.9. Within 200 ft of GGS aquatic habitat Permittee shall post and maintain signs identifying the ESAs to construction personnel every 50 ft along the edge of the ESAs.

4.10. Project-related personnel shall access the Project site during construction and development activities using existing routes and shall not cross GGS habitat outside of the Project site. Project-related vehicle traffic shall be restricted to established roads, staging, and parking areas. Vehicle speeds shall not exceed 20 miles per hour, except on county roads and state and federal highways, in order to avoid GGS on or traversing the roads. If construction of off-site routes of travel will be required, Permittee shall contact DFG prior to carrying out such an activity. DFG may require an amendment to this ITP if additional take of GGS may result from Project modification.

4.11. Permittee shall confine all Project-related parking, storage areas, laydown sites, equipment storage, and any other surface-disturbing activities to the Project site using, to the extent possible, previously disturbed areas. Additionally, Permittee shall not use or cross GGS habitat outside of the marked Project boundaries unless specifically provided for in this ITP.

4.12. Permittee shall immediately stop/repair and clean up any fuel or hazardous waste leaks or spills on the Project site during construction and development activities at the time of occurrence. Permittee shall exclude the storage and handling of

hazardous materials from the construction zone and shall properly contain and dispose of any unused or leftover hazardous products off-site.

4.13. Permittee shall provide DFG staff with reasonable access to the Project site and mitigation lands under its control, and shall otherwise fully cooperate with DFG efforts to verify compliance with or effectiveness of mitigation measures set forth in the ITP. Neither the Designated Biologist nor DFG shall be liable for any costs incurred in complying with the Conditions of Approval, including cease-work orders issued by DFG.

4.14. Permittee shall not use erosion control materials potentially harmful to GGS such as mono-filament netting (used in erosion control matting or fiber rolls) or similar material.

4.15. Upon Project completion, Permittee shall remove from the Project site and properly dispose of all construction refuse, including, but not limited to, broken equipment parts, wrapping material, cords, cables, wire, rope, strapping, twine, buckets, metal or plastic containers, and boxes.

4.16. Notwithstanding any expiration date on this ITP's take authorization, Permittee's obligations under this ITP do not end until DFG accepts the Final Mitigation Report (described in Condition 5.9) as complete.

5. Monitoring, Notification and Reporting Provisions:

5.1. If a Covered Species is killed by Project-related activities during construction, or if a Covered Species is otherwise found dead, the Designated Biologist shall immediately notify the DFG Regional Office at (707) 339-0334 or (707) 944-5517, and provide information on the location, species, number of animals injured or killed, and the ITP Number. Following the initial notification, Permittee shall send DFG a written report within two (2) calendar days. The report will include the date, time and location of the finding or incident, location of the carcass, and, if possible, should provide a photograph, cause of death, and any other pertinent information. See additional reporting requirements in Conditions 6.2 and 6.3 below.

5.2. Permittee shall monitor on-site restoration of GGS habitat for 1 year following the completion of restoration activities as described in Condition 6.7. Monitoring reports shall be submitted to DFG following the restoration implementation and 1 year after the completion of the restoration effort.

5.3. Permittee shall notify DFG fourteen calendar days before initiating in-water, ground- or vegetation-disturbing activities and shall document compliance with all Project Conditions of Approval before initiating in-water, ground- or vegetation-disturbing activities.

5.4. Permittee shall immediately notify DFG in writing if it determines that it is not in compliance with any Condition of Approval of this ITP, including, but not limited to, any actual or anticipated failure to implement mitigation measures within the time periods indicated in this ITP and/or the MMRP. Permittee shall report any non-compliance during the construction phase to DFG within 24 hours.

5.5. Should SPLs exceed 206 decibels, with a sound exposure level of 183 decibels, within a 30-foot radius around each pile, causing an increase in the area of potential take, Permittee shall notify DFG to determine if an ITP amendment, additional impact analysis, and/or additional mitigation is required.

5.6. The Designated Biologist shall be on-site weekly while construction, in-water, or ground- or vegetation-disturbing activities are taking place to: (1) minimize take of the Covered Species; (2) check for compliance with all mitigation and avoidance measures; and (3) ensure that human activities are restricted to outside of protective zones. The Designated Biologist shall also inspect material storage areas that have potential to provide retreat sites for Covered Species. The Designated Representative or Designated Biologist shall keep written observation and inspection records summarizing: oversight activities and compliance inspections, observations of Covered Species and their sign, survey results, and monitoring activities required by this ITP.

5.7. Monthly Compliance Report: Permittee shall compile the observation and inspection records identified in Condition 5.6 into a Monthly Compliance Report and submit it to DFG along with a copy of the MMRP table with notes showing the current implementation status of each mitigation measure. Monthly Compliance Reports shall be submitted to DFG's Regional Office at the address listed in the Notices section of this ITP or via e-mail to DFG's Regional Representative at mescaron@dfg.ca.gov. DFG may, at any time, increase the timing and number of compliance inspections and reports required under this provision depending upon the results of previous compliance inspections. If DFG determines the reporting schedule is inadequate, DFG will notify Permittee by letter of the new reporting schedule.

5.8. Annual Status Report: Permittee shall provide DFG with an Annual Status Report (ASR) no later than January 31 of every year beginning with issuance of the ITP and

continuing until DFG accepts the Final Mitigation Report identified below. Each ASR shall include, at a minimum: (1) a general description of the status of the Project site and construction activities, including actual or projected completion dates, if known; (2) a copy of the table in the MMRP with notes showing the current implementation status of each mitigation measure; and (3) an assessment of the effectiveness of each completed or partially completed mitigation measure in minimizing and fully mitigating for Project impacts.

5.9. Final Report: No later than 45 days after completion of the Project, including completion of all mitigation measures, Permittee shall provide DFG with a Final Mitigation Report. The Final Mitigation Report shall be prepared by the Designated Biologist and shall include, at a minimum: (1) a copy of the table in the MMRP with notes showing when each of the mitigation measures was implemented; (2) all available information about Project-related incidental take of the Covered Species; (3) information about other Project impacts on the Covered Species; (4) construction dates; (5) an assessment of the effectiveness of the ITP's Conditions of Approval in minimizing and fully mitigating Project impacts of the taking on Covered Species; (6) recommendations on how mitigation measures might be changed to more effectively minimize take and mitigate the impacts of future projects on the Covered Species; (7) and any other pertinent information, including the level of take of the Covered Species associated with the Project.

5.10. Habitat Compensation Monitoring and Reporting: If Permittee mitigates habitat impacts through the purchase of credits at a conservation bank, proof of purchase of the credits shall be provided to DFG within 18 months of the start of in-water, vegetation- or ground-disturbing activities. Alternatively, if Permittee mitigates habitat impacts through the acquisition and permanent protection of Habitat Management Lands, documentation, as described below in Conditions 7.2 and 7.4, shall be provided to DFG within 18 months of the start of in-water, vegetation- or ground-disturbing activities.

6. Take Minimization Measures:

The following requirements are intended to ensure the minimization of incidental take of Covered Species that are discovered within the work area, both prior to ground- or vegetation-disturbing activities and throughout construction of the Project. Permittee shall implement and adhere to the following conditions to minimize take of Covered Species:

Giant Garter Snake

6.1. Permittee shall conduct all vegetation- or ground-disturbing activities within GGS habitat on Sherman Island between May 1 and October 1 of any year. Once temporary access roads are in place, Permittee shall not conduct further ground-disturbing activity without approval from DFG.

6.2. If a GGS is found on the Project site, the Designated Biologist shall be notified immediately. GGS encountered in active construction areas shall be allowed to leave on their own volition. The Designated Representative shall notify DFG of the incident immediately, or no later than noon on the next business day if the incident occurs outside of normal business hours. Notification to DFG shall be via telephone or email, followed by a written incident report. Notification shall include the date, time, location and circumstances of the incident.

6.3. If a GGS is injured as a result of Project-related activities, Permittee shall immediately take the GGS to a DFG-approved wildlife rehabilitation or veterinary facility. Permittee shall identify the facility prior to the start of ground- or vegetation-disturbing activities. Permittee shall bear any costs associated with the care or treatment of such injured GGS. Permittee shall notify DFG immediately unless the incident occurs outside of normal business hours. In that event DFG shall be notified no later than noon on the next business day. Notification to DFG shall be via telephone or email, followed by a written incident report. Notification shall include the date, time, location and circumstances of the incident, and the name of the facility where the animal was taken.

6.4. The Designated Biologist shall monitor for and clear the area of GGS during the installation of the ESA and silt fencing.

6.5. Permittee shall inspect and maintain Storm Water Pollution Prevention Plan (SWPPP) measures to minimize sediment transport into sensitive habitat areas during construction. A copy of the SWPPP shall be provided to DFG upon request.

6.6. Permittee shall restore the approximately 2.22 acres of temporarily impacted GGS habitat on-site to pre-construction conditions. Permittee shall re-contour, if appropriate, and revegetate these areas with appropriate locally collected native plant species. The restoration effort shall comply with the U.S. Fish and Wildlife Service Guidelines for the Restoration and/or Replacement of GGS Habitat (USFWS, 1997) and shall be monitored for one year.

Delta Smelt

6.7. Permittee shall conduct in-water pile installation work between August 1 and October 31 of any year.

6.8. Permittee shall install trestle piles with a vibratory pile driver. Maximum pile diameter shall be 24 inches.

6.9. Permittee shall limit proofing of piles with an impact hammer to one pile per day during the installation of the marine trestle.

6.10. Permittee shall use an attenuation system to minimize hydroacoustic effects to fish during impact pile driving. The attenuation system may include, but is not limited to one or more of the following systems:

a. A confined bubble curtain
b. An unconfined bubble curtain
c. Isolation casings
d. Wooden pile cushions

6.11. It is anticipated sound pressure levels (SPLs) may reach 206 decibel (peak) and 183 decibel SEL (sound exposure level), within a 30 foot radius of each pile during installation with an impact hammer. For the purposes of this ITP, 1.09 acres is the area surrounding the piles where these levels and potential take of delta smelt may occur. Permittee shall conduct real time hydroacoustic monitoring during all trestle pile installation activities to measure efficacy of the sound attenuation system and to determine if the anticipated SPLs and associated distances from piles differ from the actual measurements. Should the hydroacoustic monitoring show the sound attenuation system is not sufficiently attenuating sound at, or below, the peak decibel level, Permittee shall halt pile driving until the sound attenuation system is repaired or augmented to ensure peak levels are not exceeded. Should the hydroacoustic monitoring show that SPL values are exceeding, or have exceeded, the above levels, and/or that the actual area of potential take extends beyond the anticipated 30-foot radius, Permittee shall either take measures to increase the effectiveness of the sound attenuation system or obtain an ITP amendment from DFG.

6.12. If at any point turbidity levels exceed the acceptable criteria established by the Regional Water Quality Control Board and permitted by the SWPPP, Permittee shall halt construction activities until turbidity levels return to acceptable levels.

Compensation for Take:

7. Mitigation Measures/Compensation for Take:
DFG has determined that permanent protection of compensatory habitat is necessary and required under CESA to fully mitigate impacts of the taking on Covered Species that will result from implementation of this Project. This determination is based on factors including an assessment of the quality of the habitat at the Project site and the increased habitat value for the Covered Species that can be achieved through land management at the mitigation location.

Giant Garter Snake

7.1. Prior to initiating in-water, ground- or vegetation-disturbing Project activities, or no later than 18 months from the start of in-water, ground- or vegetation-disturbing activities if a Funding Assurance Letter is provided pursuant to Condition 8 below, Permittee shall purchase 3.1 acres of GGS habitat conservation credits at a DFG-approved habitat conservation bank.

Or:

7.1.1. Prior to initiating in-water, ground- or vegetation-disturbing Project activities, or no later than 18 months from the start of in-water, ground- or vegetation-disturbing activities if a Funding Assurance Letter is provided pursuant to Condition 8 below, Permittee shall acquire and permanently preserve 3.1 acres of Habitat Management Lands (HM Lands) for GGS in accordance with Condition 7.3 of this ITP. The required acreage is based on factors including an assessment of the quality of the habitat at the Project site and DFG's estimate of the acreage required to provide for adequate biological carrying capacity at a replacement location. A minimum of six months prior to acquisition of the HM Lands, Permittee shall submit to DFG for approval a formal Proposed Lands for Acquisition Form (see Attachment 2B) identifying the land to be purchased as mitigation for the Project's impacts on GGS.

Delta Smelt

7.2. Prior to initiating in-water, ground- or vegetation-disturbing Project activities, or no later than 18 months from the start of in-water, ground- or vegetation-disturbing activities if a Funding Assurance Letter is provided pursuant to Condition 8 below, Permittee shall purchase 3.27 acres of delta smelt habitat mitigation credits at a DFG-approved conservation bank.

Or:

7.2.1. Prior to initiating in-water, ground- or vegetation-disturbing Project activities, or no later than 18 months from the start of in-water, ground- or vegetation-disturbing activities if a Funding Assurance Letter is provided pursuant to Condition 8 below, Permittee shall acquire and permanently preserve 3.27 acres of Habitat Management Lands (HM Lands) for delta smelt in accordance with Condition 7.3 of this ITP. The required acreage is based on factors including an assessment of the quality of the habitat at the Project site and DFG's estimate of the acreage required to provide for adequate biological carrying capacity at a replacement location. A minimum of six months prior to acquisition of the HM Lands, Permittee shall submit to DFG for approval a formal Proposed Lands for Acquisition Form (see Attachment 2B) identifying the land to be purchased as mitigation for the Project's impacts on delta smelt.

7.3. HM Land Transfer Requirements: If conservation bank credits are not purchased to fulfill Permittee's HM Land requirements, Permittee shall do all of the following to provide for the permanent protection and management of the HM Lands for GGS and delta smelt:

7.3.1. Permittee shall transfer fee title to the HM Lands to DFG or another entity under terms approved by DFG. If fee title is held by an entity other than DFG, a conservation easement in a form approved by DFG shall be recorded on title of the HM Lands. The grantee of the conservation easement may be DFG, a DFG-approved non-profit organization qualified pursuant to California Government Code section 65965, or a public agency approved by DFG and authorized to hold conservation easements. If a DFG-approved non-profit organization or authorized public agency is grantee on a conservation easement, DFG shall be named third party beneficiary;

7.3.2. Permittee shall provide a recent preliminary title report, initial hazardous materials survey report, and other necessary documents (see Attachment 2A and 2B). All documents conveying the HM Lands and all conditions of title are subject to the approval of DFG and, if applicable, the Wildlife Conservation Board and the Department of General Services;

7.3.3. Permittee shall provide for the initial protection and enhancement of HM Lands, as approved by DFG, once Permittee identifies the HM Lands;

7.3.4. Permittee shall conduct a Property Analysis Record (PAR) or PAR-equivalent analysis once the HM Lands have been identified to determine the appropriate endowment amount to fund the in-perpetuity management of HM Lands. Permittee shall provide the required endowment to DFG using the Mitigation Payment Transmittal Form (Attachment 3) after DFG reviews and approves the PAR. Permittee shall provide funding assurances for the endowment in the Funding Assurance Letter (see Condition 8 below). Interest from the endowment amount shall be available for reinvestment in the principal and for the long term operation, management, and protection of the HM Lands, including reasonable administrative overhead, biological monitoring, improvements to biological carrying capacity, law enforcement measures, and any other action designed to protect or improve the habitat values of the HM Lands. Money received by DFG pursuant to this condition shall be deposited in a special deposit account established pursuant to Fish and Game Code section 13014. Alternatively, endowment funds may be held by a DFG-approved entity qualified to hold endowment funds. DFG may pool the endowment with other endowments for the operation, management and protection of HM Lands for local populations of Covered Species;

7.3.5. Permittee shall reimburse DFG for reasonable expenses incurred during title and documentation review, expenses incurred from other state agency reviews, and overhead related to transfer of HM Lands to DFG. DFG estimates that this Project will create an additional cost to DFG of no more than $3,000 for every fee title deed or easement processed.

8. Performance Security:

Permittee may proceed with in-water, ground- or vegetation-disturbing activities before completing all of the required mitigation (including acquisition of HM Lands or purchase of habitat conservation credits), monitoring, and reporting activities only if Permittee ensures funding to complete those activities by providing to DFG, prior to commencing in-water, ground- or vegetation-disturbing activities or within 30 days after the effective date of this ITP, whichever occurs first, written documentation that Permittee has allocated sufficient funds, acceptable to and approved by DFG, in the Expenditure Authorization for the Project to ensure implementation of the Conditions of Approval of this ITP. The written documentation submitted by Permittee to satisfy this Condition shall be on official letterhead and signed by both the District Deputy Director of Project Management and the District Deputy Director of Environmental Planning and Engineering, and shall include a statement that at least $700,000.00 has been allocated specifically for the purpose of fulfilling Caltrans' mitigation obligations associated with this Permit and will not be redirected for other Project purposes. This amount is an

estimate of the funds necessary to implement the ITP's mitigation, monitoring and reporting requirements, including purchase of habitat conservation credits or land acquisition costs, costs of enhancing HM Lands, and funding of an endowment. Even if the Funding Assurance Letter is provided, Permittee shall provide proof of purchase of habitat conservation credits or complete the acquisition, protection, and transfer of all HM Lands and record the required conservation easements in favor of DFG no later than 18 months after the start of the in-water, ground- or vegetation-disturbing activities.

Amendment:
This ITP may be amended without the concurrence of Permittee as required by law, including as determined by DFG that: (1) continued implementation of the Project under existing ITP conditions would jeopardize the continued existence of the Covered Species, or (2) Project changes or changed biological conditions necessitate an ITP amendment to ensure that impacts to the Covered Species are minimized and fully mitigated.

Stop-Work Order:
DFG may issue Permittee a written stop-work order to suspend any activity covered by this ITP for an initial period of up to 25 days to prevent or remedy a violation of ITP conditions (including, but not limited to, failure to comply with reporting, monitoring, or habitat acquisition obligations) or to prevent the illegal take of an endangered, threatened, or candidate species. Permittee shall comply with the stop-work order immediately upon receipt thereof. DFG may extend a stop-work order under this provision for a period not to exceed 25 additional days, upon written notice to Permittee. DFG shall commence the formal suspension process pursuant to California Code of Regulations, Title 14, section 783.7, within five working days of issuing a stop-work order.

Compliance with Other Laws:
This ITP contains DFG's requirements for the Project pursuant to CESA. This ITP does not necessarily create an entitlement to proceed with the Project. Permittee is responsible for complying with all other applicable state, federal, and local laws.

Notices:
Permittee shall deliver the fully executed duplicate original ITP by first class mail or overnight delivery to the following address:

Habitat Conservation Planning Branch
California Department of Fish and Game
Attention: CESA Permitting Program
1416 Ninth Street, Suite 1260
Sacramento, CA 95814

Written notices, reports and other communications relating to this ITP shall be delivered to DFG by first class mail at the following addresses, or at addresses DFG may subsequently provide Permittee. Notices, reports, and other communications shall reference the Project name, Permittee, and ITP Number (2081-2009-022-03) in a cover letter and on any other associated documents.

Original cover with attachment(s) to:

Charles Armor, Regional Manager
Bay Delta Region
PO Box 47 Yountville, Ca 94599
Telephone (707) 944-5517
Fax (707) 944-5563

Copy of cover without attachment(s) to:

Office of the General Counsel
California Department of Fish and Game
1416 Ninth Street, 12th Floor
Sacramento, CA 95814

And:

Habitat Conservation Planning Branch
California Department of Fish and Game
1416 Ninth Street, Suite 1260
Sacramento, CA 95814

Unless Permittee is notified otherwise, DFG's Regional Representative for purposes of addressing issues that arise during implementation of the ITP is:

Melissa Escaron
PO Box 47
Yountville, Ca 94599
Telephone (707) 339-0334
Fax (707) 339-5563

Findings under CESA:

These findings are intended to document DFG's compliance with the specific findings requirements set forth in CESA and related regulations. (Fish & G. Code § 2081, subs. (b)-(c); Cal. Code Regs., tit. 14, §§ 783.4, subds, (a)-(b), 783.5, subd. (c)(2).)

DFG finds that issuance of this ITP complies and is consistent with the criteria governing the

issuance of ITPs under CESA:

(1) Take of Covered Species as defined in the ITP will be incidental to the otherwise lawful activities covered under the ITP;

(2) Impacts of the taking of the Covered Species will be minimized and fully mitigated through the implementation of measures required by this ITP and as described in the MMRP. Measures include: (1) Weekly biological monitoring; (2) Monthly Compliance Reports; (3) establishment of environmentally sensitive areas; (4) worker education; (5) hydroacoustic monitoring; and (6) permanent habitat protection. DFG evaluated the quality of the habitat on the Project site, the scope and extent of direct impacts, the scope and extent of indirect impacts, and other relevant information available to DFG or provided by Permittee. Based on this evaluation, DFG determined that the protection and management in perpetuity of 3.27 acres of compensatory habitat for delta smelt, and 3.1 acres of compensatory habitat for GGS that is contiguous with other protected Covered Species habitat and/or is of higher quality than the habitat being destroyed by the Project, along with the minimization, monitoring, reporting, and funding requirements of this ITP, meet the CESA issuance criteria;

(3) The take avoidance and mitigation measures required pursuant to the conditions of this ITP and its attachments are roughly proportional in extent to the impacts of the taking authorized by this ITP;

(4) The measures required by this ITP maintain Permittee's objectives to the greatest extent possible;

(5) All required measures are capable of successful implementation;

(6) The ITP is consistent with any regulations adopted pursuant to Fish and Game Code sections 2112 and 2114;

(7) Permittee has ensured adequate funding to implement the measures required by the ITP as well as for monitoring compliance with, and the effectiveness of, those measures for the Project; and

(8) Issuance of the ITP will not jeopardize the continued existence of the Covered Species based on the best scientific and other information reasonably available, and this finding includes consideration of the species' capability to survive and reproduce, and any adverse impacts of the taking on those abilities in light of (a) known population trends; (b) known threats to the species; and (c) reasonably foreseeable impacts on

the species from other related projects and activities. Moreover, DFG's finding is based, in part, on DFG's express authority to amend the terms and conditions of the ITP without concurrence of the Permittee as necessary to avoid jeopardy and as required by law.

Attachments:

ATTACHMENT 1	Mitigation Monitoring and Reporting Program
ATTACHMENT 2A,2B	Habitat Management Lands Checklist; PLFAF Form
ATTACHMENT 3	Mitigation Payment Transmittal Form
ATTACHMENT 4	Project Impacts Map

ISSUED BY THE CALIFORNIA DEPARTMENT OF FISH AND GAME

on 11/10/09.

Charles Armor, Regional Manager
BAY DELTA REGION

APPROVED AS TO FORM:

John H. Mattox
Senior Staff Counsel
Lead Counsel for CESA Permitting

ACKNOWLEDGMENT

The undersigned: 1) warrants that he or she is acting as a duly authorized representative of the Permittee, 2) acknowledges receipt of this ITP, and 3) agrees on behalf of the Permittee to comply with all terms and conditions of the ITP.

By: _____ Date: 11/16/09

Printed Name: Jeffrey G. Jensen Title: Office Chief Biological Sciences and Permits

Attachment 1

CALIFORNIA DEPARTMENT OF FISH AND GAME
MITIGATION MONITORING AND REPORTING PROGRAM (MMRP)
CALIFORNIA ENDANGERED SPECIES ACT

INCIDENTAL TAKE PERMIT NO. 2081-2009-022-03

PERMITTEE: **California Department of Transportation**

PROJECT: **Antioch Bridge Seismic Safety Project**

PURPOSE OF THE MMRP

The purpose of the MMRP is to ensure that the impact minimization and mitigation measures required by the Department of Fish and Game (DFG) for the above-referenced Project are properly implemented, and thereby to ensure compliance with section 2081(b) of the Fish and Game Code and section 21081.6 of the Public Resources Code. A table summarizing the mitigation measures required by DFG is attached. This table is a tool for use in monitoring and reporting on implementation of mitigation measures, but the descriptions in the table do not supersede the mitigation measures set forth in the California Incidental Take Permit (Permit) and in attachments to the Permit, and the omission of a permit requirement from the attached table does not relieve the Permittee of the obligation to ensure the requirement is performed.

OBLIGATIONS OF PERMITTEE

Mitigation measures must be implemented within the time periods indicated in the table that appears below. Permittee has the primary responsibility for monitoring compliance of all mitigation measures and for reporting to DFG on the progress in implementing those measures. These monitoring and reporting requirements are set forth in the Permit itself and are summarized at the front of the attached table.

VERIFICATION OF COMPLIANCE, EFFECTIVENESS

DFG may, at its sole discretion, verify compliance with any mitigation measure or independently assess the effectiveness of any mitigation measure.

TABLE OF MITIGATION MEASURES

The following items are identified for each mitigation measure: Mitigation Measure, Source, Implementation Schedule, Responsible Party, and Status/Date/Initials. The Mitigation Measure column summarizes the mitigation requirements of the Permit. The Source column identifies the Permit document that sets forth the mitigation measure. The Implementation Schedule column shows the date or phase when each mitigation measure will be implemented. The Responsible Party column identifies the person or agency that is primarily responsible for implementing the mitigation measure. The Status/Date/Initials column shall be completed by the Permittee during preparation of each Status Report and the Final Mitigation Report, and must identify the implementation status of each mitigation measure, the date that status was determined, and the initials of the person determining the status.

	Mitigation Measure	Source	Implementation Schedule	Responsible Party	Status / Date / Initials
BEFORE DISTURBING SOIL OR VEGETATION OR COMMENCING IN-WATER WORK					
1	Before initiating in-water, ground- or vegetation-disturbing Project activities, Permittee shall designate a representative (Designated Representative) responsible for communicating with DFG and overseeing compliance with this ITP. Permittee shall notify DFG in writing prior to commencement of in-water, ground- or vegetation-disturbing activities of the representative's name, business address, and contact information, and shall notify DFG in writing if a substitute representative is designated.	Permit Condition # 4.1	Before commencing in-water, ground- or vegetation-disturbing activities	Permittee	
2	At least 30 days before initiating in-water, ground- or vegetation-disturbing activities, Permittee shall submit to DFG in writing the name, qualifications, business address, and contact information for a biological monitor (Designated Biologist). The Designated Biologist shall be knowledgeable and experienced in the biology and natural history of the Covered Species and will be responsible for monitoring construction and/or in-water, ground- or vegetation-disturbing activities in areas of Covered Species habitat to help avoid the unauthorized take of individual Covered Species and to minimize disturbance of Covered Species' habitat. Permittee must obtain DFG approval of the Designated Biologist prior to the commencement of Project activities.	Permit Condition # 4.2	Before commencing in-water, ground- or vegetation-disturbing activities	Permittee	
3	To ensure compliance with the Conditions of Approval of this ITP, the Designated Biologist shall have authority, through the Engineer, to immediately stop any activity that is not in compliance with this ITP, and/or order any reasonable measure to avoid the take of an individual of the Covered Species.	Permit Condition # 4.3	Before commencing in-water, ground- or vegetation-disturbing activities	Permittee	
4	Permittee shall conduct an education program for all persons employed on the Project prior to their performing work on-site. The program shall consist of a presentation from the Designated Biologist that includes a discussion of the biology and general behavior of the Covered Species, information about the distribution and habitat needs of the Covered Species, sensitivity of the Covered Species to human activities, its status under CESA including legal protection, recovery efforts, penalties for violations and Project-specific protective measures described in this ITP. Interpretation shall be provided for non-English speaking workers, and the same instruction shall be provided for any new workers prior to their performing work on-site. Copies of this ITP shall be maintained at the worksite. Permittee shall prepare and distribute wallet-sized cards or a fact sheet handout containing this information for workers to carry on-site. Upon completion of the program, employees shall sign a form stating they attended the program and understand all protection measures. These forms shall be filed at the worksite offices and be available to DFG upon request.	Permit Condition # 4.4	Before commencing ground- or vegetation-disturbing activities	Permittee	
5	Permittee shall initiate a trash abatement program during pre-construction phases of the Project and continue the program throughout the duration of the Project. Trash and food items shall be contained in closed (raven-proof) containers and removed regularly (at least once a week) to avoid attracting opportunistic predators such as ravens, coyotes, and feral dogs.	Permit Condition # 4.5	Before commencing ground- or vegetation-disturbing activities / Entire Project	Permittee	

	Mitigation Measure	Source	Implementation Schedule	Responsible Party	Status / Date / Initials
6	Permittee shall implement dust control measures during Project activities to facilitate visibility for monitoring of the Covered Species by the Designated Biologist.	Permit Condition # 4.6	Entire Project	Permittee	
7	Permittee shall prohibit firearms and domestic dogs from the Project site and site access routes during construction of the Project, except those in the possession of authorized security personnel or local, State, or Federal law enforcement officials.	Permit Condition # 4.7	Entire Project	Permittee	
8	Permittee shall clearly delineate potential habitat of the giant garter snake within the Project limits with high visibility Environmentally Sensitive Area (ESA) fencing to minimize the disturbance of habitat. ESA fencing shall be erected as directed by the designated biologist, 200 ft from the edge of potential aquatic habitat for the giant garter snake.	Permit Condition # 4.8	Before commencing ground- or vegetation-disturbing activities /	Permittee	
9	Within 200 ft of GGS aquatic habitat Permittee shall post and maintain signs identifying the ESAs to construction personnel every 50 ft along the edge of the ESAs.	Permit Condition # 4.9	Before commencing ground- or vegetation-disturbing activities /	Permittee	
10	Permittee/personnel shall access the Project site during construction and development activities using existing routes and shall not cross GGS habitat outside of the Project site. Project-related vehicle traffic shall be restricted to established roads, staging, and parking areas. Vehicle speeds shall not exceed 20 miles per hour, except on county roads and state and federal highways, in order to avoid GGS on or traversing the roads. If construction of off-site routes of travel will be required, Permittee shall contact DFG prior to carrying out such an activity. DFG may require an amendment to this ITP if additional take of GGS may result from Project modification.	Permit Condition #4.10	Entire Project	Permittee	
11	Permittee shall confine all Project-related parking, storage areas, laydown sites, equipment storage, and any other surface-disturbing activities to the Project site using, to the extent possible, previously disturbed areas. Additionally, Permittee shall not use or cross giant garter snake habitat outside of the marked Project boundaries unless specifically provided for in this ITP.	Permit Condition # 4.11	Entire Project	Permittee	
12	Permittee shall immediately stop/repair and clean up any fuel or hazardous waste leaks or spills on the Project site during construction and development activities at the time of occurrence. Permittee shall exclude the storage and handling of hazardous materials from the construction zone and shall properly contain and dispose of any unused or leftover hazardous products off-site.	Permit Condition # 4.12	Entire Project	Permittee	
13	Permittee shall provide DFG staff with reasonable access to the Project site and mitigation lands under its control, and shall otherwise fully cooperate with DFG efforts to verify compliance with or effectiveness of mitigation measures set forth in the ITP. Neither the Designated Biologist nor DFG shall be liable for any costs incurred in complying with the Conditions of Approval, including cease-work orders issued by DFG.	Permit Conditions # 4.13	Entire Project	Permittee	

	Mitigation Measure	Source	Implementation Schedule	Responsible Party	Status / Date / Initials
14	Permittee shall not use erosion control materials potentially harmful to GGS such as mono-filament netting (used in erosion control matting or fiber rolls) or similar material.	Permit Condition # 4.14	Entire project	Permittee	
15	Permittee shall notify DFG fourteen calendar days before initiating in-water, ground- or vegetation-disturbing activities and shall document compliance with all Project Conditions of Approval before initiating in-water, ground- or vegetation-disturbing activities.	Permit Condition #5.3	14 days prior to in-water, ground- or vegetation-disturbing activities	Permittee	
16	Prior to commencing in-water, ground- or vegetation disturbing activities or within 30 days after the effective date of this ITP, whichever occurs first, Permittee shall provide written documentation that Permittee has allocated sufficient funds, acceptable to and approved by DFG, in the Expenditure Authorization for the Project to ensure implementation of the Conditions of Approval of this ITP. The written documentation submitted by the Permittee to satisfy this Condition shall be on official letterhead and signed by both the District Deputy Director of Project Management and the District Deputy Director of Environmental Planning and Engineering, and shall include a statement that at least $700,000.00 has been allocated specifically for the purpose of fulfilling Caltrans' mitigation obligations associated with this Permit and will not be redirected for other Project purposes. This amount is an estimate of the funds necessary to implement the ITP's mitigation, monitoring and reporting requirements, including habitat conservation credits or land acquisition costs, costs of enhancing HM Lands, and an endowment.	Permit Condition #8	Before commencing ground- or vegetation-disturbing activities /	Permittee	
DURING CONSTRUCTION					
17	Notwithstanding any expiration date on this ITP's take authorization, Permittee's obligations under this ITP do not end until DFG accepts the Final Mitigation Report (described in Condition 5.9) as complete.	Permit Condition # 4.16	Upon Project Completion	Permittee	
18	Upon Project completion, Permittee shall remove from the Project site and properly dispose of all construction refuse, including, but not limited to, broken equipment parts, wrapping material, cords, cables, wire, rope, strapping, twine, buckets, metal or plastic containers, and boxes.	Permit Condition # 4.15	Prior to project completion	Permittee	
19	If a Covered Species is killed by Project-related activities during construction, or if a Covered Species is otherwise found dead, the Designated Biologist shall immediately notify the DFG Regional Office at (707) 339-0334 or (707) 944-5517 and provide information on the location, species, number of animals injured or killed, and the Incidental Take Permit Number. Following the initial notification, Permittee shall send DFG a written report within two (2) calendar days. The report will include the date, time and location of the finding or incident, location of the carcass, and, if possible, should provide a photograph, cause of death, and any other pertinent information. See additional reporting requirements in Conditions 6.2 and 6.3 below.	Permit Condition # 5.1	Entire Project	Permittee	

	Mitigation Measure	Source	Implementation Schedule	Responsible Party	Status / Date / Initials
20	On-site restoration of giant garter snake habitat will be monitored for 1 year following the completion of restoration activities as described in Condition 6.7. Monitoring reports will be submitted to DFG following the restoration implementation and 1 year after the completion of the restoration effort.	Permit Condition # 5.2	Post-construction and one year after restoration implementation	Permittee	
21	Permittee shall immediately notify DFG in writing if it determines that it is not in compliance with any condition of approval of this ITP, including, but not limited to, any actual or anticipated failure to implement mitigation measures within the time periods indicated in this ITP and/or the MMRP. Permittee shall report any non-compliance during the construction phase to DFG within 24 hours.	Permit Condition # 5.4	Entire Project	Permittee	
22	Should SPLs exceed 206 decibels, with a sound exposure level of 183 decibels, within a 30-foot radius around each pile, causing an increase in the area of potential take, Permittee shall notify DFG to determine if an ITP amendment, additional impact analysis, and/or additional mitigation is required.	Condition #5.5	During in-water construction	Permittee	
23	Monthly Report: The Designated Biologist shall be on-site weekly while construction, in-water, or surface-disturbing activities are taking place to: (1) minimize take of the Covered Species; (2) check for compliance with all mitigation and avoidance measures; and (3) check ESA fencing, and that human activities are restricted to outside of these protective zones. The Designated Biologist shall also inspect material storage areas that have potential to provide retreat sites for Covered Species. These inspections shall be compiled into Monthly Compliance Reports and submitted to DFG's Regional Office listed in the Notices section of this ITP or via e-mail to DFG's Regional Representative at mescaron@dfg.ca.gov. DFG may at any time increase the timing and number of compliance inspections and reports required under this provision depending upon the results of previous compliance inspections (see Condition 5.4). All observations of Covered Species and their sign, oversight activities, verifications, compliance inspections, surveys, monitoring, and records required by this ITP shall be reported in writing to DFG by the Project Representative or Designated Biologist. Permittee shall submit reports of these activities to DFG in the next Monthly Compliance Report. DFG can change this condition at any time to require that additional reports are generated. If DFG determines the reporting schedule is inadequate, DFG will notify Permittee by letter of the new reporting schedule.	Permit Condition # 5.6	Entire Project	Permittee	
24	All observations of Covered Species and their sign, oversight activities, verifications, compliance inspections, surveys, monitoring, and records required by this ITP shall be reported in writing to DFG by the Project Representative or Designated Biologist. Permittee shall submit reports of these activities to DFG in the next Monthly Compliance Report. DFG can change this condition at any time to require that additional reports are generated. If DFG determines the reporting schedule is inadequate, DFG will notify Permittee by letter of the new reporting schedule.	Permit Condition # 5.7	Entire Project	Permittee	

	Mitigation Measure	Source	Implementation Schedule	Responsible Party	Status / Date / Initials
25	Annual Report: Permittee shall provide DFG with an Annual Status Report (ASR) no later than January 31 of every year beginning with issuance of the ITP and continuing until DFG accepts the Final Mitigation Report identified below. Each ASR shall include, at a minimum: (1) a general description of the status of the Project site and construction activities, including actual or projected completion dates, if known; (2) a copy of the table in the MMRP with notes showing the current implementation status of each mitigation measure; and (3) an assessment of the effectiveness of each completed or partially completed mitigation measure in minimizing and compensating for Project impacts.	Permit Condition # 5.8	Entire Project	Permittee	
26	Habitat Compensation Monitoring and Reporting: If Permittee mitigates habitat impacts through the purchase of credits at a conservation bank, proof of purchase of the credits shall be provided to DFG within 18 months of the start of in-water, vegetation- or ground-disturbing activities. Alternatively, if Permittee mitigates habitat impacts through the acquisition and permanent protection of Habitat Management Lands, documentation as described below in Conditions 7.2 and 7.4, shall be provided to DFG within 18 months of the start of in-water, vegetation- or ground-disturbing activities.	Permit Condition # 5.10	Within 18 months of start of in-water, vegetation- or ground-disturbing activities.	Permittee	
27	Permittee shall conduct all vegetation- or ground-disturbing activities within GGS habitat on Sherman Island between May 1 and October 1 of any year. Once temporary access roads are in place, Permittee shall not conduct further ground disturbing activity without approval from DFG.	Permit Condition # 6.1	Entire Project	Permittee	
28	If a GGS is found on the Project site, the Designated Biologist shall be notified immediately. GGS encountered in active construction areas shall be allowed to leave on their own volition. The Designated Representative shall notify DFG of the incident immediately, or no later than noon on the next business day if the incident occurs outside of normal business hours. Notification to DFG shall be via telephone or email, followed by a written incident report. Notification shall include the date, time, location and circumstances of the incident.	Permit Condition # 6.2	Entire Project	Permittee	
29	If a giant garter snake is injured as a result of Project-related activities, it shall be immediately taken to a DFG-approved wildlife rehabilitation or veterinary facility. Permittee shall identify the facility prior to the start of ground- or vegetation-disturbing activities. Permittee shall bear any costs associated with the care or treatment of such injured giant garter snake. Permittee shall notify DFG immediately unless the incident occurs outside of normal business hours. In that event DFG shall be notified no later than noon on the next business day. Notification to DFG shall be via telephone or email, followed by a written incident report. Notification shall include the date, time, location and circumstances of the incident, and the name of the facility where the animal was taken.	Permit Condition # 6.3	Entire Project	Permittee	
30	The Designated Biologist shall monitor for and clear the area of giant garter snakes during the installation of the ESA and silt fencing.	Permit Condition # 6.4	During ESA and silt fence installation	Permittee	
31	Permittee shall inspect and maintain Storm Water Pollution Prevention Plan (SWPPP) measures to minimize sediment transport into sensitive habitat areas during construction. A copy of the SWPPP shall be provided to DFG upon request.	Permit Condition # 6.5	Entire Project	Permittee	

	Mitigation Measure	Source	Implementation Schedule	Responsible Party	Status / Date / Initials
32	Permittee shall restore the approximately 2.22 acres of temporarily impacted GGS habitat on-site to pre-construction conditions. Permittee shall re-contour, if appropriate, and revegetate these areas with appropriate locally collected native plant species. The restoration effort shall comply with the U.S. Fish and Wildlife Service Guidelines for the Restoration and/or Replacement of GGS Habitat (USFWS, 1997) and shall be monitored for one year.	Permit Condition # 6.6	Upon removal of temporary access roads	Permittee	
33	All in-water pile installation work shall occur between August 1 and October 31 of any year. Permittee shall conduct in-water pile installation work between August 1 and October 31 of any year.	Permit Condition # 6.7	Entire Project	Permittee	
34	Permittee shall install trestle piles with a vibratory pile driver. Maximum pile diameter shall be 24 inches.	Permit Condition # 6.8	Entire Project	Permittee	
35	Permittee shall limit proofing of piles with an impact hammer to one pile per day during the installation of the marine trestle.	Permit Condition # 6.9	Entire Project	Permittee	
36	Permittee shall use an attenuation system to minimize hydroacoustic effects to fish during impact pile driving. The attenuation system may include, but is not limited to one or more of the following systems: a. A confined bubble curtain b. An unconfined bubble curtain c. Isolation casings d. Wooden pile cushions	Permit Condition # 6.10	Entire Project	Permittee	
37	It is anticipated sound pressure levels (SPLs) may reach 206 decibel (peak) and 183 decibel SEL (sound exposure level), within a 30 foot radius of each pile during installation with an impact hammer. For the purposes of this ITP, 1.09 acres is the area surrounding the piles where these levels and potential take of delta smelt may occur. Permittee shall conduct real time hydroacoustic monitoring during all trestle pile installation activities to measure efficacy of the sound attenuation system and to determine if the anticipated SPLs and associated distances from piles differ from the actual measurements. Should the hydroacoustic monitoring show the sound attenuation system is not sufficiently attenuating sound at, or below, the peak decibel level, Permittee shall halt pile driving until the sound attenuation system is repaired or augmented to ensure peak levels are not exceeded. Should the hydroacoustic monitoring show that SPL values are exceeding, or have exceeded, the above levels and/or that the actual area of potential take extends beyond the anticipated 30-foot radius, Permittee shall either take measures to increase the effectiveness of the sound attenuation system or obtain an ITP amendment from DFG.	Permit Condition # 6.11	Entire Project	Permittee	
38	If at any point turbidity levels exceed the acceptable criteria established by the Regional Water Quality Control Board and permitted by the SWPPP, construction activities shall halt until turbidity levels return to acceptable levels.	Permit Condition # 6.12	Entire Project	Permittee	

	Mitigation Measure	Source	Implementation Schedule	Responsible Party	Status / Date / Initials
39	Giant Garter Snake Habitat Compensation Prior to initiating in-water, ground- or vegetation-disturbing Project activities, or no later than 18 months from the start of in-water, ground- or vegetation- disturbing activities if a Funding Assurance Letter is provided pursuant to Condition 8 below, Permittee shall purchase 3.1 acres of GGS habitat conservation credits at a DFG-approved habitat conservation bank. Or: Prior to initiating in-water, ground- or vegetation-disturbing Project activities, or no later than 18 months from the start of in-water, ground- or vegetation-disturbing activities if a Funding Assurance Letter is provided pursuant to Condition 8 below, Permittee shall acquire and permanently preserve 3.1 acres of Habitat Management Lands (HM Lands) for GGS. The required acreage is based on factors including an assessment of the quality of the habitat at the Project site and DFG's estimate of the acreage required to provide for adequate biological carrying capacity at a replacement location. A minimum of six months prior to acquisition of the HM Lands, Permittee shall submit to DFG for approval a formal Proposed Lands for Acquisition Form (see Attachment 2B) identifying the land to be purchased as mitigation for the Project's impacts on GGS. Additionally, Permittee shall implement Condition 7.3 of the ITP (#41 below).	Permit Condition # 7.1 and 7.1.1	Prior to initiating in-water, ground- or vegetation-disturbing Project activities, or no later than 18 months from the start of in-water, ground- or vegetation-disturbing activities	Permittee	
40	Delta Smelt Habitat Compensation Prior to initiating in-water, ground- or vegetation-disturbing Project activities, or no later than 18 months from the start of in-water, ground- or vegetation-disturbing activities if a Funding Assurance Letter is provided pursuant to Condition 8 below, the Permittee shall purchase 3.27 acres of delta smelt habitat mitigation credits at a DFG-approved conservation bank. Or: Prior to initiating in-water, ground- or vegetation-disturbing Project activities, or no later than 18 months from the start of in-water, ground- or vegetation-disturbing activities if a Funding Assurance Letter is provided pursuant to Condition 8 below, Permittee shall acquire and permanently preserve 3.27 acres of Habitat Management Lands (HM Lands) for delta smelt. The required acreage is based on factors including an assessment of the quality of the habitat at the Project site and DFG's estimate of the acreage required to provide for adequate biological carrying capacity at a replacement location. A minimum of six months prior to acquisition of the HM Lands, Permittee shall submit to DFG for approval a formal Proposed Lands for Acquisition Form (see Attachment 2B) identifying the land to be purchased as mitigation for the Project's impacts on delta smelt. Additionally, Permittee shall implement Condition 7.3 of the ITP (#41 below).	Permit Condition # 7.2, 7.2.1	Prior to initiating in-water, ground- or vegetation-disturbing Project activities, or no later than 18 months from the start of in-water, ground- or vegetation-disturbing activities	Permittee	

	Mitigation Measure	Source	Implementation Schedule	Responsible Party	Status / Date / Initials
41	HM Land Transfer Requirements: Permittee shall do all of the following to provide for the permanent protection and management of the HM Lands for GGS and delta smelt: Permittee shall transfer fee title to the HM Lands to DFG or another entity under terms approved by DFG. If fee title is held by an entity other than DFG, a conservation easement in a form approved by DFG shall be recorded on title of the HM Lands. The grantee of the conservation easement may be DFG, a DFG-approved non-profit organization qualified pursuant to California Government Code section 65965, or a public agency approved by DFG and authorized to hold conservation easements. If a DFG-approved non-profit organization or authorized public agency is grantee on a conservation easement, DFG shall be named third party beneficiary; Permittee shall provide a recent preliminary title report, initial hazardous materials survey report, and other necessary documents (see Attachment 2A and 2B). All documents conveying the HM Lands and all conditions of title are subject to the approval of DFG and if applicable, the Wildlife Conservation Board and the Department of General Services; Permittee shall provide for the initial protection and enhancement of HM Lands, as approved by DFG, once Permittee identifies the HM Lands. DFG estimates that initial protection and enhancement will cost approximately $110,000.00/acre for 6.37 acres; Permittee shall conduct a Property Analysis Record (PAR) or PAR-equivalent analysis once the HM Lands have been identified to determine the appropriate endowment amount to fund the in-perpetuity management of HM Lands. Permittee shall provide the required endowment to DFG using the Mitigation Payment Transmittal Form (Attachment 3) after DFG reviews and approves the PAR. Permittee shall provide funding assurances for the endowment in the Funding Assurance Letter (see Condition 8 below). Interest from the endowment amount shall be available for reinvestment in the principal and for the long term operation, management, and protection of the HM Lands, including reasonable administrative overhead, biological monitoring, improvements to biological carrying capacity, law enforcement measures, and any other action designed to protect or improve the habitat values of the HM Lands. Money received by DFG pursuant to this condition shall be deposited in a special deposit account established pursuant to Fish and Game Code section 13014. Alternatively, endowment funds may be held by a DFG-approved entity qualified to hold endowment funds. DFG may pool the endowment with other endowments for the operation, management and protection of HM Lands for local populations of Covered Species; Permittee shall reimburse DFG for reasonable expenses incurred during title and documentation review, expenses incurred from other state agency reviews, and overhead related to transfer of HM Lands to DFG. DFG estimates that this Project will create an additional cost to DFG of no more than $3,000 for every fee title deed or easement processed.	Permit Condition # 7.3, 7.3.1, 7.3.2, 7.3.3, 7.3.4, 7.3.5	Prior to initiating in-water, ground- or vegetation-disturbing Project activities, or no later than 18 months from the start of in-water, ground- or vegetation-disturbing activities	Permittee	

	Mitigation Measure	Source	Implementation Schedule	Responsible Party	Status / Date / Initials
POST-CONSTRUCTION					
42	Approximately 2.22 acres of temporarily impacted giant garter snake habitat shall be restored on-site to pre-construction conditions. These areas will be re-contoured, if appropriate, and revegetated with appropriate locally collected native plant species. The restoration effort will comply with the USFWS Guidelines for the Restoration and/or Replacement of Giant Garter Snake Habitat (USFWS, 1997) and will be monitored for one year.	Permit Condition #6.6	One year after restoration implementation	Permittee	
43	No later than 45 days after completion of the Project, including completion of all mitigation measures, Permittee shall provide the DFG with a Final Mitigation Report. The Final Mitigation Report shall be prepared by the Designated Biologist and shall include, at a minimum: (1) a copy of this table with notes showing when each of the mitigation measures was implemented; (2) all available information about Project-related incidental take of the Covered Species; (3) Information about other Project impacts on the Covered Species; (4) construction dates; (5) an assessment of the effectiveness of the Permit's Conditions of Approval in minimizing and fully mitigating Project impacts of the taking on Covered Species; (6) recommendations on how mitigation measures might be changed to more effectively minimize take and mitigate the impacts of future projects on the species; and (7) any other pertinent information, including the level of take of the Covered Species associated with the Project.	Permit Condition # 5.9	Post-construction and after completion of mitigation	Permittee	

ATTACHMENT 2A
DEPARTMENT OF FISH AND GAME
HABITAT MANAGEMENT LAND ACQUISITION PACKAGE CHECKLIST FOR PROJECT APPLICANTS

The following checklist is provided to inform you of what documents are necessary to expedite Department processing of your Habitat Management Land acquisition proposal. Any land acquisition processing requests which are incomplete when received, will be returned. The Region contact will review and approve the document package and forward it to the Lands and Facilities Branch (LFB) Realty Services Coordinator with a request to process the land acquisition for formal acceptance.

To: _____
Regional Manager, Region Name

From: _____
Project Applicant

Phone: _____

Tracking #: _____
CDFG assigned permit or agreement #

Project Name: _____

Enclosed is the complete package for the ☐ Conservation Easement OR ☐ Grant Deed

Documents in this package include:

☐ Fully executed, approved as to form Conservation Easement Deed or Grant Deed.
Date executed: _____

☐ Proposed Lands for Acquisition Form (PLFAF)

☐ Phase I Environmental Site Assessment Report Date on report: _____
(An existing report may be used, but it must be less than two years old.)

☐ Preliminary Title Report(s) for subject property is enclosed and has been reviewed for encumbrances and other easements. The title report must be less than six months old when final processing is conducted.
Included are additional documents:
- ☐ document(s) to support title exceptions
- ☐ document(s) to explain title encumbrances
- ☐ a plot or map of easements/encumberances on the property

☐ Policy of Title Insurance (an existing title policy is not acceptable)

☐ County Assessor Parcel Map(s) for subject property

☐ Site Location Map (Site location with property boundaries outline on a USGS 1:24,000 scale topo)

☐ Final Permit or Agreement (or other appropriate instrument)
Type of agreement: ☐ Bank Agreement ☐ Mitigation Agreement
☐ Permit _____ Other: _____
(write in type of permit)

☐ Final Management Plan (if required prior to finalizing permit or agreement or if this package is for a Grant Deed)

☐ Biological Resources Report

☐ Draft Summary of Transactions ☐ hard copy ☐ electronic copy (both are required)

PROPOSED LANDS FOR ACQUISITION FORM ("PLFAF")

Date: _____

TO: Regional Representative
_____
_____
_____
Facsimile:

FROM:_____
_____
_____
_____

Applicant proposes that the following parcel of land be considered for approval by the Department as suitable for purposes of habitat management lands to replace the adverse environmental impacts of the Project:

Section	Township	Range	Number of Acres
_____	_____	_____	_____

Current Legal Owner(s), include Parcel Number(s):
_____
_____
_____

Location of Parcel:
_____
_____
_____
_____
_____

APPROVED ___ By:_____ DATE:_____
REJECTED ___ _____
Region

Explanation:_____
_____
_____

ATTACHMENT 3

California Department of Fish and Game

Mitigation Payment Transmittal Form

Project Applicant Instructions: Please fill out and attach this form to payment. For conservation banks, also attach the Bill(s) of Sale for credits sold. One form may be used for multiple transactions, **BUT YOU MUST USE A SEPARATE FORM FOR EACH CHECK YOU TRANSMIT**. Make sure to include Project Name, Project Tracking Number, and ASB Mitigation Tracking Number (if available) on the attached payment type.

(1) **DATE:** _____

TO: _____
[CDFG Regional Manager]

_____
[CDFG Region Office Address]

(2) **FROM:** _____
Name

_____
Mailing Address

_____
City, State, Zip

_____
Telephone Number/FAX Number

(3) **RE:** Antioch Bridge Seismic Retrofit Project
[Project Name as appears on permit/agreement]

(4) **AGREEMENT/ACCOUNT INFORMATION:**
(Check the applicable type)

□ 2081 Permit □ Conservation Bank □ 1802 Agreement

□ 2835 NCCP □ Other _____

2081-2009-022-03
[Project Tracking Number]

_____
[ASB Mitigation Tracking Number (if available)]

Index _____ PCA _____

(5) PAYMENT TYPE (One check per form only): The following funds are being remitted in connection with the above referenced project:

Check information:

Total $_____ Check No. _____

Account No. _____ Bank Routing No. _____

a. Endowment: for Long-Term Management Subtotal $_____

b. Habitat Enhancement Subtotal $_____

c. Security:

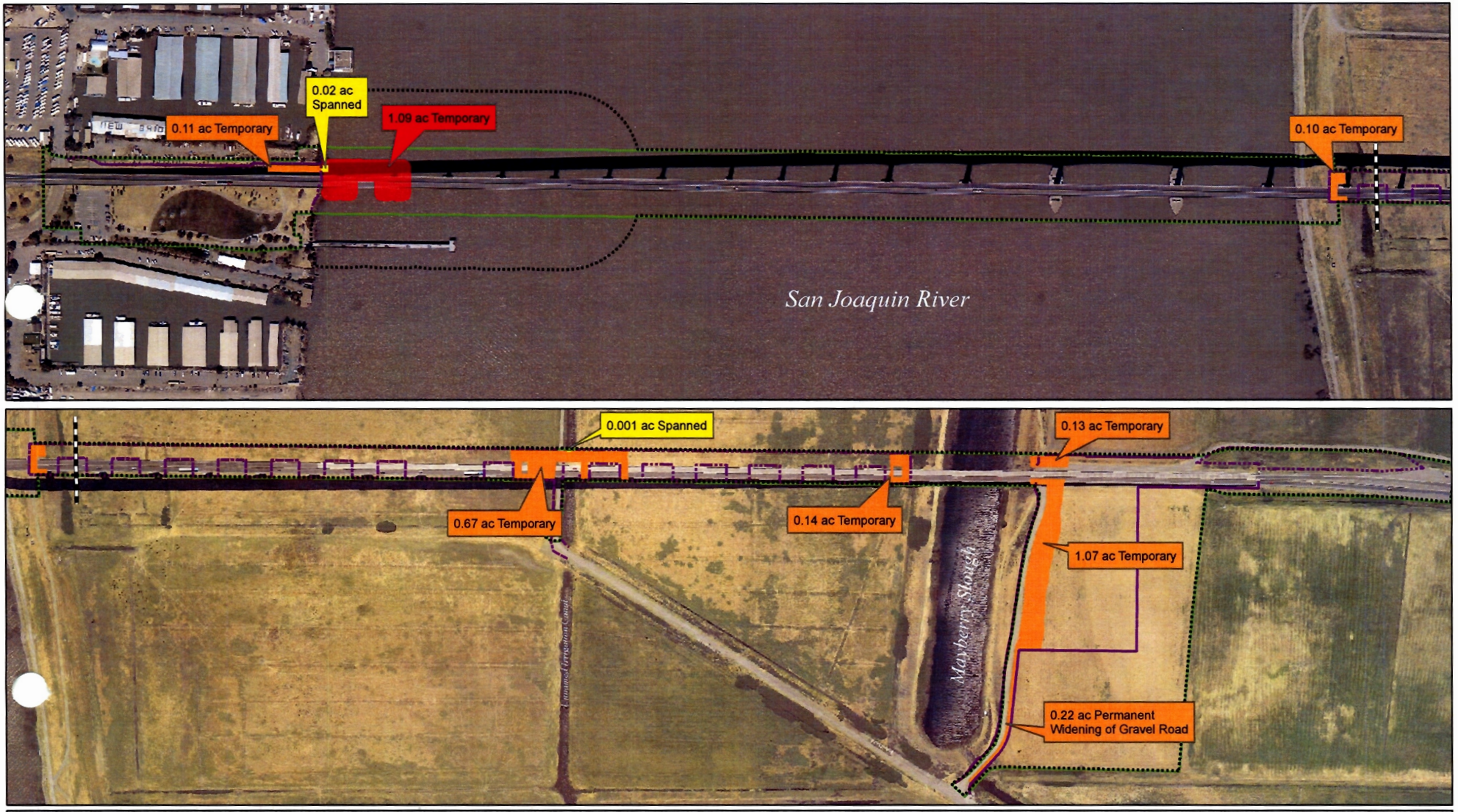
1. Cash Refundable Security Deposit Subtotal $_____

2. Letter of Credit Subtotal $_____

1. Financial Institution: _____

2. Letter of Credit Number: _____

3. Date of Expiration: _____



Attachment 4. Project impacts.

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Southwest Region
501 West Ocean Boulevard, Suite 4200
Long Beach, California 90802-4213

JUN 2 3 2009

In Response Refer To:
2009/00173

Jeffery G. Jensen
Office Chief, Office of Biological Sciences and Permits
Department of Transportation
111 Grand Avenue
P.O. Box 23660
Oakland, California 94623-0660

Dear Mr. Jensen:

Enclosed is NOAA's National Marine Fisheries Service's (NMFS) biological and conference opinion (Enclosure 1) for the proposed Antioch Bridge Seismic Retrofit project (Project) located in Contra Costa and Sacramento Counties, California, and its effects on Sacramento River Winter-run Chinook salmon (*Oncorhynchus tshawytscha*), Central Valley (CV) Spring-run Chinook salmon (*O. tshawytscha*), CV steelhead (*O. mykiss*), and Southern Distinct Population Segment (DPS) of North American green sturgeon (*Acipenser medirostris*) in accordance with section 7 of the Endangered Species Act (ESA) of 1973, as amended (16 U.S.C. 1531 *et seq.*). Your initial request for formal section 7 consultation and conferencing on this project was received on January 26, 2009. On February 6, 2009, formal consultation and conferencing was initiated by NMFS' Sacramento Area Office.

This biological and conference opinion is based primarily on the biological assessment (BA) provided on January 14, 2009. The BA incorporated recommendations and addressed NMFS comments as discussed in meetings, correspondence, and emails.

Based on the best available scientific and commercial information, the biological and conference opinion concludes that the Project, as presented by the California Department of Transportation, is not likely to jeopardize the continued existence of the listed species or destroy or adversely modify designated or proposed critical habitat. NMFS anticipates that the proposed project will result in the incidental take of CV steelhead and North American green sturgeon. An incidental take statement that includes reasonable and prudent measures and non-discretionary terms and conditions that are intended to minimize the impact of the anticipated incidental take of CV steelhead and North American green sturgeon is included with the opinion. The section 9 prohibitions against taking of listed species and the terms and conditions in the incidental take statement of this conference and biological opinion will not apply to the Southern DPS of North American green sturgeon until a final section 4(d) ruling under the ESA has been published in the Federal Register. Additionally, the analysis of project effects on proposed critical habitat for the Southern DPS of North American green sturgeon is considered a conference opinion for those effects. This conference opinion does not take the place of a biological opinion under

section 7(a)2 of the ESA. The conference opinion may be adopted as a biological opinion when the proposed critical habitat designation for the Southern DPS of North American green sturgeon becomes final if no significant new information is developed, and no significant changes to the project are made that would alter the contents, analyses or conclusions of this opinion.

Also enclosed are NMFS' Essential Fish Habitat (EFH) conservation recommendations for Pacific salmon (O. tshawytscha) as required by the Magnuson-Stevens Fishery Conservation and Management Act as amended (16 U.S.C. 1801 *et seq.*; Enclosure 2). The document concludes that the Project will adversely affect the EFH of Pacific salmon in the action area and adopts certain terms and conditions of the incidental take statement and the ESA conservation recommendations of the biological opinion as the EFH conservation recommendations.

Please contact Monica Gutierrez at our Sacramento Area Office at (916) 930-3657, or via e-mail at Monica.Gutierrez@noaa.gov, if you have any questions regarding this response or require additional information.

Sincerely,

Rodney R. McInnis
Regional Administrator

Enclosures (2)

cc: Copy to file – ARN# 151422SWR2009SA00060
NMFS-PRD, Long Beach, CA
Bryan Chesney, Long Beach, CA

Enclosure 1

BIOLOGICAL and CONFERENCE OPINION

ACTION AGENCY: California Department of Transportation

ACTION: Antioch Bridge Seismic Retrofit Project

CONSULTATION
CONDUCTED BY: Southwest Region, National Marine Fisheries Service – MG 2009/00173

FILE NUMBER: 151422SWR2009SA00060

DATE ISSUED: June 23, 2009

I. CONSULTATION HISTORY

The California Department of Transportation (Caltrans) proposes to retrofit the Antioch Bridge on State Route (SR) 160 in Contra Costa and Sacramento Counties, California. The seismic retrofit of Antioch Bridge is a necessary action for the bridge to meet current design standards. The original construction of Antioch Bridge was completed in 1978. The seismic design of the bridge was based on the criteria developed after the San Francisco Earthquake of 1971. The Loma Prieta Earthquake of 1989 prompted Caltrans to implement the Seismic Retrofit Program (Program). After the Northridge Earthquake of 1994, Caltrans implemented Phase two of the Program, which required seven state-owned toll bridges, including the Antioch Bridge, to be retrofitted.

On April 21, 2008, the first of several pre-consultation meetings was held at the Caltrans District 4 office in Oakland, California. Technical assistance was provided to Stuart Kirkham (Caltrans District 4) relating to Incidental Harassment Authorization under the Marine Mammals Protection Act and other pre-consultation discussions.

On September 10, 2008, a meeting was held at the Caltrans headquarters in Sacramento, California, to discuss design changes to the project description. In addition, John Clecker (U.S. Fish and Wildlife [USFW] Biologist) specified an in-water work window (August 1-November 30) for delta smelt (*Hypomesus transpacificus*) for the project region. Doug Hampton (National Marine Fisheries Service [NMFS] Biologist) concurred, stating that a work window of August 1-October 31 would cover both delta smelt and Chinook salmon, but that he would allow up to November 30 as a work window, provided that the project proponent incorporated appropriate minimization measures in constructing the temporary marine trestle (*e.g.* limiting pile size to no

greater than 24-inch diameter, vibrating piles). Melissa Escaron (California Department of Fish and Game [CDFG] Biologist) concurred with the work window.

On November 5, 2008, the second interagency meeting for the Antioch Bridge Seismic Retrofit Project was held at Caltrans Headquarters in Sacramento, California. At this meeting, John Clecker, suggested sending copies of the biological assessment (BA) to every party that would need the biological and conference opinion (BO). He also agreed with NMFS on the methodology Caltrans was pursing in the hydro-acoustic analysis.

On December 3, 2008, a teleconference was held between NMFS and Caltrans to confirm the in-water work windows and avoidance and minimization measures. NMFS indicated that the August 1- November 30 work window would be likely to avoid impacts to all the NMFS species for the project, except for CV steelhead. Avoidance and minimization measures for Green sturgeon were not discussed.

On January 6, 2009, another teleconference was held between NMFS, Stuart Kirkham (Caltrans District 4), and Melissa Escaron, to discuss project effects to CV steelhead and proposed mitigation. NMFS concurred with Caltrans' estimates of take for CV steelhead, and the proposed compensatory mitigation, pending review of Caltrans' analysis report on the estimates of CV steelhead.

On January 14, 2009, a meeting was held at the Caltrans Headquarters in Sacramento to discuss summary of findings, conclusions, and determinations of the draft BA.

On January 26, 2009, NMFS received a letter from Caltrans (District 4) requesting initiation of formal section 7 consultation under ESA.

II. DESCRIPTION OF THE PROPOSED ACTION

A. Construction Activities

Caltrans proposes to retrofit the Antioch Bridge to meet current seismic standards due to current insufficient bridge performance during a maximum credible earthquake. Caltrans plans to install steel cross bracing between columns to stiffen the superstructure cross frames (pier 12 to pier 31) and will install bracing to the existing cross frames at the bent caps (pier 2 to pier 40). The existing elastometric bearings will be replaced with isolation bearings (abutment 1 to pier 41). Existing curtain walls will be removed and all columns within the slab span structure (bent 42 to abutment 71) will be retrofitted. A temporary marine trestle, with an approximate length of 910 feet and a width of 25 feet, will be constructed from the south bank of the San Joaquin River to pier 11 to allow construction access to the piers in the shallow water area. The trestle platform is expected to be approximately 5 feet above the Mean Higher-High Water (MHHW). The trestle will be constructed using approximately 160, 24-inch diameter hollow steel shell piles. The piles will be installed with a vibratory hammer, which should take approximately 10 minutes per pile to install. An impact hammer will be used on every other pile to ensure that the piles meet load

bearing specifications. This will result in a maximum of 60 strikes per day. Pile installation will be limited to the in-water work window of August 1-November 30. A temporary access road on the south shore will be constructed to allow access to the temporary marine trestle. At the completion of the project, the trestle along with the piles will be removed by the same vibratory hammer used to install the piles. The duration of the vibration for removing the piles will be no longer than 30 sec/pile. Barges will be used to retrofit piers 12 to 21 and no aquatic impacts are anticipated beyond the potential installation of mooring lines.

Another temporary access road will be constructed from the southernmost bridge support on Sherman Island (pier 22) to the last bridge support of Mayberry Slough (pier 38) to provide construction access for retrofit work. There will be construction of another temporary access road that parallels the slab span structure on both sides, north of Mayberry Slough, to facilitate removal of the curtain walls from the slab structure and reinforce existing columns and abutments and to allow work for the permanent widening of an existing access road along Mayberry Slough to access piers north of Mayberry Slough. There is no anticipated aquatic disturbance during the construction of the temporary access roads. The proposed project is scheduled to begin mid-2010 and end in late 2012.

B. Action Area

Action area is defined as areas to be affected directly or indirectly by the Federal action and not merely the immediate area involved in the action (50 CFR 402.02). For purposes of this consultation, the action area consists of two components. The terrestrial component of the action area is defined by: 1) the project footprint, including all cleared areas, and staging areas; and 2) construction noise levels in excess of ambient conditions. The aquatic component of the action area is defined by: 1) the segment of the Feather River upstream and downstream of bridge construction sites where pile driving sound noise levels are expected to exceed ambient conditions; 2) construction-related water quality impacts in excess of ambient conditions; and 3) operational stormwater quality impacts in excess of ambient conditions. A plan view map of the project vicinity showing the action area boundary is presented in Figure 1.

The proposed Antioch Bridge Seismic Retrofit project is located along a two mile (mi) stretch of SR 160, from the southern limit of the project at Post Mile (PM) 0.8 in Contra Costa County to PM 1.3 at the Contra Costa/Sacramento County line, and from PM 0 to PM 1.3 in Sacramento County, on Sherman Island (Figure 1). The bridge currently supports SR 160 and connects the City of Antioch on the south bank of the San Joaquin River to Sherman Island on the north. It spans the 3,600-foot (ft) width of the river and over 4,000 feet of Sherman Island, before touching down just north of Mayberry Slough. The San Joaquin River is relatively shallow on the south side, with depths of less than 10 ft out to pier 11. The main channel extends between piers 12 and 20 with deep water passage between piers 19 and 20 near the northern shore. On the north side of the river, Sherman Island supports irrigated pasture and irrigated crops as well as ruderal vegetation in fallow fields. Mayberry Slough and an irrigation canal cross the project action area in the vicinity of piers 32, 39, and 40, respectively.

The project limits, which include Caltrans right-of-way (ROW) and temporary construction easements, cover approximately 62 acres (ac), including 7.5 ac on the south shore of the San Joaquin River in Contra Costa County, 21 ac of the San Joaquin River, and 33.5 ac on Sherman Island in Sacramento County. The action area consists of the project's footprint including areas for access and staging. No areas of indirect effects are anticipated. The action area also includes the project limit, plus an additional 8577 m zone around the temporary trestle which represents the extent of elevated underwater sound pressure levels that may result in adverse behavioral responses to listed species.

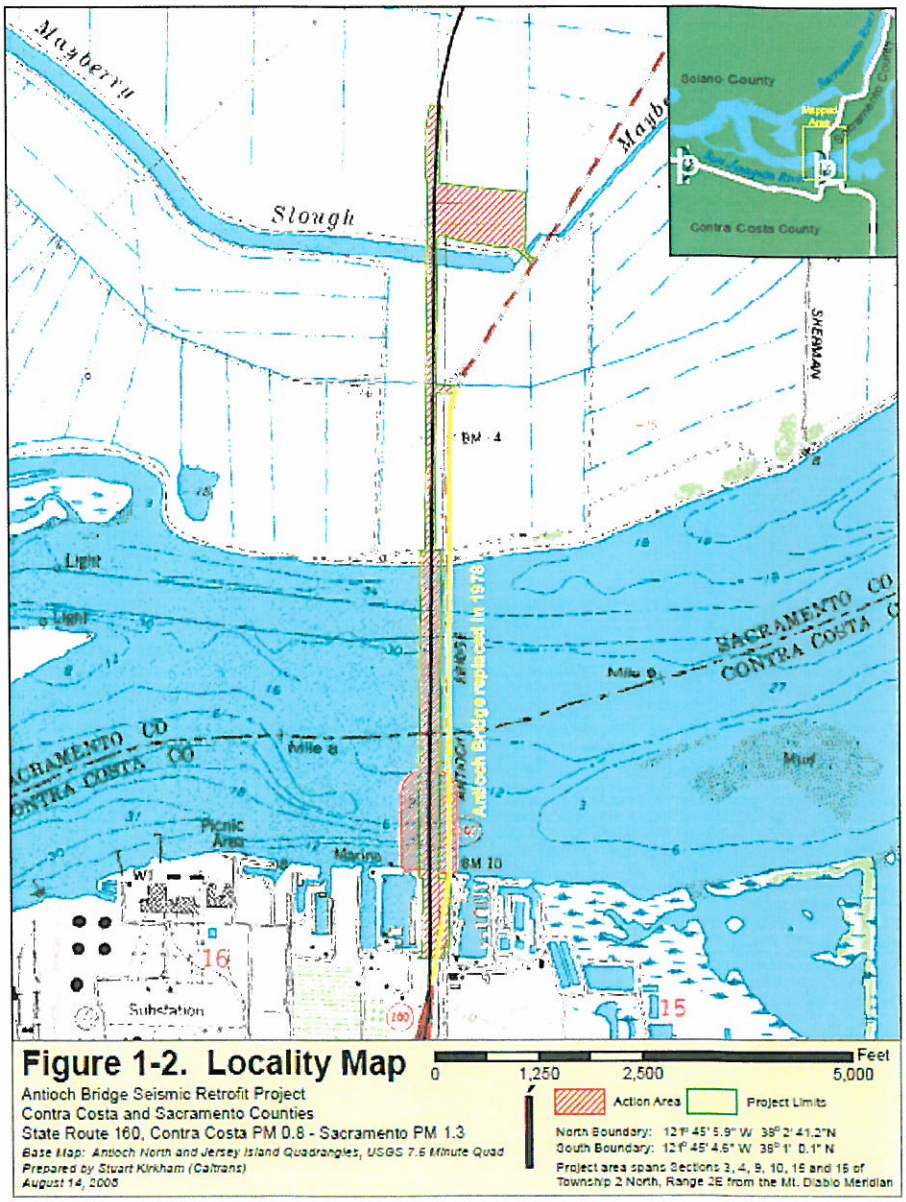


Figure 1. Antioch Bridge Seismic Retrofit project area map (Kirkham 2008)

C. Proposed Conservation Measures

The following conservation measures have been incorporated into the project design to avoid and/or minimize potential adverse effects of the proposed project on special status fish species and their designated and/or proposed critical habitats.

1. The Project Delivery Team (PDT) altered the design strategy such that deep water permanent pile driving to reinforce the foundations of the bridge columns will be unnecessary, a change which will greatly reduce the potential for effects to the listed ESA fish species in the San Joaquin River. Additionally, coordination efforts concerning the temporary marine trestle have refined the design parameters of the temporary structure to use a vibratory hammer for pile driving and to limit the pile size to a maximum diameter of 24 in, which will minimize the hydro-acoustic signature and effects on earlier life stages and smaller individuals of listed anadromous fish. Caltrans will proof one pile per day for every 4 to 6 piles. In other words, one pile per day (thus, either 1 of 4 or 1 of 6) will be tested with an impact hammer to see if the pile will withstand the load that the trestle will have to bear.

2. An in-water work window will be established from August 1 to November 30. This will help avoid any direct impacts to most ESA-listed species covered under this consultation. However, adult and juvenile CV steelhead and green sturgeon may be present in the action area during the proposed in-water construction period.

3. Barges will be used to retrofit piers 12 to 21, and no aquatic impacts are anticipated from this activity.

4. Bridge cross bracings that will be installed between bridge columns will be anchored to the columns using a drill and bond method. This method will reduce the amount of concrete debris that could potentially fall into the San Joaquin River.

5. This project will not require on-site borrow or disposal of excavated material. Gravel and rock will be imported for construction of the temporary access road and road widening. These materials will be removed upon completion of the project, and removal and disposal of this material will be implemented through contractors and subcontractors as part of the Caltrans standard Best Management Practices (BMPs) and Stormwater Pollution Prevention Plan (SWPPP). BMPs and SWPPP measures are a standard part of the plans and specifications for this project and are included in the California Central Valley Regional Water Quality Control Board (CVRWQCB) Section 401 Water Quality Certification.

III. STATUS OF THE SPECIES AND CRITICAL HABITAT

The following Federally listed species evolutionary significant units (ESU) or distinct population segments (DPS) and designated or proposed critical habitat occur in the action area and may be affected by the proposed project:

Sacramento River winter-run Chinook salmon ESU (*Oncorhynchus tshawytscha*) endangered (June 28, 2005, 70 FR 37160)
Sacramento River winter-run Chinook salmon designated critical habitat (June 16, 1993, 58 FR 33212)
Central Valley spring-run Chinook salmon ESU (*Oncorhynchus tshawytscha*) threatened (June 28, 2005, 70 FR 37160)
Central Valley spring-run Chinook salmon designated critical habitat (September 2, 2005, 70 FR 52488)
Central Valley steelhead DPS (*Oncorhynchus mykiss*) threatened (January 5, 2006, 71 FR 834)
Central Valley steelhead designated critical habitat (September 2, 2005, 70 FR 52488)
Southern DPS of North American green sturgeon (*Acipenser medirostris*) threatened (April 7, 2006, 70 FR 17757)
Southern DPS of North American green sturgeon proposed critical habitat (September 8, 2008, 73 FR 52084)

A. Species and Critical Habitat Listing Status

In 2005, NMFS completed an updated status review of 16 salmon ESUs, including Sacramento River winter-run Chinook salmon and Central Valley (CV) spring-run Chinook salmon, and concluded that the species' status should remain as previously listed (June 28, 2005, 70 FR 37160). On January 5, 2006, NMFS published a final listing determination for 10 steelhead DPSs, including CV steelhead. The new listing concludes that CV steelhead will remain listed as threatened (71 FR 834).

1. Sacramento River Winter-run Chinook salmon

Sacramento River winter-run Chinook salmon were originally listed as threatened in August 1989, under emergency provisions of the ESA, and formally listed as threatened in November 1990 (55 FR 46515). The ESU consists of only one population that is confined to the upper Sacramento River in California's Central Valley. The Livingston Stone National Fish Hatchery population has been included in the listed Sacramento River winter-run Chinook salmon population as of June 28, 2005 (70 FR 37160). NMFS designated critical habitat for winter-run Chinook salmon on June 16, 1993 (58 FR 33212). The ESU was reclassified as endangered on January 4, 1994 (59 FR 440), due to increased variability of run sizes, expected weak returns as a result of two small year classes in 1991 and 1993, and a 99 percent decline between 1966 and 1991. NMFS reaffirmed the listing of Sacramento River winter-run Chinook salmon as

endangered on June 28, 2005 (70 FR 37160). The critical habitat designation includes the Sacramento River from Keswick Dam, Shasta County (River Mile 302) to Chipps Island (River Mile 0) at the westward margin of the Sacramento-San Joaquin Delta; all waters from Chipps Island westward to Carquinez Bridge, including Honker Bay, Grizzly Bay, Suisun Bay, and Carquinez Strait; all waters of the San Pablo Bay westward of the Carquinez Bridge; and all waters of San Francisco Bay (north of the San Francisco/Oakland Bay Bridge) from San Pablo Bay to the Golden Gate Bridge (58 FR 33212). Designated critical habitat for Sacramento River winter-run Chinook salmon does not occur within the proposed project's action area.

2. CV spring-run Chinook salmon

NMFS listed the CV spring-run Chinook salmon ESU as threatened on September 16, 1999 (64 FR 50394). In June 2004, NMFS proposed that CV spring-run Chinook salmon remain listed as threatened (69 FR 33102). This proposal was based on the recognition that although CV spring-run Chinook salmon productivity trends are positive, the ESU continues to face risks from having a limited number of remaining populations (*i.e.*, 3 existing independent populations from an estimated 17 historical populations), a limited geographic distribution, and potential hybridization with Feather River Hatchery (FRH) spring-run Chinook salmon, which until recently were not included in the ESU and are genetically divergent from other populations in Mill, Deer, and Butte creeks. On June 28, 2005, after reviewing the best available scientific and commercial information, NMFS issued its final decision to retain the status of CV spring-run Chinook salmon as threatened (70 FR 37160). This decision also included the FRH spring-run Chinook salmon population as part of the CV spring-run Chinook salmon ESU. Critical habitat was designated for CV spring-run Chinook salmon on September 2, 2005 (70 FR 52488). Designated critical habitat includes approximately 8,935 net miles (mi) of riverine habitat and 470 mi^2 of estuarine habitat (primarily in San Francisco-San Pablo-Suisun Bays) in California (70 FR 52488). Designated critical habitat for CV spring-run Chinook salmon does not occur within the proposed project's action area.

3. CV steelhead

CV steelhead were originally listed as threatened on March 19, 1998 (63 FR 13347). This DPS consists of steelhead populations in the Sacramento and San Joaquin river basins in California's Central Valley. In June 2004, after a complete status review of the 26 west coast salmon DPSs, NMFS proposed that CV spring-run Chinook salmon remain listed as threatened (69 FR 33102), while the other Chinook salmon and steelhead were further reviewed. On June 28, 2005, after reviewing the best available scientific and commercial information, NMFS issued its final decision to retain the status of CV steelhead as threatened (70 FR 37160). This decision also included the Coleman National Fish Hatchery and FRH steelhead populations. These populations were previously included in the DPS but were not deemed essential for conservation and thus not part of the listed steelhead population. Critical habitat was designated for CV steelhead on September 2, 2005 (70 FR 52488). Critical habitat includes the stream channels to the ordinary high water line within designated stream reaches such as those of the American, Feather, and Yuba Rivers, and Deer, Mill, Battle, Antelope, and Clear Creeks in the Sacramento

River basin; the Calaveras, Mokelumne, Stanislaus, and Tuolumne Rivers in the San Joaquin River basin; and, the Sacramento and San Joaquin Rivers and Delta. Designated critical habitat for CV steelhead does occur within the proposed project's action area.

4. Southern DPS of North American Green Sturgeon

The Southern DPS of North American green sturgeon was listed as threatened on April 7, 2006, (70 FR 17386). The Southern DPS presently contains only a single spawning population in the Sacramento River, and adults and juveniles may occur within the action area. NMFS issued proposed critical habitat for the Southern DPS of North American green sturgeon on September 8, 2008 (73 FR 52084). The areas proposed as critical habitat include: coastal U.S. marine waters within 110 meters (m) depth from Monterey Bay, California (including Monterey Bay), north to Cape Flattery, Washington, including the Strait of Juan de Fuca, Washington, to its United States boundary; the Sacramento River, lower Feather River, and lower Yuba River in California; the Sacramento-San Joaquin Delta and Suisun, San Pablo, and San Francisco bays in California; the lower Columbia River estuary; and certain coastal bays and estuaries in California (Humboldt Bay), Oregon (Coos Bay, Winchester Bay, and Yaquina Bay), and Washington (Willapa Bay and Grays Harbor). Proposed critical habitat for Southern DPS of North American green sturgeon does occur within the proposed project's action area.

B. Species Life History, Population Dynamics, and Likelihood of Survival and Recovery

1. Chinook Salmon

a. General Life History

Chinook salmon exhibit two generalized freshwater life history types (Healey 1991). "Stream-type" Chinook salmon, enter freshwater months before spawning and reside in freshwater for a year or more following emergence, whereas "ocean-type" Chinook salmon spawn soon after entering freshwater and migrate to the ocean as fry or parr within their first year. Spring-run Chinook salmon exhibit a stream-type life history. Adults enter freshwater in the spring, hold over summer, spawn in fall, and the juveniles typically spend a year or more in freshwater before emigrating. Winter-run Chinook salmon are somewhat anomalous in that they have characteristics of both stream- and ocean-type races (Healey 1991). Adults enter freshwater in winter or early spring, and delay spawning until spring or early summer (stream-type). However, juvenile winter-run Chinook salmon migrate to sea after only 4 to 7 months of river life (ocean-type). Adequate instream flows and cool water temperatures are more critical for the survival of Chinook salmon exhibiting a stream-type life history due to over summering by adults and/or juveniles.

Chinook salmon typically mature between 2 and 6 years of age (Myers *et al.* 1998). Freshwater entry and spawning timing generally are thought to be related to local water temperature and flow regimes. Runs are designated on the basis of adult migration timing; however, distinct runs also differ in the degree of maturation at the time of river entry, thermal regime and flow

characteristics of their spawning site, and the actual time of spawning (Myers *et al.* 1998). Both spring-run and winter-run Chinook salmon tend to enter freshwater as immature fish, migrate far upriver, and delay spawning for weeks or months. For comparison, fall-run Chinook salmon enter freshwater at an advanced stage of maturity, move rapidly to their spawning areas on the mainstem or lower tributaries of the rivers, and spawn within a few days or weeks of freshwater entry (Healey 1991).

During their upstream migration, adult Chinook salmon require stream flows sufficient to provide olfactory and other orientation cues used to locate their natal streams. Adequate stream flows are necessary to allow adult passage to upstream holding habitat. The preferred temperature range for upstream migration is 38 °F to 56 °F (Bell 1991; CDFG 1998). Boles (1988) recommends water temperatures below 65 °F for adult Chinook salmon migration, and Lindley *et al.* (2004) report that adult migration is blocked when temperatures reach 70 °F, and that fish can become stressed as temperatures approach 70 °F. Reclamation reports that spring-run Chinook salmon holding in upper watershed locations prefer water temperatures below 60 °F; although salmon can tolerate temperatures up to 65 °F before they experience an increased susceptibility to disease.

Information on the migration rates of adult Chinook salmon in freshwater is scant and primarily comes from the Columbia River basin where information regarding migration behavior is needed to assess the effects of dams on travel times and passage (Matter *et al.* 2003). Keefer *et al.* (2004) found migration rates of Chinook salmon ranging from approximately 10 kilometers (km) per day to greater than 35 km per day and to be primarily correlated with date, and secondarily with discharge, year, and reach, in the Columbia River basin. Matter *et al.* (2003) documented migration rates of adult Chinook salmon ranging from 29 to 32 km per day in the Snake River. Adult Chinook salmon inserted with sonic tags and tracked throughout the Delta and lower Sacramento and San Joaquin rivers were observed exhibiting substantial upstream and downstream movement in a random fashion while on their upstream migration (California Bay-Delta Authority (CALFED) 2001). Adult salmonids migrating upstream are assumed to make greater use of pool and mid-channel habitat than channel margins (Stillwater Sciences 2004), particularly larger salmon such as Chinook salmon, as described by Hughes (2004). Adults are thought to exhibit crepuscular behavior during their upstream migrations; meaning that they primarily are active during twilight hours. Recent hydroacoustic monitoring showed peak upstream movement of adult CV spring-run Chinook salmon in lower Mill Creek, a tributary to the Sacramento River, occurring in the 4-hour period before sunrise and again after sunset.

Spawning Chinook salmon require clean, loose gravel in swift, relatively shallow riffles or along the margins of deeper runs, and suitable water temperatures, depths, and velocities for redd construction and adequate oxygenation of incubating eggs. Chinook salmon spawning typically occurs in gravel beds that are located at the tails of holding pools (USFWS 1995a). The range of water depths and velocities in spawning beds that Chinook salmon find acceptable is very broad. The upper preferred water temperature for spawning Chinook salmon is 55 °F to 57 °F (Chambers 1956; Smith 1973; Bjornn and Reiser 1991; Snider 2001).

During the 4 to 6 week period when alevins remain in the gravel, they utilize their yolk-sac to nourish their bodies. As their yolk-sac is depleted, fry begin to emerge from the gravel to begin exogenous feeding in their natal stream. The post-emergent fry disperse to the margins of their natal stream, seeking out shallow waters with slower currents, finer sediments, and bank cover such as overhanging and submerged vegetation, root wads, and fallen woody debris, and begin feeding on zooplankton, small insects, and other micro-crustaceans. As they switch from endogenous nourishment to exogenous feeding, the fry's yolk-sac is reabsorbed, and the belly suture closes over the former location of the yolk-sac (button-up fry). Fry typically range from 25 mm to 40 mm during this stage. Some fry may take up residence in their natal stream for several weeks to a year or more, while others actively migrate, or are displaced downstream by the stream's current. Once started downstream, fry may continue downstream to the estuary and rear, or may take up residence in river reaches along the way for a period of time ranging from weeks to a year (Healey 1991).

Rearing fry seek nearshore habitats containing beneficial aspects such as riparian vegetation and associated substrates important for providing aquatic and terrestrial invertebrates, predator avoidance, and slower velocities for resting (NMFS 1996a). The benefits of shallow water habitats for salmonid rearing also have recently been realized as shallow water habitat has been found to be more productive than the main river channels, supporting higher growth rates, partially due to higher prey consumption rates, as well as favorable environmental temperatures (Sommer *et al.* 2001).

When juvenile Chinook salmon reach a length of 50 to 57 mm, they move into deeper water with higher current velocities, but still seek shelter and velocity refugia to minimize energy expenditures. In the mainstems of larger rivers, juveniles tend to migrate along the margins and avoid the elevated water velocities found in the thalweg of the channel. When the channel of the river is greater than 9 to 10 feet in depth, juvenile salmon tend to inhabit the surface waters (Healey 1982). Migrational cues, such as increasing turbidity from runoff, increased flows, changes in day length, or intraspecific competition from other fish in their natal streams may spur outmigration of juveniles when they have reached the appropriate stage of maturation (Kjelson *et al.* 1982; Brandes and McLain 2001).

Similar to adult movement, juvenile salmonid downstream movement is primarily crepuscular. Martin *et al.* (2001) found that the daily migration of juveniles passing Red Bluff Diversion Dam (RBDD) is highest in the four hour period prior to sunrise. Juvenile Chinook salmon migration rates vary considerably presumably depending on the physiological stage of the juvenile and hydrologic conditions. Kjelson *et al.* (1982) found fry Chinook salmon to travel as fast as 30 km per day in the Sacramento River and Sommer *et al.* (2001) found rates ranging from approximately 0.5 miles up to more than 6 miles per day in the Yolo Bypass. As Chinook salmon begin the smoltification stage, they prefer to rear further downstream where ambient salinity is up to 1.5 to 2.5 parts per thousand (Healey 1980; Levy and Northcote 1981).

Fry and parr may rear within riverine or estuarine habitats of the Sacramento River, the Delta, and their tributaries. In addition, CV Chinook salmon juveniles have been observed rearing in

the lower reaches of non-natal tributaries and intermittent streams in the Sacramento Valley during the winter months (Maslin *et al.* 1997; Snider 2001). Within the Delta, juvenile Chinook salmon forage in shallow areas with protective cover, such as intertidal and subtidal mudflats, marshes, channels, and sloughs (McDonald 1960; Dunford 1975). Cladocerans, copepods, amphipods, and larvae of diptera, as well as small arachnids and ants are common prey items (Kjelson *et al.* 1982; Sommer *et al.* 2001; MacFarlane and Norton 2002). Shallow water habitats are more productive than the main river channels, supporting higher growth rates, partially due to higher prey consumption rates, as well as favorable environmental temperatures (Sommer *et al.* 2001). Optimal water temperatures for the growth of juvenile Chinook salmon in the Delta are between 54 to 57 °F (Brett 1952). In Suisun and San Pablo Bays water temperatures reach 54 °F by February in a typical year. Other portions of the Delta (*i.e.*, South Delta and Central Delta) can reach 70 °F by February in a dry year. However, cooler temperatures are usually the norm until after the spring runoff has ended.

Within the estuarine habitat, juvenile Chinook salmon movements are dictated by the tidal cycles, following the rising tide into shallow water habitats from the deeper main channels, and returning to the main channels when the tide recedes (Levings 1982; Levy and Northcote 1982; Levings *et al.* 1986; Healey 1991). As juvenile Chinook salmon increase in length, they tend to school in the surface waters of the main and secondary channels and sloughs, following the tides into shallow water habitats to feed (Allen and Hassler 1986). In Suisun Marsh, Moyle *et al.* (1989) reported that Chinook salmon fry tend to remain close to the banks and vegetation, near protective cover, and in dead-end tidal channels. Kjelson *et al.* (1982) reported that juvenile Chinook salmon demonstrated a diel migration pattern, orienting themselves to nearshore cover and structure during the day, but moving into more open, offshore waters at night. The fish also distributed themselves vertically in relation to ambient light. During the night, juveniles were distributed randomly in the water column, but would school up during the day into the upper 3 meters of the water column. Available data indicate that juvenile Chinook salmon use Suisun Marsh extensively both as a migratory pathway and rearing area as they move downstream to the Pacific Ocean. Juvenile Chinook salmon were found to spend about 40 days migrating through the Delta to the mouth of San Francisco Bay and grew little in length or weight until they reached the Gulf of the Farallons (MacFarlane and Norton 2002). Based on the mainly ocean-type life history observed (*i.e.*, fall-run Chinook salmon) MacFarlane and Norton (2002) concluded that unlike other salmonid populations in the Pacific Northwest, CV Chinook salmon show little estuarine dependence and may benefit from expedited ocean entry.

b. *Sacramento River Winter-Run Chinook Salmon*

Sacramento River winter-run Chinook salmon adults enter the San Francisco Bay between November and June, with a peak occurring in March (Yoshiyama *et al.* 1998; Moyle 2002). Spawning occurs primarily from mid April to mid August, with the peak activity occurring in May and June in the Sacramento River reach between Keswick dam and Red Bluff Diversion Dam (RBDD) (Vogel and Marine 1991). The majority of Sacramento River winter-run Chinook salmon spawners are 3 years old.

Sacramento River winter-run Chinook salmon fry begin to emerge from the gravel in late June to early July and continue through October (Fisher 1994), with emergence generally occurring at night. Post-emergent fry disperse to the margins of the river, seeking out shallow waters with slower currents, finer sediments, and bank cover such as overhanging and submerged vegetation, root wads, and fallen woody debris, and begin feeding on small insects and crustaceans.

Emigration of juvenile winter-run past RBDD may begin as early as mid July, typically peaks in September, and can continue through March in dry years (Vogel and Marine 1991; NMFS 1997). From 1995 to 1999, all Sacramento River winter-run Chinook outmigrating as fry passed RBDD by October, and all outmigrating pre-smolts and smolts passed RBDD by March (Table 1; Martin *et al.* 2001).

Juvenile Sacramento River winter-run Chinook salmon occur in the Delta primarily from November through early May based on data collected from trawls in the Sacramento River at West Sacramento (RM 57) (USFWS 2001). The timing of migration may vary somewhat due to changes in river flows, dam operations, and water year type. Winter-run Chinook salmon juveniles remain in the Delta until they reach a fork length of approximately 118 millimeters (mm) and are from 5 to 10 months of age, and then begin emigrating to the ocean as early as November, continuing through May (Fisher 1994; Myers *et al.* 1998).

(1) Population Dynamics. Historical Sacramento River winter-run Chinook salmon population estimates were as high as 100,000 fish in the 1960s; however, populations declined below 200 fish in the 1990s (Good *et al.* 2005). Population estimates in 2003 (8,218), 2004 (7,869), 2005 (15,875), and 2006 (17,304) show a recent increase in the population size (CDFG 2009) and a 4-year average of 12,317 (2003 through 2006). The 2006 run was the highest since the listing. However, the population estimate for winter-run Chinook salmon in 2007 was only 2,542 and 2,850 for 2008 (CDFG 2009). The saltwater life history traits and food requirements of winter-run Chinook salmon and fall-run Chinook salmon are similar. Therefore, the unusual and poor ocean conditions that caused the drastic decline in returning fall run Chinook salmon populations coast wide in 2007 and 2008 (Lindley *et al.* 2009) are suspected to have also caused the observed decrease in the winter-run Chinook salmon spawning population during this period (Oppenheim 2008). Two current methods are utilized to estimate the juvenile production of Sacramento River winter-run Chinook salmon: the Juvenile Production Estimate (JPE) method, and the Juvenile Production Index (JPI) method (Gaines and Poytress 2004). Gaines and Poytress (2004) estimated the juvenile population of Sacramento River winter-run Chinook salmon exiting the upper Sacramento River at RBDD to be 3,707,916 juveniles per year using the JPI method between the years 1995 and 2003 (excluding 2000 and 2001). Using the JPE method, they estimated an average of 3,857,036 juveniles exiting the upper Sacramento River at RBDD between the years of 1996 and 2003 (Gaines and Poytress 2004). Averaging these 2 estimates yields an estimated juvenile population size at RBDD of 3,782,476.

Based on the RBDD counts, the population showed steady growth from the 1990s through 2006 with positive short-term trends. However, an age-structured density-independent model of spawning escapement by Botsford and Brittnacker in 1998 (as referenced in Good *et al.* 2005)

assessing the viability of Sacramento River winter-run Chinook salmon found the species was certain to fall below the quasi-extinction threshold of 3 consecutive spawning runs with fewer than 50 females (Good *et al.* 2005). Lindley *et al.* (2003) assessed the viability of the population using a Bayesian model based on spawning escapement that allowed for density dependence and a change in population growth rate in response to conservation measures and found a biologically significant expected quasi-extinction probability of 28 percent. Although the status of the Sacramento River winter-run Chinook salmon population has improved over the last two decades since its listing, the recent severe declines illustrate the volatility of this small, single population ESU. Because there is only one population, and it depends on cold-water releases from Shasta Dam to provide suitable spawning habitat, the ESU is highly vulnerable to a prolonged drought resulting in depletion of the cold-water pool in Shasta Lake (Good *et al.* 2005).

Although NMFS proposed that this ESU be upgraded from endangered to threatened status in 2005, the Final Listing Determination (June 28, 2005, 70 FR 37160) maintained the status of the Sacramento River winter-run Chinook salmon ESU as endangered. This population remains below the draft recovery goals established for the run (NMFS 1997, 1998) and the naturally spawned component of the ESU is dependent on one extant population in the Sacramento River. In general, the draft recovery criteria for Sacramento River winter-run Chinook salmon include a mean annual spawning abundance over any 13 consecutive years of at least 10,000 females with a concurrent geometric mean of the cohort replacement rate greater than 1.0. Recent trends in Sacramento River winter-run Chinook salmon abundance and cohort replacement remain positive, indicating some recovery since the listing. However, the population remains well below the recovery goals of the draft recovery plan, and is particularly susceptible to extinction because of the reduction of the genetic pool to one population.

Hydropower, flood control, and water supply dams of the CVP, SWP, and other municipal and private entities have permanently blocked or hindered salmonid access to historical spawning and rearing grounds. Clark (1929) estimated that originally there were 6,000 linear miles of salmon habitat in the Central Valley system and that 80 percent of this habitat had been lost by 1928. Yoshiyama *et al.* (1996) calculated that roughly 2,000 linear miles of salmon habitat was actually available before dam construction and mining, and concluded that 82 percent is not accessible today. The percentage of habitat loss for steelhead is presumably greater, because steelhead were more extensively distributed upstream than Chinook salmon.

As a result of migrational barriers, winter-run populations have been confined to lower elevation mainstems that historically only were used for migration and rearing. Population abundances have declined in these streams due to decreased quantity and quality of spawning and rearing habitat. Higher temperatures at these lower elevations during late-summer and fall are also a major stressor to adult and juvenile salmonids. According to Lindley *et al.* (2004), of the four independent populations of winter-run that occurred historically, only one mixed stock of winter-run remains below Keswick Dam. Similarly, of the 19 independent populations of spring-run that occurred historically, only three independent populations remain in Deer, Mill, and Butte Creeks (Lindley *et al.* 2007). Dependent populations of spring-run continue to occur in Big Chico, Antelope, Clear, Thomes, and Beegum Creeks and the Yuba River, but rely on the extant

independent populations for their continued survival. CV steelhead historically had at least 81 independent populations based on Lindley *et al.*'s (2006) analysis of potential habitat in the Central Valley. However, due to dam construction, access to 38 percent of all spawning habitat has been lost, as well as access to 80 percent of the historically available habitat.

Lindley *et al.* (2007) state that the winter-run Chinook salmon population fails the "representation and redundancy rule" because it has only one population and that population spawn outside of the eco-region in which it evolved. In order to satisfy the "representation and redundancy rule," at least two populations of winter-run Chinook salmon would have to be re-established in the basalt- and porous-lava region of its origin. An ESU represented by only one spawning population at moderate risk of extinction is at a high risk of extinction over an extended period of time (Lindley *et al.* 2007).

(2) Viable Salmonid Population Summary for Sacramento River Winter-Run Chinook Salmon. McElhany *et al.* (2000) define a viable salmonid population (VSP) as an independent population that has a negligible probability of extinction over a 100-year time frame. The VSP concept provides specific guidance for estimating the viability of populations and larger-scale groupings of Pacific salmonids such as ESU or DPS. Four VSP parameters form the key to evaluating population and ESU/DPS viability: (1) abundance; (2) productivity (*i.e.*, population growth rate); (3) population spatial structure; and (4) diversity (McElhany *et al.* 2000).

Abundance. Redd and carcass surveys, and fish counts, suggest that the abundance of winter-run Chinook salmon has been increasing. The depressed 2007 and 2008 abundance estimates are significant exceptions to this trend and may represent a new cycle of poor ocean productivity. Population growth is estimated to be positive in the short-term trend at 0.26; however, the long-term trend is negative, averaging -0.14. Recent winter-run Chinook salmon abundance represents only 3 percent of the maximum post-1967, 5-year geometric mean, and is not yet well established (Good *et al.* 2005).

Productivity. Prior to the recent declines, ESU productivity had been positive over the short term, and adult escapement and juvenile production were been increasing annually (Good *et al.* 2005). The long-term trend for the ESU remains negative however, as the cohort replacement rate (CRR) estimate suggests a reduction in productivity for the 1998-2001 cohorts.

Spatial Structure. The greatest risk factor for winter-run Chinook salmon lies with their spatial structure (Good *et al.* 2005). The remnant population cannot access historical winter-run habitat and must be artificially maintained in the Sacramento River by a regulated, finite cold water pool from Shasta Dam. Winter-run Chinook salmon require cold water temperatures in summer that simulate their upper basin habitat, and they are more likely to be exposed to the impacts of drought in a lower basin environment. Battle Creek remains the most feasible opportunity for the ESU to expand its spatial structure, which currently is limited to the upper 25-mile reach of the mainstem Sacramento River below Keswick Dam.

Diversity. The second highest risk factor for the Sacramento River winter-run Chinook salmon

ESU has been the detrimental effects on its diversity. The genetics of the present winter-run population has resulted from the introgression of several stocks that occurred when Shasta Dam blocked access to the upper watershed. A second genetic bottleneck occurred with the construction of Keswick Dam; there may have been several others within the recent past (Good *et al.* 2005). Concerns of genetic introgression with hatchery populations are also increasing. Although Livingston Stone National Fish Hatchery (LSNFH) is characterized as one of the best examples of a conservation hatchery operated to maximize genetic diversity and minimize domestication of the offspring produced in the hatchery, it still faces some of the same diversity issues as other hatcheries in reducing the diversity of the naturally-spawning population. Therefore, Lindley *et al.* (2007) characterizes hatchery influence as a looming concern with regard to diversity. Even with a small contribution of hatchery fish to the natural spawning population, hatchery contributions could compromise the long term viability and extinction risk of winter-run.

NMFS concludes that the current diversity in this ESU is much reduced compared to historic levels, and that winter-run are at a high risk of extinction based on the spatial structure and diversity VSP parameters.

c. *CV Spring-Run Chinook Salmon*

Historically the spring-run Chinook salmon were the second most abundant salmon run in the Central Valley (CDFG 1998). These fish occupied the upper and middle reaches (1,000 to 6,000 foot elevations) of the San Joaquin, American, Yuba, Feather, Sacramento, McCloud and Pit Rivers, with smaller populations in most tributaries with sufficient habitat for over-summering adults (Stone 1874; Rutter 1904; Clark 1929). The Central Valley drainage as a whole is estimated to have supported spring-run Chinook salmon runs as large as 600,000 fish between the late 1880s and 1940s (CDFG 1998). Before the construction of Friant Dam, nearly 50,000 adults were counted in the San Joaquin River alone (Fry 1961). Construction of other low elevation dams in the foothills of the Sierras on the American, Mokelumne, Stanislaus, Tuolumne, and Merced Rivers extirpated CV spring-run Chinook salmon from these watersheds. Naturally-spawning populations of CV spring-run Chinook salmon currently are restricted to accessible reaches of the upper Sacramento River, Antelope Creek, Battle Creek, Beegum Creek, Big Chico Creek, Butte Creek, Clear Creek, Deer Creek, Feather River, Mill Creek, and Yuba River (CDFG 1998).

Adult CV spring-run Chinook salmon leave the ocean to begin their upstream migration in late January and early February (CDFG 1998a) and enter the Sacramento River between March and September, primarily in May and June (Table 2; Yoshiyama *et al.* 1998; Moyle 2002). Lindley *et al.* (2006a) indicate adult CV spring-run Chinook salmon enter native tributaries from the Sacramento River primarily between mid April and mid June. Typically, spring-run Chinook salmon utilize mid- to high-elevation streams that provide appropriate temperatures and sufficient flow, cover, and pool depth to allow over-summering while conserving energy and allowing their gonadal tissue to mature (Yoshiyama *et al.* 1998). Spring-run Chinook salmon spawning occurs between September and October depending on water temperatures. Between 56

and 87 percent of adult spring-run Chinook salmon that enter the Sacramento River basin to spawn are 3 years old (Calkins *et al.* 1940; Fisher 1994).

Table 1. The temporal occurrence of adult and juvenile Sacramento River winter-run Chinook salmon in the Sacramento River.

Adult Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Sacramento River basin[1]												
Sacramento River[2]												
Juvenile Location	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Sacramento River at Red Bluff[3]												
Sacramento River at Red Bluff[2]												
Sacramento River at Knights Landing[4]												
Lower Sacramento River (seine)[5]												
West Sacramento River (trawl)[5]												
Relative Abundance:	=High		=Medium		=Low							

Sources: [1]Yoshiyama *et al.* (1998); Moyle (2002); [2]Meyers *et al.* (1998); [3]Martin *et al.* (2001); [4]Snider and Titus (2000); [5]USFWS (2001)

Table 2. The temporal occurrence of adult and juvenile Central Valley spring-run Chinook salmon in the Sacramento River.

Adult Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Sacramento River basin[1,2]												
Sacramento River[3]												
Mill Creek[4]												
Deer Creek[4]												
Butte Creek[4]												
Juvenile Location	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Sacramento River Tributaries												
Upper Butte Creek												
Mill, Deer, Butte Creeks												
Sacramento River @ RBDD												
Sacramento River @ Knights Landing												
Relative Abundance:	=High		=Medium		=Low							

Sources: [1]Yoshiyama *et al.* (1998); [2]Moyle (2002); [3]Meyers *et al.* (1998); [4]Lindley *et al.* (2007); [5]CDFG (1998); [6]McReynolds *et al.* (2005); Ward *et al.* (2002, 2003); [7]Snider and Titus (2000)

Spring-run Chinook salmon fry emerge from the gravel from November to March (Moyle 2002) and emigration timing is highly variable, as they may migrate downstream as young-of-the-year

(YOY) or as juveniles or yearlings. The modal size of fry migrants at approximately 40 mm between December and April in Mill, Butte, and Deer creeks reflects a prolonged emergence of fry from the gravel (Lindley *et al.* 2006a). Studies in Butte Creek (Ward *et al.* 2002, 2003; McReynolds *et al.* 2005) found the majority of CV spring-run Chinook salmon migrants to be fry occurring primarily during December, January, and February, and that these movements appeared to be influenced by flow. Small numbers of CV spring-run Chinook salmon remained in Butte Creek to rear and migrate as yearlings later in the spring. Juvenile emigration patterns in Mill and Deer creeks are very similar to patterns observed in Butte Creek, with the exception that Mill and Deer creeks juveniles typically exhibit a later YOY migration and an earlier yearling migration (Lindley *et al.* 2006a).

Once juveniles emerge from the gravel they initially seek areas of shallow water and low velocities while they finish absorbing their yolk sac (Moyle 2002). Many will also disperse downstream during high-flow events. As is the case in other salmonids, there is a shift in microhabitat use by juveniles to deeper, faster water as they grow. Microhabitat use can be influenced by the presence of predators which can force fish to select areas of heavy cover and suppress foraging in open areas (Moyle 2002). Peak movement of juvenile CV spring-run Chinook salmon in the Sacramento River at Knights Landing occurs in December, and again in March and April. However, juveniles are also observed between November and the end of May (Snider and Titus 2000). Based on the available information, the emigration timing of CV spring-run Chinook salmon appears highly variable (CDFG 1998). Some fish may begin emigrating soon after emergence from the gravel, whereas others over summer and emigrate as yearlings with the onset of intense fall storms (CDFG 1998).

(1) Population Dynamics. The CV spring-run Chinook salmon ESU has displayed broad fluctuations in adult abundance, ranging from 1,403 in 1993 to 25,890 in 1982. The average abundance for the ESU was 12,590 for the period of 1969 to 1979, 13,334 for the period of 1980 to 1990, 6,554 from 1991 to 2001, and 16,349 between 2002 and 2005. For the period of 2006 to 2008 the average abundance for the ESU fell to a low of 854 (CDFG 2009). Sacramento River tributary populations in Mill, Deer, and Butte creeks are probably the best trend indicators for the CV spring-run Chinook ESU as a whole because these streams contain the primary independent populations within the ESU. Generally, these streams have shown a positive escapement trend since 1991. Escapement numbers are dominated by Butte Creek returns, which have averaged over 7,000 fish since 1995 (until 2005). During this same period, adult returns on Mill Creek have averaged 778 fish, and 1,463 fish on Deer Creek. Although recent trends are positive, annual abundance estimates display a high level of fluctuation, and the overall number of CV spring-run Chinook salmon remains well below estimates of historic abundance. Additionally, in 2003 high water temperatures, high fish densities, and an outbreak of Columnaris Disease (*Flexibacter Columnaris*) and Ichthyophthiriasis (*Ichthyophthirius multifiis*) contributed to the pre-spawning mortality of an estimated 11,231 adult spring-run Chinook salmon in Butte Creek. Most recently, returns on Butte, Mill, and Deer creeks have been the lowest since prior to 2000, with the 2008 estimate on Butte Creek at 3,935, 362 on Mill Creek and 140 on Deer Creek.

(2) Viable Salmonid Population Summary for Central Valley Spring-Run Chinook

Salmon. The following provides the evaluation of the likelihood of viability for the threatened spring-run ESU based on the VSP parameters of abundance, productivity, spatial structure, and diversity.

Abundance. The CV spring-run Chinook salmon ESU has experienced a trend of increasing abundance in some natural populations, most dramatically in the Butte Creek population (Good *et al.* 2005). There has been more opportunistic utilization of migration-dependent streams overall. The Feather River Hatchery (FRH) spring-run stock has been included in the ESU based on its genetic linkage to the natural population and the potential development of a conservation strategy for the hatchery program.

Productivity. The 5-year geometric mean for the extant Butte, Deer, and Mill Creek spring-run populations ranges from 491 to 4,513 fish (Good *et al.* 2005), indicating increasing productivity over the short-term and projected as likely to continue (Good *et al.* 2005). The productivity of the Feather River and Yuba River populations and contribution to the CV spring-run ESU currently is unknown.

Spatial Structure. Spring-run Chinook salmon presence has been reported more frequently in several upper Central Valley creeks, but the sustainability of these runs is unknown. Butte Creek spring-run cohorts have recently utilized all available habitat in the creek; the population cannot expand further and it is unknown if individuals have opportunistically migrated to other systems. The spatial structure of the spring-run ESU has been seriously compromised by the extirpation of all San Joaquin River basin spring-run populations.

Diversity. The CV spring-run ESU fails to meet the "representation and redundancy rule," since the Northern Sierra Nevada is the only diversity group in the spring-run ESU that contains demonstrably viable populations out of at least 3 diversity groups that historically contained them. Independent populations of spring-run only occur within the Northern Sierra Nevada diversity group. The Northwestern California diversity group contains a few ephemeral populations of spring-run that are likely dependent on the Northern Sierra Nevada populations for their continued existence. The spring-run populations that historically occurred in the Basalt and Porous Lava, and Southern Sierra Nevada, diversity groups have been extirpated. Over the long term, the three remaining independent populations are considered to be vulnerable to catastrophic events, such as volcanic eruptions from Mount Lassen or large forest fires due to the close proximity of their headwaters to each other. Drought is also considered to pose a significant threat to the viability of the spring-run populations in the Deer, Mill and Butte Creek watersheds due to their close proximity to each other. Feather River spring-run have introgressed with the fall-run, and it appears that the Yuba River population may have been impacted by FRH fish straying into the Yuba River. Additionally, the diversity of the spring-run ESU has been

further reduced with the loss of the San Joaquin River basin spring-run populations.

Butte Creek and Deer Creek spring-run are at low risk of extinction, satisfying both population viability analysis and other viability criteria. Mill Creek is at moderate extinction risk according to the PVA, but appear to satisfy the other viability criteria for low risk status (Lindley *et al.* 2007). Spring-run fail the representation and redundancy rule for ESU viability, as their current distribution has been severely constricted. Therefore, spring-run are at moderate risk of extinction over an extended period of time.

2. CV steelhead

a. General Life History

Steelhead can be divided into two life history types, summer-run steelhead and winter-run steelhead, based on their state of sexual maturity at the time of river entry and the duration of their spawning migration, stream-maturing and ocean-maturing. Only winter steelhead currently are found in California Central Valley rivers and streams (McEwan and Jackson 1996), although there are indications that summer steelhead were present in the Sacramento River system prior to the commencement of large-scale dam construction in the 1940s (Interagency Ecological Program (IEP) Steelhead Project Work Team 1999). At present, summer steelhead are found only in North Coast drainages, mostly in tributaries of the Eel, Klamath, and Trinity river systems (McEwan and Jackson 1996).

CV steelhead generally leave the ocean from August through April (Busby *et al.* 1996) and enter freshwater from August to November and spawn from December to April in small streams and tributaries where cool, well oxygenated water is available year-round (Table 3; Williams 2006; Hallock *et al.* 1961; McEwan and Jackson 1996). Timing of upstream migration is correlated with higher flow events, such as freshets or sand bar breaches, and associated lower water temperatures. Unlike Pacific salmon, steelhead are iteroparous, or capable of spawning more than once before death (Busby *et al.* 1996). However, it is rare for steelhead to spawn more than twice before dying; most that do so are females (Busby *et al.* 1996). Iteroparity is more common among southern steelhead populations than northern populations (Busby *et al.* 1996). Although one-time spawners are the great majority, Shapolov and Taft (1954) reported that repeat spawners are relatively numerous (17.2 percent) in California streams.

Spawning occurs during winter and spring months. The length of time it takes for eggs to hatch depends mostly on water temperature. Hatching of steelhead eggs in hatcheries takes about 30 days at 51 degrees Fahrenheit (F). Fry emerge from the gravel usually about four to six weeks after hatching, but factors such as redd depth, gravel size, siltation, and temperature can speed or retard this time (Shapovalov and Taft 1954). Newly emerged fry move to the shallow, protected areas associated with the stream margin (McEwan and Jackson 1996) and they soon move to other areas of the stream and establish feeding locations, which they defend (Shapovalov and Taft 1954).

Table 3. The temporal occurrence of adult and juvenile Central Valley steelhead in the Central Valley.

Adult Location	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Sacramento River basin[1, 2]												
Sacramento River at Red Bluff[2, 3]												
Mill, Deer Creeks[4]												
Sacramento River at Fremont Weir[6]												
San Joaquin River[7]												
Juvenile Location	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Sacramento River[1, 2]												
Sacramento River at Knights Landing[2, 8]												
Sacramento River at Knights Landing[9]												
Chipps Island (wild)[10]												
Mossdale[8]												
Woodbridge Dam[11]												
Stanislaus River at Caswell[12]												
Sacramento River at Hood[13]												

Relative Abundance: =High =Medium =Low

Sources: [1] Hallock (1961); [2] McEwan (2001); [3] USFWS unpublished data; [4] CDFG (1995); [5] Hallock *et al.* (1957); [6] Bailey (1954); [7] CDFG Steelhead Report Card Data; [8] CDFG unpublished data; [9] Snider and Titus (2000); [10] Nobriga and Cadrett (2003); [11] Jones & Stokes Associates, Inc. (2002); [12] S.P. Cramer and Associates, Inc. (2000); [13] Schaffter (1980)

Steelhead rearing during the summer takes place primarily in higher velocity areas in pools, although young-of-the-year also are abundant in glides and riffles. Productive steelhead habitat is characterized by complexity, primarily in the form of large and small woody debris. Cover is an important habitat component for juvenile steelhead both as velocity refugia and as a means of avoiding predation (Meehan and Bjornn 1991).

Juvenile steelhead emigrate episodically from natal streams during fall, winter, and spring high flows. Emigrating CV steelhead use the lower reaches of the Sacramento River and the Delta for rearing and as a migration corridor to the ocean. Juvenile CV steelhead feed mostly on drifting aquatic organisms and terrestrial insects and will also take active bottom invertebrates (Moyle 2002). Some may utilize tidal marsh areas, non-tidal freshwater marshes, and other shallow water areas in the Delta as rearing areas for short periods prior to their final emigration to the sea. Hallock *et al.* (1961) found that juvenile steelhead in the Sacramento River basin migrate downstream during most months of the year, but the peak period of emigration occurred in the spring with a much smaller peak in the fall. Nobriga and Cadrett (2003) also have verified these temporal findings based on analysis of captures at Chipps Island.

(1) Population Dynamics. Historic CV steelhead run sizes are difficult to estimate given the paucity of data, but may have approached one to two million adults annually (McEwan 2001). By the early 1960s the steelhead run size had declined to about 40,000 adults (McEwan 2001). Over the past 30 years, the naturally-spawned steelhead populations in the upper Sacramento River have declined substantially. Hallock *et al.* (1961) estimated an average of 20,540 adult steelhead through the 1960s in the Sacramento River, upstream of the Feather River. Steelhead counts at the RBDD declined from an average of 11,187 for the period of 1967 to 1977, to an average of approximately 2,000 through the early 1990s, with an estimated total annual run size for the entire Sacramento-San Joaquin system, based on RBDD counts, to be no more than 10,000 adults (McEwan and Jackson 1996, McEwan 2001). Steelhead escapement surveys at RBDD ended in 1993 due to changes in dam operations.

Recent estimates from trawling data in the Delta indicate that approximately 100,000 to 300,000 (mean 200,000) smolts emigrate to the ocean per year, representing approximately 3,600 female steelhead spawners in the Central Valley basin (Good *et al.* 2005). This can be compared with McEwan's (2001) estimate of one million to two million spawners before 1850, and 40,000 spawners in the 1960s.

Existing wild steelhead stocks in the Central Valley are mostly confined to the upper Sacramento River and its tributaries, including Antelope, Deer, and Mill creeks and the Yuba River. Populations may exist in Big Chico and Butte creeks and a few wild steelhead are produced in the American and Feather rivers (McEwan and Jackson 1996). Recent snorkel surveys (1999 to 2002) indicate that steelhead are present in Clear Creek (J. Newton, USFWS, pers. comm. 2002, as reported in Good *et al.* 2005). Because of the large resident *O. mykiss* population in Clear Creek, steelhead spawner abundance has not been estimated.

Until recently, CV steelhead were thought to be extirpated from the San Joaquin River system. Recent monitoring has detected small self-sustaining populations of steelhead in the Stanislaus, Mokelumne, and Calaveras rivers, and other streams previously thought to be devoid of steelhead (McEwan 2001). On the Stanislaus River, steelhead smolts have been captured in rotary screw traps at Caswell State Park and Oakdale each year since 1995 (S.P. Cramer and Associates Inc. 2000, 2001).

It is possible that naturally-spawning populations exist in many other streams but are undetected due to lack of monitoring programs (IEP Steelhead Project Work Team 1999). Incidental catches and observations of steelhead juveniles also have occurred on the Tuolumne and Merced rivers during fall-run Chinook salmon monitoring activities, indicating that steelhead are widespread throughout accessible streams and rivers in the Central Valley (Good *et al.* 2005). CDFG staff has prepared juvenile migrant CV steelhead catch summaries on the San Joaquin River near Mossdale representing migrants from the Stanislaus, Tuolumne, and Merced rivers. Based on trawl recoveries at Mossdale between 1988 and 2002, as well as rotary screw trap efforts in all three tributaries, CDFG staff stated that it is "clear from this data that rainbow trout do occur in all the tributaries as migrants and that the vast majority of them occur on the Stanislaus River" (Letter from Dean Marston, CDFG, to Madelyn Martinez, NMFS, January 9, 2003b). The documented returns on the order of single fish in these tributaries suggest that existing populations of CV steelhead on the Tuolumne, Merced, and lower San Joaquin rivers are severely depressed.

Lindley *et al.* (2006b) indicated that prior population census estimates completed in the 1990s found the CV steelhead spawning population above RBDD had a fairly strong negative population growth rate and small population size. Good *et al.* (2005) indicated the decline was continuing as evidenced by new information (Chipps Island trawl data). CV steelhead populations generally show a continuing decline, an overall low abundance, and fluctuating return rates.

(2) Viable Salmonid Population Summary for Central Valley Steelhead. In order to determine the current likelihood of viability of the CV steelhead DPS, we used the historical population structure of CV steelhead presented in Lindley *et al.* (2006) and the concept of VSP for evaluating populations described by McElhany *et al.* (2000). While McElhany *et al.* (2000) introduced and described the concept of VSP, Lindley *et al.* (2007) applied the concept to the CV steelhead DPS. The following provides the evaluation of the likelihood of viability for the threatened CV steelhead DPS based on the VSP parameters of abundance, productivity, spatial structure, and diversity.

Abundance. All indications are that natural CV steelhead have continued to decrease in abundance and in the proportion of natural fish over the past 25 years (Good *et al.* 2005); the long-term trend remains negative. There has been little steelhead population monitoring despite 100 percent marking of hatchery steelhead since 1998. Hatchery production and returns are far greater than those of natural fish and include significant numbers of non-DPS-origin Eel River steelhead stock.

Productivity. An estimated 100,000 to 300,000 natural juvenile steelhead are estimated to leave the Central Valley annually, based on rough calculations from sporadic catches in trawl gear (Good *et al.* 2005). Concurrently, one million in-DPS hatchery steelhead smolts and another half million out-of-DPS hatchery steelhead smolts are released annually in the Central Valley. The estimated ratio of non-clipped to clipped steelhead has decreased from 0.3 percent to less than 0.1 percent, with a net decrease to one-third of wild female spawners from 1998 to 2000 (Good *et al.* 2005).

Spatial Structure. Steelhead appear to be well-distributed where found throughout the Central Valley (Good *et al.* 2005). Until recently, there was very little documented evidence of steelhead due to the lack of monitoring efforts. Since 2000, steelhead have been confirmed in the Stanislaus and Calaveras rivers.

Diversity. Analysis of natural and hatchery steelhead stocks in the Central Valley reveal genetic structure remaining in the DPS (Nielsen *et al.* 2003). There appears to be a great amount of gene flow among upper Sacramento River basin stocks, due to the post-dam, lower basin distribution of steelhead and management of stocks. Recent reductions in natural population sizes have created genetic bottlenecks in several CV steelhead stocks (Good *et al.* 2005; Nielsen *et al.* 2003). The out-of-basin steelhead stocks of the Nimbus and Mokelumne River hatcheries are not included in the CV steelhead DPS.

Lindley *et al.* (2007) indicated that prior population census estimates completed in the 1990s found the CV steelhead spawning population above RBDD had a fairly strong negative population growth rate and small population size. Good *et al.* (2005) indicated the decline was continuing as evidenced by new information (Chipps Island trawl data). CV steelhead populations generally show a continuing decline, an overall low abundance, and fluctuating return rates. The future of CV steelhead is uncertain due to limited data concerning their status. However, Lindley *et al.* (2007) concluded that there is sufficient evidence to suggest that the DPS is at moderate to high risk of extinction.

3. Southern DPS of North American Green Sturgeon

a. General Life History

North American green sturgeon are widely distributed along the Pacific Coast and have been documented offshore from Ensenada Mexico to the Bering Sea and found in rivers from British Columbia to the Sacramento River (Moyle 2002). As is the case for most sturgeon, North American green sturgeon are anadromous; however, they are the most marine-oriented of the sturgeon species (Moyle 2002). In North America, spawning populations of the anadromous green sturgeon currently are found in only three river systems, the Sacramento and Klamath rivers in California and the Rogue River in southern Oregon.

Two green sturgeon DPSs were identified based on evidence of spawning site fidelity (indicating multiple DPS tendencies), and on the preliminary genetic evidence that indicate differences at

least between the Klamath River and San Pablo Bay samples (Adams *et al.* 2002). The Northern DPS includes all green sturgeon populations starting with the Eel River and extending northward. The southern DPS would include all green sturgeon populations south of the Eel River with the only known spawning population being in the Sacramento River.

The southern DPS of North American green sturgeon life cycle can be broken into three distinct phases based on developmental stage and habitat use: (1) year-round juveniles, (2) pre-and post-spawning adults, and (3) adult and sub-adult summer residents.

Southern DPS green sturgeon adults begin their upstream spawning migrations into the San Francisco Bay in March, reach Knights Landing during April, and spawn between March and July (Heublein *et al.* 2006). Peak spawning is believed to occur between April and June and thought to occur in deep turbulent pools (Adams *et al.* 2002). Substrate is likely large cobble but can range from clean sand to bedrock (USFWS 2002). Newly hatched green sturgeon are approximately 12.5 to 14.5 mm in length. According to Heublein (2006), all adults leave the Sacramento River prior to September 1.

Adult green sturgeon in the San Francisco Estuary make significant long-distance movements with distinct directionality and are not related to salinity, current, or temperature, but resource availability (Kelley *et al.* 2007). The majority of green sturgeon in the Rogue River emigrated from freshwater habitat in December after water temperatures dropped (Erickson *et al.* 2002). Green sturgeon were most often found at depths greater than 5 meters with low or no current during summer and autumn months (Erickson *et al.* 2002). Holding in deep pools is a way to conserve energy and utilize abundant food resources. Based on captures of adult green sturgeon in holding pools on the Sacramento River above the Glenn-Colusa Irrigation District (GCID) diversion (RM 205), the documented presence of adults in the Sacramento River during the spring and summer months, and the presence of larval green sturgeon in late summer in the lower Sacramento River indicating spawning ocurrence, it appears adult green sturgeon could possibly utilize a variety of freshwater and brackish habitats for up to nine months of the year (Beamesderfer *et al.* 2004; S.P. Cramer & Associates, Inc., pers. comm. 2006).

Based on the distribution of sturgeon eggs, larva, and juveniles in the Sacramento River, CDFG (2002) indicated that southern DPS of green sturgeon spawn in late spring and early summer above Hamilton City possibly to Keswick Dam. Adult green sturgeon are believed to spawn every 3 to 5 years and reach sexual maturity only after several years of growth (Table 4; CDFG 2002). Adult female green sturgeon produce between 60,000 and 140,000 eggs each reproductive cycle, depending on body size, with a mean egg diameter of 4.3 mm (Moyle *et al.* 1992; Van Eenennaam *et al.* 2001).

After approximately 10 days larvae begin feeding, growing rapidly, and young green sturgeon appear to rear for the first 1 to 2 months in the Sacramento River between Keswick Dam and Hamilton City (CDFG 2002). Juvenile green sturgeon first appear in USFWS sampling efforts at RBDD in June and July at lengths ranging from 24 to 31 mm fork length (CDFG 2002; USFWS 2002). The mean yearly total length of post-larval green sturgeon captured in rotary screw traps

Table 4. The temporal occurrence of adult, larval and post-larval, juvenile, and coastal migrant Southern DPS of North American green sturgeon.

Adult Location (≥13 yrs for females, ≥9 yrs for males)	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Upper Sac River[1, 2, 3]												
SF Bay Estuary[4, 8]												
Larval / Post-Larval Location (≤10 mos)	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
RBDD, Sac River[5]												
GCID, Sac River[5]												
Juvenile Location (>10 mos and ≤3 yrs)												
South Delta*[6]												
Sac-SJ Delta[6]												
Sac-SJ Delta[5]												
Suisun Bay[5]												
Coastal Migrant Location (3-13 yrs for females, 3-9 yrs for males)												
Pacific Coast[3, 7]												

Relative Abundance: =High =Medium =Low

Sources: [1] USFWS (2002); [2] Moyle *et al.* (1992); [3] Adams *et al.* (2002) and NMFS (NMFS 2005a); [4] Kelley *et al.* (2006); [5] CDFG (2002); [6] IEP Relational Database, fall midwater trawl green sturgeon captures from 1969 to 2003; [7] Nakamoto *et al.* (1995); [8] Heublein (2006) *Fish Facility salvage operations

at the RBDD ranged from 26 mm to 34 mm between 1995 and 2000 indicating they are approximately 2 weeks old. The mean yearly total length of post-larval green sturgeon captured in the GCID rotary screw trap, approximatley 30 miles downstream of RBDD, ranged from 33 mm to 44 mm between 1997 and 2005 (CDFG, unpublished data) indicating they are approximately 3 weeks old (Van Eenennaam *et al.* 2001).

Green sturgeon larvae do not exhibit the initial pelagic swim-up behavior characteristic of other *Acipenseridae*. They are strongly oriented to the bottom and exhibit nocturnal activity patterns. Under laboratory conditions green sturgeon larvae cling to the bottom during the day and move into the water column at night (Van Eenennaam *et al.* 2001). After six days, the larvae exhibit nocturnal swim-up activity (Deng *et al.* 2002) and nocturnal downstream migrational movements (Kynard *et al.* 2005). Juvenile green sturgeon continue to exhibit nocturnal behavior beyond the metamorphosis from larvae to juvenile stages. Kynard *et al.*'s (2005) laboratory studies indicated that juvenile fish continued to migrate downstream at night for the first six months of life. When ambient water temperatures reached 46 degrees F, downstream migrational behavior diminished and holding behavior increased. These data suggests that 9-to 10-month-old fish would hold over in their natal rivers during the ensuing winter following hatching, but at a location downstream of their spawning grounds. Juvenile green sturgeon have been salvaged at the Harvey O. Banks Pumping Plant and the John E. Skinner Fish Facility (Fish Facilities) in the South Delta, and captured in trawling studies by the CDFG during all months of the year (CDFG 2002). The majority of these fish were between 200 and 500 mm indicating they were from 2 to 3 years of age based on Klamath River age distribution work by Nakamoto *et al.* (1995). The lack of a significant proportion of juveniles smaller than approximately 200 mm in Delta captures indicate juvenile Southern DPS North American green sturgeon likely hold in the mainstem Sacramento River as suggested by Kyndard *et al.* (2005).

(1) Population Dynamics. Limited population abundance information comes from incidental captures of North American green sturgeon from the white sturgeon monitoring program by the CDFG sturgeon tagging program (CDFG 2002). By comparing ratios of white sturgeon to green sturgeon captures CDFG provides estimates of adult and sub-adult North American green sturgeon abundance. Estimated abundance between 1954 and 2001 ranged from 175 fish to more than 8,000 per year and averaged 1,509 fish per year. Unfortunately there are many biases and errors associated with these data and CDFG does not consider these estimates reliable. Fish monitoring efforts at RBDD and GCID on the upper Sacramento River have captured between 0 and 2,068 juvenile North American green sturgeon per year (Adams *et al.* 2002). The only existing information regarding changes in the abundance of the Southern DPS of green sturgeon includes changes in abundance at the John E. Skinner Fish Facility between 1968 and 2001. The average number of North American green sturgeon taken per year at the State Facility prior to 1986 was 732; from 1986 on, the average per year was 47 (70 FR 17386). For the Harvey O. Banks Pumping Plant, the average number prior to 1986 was 889; from 1986 to 2001 the average was 32 (70 FR 17386). In light of the increased exports, particularly during the previous 10 years, it is clear that the abundance of the Southern DPS of North American green sturgeon is dropping. Additional analysis of North American green and white sturgeon taken at the Fish Facilities indicate that take of both North American green and white sturgeon per acre-foot of

water exported has decreased substantially since the 1960s (70 FR 17386). Catches of sub-adult and adult North American green sturgeon by the IEP between 1996 and 2004 ranged from 1 to 212 green sturgeon per year (212 occurred in 2001); however, the portion of the Southern DPS of North American green sturgeon is unknown as these captures were primarily located in San Pablo Bay. Recent spawning population estimates using sibling based genetics by Israel (2006) indicate a maximum spawning population of 32 spawners in 2002, 64 in 2003, 44 in 2004, 92 in 2005, and 124 in 2006 above RBDD (with an average of 71). Based on the length and estimated age of post-larvae captured at RBDD (approximately two weeks of age) and GCID (downstream, approximately three weeks of age), it appears some of Southern DPS North American green sturgeon are spawning above RBDD. Note, there are many assumptions with this interpretation (*i.e.*, equal sampling efficiency and distribution of post-larvae across channels), and this information should be considered cautiously.

There are at least two records of confirmed adult sturgeon observation in the Feather River (Beamesderfer *et al.* 2004), however, there are no observations of juvenile or larval sturgeon even prior to the 1960s when Oroville Dam was built (NMFS 2005a). There are also unconfirmed reports that green sturgeon may spawn in the Feather River during high flow years (CDFG 2002).

Spawning in the San Joaquin River system has not been recorded, but alterations of the San Joaquin River tributaries (Stanislaus, Tuolumne, and Merced rivers) and its mainstem occurred early in the European settlement of the region. During the later half of the 1800s impassable barriers were built on these tributaries where the water courses left the foothills and entered the valley floor. Therefore, these low elevation dams have blocked potentially suitable spawning habitats located further upstream for over a century. Additional destruction of riparian and stream channel habitat by industrialized gold dredging further disturbed any valley floor habitat that was still available for sturgeon spawning. It is likely that both white and green sturgeon utilized the San Joaquin River basin for spawning prior to the onset of European influence, based on past use of the region by populations of CV spring-run Chinook salmon and CV steelhead. These two populations of salmonids have either been extirpated or greatly diminished in their use of the San Joaquin River basin over the past two centuries (Adams *et al.* 2002; Moyle 2002; Lindley *et al.* 2004).

(2) Population Viability Summary for the Southern DPS of North American Green Sturgeon. The Southern DPS of North American green sturgeon was not included or analyzed in recent efforts to characterize the status and viability of Central Valley salmonid populations (Lindley *et al.* 2006; Good *et al.* 2005). However, the following summaries have been compiled from the best available data and information on North American green sturgeon to provide a general synopsis of the viability parameters for this DPS.

Abundance. Currently, there are no reliable data on population sizes, and data on population trends are also lacking. Fishery data collected at Federal and State pumping facilities in the Delta indicate a decreasing trend in abundance between 1968 and 2006 (70 FR 17386).

Productivity. There is insufficient information to evaluate the productivity of green sturgeon. However, as indicated above, there appears to be a declining trend in abundance, which indicates low to negative productivity.

Spatial Structure. Current data indicate that the Southern DPS of North American Green Sturgeon is comprised of a single population that spawns in the Sacramento River above and below RBDD. Although some individuals have been observed in the Feather and Yuba rivers, it is not yet known if these fish represent separate spawning populations. Therefore, the apparent presence of a single reproducing population puts the DPS at risk, due to extremely limited spatial structure.

Diversity. Green sturgeon genetic analyses shows strong differentiation between northern and southern populations, and therefore, the species was divided into Northern and Southern DPS's. However, the genetic diversity of the Southern DPS is not well understood.

The majority of the NMFS Biological Review Team (BRT) (NMFS 2005) felt that the blockage of green sturgeon spawning from what were certainly their historic spawning areas above Shasta Dam and the accompanying decrease in spawning habitat in the Feather River with the construction of Oroville Dam made the Southern green sturgeon DPS likely to become endangered in the foreseeable future throughout all of its range. Due to substantial habitat loss, and the decline in abundance observed at water pumping facilities, and the occurrence of only one breeding populations, the Southern DPS of North American green sturgeon remains at a moderate to high risk of extinction.

C. Factors Affecting the Species and Critical Habitat

Water development, water quality, over-harvesting, and disease and predation are some of the many issues affecting the decline of listed anadromous fish species in California. Hydropower, flood control, and water supply dams of the Federal Central Valley Project (CVP), State Water Project (SWP), and other municipal and private entities have permanently blocked or hindered salmonid and green sturgeon access to historical spawning and rearing grounds. Clark (1929) estimated that originally there were 6,000 linear miles of salmon habitat in the Central Valley system and that 80 percent of this habitat had been lost by 1928. Yoshiyama *et al.* (1996) calculated that roughly 2,000 linear miles of salmon habitat was actually available before dam construction and mining, and concluded that 82 percent is not accessible today.

As a result of migrational barriers, spring-run Chinook salmon, and steelhead populations have been confined to lower elevation mainstems that historically only were used for migration. Higher temperatures at these lower elevations during late-summer and fall are a major stressor to adult and juvenile salmonids. Thus, population abundances have declined in these streams due to decreased quantity and quality of spawning and rearing habitat. Green sturgeon populations were likely also affected by barriers and alterations to the natural hydrology. In particular, the RBDD blocked all access to the primary spawning habitat in the Sacramento River for many years under the old operational procedures, and continues to block a significant portion of the

adult spawning run under current operationl procedures.

Water diversions for irrigated agriculture, municipal and industrial use, and managed wetlands are found throughout the Central Valley. Thousands of small and medium-size water diversions exist along the Sacramento and San Joaquin Rivers, and their tributaries. Although efforts have been made in recent years to screen some of these diversions, many remain unscreened. Depending on the size, location, and season of operation, these unscreened diversions entrain and kill many life stages of aquatic species, including juvenile salmonids and green sturgeon. For example, as of 1997, 98.5 percent of the 3,356 diversions included in a Central Valley database were either unscreened or screened insufficiently to prevent fish entrainment (Herren and Kawasaki 2001).

Levee development in the Central Valley affects spawning habitat, freshwater rearing habitat, freshwater migration corridors, and estuarine habitat PCEs. The construction of levees disrupts the natural processes of the river, resulting in a multitude of habitat-related effects. Many of these levees use angular rock (riprap) to armor the bank from erosion. The effects of channelization, and riprapping, include the alteration of river hydraulics and cover along the bank as a result of changes in bank configuration and structural features (Stillwater Sciences 2006). These changes affect the quantity and quality of nearshore habitat for juvenile salmonids and have been thoroughly studied (USFWS 2000; Schmetterling *et al.* 2001; Garland *et al.* 2002). Simple slopes protected with rock revetment generally create nearshore hydraulic conditions characterized by greater depths and faster, more homogeneous water velocities than occur along natural banks. Higher water velocities typically inhibit deposition and retention of sediment and woody debris. These changes generally reduce the range of habitat conditions typically found along natural shorelines, especially by eliminating the shallow, slow-velocity river margins used by juvenile fish as refuge and escape from fast currents, deep water, and predators (Stillwater Sciences 2006).

Increased sedimentation resulting from agricultural and urban practices within the Central Valley is one of the primary causes of salmonid habitat degradation (NMFS 1996a). Sedimentation can adversely affect salmonids during all freshwater life stages by: clogging or abrading gill surfaces, adhering to eggs, hampering fry emergence (Phillips and Campbell 1961), burying eggs or alevins, scouring and filling in pools and riffles, reducing primary productivity and photosynthesis activity (Cordone and Kelley 1961), and affecting intergravel permeability and dissolved oxygen (DO) levels. Excessive sedimentation over time can cause substrates to become embedded, which reduces successful salmonid spawning and egg and fry survival (Waters 1995). In addition, urban storm water and agricultural runoff may be contaminated with pesticides, oil, grease, heavy metals, polycyclic aromatic hydrocarbons (PAHs), and other organics and nutrients (Regional Board 1998) that can potentially destroy aquatic life necessary for salmonid and green sturgeon survival (NMFS 1996a, b). Point source (PS) and non-point source (NPS) pollution occurs in almost every area where urbanization activity influences the watershed. Impervious surfaces (*i.e.*, concrete, asphalt, and buildings) reduce water infiltration and increase runoff, thus creating greater flood hazard (NMFS 1996a, b). Flood control and land drainage schemes may increase the flood risk downstream by concentrating runoff. A flashy

discharge pattern results in increased bank erosion with subsequent loss of riparian vegetation, undercut banks and stream channel widening. In addition to the PS and NPS inputs from urban runoff, juvenile salmonids and green sturgeon are exposed to increased water temperatures as a result of thermal inputs from municipal, industrial, and agricultural discharges.

These human activities have led to increased water temperatures, decreased DO levels, and increased turbidity and contaminant loads have degraded the quality of the aquatic habitat for the rearing and migration of salmonids and green sturgeon. Most anthropogenic chemicals and waste materials including toxic organic and inorganic chemicals eventually accumulate in the sediment (Ingersoll 1995). Direct exposure to contaminated sediments may cause deleterious effects to listed salmonids and green sturgeon. This may occur if a fish swims through a plume of the resuspended sediments or rests on contaminated substrate and absorbs the toxic compounds through one of several routes: dermal contact, ingestion, or uptake across the gills. Elevated contaminant levels may be found in localized "hot spots" where discharge occurs or where river currents deposit sediment loads. Sediment contaminant levels can thus be significantly higher than the overlying water column concentrations (Environmental Protection Agency [EPA] 1994). However, the more likely route of exposure to salmonids and sturgeon is through the food chain, when fish feed on organisms that are contaminated with toxic compounds. Prey species become contaminated either by feeding on the detritus associated with the sediments or dwelling in the sediment itself. Therefore, the degree of exposure to the forage base they consume. Response of salmonids and green sturgeon to contaminated sediments is similar to water borne exposures.

Extensive ocean recreational and commercial troll fisheries for Chinook salmon exist along the Northern and Central California coast, and an inland recreational fishery exists in the Central Valley for Chinook salmon and steelhead. Ocean harvest of Central Valley Chinook salmon is estimated using an abundance index, called the Central Valley Index (CVI). The CVI is the ratio of Chinook salmon harvested south of Point Arena (where 85 percent of Central Valley Chinook salmon are caught) to escapement (adult spawner populations that have "escaped" the ocean fisheries and made it into the rivers to spawn). CWT returns indicate that Sacramento River salmon congregate off the California coast between Point Arena and Morro Bay.

Since 1970, the CVI for Sacramento River winter-run Chinook salmon generally has ranged between 0.50 and 0.80. In 1990, when ocean harvest of winter-run Chinook salmon was first evaluated by NMFS and the Pacific Fisheries Management Council (PFMC), the CVI harvest rate was near the highest recorded level at 0.79. NMFS determined in a 1991 biological opinion that continuance of the 1990 ocean harvest rate would not prevent the recovery of Sacramento River winter-run Chinook salmon. Through the early 1990s, the ocean harvest index was below the 1990 level (*i.e.*, 0.71 in 1991 and 1992, 0.72 in 1993, 0.74 in 1994, 0.78 in 1995, and 0.64 in 1996). In 1996 and 1997, NMFS issued a biological opinion which concluded that incidental ocean harvest of winter-run represented a significant source of mortality to the endangered population, even though ocean harvest was not a key factor leading to the decline of the population. As a result of these biological opinions, measures were developed and implemented by the PFMC, NMFS, and CDFG to reduce ocean harvest by approximately 50 percent. In 2001,

the CVI dropped to 0.27, most likely due to the reduction in harvest and the higher abundance of other salmonids originating from the Central Valley (Good *et al.* 2005).

In-river recreational fisheries historically have taken CV spring-run Chinook salmon throughout the species' range. During the summer, holding adult CV spring-run Chinook salmon are easily targeted by anglers when they congregate in large pools. Poaching also occurs at fish ladders, and other areas where adults congregate; however, the significance of poaching on the adult population is unknown. Specific regulations for the protection of CV spring-run Chinook salmon in Mill, Deer, Butte, and Big Chico Creeks and the Yuba River have been added to the existing CDFG regulations. The current regulations, including those developed for Sacramento River winter-run Chinook salmon provide some level of protection for spring-run fish (CDFG 1998).

There is little information on steelhead harvest rates in California. Hallock *et al.* (1961) estimated that harvest rates for Sacramento River steelhead from the 1953-1954 through 1958-1959 seasons ranged from 25.1 percent to 45.6 percent assuming a 20 percent non-return rate of tags. The average annual harvest rate of adult steelhead above RBDD for the 3-year period from 1991-1992 through 1993-1994 was 16 percent (McEwan and Jackson 1996). Since 1998, all hatchery steelhead have been marked with an adipose fin clip allowing anglers to distinguish hatchery and wild steelhead. Current regulations restrict anglers from keeping unmarked steelhead in Central Valley streams. Overall, this regulation has greatly increased protection of naturally produced adult steelhead; however, the total number of CV steelhead contacted might be a significant fraction of basin-wide escapement, and even low catch-and-release mortality may pose a problem for wild populations (Good *et al.* 2005).

Commercial harvest of white sturgeon results in the incidental bycatch of green sturgeon primarily along the Oregon and Washington coasts and within their coastal estuaries. Oregon, Washington and California have recently prohibited the retention of green sturgeon in their waters for commercial and recreational fisheries. Adams *et al.* (2002, 2007) reported harvest of green sturgeon from California, Oregon, and Washington between 1985 and 2001. Total captures of green sturgeon in the Columbia River Estuary by commercial means ranged from 240 fish per year to 6,000. Catches in Willapa Bay and Grays Harbor by commercial means combined ranged from 9 fish to 2,494 fish per year. Emmett *et al.* (1991) indicated that averages of 4.7 to 15.9 tons of green sturgeon were landed annually in Grays Harbor and Willapa Bay respectively. Overall, captures appeared to be dropping through the years; however, this could be related to changing fishing regulations. Adams *et al.* (2002, 2007) also reported sport fishing captures in California, Oregon, and Washington. Within the San Francisco Estuary, green sturgeon are captured by sport fisherman targeting white sturgeon, particularly in San Pablo and Suisun bays (Emmett *et al.* 1991). However, recent changes to fishing regulations have made it illegal keep green sturgeon for harvest. Based on new research by Israel (2006 and past tagged fish returns reported by CDFG (2002)), a high proportion of green sturgeon present in the Columbia River, Willapa Bay, and Grays Harbor (as much as 80 percent in the Columbia River) may be Southern DPS North American green sturgeon. This indicates a potential threat to the Southern DPS North American green sturgeon population.

Infectious disease is one of many factors that influence adult and juvenile salmonid survival. Salmonids are exposed to numerous bacterial, protozoan, viral, and parasitic organisms in spawning and rearing areas, hatcheries, migratory routes, and the marine environment (NMFS 1996a, 1996b, 1998). Specific diseases such as bacterial kidney disease, *Ceratomyxosis shasta* (C-shasta), columnaris, furunculosis, infectious hematopoietic necrosis, redmouth and black spot disease, whirling disease, and erythrocytic inclusion body syndrome are known, among others, to affect steelhead and Chinook salmon (NMFS 1996a, 1996b, 1998). Very little current or historical information exists to quantify changes in infection levels and mortality rates attributable to these diseases; however, studies have shown that wild fish tend to be less susceptible to pathogens than are hatchery-reared fish. Nevertheless, wild salmonids may contract diseases that are spread through the water column (*i.e.*, waterborne pathogens) as well as through interbreeding with infected hatchery fish. The stress of being released into the wild from a controlled hatchery environment frequently causes latent infections to convert into a more pathological state, and increases the potential of transmission from hatchery reared fish to wild stocks within the same waters.

Accelerated predation also may be a factor in the decline of listed salmonids and green sturgeon. Human-induced habitat changes such as alteration of natural flow regimes and installation of bank revetment and structures such as dams, bridges, water diversions, piers, and wharves often provide conditions that both disorient juvenile fish and attract predators (Stevens 1961; Decato 1978; Vogel *et al.* 1988; Garcia 1989). On the mainstem Sacramento River, high rates of predation are known to occur at the RBDD, Anderson-Cottonwood Irrigation District's (ACID) diversion dam, GCID's diversion facility, areas where rock revetment has replaced natural river bank vegetation, and at South Delta water diversion structures (*e.g.*, Clifton Court Forebay; CDFG 1998). In passing the dam, juveniles are subject to conditions which greatly disorient them, making them highly susceptible to predation by fish or birds. Sacramento pikeminnow (*Ptychocheilus grandis*) and striped bass congregate below the dam and prey on juvenile salmon in the tail waters. The Sacramento pikeminnow is a species native to the Sacramento River basin and has co-evolved with the anadromous salmonids in this system. However, rearing conditions in the Sacramento River today (*e.g.* warm water, low-irregular flow, standing water, and water diversions) compared to its natural state and function decades ago in the pre-dam era, are more conducive to warm water species such as Sacramento pikeminnow and striped bass than to native salmonids.

For listed salmonids and green sturgeon, the construction of high dams for hydropower, flood control, and water supply resulted in the loss of vast amounts of upstream habitat (*i.e.*, approximately 80 percent, or a minimum linear estimate of over 1,000 stream miles), and often resulted in precipitous declines in affected populations. For example, the completion of Friant Dam in 1947 has been linked with the extirpation of spring-run Chinook salmon in the San Joaquin River upstream of the Merced River within just a few years. The reduced populations that remain below Central Valley dams are forced to spawn in lower elevation tailwater habitats of the mainstem rivers and tributaries that were previously not used for this purpose. This habitat is entirely dependent on managing reservoir releases to maintain cool water temperatures suitable

for spawning, and/or rearing. This requirement has been difficult to achieve in all water year types and for all life stages of affected species. CV steelhead, in particular, seem to require the qualities of small tributary habitat similar to what they historically used for spawning; habitat that is largely unavailable to them under the current water management scenario. All salmonid species considered in this consultation have been adversely affected by the production of hatchery fish associated with the mitigation for the habitat lost to dam construction (*e.g.*, from genetic impacts, increased competition, exposure to novel diseases, *etc.*).

Similar to the listed salmonids, the Southern DPS of North American green sturgeon have been negatively impacted by hydroelectric and water storage operations in the Central Valley which ultimately affect the hydrology and accesibility of Central Valley rivers and streams to anadromous fish. Anthropogenic manipulations of the aquatic habitat, such as dredging, bank stabilization, and waste water discharges have also degraded the quality of the Central Valley's waterways for green sturgeon.

IV. ENVIRONEMENTAL BASELINE

The environmental baseline "includes the past and present impacts of all Federal, State, or private actions and other human activities in the action area, the anticipated impacts of all proposed Federal projects in the action area that have already undergone formal or early section 7 consultation, and the impact of State or private actions which are contemporaneous with the consultation in process" (50 CFR §402.02).

A. Status of the Species and Critical Habitat within the Action Area

1. Status of the Species within the Action Area

The action area functions primarily as a migratory corridor for adult and juvenile CV steelhead. All adult CV steelhead originating in the San Joaquin River watershed will have to migrate through the action area in order to reach their spawning grounds and to return to the ocean following spawning. Likewise, all CV steelhead smolts originating in the San Joaquin River watershed will also have to pass through the action area during their emigration to the ocean. The waterways in the action area also are expected to provide some rearing benefit to emigrating steelhead smolts as they move through the action area.

The action area also functions as migratory, holding and rearing habitat for adult and juvenile Southern DPS of North American green sturgeon. Green sturgeon presence in the action area could occur in any month as juveniles, and may reside in freshwater habitats throughout their first few years of growth. Adults are likely to be present in the winter and early spring (outside of in-water work window) as they move through the Delta towards their spawning grounds in the upper Sacramento River watershed.

The following are status summaries of these species and their habitat within the San Joaquin River and action area.

a. Sacramento River Winter-Run Chinook Salmon

The temporal occurrence of Sacramento River winter-run Chinook salmon smolts and juveniles in the action area are best described by the salvage records of the CVP and SWP fish handling facilities. Based on salvage records covering the last 8 years at the CVP and SWP, Sacramento River winter-run Chinook salmon are typically present in the Western and Central Delta action area starting in December. Their presence peaks in March and then rapidly declines from April through June. Nearly 50 percent of the average annual salvage of Sacramento River winter-run Chinook salmon juveniles occurs in March (48.8 percent). Salvage in April accounts for only 2.8 percent of the average annual salvage and falls to less than 1 percent for May and June combined. The presence of juvenile Sacramento River winter-run Chinook salmon in the Western and Central Delta is a function of river flows on the Sacramento River, where the fish are spawned, and the demands for water diverted by the SWP and CVP facilities. When conditions on the Sacramento River are conducive to stimulating outmigrations of juvenile Sacramento River winter-run Chinook salmon, the draw of the CVP and SWP pumping facilities pulls a portion of these emigrating fish through one of the four access points on the Sacramento River (Georgiana Slough, the Delta Cross Channel, Three Mile Slough, and the San Joaquin River via Broad Slough) into the channels of the Western and Central Delta, including the lower sections of the San Joaquin River. The combination of pumping rates and tidal flows moves these fish into the western delta portion of the action area. When the combination of pumping rates and fish movements are high, significant numbers of juvenile Sacramento River winter-run Chinook salmon are drawn into the action area.

b. *CV spring-Run Chinook salmon*

Like the Sacramento River winter-run Chinook salmon, the presence of juvenile CV spring-run Chinook salmon in the action area is under the influence of the CVP and SWP water diversions and the flows on the Sacramento River and its tributary watersheds. Currently, all known populations of CV spring-run Chinook salmon inhabit the Sacramento River watershed. The San Joaquin River watershed populations have been extirpated, with the last known runs on the San Joaquin River being extirpated in the late 1940s and early 1950s by the construction of Friant Dam and the opening of the Kern-Friant irrigation canal.

Juvenile CV spring-run Chinook salmon first begin to appear in the San Joaquin River basin in January. A significant presence of fish does not occur until March (20.1 percent of average annual salvage) and peaks in April (66.8 percent of average annual salvage). By May, the salvage of CV spring-run Chinook salmon juveniles declines sharply (11.5 percent of average annual salvage) and essentially ends by the end of June (1.3 percent of average annual salvage).

c. *CV steelhead*

The CV steelhead DPS occurs in both the Sacramento River and the San Joaquin River watersheds. However the spawning population of fish is much greater in the Sacramento River

watershed and accounts for nearly all of the DPS' population. Like Sacramento River Chinook salmon, Sacramento River steelhead can be drawn into the Central and Western Delta by the actions of the CVP and SWP water diversion facilities. Small, remnant populations of CV steelhead are known to occur on the Stanislaus River and the Tuolumne River and their presence is assumed on the Merced River due to proximity, similar habitats, historical presence, and recent otolith chemistry studies verifying at least one steelhead in the limited samples collected from the river. CV steelhead smolts first start to appear in the action area in November based on the records from the CVP and SWP fish salvage facilities. Their presence increases through December and January (22.5 percent of average annual salvage) and peaks in February (34.6 percent) and March (31.6 percent) before rapidly declining in April (7.8 percent). By June, the emigration has essentially ended, with only a small number of fish being salvaged through the summer at the CVP and SWP.

Steelhead smolt production originating in the San Joaquin River basin (all natural) are monitored by Kodiak trawls conducted by the USFWS and CDFG on the mainstem of the San Joaquin River just above the Head of Old River Barrier during the Vernalis Adaptive Management Program (VAMP) experimental period. These efforts routinely catch low numbers of outmigrating steelhead smolts from the San Joaquin Basin. Monitoring is less frequent prior to the VAMP, therefore emigrating steelhead smolts have a lower probability of being detected. Rotary screw trap (RST) monitoring on the Stanislaus River at Caswell State Park and further upriver near the City of Oakdale indicate that smolt sized fish start emigrating downriver in January and can continue through late May. Fry sized fish (30 to 50 mm) are captured at the Oakdale RST starting as early as April and continuing through June. Adult escapement numbers have been monitored for the past several years with the installation of an Alaskan style weir on the lower Stanislaus River near Riverbank. Typically, very few adult steelhead have been observed moving upstream past the weir. However, in 2006 to 2007, the weir was left in through the winter and spring and seven adult steelhead were counted moving upstream. Natural steelhead production also occurs on the Calaveras River, which empties into the San Joaquin River. Monitoring is conducted by RSTs in the upper reaches of the river below New Hogan Dam. Emigration of smolts from this watershed is highly correlated with stream flow conditions, and passage of smolts through the valley floor section of the watercourse is predicated on the river maintaining connectivity with the Delta. Steelhead smolt migrations are likewise monitored at several sites on the Sacramento River by the USFWS and CDFG. An important monitoring station for tracking smolt numbers is the Chipps Island station in the western Delta. This monitoring site collects steelhead smolts produced within the entire Central Valley basin.

d. *Southern DPS of North American Green Sturgeon*

Juvenile green sturgeon from the Southern DPS are routinely collected at the SWP and CVP salvage facilities throughout the year. However, numbers are considerably lower than for other species of fish monitored at the facilities. Based on the salvage records from 1981 through 2007, green sturgeon may be present during any month of the year, and have been particularly prevalent during July and August. The sizes of these fish are less than 1 meter and average 330 mm with a range of 136 mm to 774 mm. The size range indicates that these are sub-adult fish rather than

adult or larval/juvenile fish. It is believed that these sub-adult fish utilize the Delta for rearing for up to a period of approximately 3 years. The proximity of the CVP and SWP facilities to the action area would indicate that sub-adult green sturgeons have a strong potential to be present within the action area during the installation of the piles in the San Joaquin River. Juvenile green sturgeon have also previously been captured at Santa Clara Shoals during fish monitoring studies (Radtke 1966).

2. Status of Critical Habitat Within the Action Area

The action area is predominately within the San Joaquin Delta sub-basin (Hydrologic Unit [HU] # 18040003) and is included in the critical habitat designated for CV steelhead and proposed critical habitat for North American green sturgeon. A small portion of the western Delta around the confluence of the Sacramento and San Joaquin Rivers and waters westwards towards Chipps Island as well as the mainstem Sacramento River are also designated critical habitat for winter-run and spring-run Chinook salmon. This opinion will focus on the mainstem San Joaquin River at Sherman Island, outside of the designated critical habitat for winter-run and spring-run Chinook salmon.

The San Joaquin Delta HU is in the southwestern portion of the CV steelhead DPS range and includes portions of the south, central and western Delta channel complex. The San Joaquin Delta HU encompasses approximately 628 square miles, with 455 miles of stream channels (at 1:100,000 hydrography). The critical habitat analytical review team (CHART) identified approximately 276 miles of occupied riverine/estuarine habitat in this hydrologic subunit area (HSA) that contained one or more PCEs for the CV steelhead DPS (NMFS 2005). The PCEs of steelhead habitat within the action area also apply to green sturgeon, and include freshwater rearing habitat, freshwater migration corridors, and estuarine areas. The essential features of these PCEs included the following: sufficient water quantity and floodplain connectivity to form and maintain physical habitat conditions necessary for salmonid development and mobility, sufficient water quality, food and nutrients sources, natural cover and shelter, migration routes free from obstructions, natural levels of predation, holding areas for juveniles and adults, and shallow water areas and wetlands. Habitat within the action area is primarily utilized for freshwater rearing and migration by CV steelhead and North American green sturgeon juveniles and smolts and for adult upstream migration. No spawning of CV steelhead and North American green sturgeon occur within the action area.

The general condition and function of freshwater rearing and migration habitats has already been described in the *Status of the Species and Critical Habitat* section of this biological opinion. The substantial degradation over time of several of the essential features of these PCEs has diminished the function and condition of the habitats in the action area. This area currently provides only rudimentary functions compared to its historical status. The natural floodplains have essentially been eliminated, and the once extensive wetlands and riparian zones have been cleared for farming. Little riparian vegetation remains in the Delta, limited mainly to tules growing along the foot of artificial levee banks. Numerous artificial channels also have been created to bring water to irrigated lands that historically did not have access to the river channels

(*i.e.*, Victoria Canal, Grant Line Canal, Fabian and Bell Canal, Woodward Cut, *etc.*). These artificial channels have disturbed the natural flow of water through the Delta. As a byproduct of this intensive engineering of the Delta's hydrology, numerous irrigation diversions have been placed along the banks of the flood control levees to divert water from the area's waterways to the agricultural lands of the Delta's numerous "reclaimed" islands. Most of these diversions are not screened adequately to protect migrating fish from entrainment. Sections of the Delta have been routinely dredged by DWR to provide adequate intake depth for these agricultural water diversions, particularly in the South Delta. Likewise, the main channels of the San Joaquin River and the Sacramento River have been routinely dredged by the Corps to create an artificially deep channel to provide passage for ocean going commercial shipping to the Port of Stockton and the Port of Sacramento.

Water flow through the Delta is highly manipulated to serve human purposes. Rainfall and snowmelt is captured by reservoirs in the upper watersheds, from which its release is dictated primarily by downstream human needs. The SWP and CVP pumps draw water towards the southwest corner of the Delta which creates a net upstream flow of water towards their intake points. Fish, and the forage base they depend upon for food, are drawn along with the current towards these diversion points. In addition to the altered flow patterns in the Delta, numerous discharges of treated wastewater from sanitation wastewater treatment plants (*e.g.*, Cities of Pittsburg and Antioch) and the untreated discharge of numerous agricultural waste ways are emptied into the waters of the San Joaquin River and the channels of the Delta. This leads to cumulative additions to the system of thermal effluent loads as well as cumulative loads of potential contaminants (*i.e.*, selenium, boron, endocrine disruptors, pesticides, biostimulatory compounds, *etc.*).

Those members of the CV steelhead DPS that spawn in the San Joaquin system must pass through the San Joaquin Delta HSA to reach their upstream spawning and freshwater rearing areas on the tributary watersheds, in addition, also providing rearing and migratory habitat for North American green sturgeon. Therefore, it is of critical importance to the long-term viability of the San Joaquin River basin portion of the CV steelhead DPS and North American green sturgeon to maintain a functional migratory corridor and freshwater rearing habitat through the action area and the San Joaquin Delta HSA.

B. Factors Affecting the Species and Habitat in the Action Area

The Project study area is located in the Sacramento-San Joaquin Delta subsection of the Great Valley ecological sub-region (Miles and Goudey 1997). This region is characterized by a low, level plain at the confluence of the Sacramento and San Joaquin Rivers. Numerous artificial levees have been constructed throughout the region to reclaim lands for agricultural production.

Historically, the interplay between deposited sediments, plant growth, daily tidal flooding, and seasonal flooding resulted in a complex distribution of elevated waterways, vegetated islands, and nearshore tidal and subtidal habitats. This interplay continues today, but has been dramatically altered by human activities over the last two centuries.

Early Delta modifications were designed to enable navigation, control flooding of settled areas, and allow farming on the rich islands laced throughout the tidal Delta. Later, freshwater from the tidal Delta was exported to other communities and agricultural lands throughout the Central Valley and beyond to southern California. Water conveyance structures such as canals, cross channels, and interties significantly altered natural features. The pumping facilities at the Federal CVP, beginning in 1940, and the SWP, beginning in 1960, substantially decreased the outflow of fresh water from the Delta. Water movement patterns have been altered at both local and broad scales (The Bay Institute 1998). The balance between natural sedimentation rates and varying sea levels was altered by sediment deposition associated with placer mining in the Central Valley watershed along much of the western slopes of the Sierra Mountains from the 1860s to the 1880s, and by the direct filling of portions of the San Francisco Bay and estuary to accommodate shoreline development. The combination of these activities significantly reduced the aerial extent of freshwater marshes, once a dominant feature in the Delta habitat mosaic.

The flow of freshwater into the estuary has been greatly reduced by water diversions largely to support irrigated agriculture (Nichols 2007). Many stressors, such as chemical pollution, dissolved oxygen, water temperature, reversed flows, etc., in the Delta have resulted in the detriment of salmonids and sturgeon. Water diversions and water exports are a big part of the modified Delta and are a significant cause of the loss and decline of many resident and migratory fish species. As of April 1997, 3,356 diversions have been located and mapped using GPS in the Central Valley (Herren and Kawasaki 2001). Of these, 298 diversions were found within the San Joaquin River Basin. The Federal and State pumping plants draw off much of the inflowing freshwater of the San Joaquin River (Herbold and Moyle 1989). Spring- and fall-runs of salmon formerly existed in the major San Joaquin River tributaries and in the upper San Joaquin River, and there also may have been a late-fall-run present in the mainstem (Yoshiyama *et al.* 2001). However, all salmon runs in the San Joaquin River above the confluence of the Merced River were extirpated by the late-1940s (Yoshiyama *et al.* 2001).

Sources of selenium input to the Delta include: oil refinery effluents from five refineries in the Delta; agricultural drainage discharged through the San Joaquin River; direct discharge of agricultural drainage through a proposed extension of the San Luis Drain; and effluents from municipal wastewater treatment plants (Presser *et al.* 2008). The greatest increase in selenium uptake seems to occur along the pathway from water to algae and zooplankton where selenium is bioaccumulated several hundredfold. Fish consume organisms at lower trophic levels and, in general, seem to accumulate selenium to whole-body concentrations found in their food. Low waterborne concentrations of selenium that are readily bioaccumulated in plankton and detrital food pathways are, therefore, a threat to organisms, such as fish at the top of the trophic structure (Hamilton *et al.* 1990). For example, the introduction of the overbite clam (*Corbula amurensis*) has caused harm to green and white sturgeon. Overbite clams accumulate high levels of selenium and other toxic material and pass it on to sturgeon that consume overbite clams (Moyle 2002). Reproductive failure in fish exposed to elevated concentrations of selenium in the environment is probably due to bioaccumulation in the ovaries and their progeny, which causes lethal edema in larvae (Hamilton *et al.* 1990). Early life stages of salmonids and sturgeon are

generally more sensitive to toxicant stresses because of the lack or underdevelopment of metabolic mechanisms essential for handling toxicant stresses, or interference with metabolic processes that are vital to developing organisms (Hamilton *et al.* 1990) (green sturgeon are four times more sensitive than white sturgeon(Woodbury 2009)). Juvenile chinook salmon are exposed to selenium while they undergo parr-smolt transformations in the Sacramento-San Joaquin Delta. According to a study done by Hamilton *et al.* (1990), selenium reduced survival and growth in salmonids in freshwater and only reduced growth in fish that were in brackish water.

Invasive organisms, from plants to fish, are prevalent in the Delta. Introduced exotic species continue to change the area's biota by altering its food webs (Nichols 2007). California has the highest number of fish introductions of any state in the United States. Species invasion is a complex process with multiple steps: transport, release, establishment, spread, and integration. The movements of invaders between watersheds in California are primarily related to water transfers (*i.e.*, aqueducts, canals, and diversions) and salinity gradient in the Delta. Invasive and/or exotic species that become widely established are typically spread by humans (as opposed to natural dispersal from a center of origin). On a watershed basis, there have been relatively few extinctions of native fishes in California, although declining abundances of many native species suggests that the full impact of alien fishes has not yet occurred (Marchetti *et al.* 2004). Invasive species that affect ecosystem processes may indirectly impact populations of native species (see Figure 2). Invasive species can replace native species in their trophic level and can alter properties of an ecosystem.

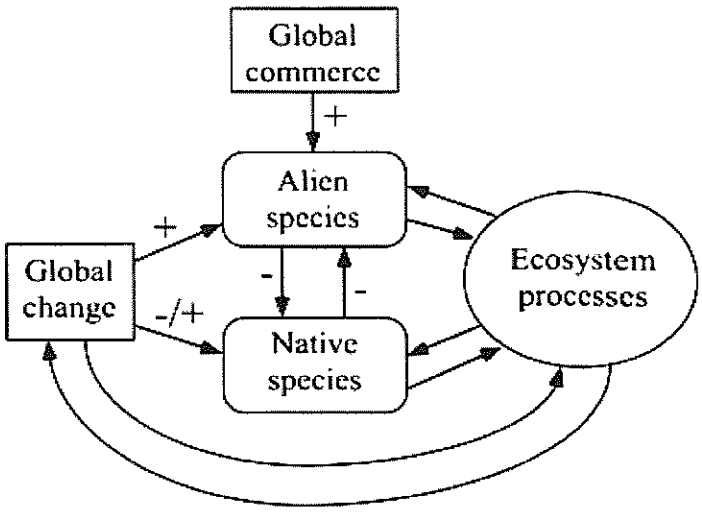


Figure 2 shows how alien species can indirectly and directly impact native species (Dukes and Mooney 2004)

In an uninvaded ecosystem, the value of the ecosystem function may vary over time due to shifts

in species dominance. As an invasion progresses, the invader makes up an increasing proportion of biomass at its trophic level. Thus, the decline of listed anadromous fish can be directly attributed to competition with or predation by fish species that were introduced for sport fishing (Dukes and Mooney 2004). Introduced fish and invertebrates change the availability of food and cover, which results in the detriment of listed juvenile salmonids and sturgeon. Introduced fish species (*e.g.* striped bass) tend to be more abundant and thus can out-compete native salmon, sturgeon, and steelhead by limiting their benthic food source (Moyle 2002).

V. EFFECTS OF THE ACTION

Pursuant to Section 7(a)(2) of the ESA (16 U.S.C. §1536), Federal agencies are directed to ensure that their activities are not likely to jeopardize the continued existence of any listed species or result in the destruction or adverse modification of critical habitat. This biological opinion assesses the effects of Antioch Bridge Seismic Retrofit project on CV steelhead, their designated critical habitat, the Southern DPS of North America green sturgeon, and their proposed critical habitat. The proposed Project is likely to adversely affect listed species and critical habitat through vibration of the piles for the temporary marine trestle. In the *Description of the Proposed Action* section of this Opinion, NMFS provided an overview of the action. In the *Status of the Species* and *Environmental Baseline* sections of this Opinion, NMFS provided an overview of the threatened and endangered species and critical habitat that are likely to be adversely affected by the activity under consultation.

Regulations that implement section 7(b)(2) of the ESA require NMFS to evaluate the direct and indirect effects of Federal actions and actions that are interrelated with or interdependent to the Federal action to determine if it would be reasonable to expect them to appreciably reduce listed species' likelihood of both surviving and recovering in the wild by reducing their reproduction, numbers, or distribution (16 U.S.C. §1536; 50 CFR 402.02). Section 7 of the ESA also requires NMFS to determine if Federal actions would appreciably diminish the value of critical habitat for the conservation of listed species (16 U.S.C. §1536). This biological opinion does not rely on the regulatory definition of "destruction or adverse modification" of critical habitat at 50 CFR 402.02. Instead, we have relied upon the statutory provisions of the ESA to complete the following analysis with respect to critical habitat.

A. Approach to the Assessment

NMFS generally approaches "jeopardy" analyses in a series of steps. First, NMFS evaluates the available evidence to identify direct and indirect physical, chemical, and biotic effects of the proposed actions (these effects include direct impacts to a species habitat; modifications to something in the species' environment - such as reducing a species' prey base, enhancing populations of predators, altering its spawning substrate, altering its ambient temperature regimes; or adding something novel to a species' environment - such as introducing exotic competitors or disruptive noises). Once NMFS has identified the effects of the action, the available evidence is evaluated to identify a species' likelihood and extent of exposure to any adverse effects caused by the action (*i.e.* the extent of spatial and temporal overlap between the

species and the effects of the action). Once NMFS has identified the level of exposure that a species will have to the effects of the action, the available evidence is evaluated to identify the species' probable response, including physical and behavioral reactions, to these effects. These responses then will be assessed to determine if they can reasonably be expected to reduce a species' reproduction, numbers, or distribution (for example, by changing birth, death, immigration, or emigration rates; increasing the age at which individuals reach sexual maturity; decreasing the age at which individuals stop reproducing; among others). The available evidence is then used to determine if these reductions, if there are any, could reasonably be expected to appreciably reduce a species' likelihood of surviving and recovering in the wild.

1. Information Available for the Assessment

To conduct the assessment, NMFS examined an extensive amount of evidence from a variety of sources. Detailed background information on the status of these species and critical habitat has been published in a number of documents including peer reviewed scientific journals, primary reference materials, governmental and non-governmental reports, the biological assessment for this project, and project meeting notes. Additional information investigating the effects of the project's actions on the listed species in question, their anticipated response to these actions, and the environmental consequences of the actions as a whole was obtained from the aforementioned resources. For information that has been taken directly from published, citable documents, those citations have been referenced in the text and listed at the end of this document.

2. Assumptions Underlying This Assessment

In the absence of definitive data or conclusive evidence, NMFS must make a logical series of assumptions to overcome the limits of the available information. These assumptions will be made using sound, scientific reasoning that can be logically derived from the available information. The progression of the reasoning will be stated for each assumption, and supporting evidence cited.

The potential adverse effects to listed species resulting from the proposed construction of the Antioch Bridge and the implementation of the minimization measures are primarily associated with elevated underwater sound pressure levels generated during pile driving. However, other potential impacts to listed salmonids and green sturgeon and designated critical habitat include turbidity resulting from ground disturbance for areas associated with bridge construction and mitigation.

The information used in this assessment includes *Status of the Species* and *Environmental Baseline* sections of this biological opinion, studies and accounts of the impacts of construction and pile driving activities on anadromous fish.

B. Assessment

The proposed project includes actions that may adversely affect several life stages of listed fish

species. Adverse effects to these species and their habitat may result from changes in water quality from construction activities, loss of riparian vegetation from construction activities, and physical injury and harassment of juveniles and adults from exposure to elevated levels of underwater sound produced during pile driving. The project includes integrated design features to avoid and minimize many of these potential impacts.

There will not be any long term changes to the footprint of the bridge or other habitat features within the action area, thus, there will only be short term exposure to construction related impacts to listed fish. During the period of August-October, adult CV steelhead enter freshwater to spawn, with a peak migration period of September-October (Moyle 2002). The steelhead migration period overlaps the pile driving in-water work window (August-November), and thus some of the adult fish moving into the San Joaquin watershed are likely to be exposed to the effects of the in-water work activities. Adult green sturgeon upstream migration occurs from March through July (Moyle *et al.* 1995). Although some of these fish migrate through the action area, they will likely not be present when in-water construction activities are proposed to occur. However, there is a possibility that some of these fish may occur within the action area and be exposed to the effects of the in-water work activities as they migrate back downstream in the fall months following spawning. There is also the potential for juveniles to be rearing and feeding in the Delta and around the action area year round, so a small proportion of the juvenile population may be exposed to the effects of the in-water work activities.

The action area also functions as a migratory corridor and rearing habitat for juvenile Sacramento River winter-run Chinook salmon, CV spring-run Chinook salmon ESUs, green sturgeon, and CV steelhead from the Sacramento River watershed that are drawn into the Central and South Delta by the actions of the CVP and SWP water diversion facilities and must therefore emigrate towards the ocean through the lower San Joaquin River system. Winter- and spring-run Chinook salmon, like green sturgeon, only spawn in the upper Sacramento River watershed. Construction of low elevation dams in the foothills of the Sierras on the American, Mokelumne, Stanislaus, Tuolumne, and Merced Rivers extirpated CV spring-run Chinook salmon from these watersheds. Naturally-spawning populations of CV spring-run Chinook salmon currently are restricted to accessible reaches of the upper Sacramento River. Therefore, adult Chinook salmon are unlikely to migrate through the action area or be exposed to the effects of the in-water work activities. Their designated critical habitat does not extend east of Suisun Bay (towards San Joaquin River). In addition, their migration timing (January through April for winter-run and March through May for spring-run) do not coincide with the proposed in-water work window.

The temporal occurrence of Sacramento River winter-run Chinook salmon smolts and juveniles in the action area are best described by the salvage records of the CVP and SWP fish handling facilities. Based on salvage records covering the last 8 years at the CVP and SWP, Sacramento River winter-run Chinook salmon are typically present in the Western and Central Delta action area starting in December. Their presence peaks in March and then rapidly declines from April through June. Nearly 50 percent of the average annual salvage of Sacramento River winter-run Chinook salmon juveniles occurs in March (48.8 percent). Salvage in April accounts for only 2.8 percent of the average annual salvage and falls to less than 1 percent for May and June combined.

The presence of juvenile Sacramento River winter-run Chinook salmon in the Western and Central Delta is a function of river flows on the Sacramento River, where the fish are spawned, and the demands for water diverted by the SWP and CVP facilities. When conditions on the Sacramento River are conducive to stimulating outmigrations of juvenile Sacramento River winter-run Chinook salmon, the draw of the CVP and SWP pumping facilities pulls a portion of these emigrating fish through one of the four access points on the Sacramento River (Georgiana Slough, the Delta Cross Channel, Three Mile Slough, and the San Joaquin River via Broad Slough) into the channels of the Western and Central Delta, including the lower sections of the San Joaquin River. The combination of pumping rates and tidal flows moves these fish into the western delta portion of the action area. When the combination of pumping rates and fish movements are high, significant numbers of juvenile Sacramento River winter-run Chinook salmon are drawn into the action area. Like the Sacramento River winter-run Chinook salmon, the presence of juvenile CV spring-run Chinook salmon in the action area are under the influence of the CVP and SWP water diversions and the flows on the Sacramento River and its tributary watersheds. Currently, all known populations of CV spring-run Chinook salmon inhabit the Sacramento River watershed. The San Joaquin River watershed populations have been extirpated, with the last known runs on the San Joaquin River being extirpated in the late 1940s and early 1950s by the construction of Friant Dam and the opening of the Kern-Friant irrigation canal.

Juvenile CV spring-run Chinook salmon would first begin to appear in the action area in January. A significant presence of fish do not occur until March (20.1 percent of average annual salvage) and peak in April (66.8 percent of average annual salvage). By May, the salvage of CV spring-run Chinook salmon juveniles decline sharply (11.5 percent of average annual salvage) and essentially end by the end of June (1.3 percent of average annual salvage).

1. Pile Driving and Bridge Construction

The proposed project includes installation of a temporary trestle (approximately 910 ft long) that will be constructed from the south end of the bridge. The proposed project will require two 24-inch diameter steel shell piles for every 25 feet of trestle and around the piers. The driving of steel piles for the temporary trestle will occur in water less than 10 feet in depth. There will be approximately 160 piles driven to a depth of 50 feet to support the temporary trestle. Four to six piles supporting between two to three sections of the trestle will be installed per day. Water depths would range from the shore or mud during lower tides to about 10 feet (3 meters). These piles would be vibrated in for approximately ten minutes per pile and one pile per each section (approximately 36 sections in total) will be driven with an impact hammer for approximately 20 blows per pile to verify the bearing capacity of the pile. This would equate to a maximum of 3,600 seconds of vibratory pile installation and 60 hammer strikes per day. The impact radius for 4 piles/day around a single pile for 187 dB SEL would be at a distance of 190 ft. The impact radius for 6 piles/day around a single pile for 187 dB SEL would be at a distance of 235 ft. The impact radius for a single strike of 206 dB_{peak} would be 45 ft.

NMFS uses a single strike peak sound pressure level (SPL) of 206 dB and an accumulated sound exposure level (SEL) of 187 dB to correlate underwater sound with potential injury to fish. These are the thresholds that indicate the onset of physical injury. The SPL is an expression of the sound pressure using the decibel scale and the standard reference pressures of micro-Pascal (1 μPa) for water and biological tissues. SEL is the exposure of fish to a total amount of energy (*i.e.*, dose) that can be used to determine a physical injury response. In other words, it is the time-integrated, sound-pressure-squared level. Because sound is a form of energy, the damage potential of a given sound environment will depend not only on its level, but also its duration. The root-mean-square (RMS) is 150 dB for a behavioral response in a fish. The level is determined by analyzing the waveform and computing the square root of the average of the squared pressures over the time period that comprises that portion of the waveform containing 90% of the sound (pressure squared) energy (Hastings and Popper 2005). This calculated RMS SPL is described as "RMS (impulse)" and is used to report an overall average SPL for a single pile driving pulse (Hastings and Popper 2005). Because all SEL measurements are normalized to a one second time interval, it may be used to compare the energy content of different exposures to sound. SEL is calculated by summing the cumulative pressure squared ($p2$) over time and is often used as an indication of the energy dose.

The installation of steel piles with a vibratory hammer in the San Joaquin River is expected to result in adverse effects to exposed fish due to high levels of underwater sound that will be produced. Adverse effects can range from physical injury to the exposed fish, sometimes resulting in death, to lesser impacts, such as behavioral modifications or increased susceptibility to predation, which do not necessarily result in death or long term adverse impacts by themselves. The degree to which an individual fish exposed to underwater sound will respond (from a startle response to immediate mortality) is dependent on a number of variables such as the species of fish, size of the fish, presence of a swimbladder, sound pressure intensity and frequency, shape of the sound wave (rise time), depth of the water around the pile and the bottom substrate composition and texture. Injury is expected if either: 1) the peak pressure of any strike exceeds 206 dB (re: 1 μPa); or 2) SEL, accumulated over all pile strikes, exceeds 187 dB (re: 1 μPa_2*sec) for fishes 2 grams or larger and 183 dB (re: 1 μPa_2*sec) for fishes smaller than 2 grams. Because all ESA-listed fish in the action area during pile driving are expected to be larger than 2 grams, the threshold for accumulated SEL used in this analysis is 187 dB.

a. Immediate Mortality of Fish from Pile Driving

The effect of pile driving on free swimming fish depends on the duration, frequency (Hz), and pressure (dB) of the compression wave. Rassmusen (1967) found that the immediate mortality of juvenile fish may occur at sound pressure levels exceeding 206 dB. Due to their size, adult CV steelhead and green sturgeon can tolerate higher pressure levels and immediate mortality rates for adults are expected to be less than those experienced by juveniles. As sound pressure levels are not expected to exceed 187 dB, no immediate mortality of juvenile or adult fish is expected.

b. Injury of Fish from Pile Driving

High levels of underwater acoustic noises have been shown to have adverse impacts upon the auditory sensory organs of fish within close proximity of the noise source. The loss of hearing sensitivity may adversely affect a salmonids' ability to orient itself (*i.e.*, due to vestibular damage), detect predators, locate prey, or sense their acoustic environment. Chronic noise exposure can reduce a fish's ability to detect piscine predators either by reducing the sensitivity of the auditory response or by masking the noise of an approaching predator. Disruption of the exposed fish's ability to maintain position or swim with the school will enhance its potential as a target for predators. Unusual behavior or swimming characteristics single out an individual fish and allow a predator to focus its attack upon that fish more effectively. Swimbladders, which are inflated with gas, can expand rapidly as the pressure waves pass through the fish and can press against, and strain, adjacent organs, such as the liver and kidney (Keevin and Hempen 1997). In addition, this pneumatic compression causes demonstrable injury, in the form of ruptured capillaries, internal bleeding, and maceration of highly vascular organs (Caltrans 2002). Hastings and Popper (2005) also noted that sound waves can cause different types of tissues to vibrate at different frequencies, and that this differential vibration can cause tearing of mesenteries and other sensitive connective tissues. Exposure to high noise levels can also lead to injury through "rectified diffusion," the formation and growth of bubbles in tissues. These bubbles can cause inflammation, cellular damage, and blockage or rupture of capillaries, arteries, and veins (Crum and Mao 1996; Stroetz *et al.* 2001; Vlahakis and Hubmayr 2000). Death from barotrauma and rectified diffusion injuries can be instantaneous, or delayed for minutes, hours or even days after exposure.

c. Behavioral Responses of Fish from Pile Driving

Behavioral responses to high noise levels can be in the form of a startled response, avoidance, agitation, etc. These behavioral responses can also lead to increased susceptibility to predation. In addition, elevated SPLs from impact and vibratory pile driving could conceivably delay the migration of fish and affect their foraging and migratory behavior.

d. Summary of Effects from Pile Driving

The activities related to pile driving are temporary and will only last the duration of the in-water work activities. Sublethal and/or subinjurious effects to juvenile CV steelhead and green sturgeon, including altered behavior, auditory masking, and temporary hearing threshold shifts can affect vulnerability to predation, foraging success, and other factors that influence survival and fitness. Pile driving will take place during each in-water work window during the bridge construction period (*i.e.*, concurrently with pile driving during temporary trestle installation and during removal of the temporary piles as elements of bridge construction are completed). Because daily pile driving activities will be separated by overnight rest periods when migration can proceed uninhibited, upstream and downstream migration of listed fish are not expected to be significantly delayed. The populations of these fish in the San Joaquin River represent a small number of the entire population in the Central Valley, and the action is expected to have little impact upon the entire DPS. There is potential for adult CV steelhead and green sturgeon to be adversely effected from pile driving activities, however, it is expected to be relatively low due to

their larger bodies (above two grams) and pile driving activities occurring only in the daytime which would avoid corpuscular and nocturnal periods when steelhead and sturgeon migratory activity is highest.

3. Water Quality

NMFS anticipates that some local increases in turbidity will result as a consequence of these actions. The increases in local turbidity levels are associated with the re-suspension of bottom sediments during the piling removal and installation phase of the construction process. The proposed in-water construction activities are not expected to lead to significant impacts to water quality in the action area. There are expected to be minor, short term increases in turbidity and sedimentation in localized areas due to the driving and removal of temporary piles. The expected increases in turbidity and suspended sediment may disrupt feeding and migratory behavior of listed fish over a small area for a short period of time. The turbidity associated with installation and removal of piles could result in localized displacement and likely behavioral modifications to individual salmonids and green sturgeon if they do not readily move away from the areas directly affected by the project. Turbidity and sedimentation events are not expected to affect feeding success of green sturgeon as they are not known to rely heavily on visual cues for feeding (Sillman *et al.* 2005). These temporary behavioral changes are not expected to result in injury or death of listed salmonids and green sturgeon. NMFS does not anticipate that turbidity levels associated with the pile driving will increase to deleterious levels. Furthermore, turbidity conditions are expected to return to ambient levels within hours to days of the termination of pile driving actions. Moreover, based on the timing of the pile driving actions, NMFS does not expect listed salmonids to be adversely effected by sedimentation and turbidity in the San Joaquin River. Green sturgeon, which can occupy waters containing variable levels of suspended sediment and thus turbidity, are not expected to be impacted by the slight increase in the turbidity levels anticipated from the pile driving action as explained above.

Unanticipated spills into the San Joaquin River, such as toxic substances used at construction sites (gasoline and lubricants) can lead to adverse effects and mortality in juvenile and adult salmonids and green sturgeon. If these toxins seep into the water, these substances can kill aquatic organisms through exposure to lethal concentrations or exposure to non-lethal levels that cause physiological stress and increased susceptibility to other sources of mortality. However, NMFS expects that Caltrans will adhere to the standard BMP's and SWPPP during construction activities to prevent these kinds of effects on listed salmonids and green sturgeon. Therefore, NMFS does not expect the Project will result in water contamination that will injure or kill listed anadromous fish.

3. Effects on Designated or Proposed Critical Habitat Primary Constituent Elements (PCEs)

The basic premise to the conservation value of an overall critical habitat designation is the sum of the values of the components that comprise the habitat. For example, the conservation value of listed salmonid critical habitat is determined by the conservation value of the watersheds that make up the designated area. In turn, the conservation value of the specific watershed is

comprised of the sum of the value of the PCEs that make up the area. PCEs are specific areas or functions, such as spawning or rearing habitat, that support different life history stages or requirements of the species. The conservation value of the PCE is the sum of the quantity, quality, and availability of the essential features of that PCE. Essential features are the specific processes, variables or elements that comprise a PCE. Thus, an example of a PCE would be spawning habitat and the essential features of that PCE are conditions such as clean spawning gravels, appropriate timing and duration of certain water temperatures, and water quality free of pollutants.

Therefore, reductions in the quantity, quality, or availability of one or more essential feature reduce the value of the PCE, which in turn reduces the function of the sub-area (*e.g.*, watersheds), which in turn reduces the function of the overall designation. In the strictest interpretation, reductions to any one essential feature or PCE would equate to a reduction in the value of the whole. However there are other considerations. We look to various factors to determine if the reduction in the value of an essential feature or PCE would affect higher levels of organization. For example:

- The timing, duration and magnitude of the reduction
- The permanent or temporary nature of the reduction
- Whether the essential feature or PCE is limiting (in the action area or across the designation) to the recovery of the species or supports a critical life stage in the recovery needs of the species (for example, juvenile survival is a limiting factor in recovery of the species and the habitat element supports juvenile survival).

In our assessment, we combine information about the contribution of constituent elements of critical habitat (or of the physical, chemical, or biotic phenomena that give the designated area value for the conservation of listed species) to the conservation value of those areas of critical habitat that occur in the action area, given the physical, chemical, biotic, and ecological processes that produce and maintain those constituent elements in the action area. We use the conservation value of those areas of designated critical habitat that occur in the action area as our point of reference for this comparison. For example, if the critical habitat in the action area has limited current value or potential value for the conservation of listed species, that limited value is our point of reference for our assessment of the consequences of the added effects of the proposed action on that conservation value.

a. Estuarine Migratory Corridors

Ideal estuarine areas are free of migratory obstructions with water quality, water quantity, and salinity conditions supporting juvenile and adult physiological transitions between fresh and salt water. Natural cover such as submerged and overhanging large woody material, aquatic vegetation, and side channels, are necessary for juvenile and adult foraging. Current estuarine areas are degraded as a result of human activities such as levee construction, urbanization and water exports.

The trestle for the Antioch Bridge is only temporary and will not obstruct the migratory pathway for exposed fish. Fish that use the action area as a migratory corridor will be able to continue using the channel during and after construction of the Antioch Bridge.

b. Estuarine Feeding and Rearing Habitat

Presence of the temporary piles will effect 0.011 ac (estimated as the cross-sectional area of 160 piles of 24-inch diameter) of foraging habitat. Estuarine rearing habitats support juvenile rearing and feeding, and function as migratory corridors for adult fish. Rearing habitat condition is strongly affected by habitat complexity, food supply, and presence of predators of juvenile salmonids. Salmonids such as CV steelhead rely more heavily on freshwater rearing habitat and green sturgeon rely more on the condition of the benthos which will not be affected. Prey species for juvenile and adult CV steelhead and green sturgeon within bays and estuaries primarily consist of benthic invertebrates and fish, including crangonid shrimp, callianassid shrimp, burrowing thalassinidean shrimp, amphipods, isopods, clams, annelid worms, crabs, sand lances, and anchovies. These prey species are critical for the rearing, foraging, growth, and development of these fish within the bays and estuaries. Currently, the estuary provides these food resources, although annual fluctuations in the population levels of these food resources may diminish the contribution of one group to the diet of green sturgeon relative to another food source. The recent spread of the Asian overbite clam has shifted the diet profile of white sturgeon to this invasive species. The overbite clam now makes up a substantial proportion of the white sturgeon's diet in the estuary. NMFS assumes that green sturgeon have also altered their diet to include this new food source based on its increased prevalence in the benthic invertebrate community.

Impacts to foraging habitat associated with the proposed action are minimal and temporary, and will not appreciably diminish the conservation value of the critical habitat, thus will have little impact to the exposed fish

c. Summary of PCEs in the Action Area

The PCEs of critical habitat that will be adversely affected include estuarine rearing and feeding sites for juveniles and estuarine migration corridors for both juveniles and adults. The temporary trestle piles will be removed upon completion of the proposed action. Therefore, NMFS expects that nearly all of the adverse effects to critical habitat from this project will be minimal and short-term and will not affect future generations of listed fish beyond the construction period of the project.

VI. 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 ESA.

Land surrounding the Caltrans ROW in the action area belongs to the California Department of Water Resources. They lease the land to tenants for grazing cattle. The southern part of this action area is located in the East Bay Regional Park District's Oakley Regional Park and includes a small portion of a developed marina.

Non-Federal actions that may affect the action area include ongoing agricultural activities and increased urbanization. Agricultural practices in and upstream of the San Joaquin River may adversely affect riparian and wetland habitats through upland modifications of the watershed that lead to increased siltation or reductions in water flow in stream channels flowing into the San Joaquin River. Unscreened agricultural diversions throughout the Delta entrain fish including juvenile salmonids and green sturgeon. Grazing activities from dairy and cattle operations can degrade or reduce suitable critical habitat for listed salmonids by increasing erosion and sedimentation as well as introducing nitrogen, ammonia, and other nutrients into the watershed, which then flow into the receiving waters of the San Joaquin River. Stormwater and irrigation discharges related to both agricultural and urban activities contain numerous pesticides and herbicides that may adversely affect salmonid reproductive success and survival rates (Dubrovsky *et al.* 1998, 2000; Daughton 2003).

Global climate change is a broad-scale cumulative effect that is likely to affect the action area. The world is about 1.3 °F warmer today than a century ago and the latest computer models predict that, without drastic cutbacks in emissions of carbon dioxide and other gases released by the burning of fossil fuels, the average global surface temperature may rise by two or more degrees in the 21st century (Intergovernmental Panel on Climate Change (IPCC) 2001). Much of that increase will likely occur in the oceans, and evidence suggests that the most dramatic changes in ocean temperature are now occurring in the Pacific (Noakes 1998). Using objectively analyzed data Huang and Liu (2000) estimated a warming of about 0.9 degrees F per century in the Northern Pacific Ocean.

Sea levels are expected to rise by 0.5 to 1.0 meters (m) in the northeastern Pacific coasts in the next century, mainly due to warmer ocean temperatures, which lead to thermal expansion much the same way that hot air expands. This will cause increased sedimentation, erosion, coastal flooding and permanent inundation of low-lying natural ecosystems within the action area (*i.e.*, salt marsh, riverine, mud flats) affecting critical habitat PCEs. Increased winter precipitation, decreased snow pack, and permafrost degradation could affect the flow and temperature of rivers and streams, with negative impacts on fish populations and the habitat that supports them.

Summer droughts along the South Pacific coast and in the interior of the northwest Pacific coastlines will mean decreased stream flow in those areas, decreasing salmonid survival and reducing water supplies in the dry summer season when irrigation and domestic water use are greatest. Global climate change may also change the chemical composition of the water that fish inhabit: the amount of oxygen in the water may decline, while pollution, acidity, and salinity levels may increase. This will allow for more invasive species to over take native fish species and impact predator-prey relationships (Stachowicz *et al.* 2002; Peterson and Kitchell 2001).

An alarming prediction is that Sierra snow packs are expected to decrease with global warming and that the majority of runoff in California will be from rainfall in the winter rather than from melting snow pack in the mountains (CDWR 2006). This will alter river runoff patterns and transform the tributaries that feed the Central Valley from a spring/summer snowmelt dominated system to a winter rain dominated system. It can be hypothesized that summer temperatures and flow levels will become unsuitable for salmonid survival. The cold snowmelt that furnishes the late spring and early summer runoff will be replaced by warmer precipitation runoff. This should truncate the period of time that suitable cold-water conditions exist below existing reservoirs and dams due to the warmer inflow temperatures to the reservoir from rain runoff. Without the necessary cold-water pool developed from melting snow pack filling reservoirs in the spring and early summer, late summer and fall temperatures below reservoirs, such as Shasta Lake and Lake Oroville, potentially could rise above thermal tolerances for juvenile and adult salmonids (*i.e.* CV steelhead) that must hold below the dam over the summer and fall periods.

Anticipated climate change may affect spatial and temporal precipitation patterns along with the intensity and duration of precipitation within the San Joaquin River watershed. Ambient air temperatures in California are projected to increase several degrees centigrade (^{o}C) by the end of this century. As a result, it is possible that less precipitation will occur as snowfall and more will occur as rain in future years. The effect of climate change is anticipated to be more winter and less spring and summer run-off within the watershed. In addition, expected run-off is anticipated to be warmer, possibly affecting the ability to meet downstream water temperature objectives to protect salmon, steelhead and green sturgeon. A reduction in snowpack combined with increased ambient air temperatures is expected to result in earlier melting of snow and less run-off from the snowpack than that which occurs today. A change in the run-off pattern within the San Joaquin River watershed will likely affect reservoir storage and downstream river flows due to more frequent spillway releases. Currently, summer water temperatures often are close to the upper tolerance limits for salmon and steelhead and any increase in ambient air temperatures as a result of climate change is anticipated to make it more difficult at the very least, if not impossible, to meet established water temperature objectives on the San Joaquin River. Reduced reservoir storage as a result of the anticipated change in run-off pattern may also affect the availability of a cold water supply necessary to maintain river temperatures downstream.

There are no specific plans for development within the action area of the proposed project. Therefore, further cumulative effects beyond those described above are not expected.

VII. INTEGRATION AND SYNTHESIS

This section integrates the current conditions described in the status of the species and the environmental baseline for the action area with the effects of the proposed action and the cumulative effects of future actions. The purpose of this synthesis is to develop an understanding of the likely short-term and long-term responses of listed species and critical habitat to the proposed project.

A. Summary of Status of the Species and Environmental Baseline

The San Joaquin River basin historically contained numerous independent populations of CV steelhead and spring-run Chinook salmon (Lindley *et al.* 2006, 2007). Potentially, the Southern DPS of North American green sturgeon were also present in these watersheds prior to anthropogenic changes. The suitability of these watersheds to support these runs of fish changed with the onset of human activities in the region. Human intervention in the region initially captured mountain runoff in foothill reservoirs which supplied water to farms and urban areas. As demand grew, these reservoirs were enlarged or additional dams were constructed higher in the watershed to capture a larger fraction of the annual runoff. San Joaquin Valley agriculture created ever greater demands on the water captured by these reservoirs, diminishing the flow of water remaining in the region's rivers, and negatively impacting regional populations of anadromous fish. Reclamation actions eliminated vast stretches of riparian habitat and seasonal floodplains from the San Joaquin River watershed and Delta through the construction of levees and the armoring of banks with rock riprap for flood control. Construction of extensive water conveyance systems and water diversions altered the flow characteristics of the Delta region. These anthropogenic actions resulted in substantial degradation of the functional characteristics of the aquatic habitat in the watershed upon which the region's anadromous fish populations depended.

Presently, CV spring-run Chinook salmon have been functionally extirpated from the San Joaquin River basin. Populations of CV steelhead in the San Joaquin River basin have been substantially diminished to only a few remnant populations in the lower reaches of the Stanislaus, Tuolumne, and Merced Rivers below the first foothill dams. The Southern DPS of North American green sturgeon have not been documented spawning in the San Joaquin River, but human alterations, which have been ongoing for over 100 years in the watershed, may have extirpated local populations before accurate records were maintained. Since the viability of small remnant populations of CV steelhead in the San Joaquin River basin is especially tenuous and such populations are susceptible to temporally rapid decreases in abundance and possess a greater risk of extinction relative to larger populations (Pimm *et al.* 1988; Berger 1990; Primack 2004), activities that reduce the quality and quantity of habitats, or that preclude the formation of independent population units (representation and redundancy rule cited by Lindley *et al.* 2007), are expected to drive the species towards extinction as individual populations within the larger DPS become extinct (McElhany *et al.* 2000). Therefore, activities having severe impacts on steelhead populations or destroying designated critical habitat, within these smaller population units have significant implications for the DPS as a whole.

a. CV Steelhead

Estimates of adult escapement of steelhead to these watersheds are typically only a few dozen or so. This is reflected by the low number of smolts captured by monitoring activities throughout the year in different tributaries (*i.e.*, rotary screw traps on the Stanislaus, Tuolumne, Merced, and Calaveras Rivers, and the Mossdale trawls on the San Joaquin River below the confluence of these three east side tributaries) in which only a few dozen smolts to several hundred smolts are

collected each year (Marston 2004; Cramer 2005). These capture numbers have been extrapolated to estimate an annual population of only a few thousand juvenile steelhead smolts basin-wide in the San Joaquin River region. The Stanislaus River weir, which is used to count adult steelhead passing through the counting chamber or dead carcasses floating back onto the weir, has only recorded a few adult fish each year it has been in use. This is indicative of the low escapement numbers for adult steelhead in this watershed (Cramer 2005). The other San Joaquin tributaries are thought to have similar or even lower numbers based on the superiority of the Stanislaus River in terms of habitat and water quality for CV steelhead.

Under these low adult escapement conditions, the loss of one individual female's reproductive capacity through mortality can have a relatively high impact on a given watershed's potential population if the number of adults returning to each stream is low. Loss of one female with an expected egg capacity of 5,000 eggs represents approximately 50 to 100 smolts returning to the ocean (Good *et al.* 2005) a significant proportion of the total production from the San Joaquin basin.

b. Southern DPS of North American Green Sturgeon

Southern DPS green sturgeon were also present in these watersheds prior to anthropogenic changes. The suitability of these watersheds to support these runs of fish changed with the onset of human activities in the region. Southern DPS green sturgeon have not been documented utilizing the San Joaquin River as a spawning river in recorded history but human alterations, which have been ongoing for over 100 years in the watershed, may have extirpated these populations before accurate records were maintained. However, fish survey records indicate that juvenile and sub-adult green sturgeon make use of the lower San Joaquin River for rearing purposes during the first several years of their life.

The basic pattern described for adult green sturgeon migrations into the Delta region from the San Francisco Bay estuary is that adult fish enter the Delta region starting in late winter or early spring and migrate upstream towards the stretch of the Sacramento River between Red Bluff and Keswick Dam. After spawning, adults return downstream and re-enter the Delta in the fall and winter months. Juvenile and larval green sturgeon begin to show up in rotary screw trap catches along the Sacramento River starting in summer (Beamesderfer *et al.* 2004) and could be expected to reach the Delta by fall. The extent and duration of these fish entering and remaining in the San Joaquin River within the action area is unclear, but because of the habitat similarities and lack of barriers between the action area and documented sturgeon habitat in the Delta, NMFS believes that green sturgeon could be found during any month of the year within the action area. Southern DPS green sturgeon have not been documented utilizing the San Joaquin River as a spawning river in recorded history but human alterations, which have been ongoing for over 100 years in the watershed, may have extirpated these populations before accurate records were maintained. However, fish survey records indicate that juvenile and sub-adult green sturgeon make use of the lower San Joaquin River for rearing purposes during the first several years of their life. Juvenile and adult green sturgeon are likely to be present in the Delta during the construction phase of the project, as juveniles and adults utilize the Delta for rearing on a year-round basis prior to

migrating to the ocean.

c. Designated and Proposed Critical Habitat

The evidence presented in the Status of Species and Environmental Baseline sections indicate that past and present activities within the San Joaquin River basin have caused significant habitat loss, degradation and fragmentation. This has significantly reduced the quality and quantity of the remaining freshwater rearing sites and the migratory corridors within the lower valley floor reaches of the San Joaquin River for the CV steelhead population. Alterations in the geometry of the San Joaquin River Basin, removal of riparian vegetation and shallow water habitat, construction of armored levees for flood protection, changes in river flow created by demands of water diverters, and the influx of contaminants from agricultural and urban dischargers have also substantially reduced the functionality of the region's waterways. Additional losses of freshwater spawning sites, rearing sites, and migratory corridors have occurred upstream of the action area in the tributaries of the San Joaquin and Sacramento River basins, further reducing the overall conservation value of the critical habitat designation.

The current condition of proposed critical habitat for the Southern DPS of green sturgeon is degraded over its historical conditions. In particular, passage and water flow PCEs have been impacted by human actions, substantially altering the historical river characteristics in which the Southern DPS of green sturgeon evolved. The conservation value of green sturgeon proposed critical habitat has suffered similar types of degradation as already described for CV steelhead critical habitat. In addition, the alterations to the Sacramento-San Joaquin River Delta, as part of proposed critical habitat, may have a particularly strong impact on the survival and recruitment of juvenile green sturgeon due to their protracted rearing time in the delta and estuary. Loss of individuals during this phase of the life history of green sturgeon represents losses to multiple year classes rearing in the Delta, which can ultimately impact the potential population structure for decades to come.

B. Summary of the Effects of the Proposed Action on Listed Species Likelihood of Survival and Recovery

Under the proposed Antioch Bridge Seismic Retrofit project, adverse impacts to listed species stemming from increased sedimentation and acoustic impacts from pile driving are expected to occur. These impacts may cause physiological stress to the extent that the normal behavior patterns (*e.g.*, feeding, sheltering and migration) of affected individuals may be disrupted. Overall, the changes in turbidity and suspended sediment associated with this project are expected to adversely affect listed species primarily by low-level, short-term alteration of habitat conditions, which may reduce feeding or increase predation rates for juveniles. The potential for the increase in suspended sediment to adversely affect adult green sturgeon is unclear. However, because sturgeon are demersal fish closely associated with the bottom substrate, feed by taste and feel with their barbels, and even shovel up sediment with their snouts when searching for food, it is expected that they would be unaffected by the levels and duration of turbidity expected to be produced by the proposed project. Potential impacts are expected to be minimized by meeting

CVRWQCB water quality objectives, Caltrans water pollution specifications, implementing "best management practices" for erosion control, staging equipment outside of the riparian corridor, limiting the amount of riparian vegetation removal, and restoring disturbed riparian habitat values at the project site.

Pile driving activities are scheduled to occur August 1-November 30. Elevated levels of underwater sound around the pile driving activities may cause mortality, injury, or temporary behavioral changes to exposed fish These impacts will be substantially minimized by the pile driving work window restrictions. Loss of hearing sensitivities in juvenile fish will expose them to higher risks of predation. Fish with impacted hearing capacities will have a lower ability to detect predators and may be unable to maintain position in the water column (due to inner ear equilibrium factors). Underwater noise from pile driving may cause startling and/or avoidance of preferred habitat by fish in the immediate vicinity of the project site. The startling of fish can cause harm by temporarily disrupting normal behaviors that are essential to growth and survival such as feeding, sheltering, and migrating. Disruption of these behaviors would occur for specific periods during daylight operation hours of the pile driving hammer. Construction lapses, including daily breaks and nighttime non-working periods, as well as long periods when no pile driving is scheduled to occur, will allow fish to migrate through the action area and minimize the extent of impacts to populations. NMFS believes that the limited exposure to underwater sound levels associated with the proposed project is unlikely to significantly affect growth or survival of exposed adult and juvenile salmonids and green sturgeon.

a. CV Steelhead

NMFS anticipates that the proposed project will result in the exposure of a small number of adult and juvenile CV steelhead to temporary increased levels of turbidity and suspended sediment, as well as noise from pile driving activities. The exposure to noise in particular is expected to adversely affect a small number of individuals. Noise may delay or impede fish migration causing increased energy expenditure by affected individuals, but as sound pressure levels are not expected to exceed a peak of 206 dB, no direct and/or immediate mortality of juvenile or adult fish is expected. However, fish exposed to an SEL exceeding 187 dB can be physically injured, and potentially lead to indirect mortality.

The elevated stress levels may degrade the fish's health and the reproductive potential of adults, and increase the potential of juveniles to be preyed upon by striped bass or other large predators due to impaired behavioral and physiological responses. Individuals that appear different in their behavior attract predators, and thus experience higher mortality due to predator attacks. Even so, given the low level of exposure expected to result from adherence to the limited seasonal and diurnal in-water work windows, the limited adverse response expected from the few individuals that are exposed to these adverse effects, and the relatively small contribution to juvenile production that the San Joaquin River Basin provides to the overall population numbers for the CV steelhead DPS, it is expected that the effects of the proposed project, when considered in the context of the current baseline and likely future cumulative effects, would not appreciably reduce the likelihood of survival and recovery of the CV steelhead DPS throughout its range.

b. Southern DPS of North American Green Sturgeon

NMFS anticipates that the proposed project will result in the exposure of a small number of adult and juvenile North American green sturgeon to increased levels of turbidity and suspended sediment, as well as noise from pile driving activities. Given the previous analysis showing that green sturgeon are relatively tolerant of turbid/low light environments, the turbidity effects associated with the proposed project are not expected to result in measurable impacts to green sturgeon. The exposure to noise in particular is expected to adversely affect a small number of individuals. Noise may displace or impede fish that are rearing or holding in the action area causing disruptions in feeding and sheltering behavior of individuals. Prolonged exposure to high sound levels may also result in temporary impacts to the hearing ability of exposed fish, but sound pressure levels are not expected to exceed 206 dB, so no direct and/or immediate mortality of juvenile or adult fish is expected. However, fish exposed to an accumulated SEL exceeding 187 dB can be physically injured, and potentially lead to indirect mortality.

The elevated stress levels associated with sound exposure may degrade the fish's health and the reproductive potential of adults, and increase the potential of juveniles to be preyed upon by striped bass or other large predators due to impaired behavioral and physiological responses. Individuals that appear different in their behavior attract predators, and thus experience higher mortality due to predator attacks. Due to the lack of general abundance information regarding the Southern DPS of North American green sturgeon in the San Joaquin River, a variety of estimates must be utilized to determine the range of potential effects resulting from the take of a small number of green sturgeon due to the proposed action. Compared to the estimated population sizes suggested by the CDFG tagging efforts (CDFG 2002b), juvenile and sub-adult captures passing Red Bluff Diversion Dam, and past Interagency Ecological Program (IEP) sampling efforts, the low level of take estimated from the proposed project would impact a very small proportion of the adult and sub-adult North American green sturgeon DPS. Ratios of tagged white to green sturgeon in San Pablo Bay have generated population estimates averaging 12,499 sub-adult and adult green sturgeon. Captures of juvenile green sturgeon passing Red Bluff Diversion Dam have exceeded 2,000 individuals in some years. Utilizing trap efficiency estimates generated for salmonids at this sampling site (Marten *et al.* 2001) the total estimate of juvenile green sturgeon passing RBDD would be in excess of 20,000 fish during that sampling period. Given these juvenile population estimates, the low level of incidental take of North American green sturgeon that is expected to result from the proposed project would represent a very small proportion of the standing population and is not expected to appreciably reduce the likelihood of survival and recovery of the Southern DPS of North American green sturgeon.

C. Summary of Effects of the Proposed Action on Critical Habitat

The effects of the proposed Antioch Bridge Seismic Retrofit project is expected to have minimal adverse effects upon the functionality and conservation value of the freshwater rearing and migratory corridors designated or proposed as critical habitat in the San Joaquin River. Impacts to the designated and proposed critical habitat within the action area that are related to the

construction actions are expected to be temporary, lasting only as long as the pile driving and mooring lines installation/removal activities. The construction actions should never impede or prevent migratory potential in the channel of the San Joaquin River due to numerous factors, including: timing of work, location of the action (large open migratory habitat still accessible to fish), and protective measures implemented to minimize impacts to the river during construction (*i.e.*, BMPs and SWPPP). Temporary loss of foraging habitat is minimal, given the small footprint of the pile driving compared to the available habitat.

NMFS expects that nearly all of the adverse effects to critical habitat from this project will be of a short-term nature and will not affect future generations of listed fish beyond the construction period of the project.

VIII. CONCLUSION

After reviewing the best scientific and commercial data available, including the environmental baseline, the effects of the proposed project, and the cumulative effects, it is NMFS biological opinion that the Antioch Bridge Seismic Retrofit project is not likely to jeopardize the continued existence of endangered Sacramento River Winter-run Chinook salmon, threatened CV Spring-run Chinook salmon, threatened CV steelhead, or threatened Southern DPS of North American green sturgeon, and is not likely to destroy or adversely modify designated or proposed critical habitat for these species.

IX. INCIDENTAL TAKE STATEMENT

Section 9 of the ESA and Federal regulation pursuant to section 4(d) of the ESA prohibit the take of endangered and threatened species, respectively, without special exemption. Take is defined as to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or to attempt to engage in any such conduct. Harm is further defined by NMFS as an act which kills or injures fish or wildlife. Such an act may include significant habitat modification or degradation where it actually kills or injures fish or wildlife by significantly impairing essential behavioral patterns, including breeding, spawning, rearing, migrating, 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 the purpose of the agency action is not considered to be prohibited taking under the ESA provided that such taking is in compliance with the terms and conditions of this incidental take statement.

The listing of the Southern DPS of North American green sturgeon became effective on July 7, 2006, and some or all of the ESA section 9(a) prohibitions against take will become effective upon the future issuance of protective regulations under section 4(d). Because there are no section 9(a) prohibitions at this time, the incidental take statement, as it pertains to the Southern DPS of North American green sturgeon, does not become effective until the issuance of a final 4(d) regulation, as appropriate.

The measures described below are non-discretionary, and must be undertaken by Caltrans, as appropriate, 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 assume and implement the terms and conditions or (2) fails to require any contractors to adhere to the terms and conditions of the incidental take statement through enforceable terms that are added to any contract, permit or grant documents, the protective coverage of section 7(o)(2) may lapse. In order to monitor the impact of incidental take, Caltrans must report the progress of the action and its impact on the species to NMFS as specified in the incidental take statement [50 CFR §402.14(i)(3)].

A. Amount or Extent of Take

NMFS anticipates incidental take of CV steelhead and the Southern DPS of North American green sturgeon from impacts directly related to pile driving activities and impairment of essential behavior patterns as a result of these activities. The incidental take is expected to be in the form of harm, harassment, or mortality of CV steelhead and green sturgeon, resulting from the installation and removal of temporary piles. Incidental take is expected to occur from August 1 through November 30, when CV steelhead and green sturgeon could potentially be in the action area. Moreover, it is not possible to monitor the resulting take given the site conditions present (high natural turbidity), and the likelihood that the full extent of these effects may be delayed for hours or days after initial exposure, perhaps longer. Therefore, NMFS cannot predict what proportion of the migrating fish will be exposed to elevated noise levels and what proportion will move through the action area at night or during other periods when pile driving is not occurring. Therefore, NMFS has designated specific project elements and effects to act as ecological surrogates for the extent of take anticipated to result from the Antioch Bridge Seismic Retrofit project.

1. Ecological Surrogates

The most appropriate ecological surrogates for the extent of take caused by the Project are: the amount, duration and timing of pile driving and pile removal associated with the construction and removal of the temporary trestle, and the amount, duration and timing of increased turbidity caused by these pile driving and removal activities.

- The analysis of the effects of the proposed project anticipates the installation and subsequent removal of up to 160, 24-inch diameter hallow steel shell piles during the in-water work window between August 1 and November 30, during daylight hours, for one season.

  Specifically, the areas in which take is expected to occur from pile driving within the San Joaquin River are:

  a. within 12 meters of the unattenuated impact pile driving necessary to establish the baseline SPLs for the monitoring, assuming that the peak underwater noise levels

experienced by ESA listed fish within this area will exceed the 206 dB_{peak} injury threshold for a single pile strike (equivalent to no more than 207 dB_{peak} measured 10 meters from the pile);

b. within 6,600 feet of vibratory pile driving, where NMFS expects significant behavioral effects on ESA-listed fish due to SPLs in excess of 150 dB_{rms} (equivalent to 191 dB_{peak} measured at 10 meters from each pile).

NMFS expects that noise levels outside of these areas will not exceed the above described thresholds.

- The analysis of the effects of the proposed project anticipates that the turbidity levels produced by installation/removal of piles will not exceed those permitted under the project SWPPP and that if turbidity levels approach or exceed the acceptable criteria established by the Regional Water Quality Control Board (RWQCB), construction activities will be halted until turbidity levels return to within acceptable levels.

If these ecological surrogates are not met and maintained, the proposed Antioch Bridge Seismic Retrofit project will be considered to have exceeded anticipated take levels, triggering the need to reinitiate consultation on the Project.

B. Effect of Take

NMFS has determined that the level of take resulting from the construction of the proposed project is not likely to jeopardize the continued existence of CV steelhead or the Southern DPS of North American green sturgeon, and is not likely to destroy or adversely modify designated critical habitat for CV steelhead or proposed critical habitat for the Southern DPS of North American green sturgeon.

C. Reasonable and Prudent Measures

NMFS has determined that the following reasonable and prudent measures (RPMs) are necessary and appropriate to minimize the incidental take of listed anadromous fish.

1. Real time monitoring shall be conducted to ensure that underwater sound levels analyzed in this biological opinion (150 db RMS, 187 dB accumulated SEL, and 206 peak SPL) are not exceeded.

2. Measures shall be taken to maintain, monitor, and adaptively manage all conservation measures throughout the life of the project to ensure their effectiveness.

D. Terms and Conditions

In order to be exempt from the prohibitions of section 9 of the ESA, Caltrans must comply with the following terms and conditions, which implement the reasonable and prudent measures described above and outline required reporting/monitoring requirements. These terms and conditions are non-discretionary:

1. Real time monitoring shall be conducted to ensure that underwater sound levels analyzed in this biological opinion (150 db RMS, 187 dB accumulated SEL, and 206 peak SPL) are not exceeded.

    a. Caltrans shall monitor underwater sound during all impact hammer pile driving activities on land or in water whenever there is a possibility the activity may exceed the 206 dB peak sound level. If underwater sound produced during five or more strikes on a single day exceeds the maximum allowable level of 206 dB_{peak} at 14 meters from the pile being installed, then NMFS must be contacted within 24 hours.

    b. Caltrans shall submit to NMFS daily hydroacoustic monitoring reports (by noon of the day following pile driving) that provide data regarding the actual (or estimated using propagation models) distance to the NMFS thresholds (150 db RMS, 187 dB accumulated SEL, and 206 peak SPL) used in this biological opinion to determine adverse effects to listed species. Specifically, the reports shall:

        - Describe the locations of hydroacoustic monitoring stations that were used to document the extent of the underwater sound footprint during pile-driving activities, including the number, location, distances, and depths of hydrophones and associated monitoring equipment;

        - Include the total number of pile strikes per pile, the interval between strikes, the peak/RMS SPL and SEL per strike, and accumulated SEL per day for each hydroacoustic monitor deployed.

        - Include a monitoring and reporting program that will include provisions to provide daily summaries of the hydroacoustic monitoring results to NMFS, as well as more comprehensive summary reports on a monthly basis during the pile-driving season.

    c. Caltrans shall submit to NMFS a hydroacoustic monitoring summary due 30 days following pile driving that provides a review of the monitoring data and process, as well as any problems that were encountered.

    d. Pile driving shall occur only during daylight hours from one hour after sunrise to one hour before sunset. This is to ensure that pile driving does not occur at dawn or dusk, during peak salmonid migration and feeding times.

2. Measures shall be taken to maintain, monitor, and adaptively manage all conservation measures throughout the life of the project to ensure their effectiveness.

   a. Caltrans shall monitor and maintain all riparian plantings for 5 years, and provide irrigation, fertilization and replacement plantings as necessary to insure full and rapid recovery of disturbed riparian habitat features

   b. If a listed species is observed injured or killed by project activities, Caltrans shall contact NMFS within 48 hours at 650 Capitol Mall, Suite 8-300, Sacramento, CA 95814. Notification shall include species identification, the number of fish, and a description of the action that resulted in take. If possible, dead individuals shall be collected, placed in an airtight bag, and refrigerated with the aforementioned information until further direction is received from NMFS.

Annual updates and reports required by these terms and conditions shall be submitted by December 31 of each year during the construction period to:

Sacramento Area Office
National Marine Fisheries Service
650 Capitol Mall, Suite 8-300
Sacramento CA 95814
FAX: (916) 930-3629
Phone: (916) 930-3600

XI. CONSERVATION RECOMMENDATIONS

Section 7(a)(1) of the Act directs Federal agencies to utilize their authorities to further the purposes of the ESA 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.

1. Caltrans should support and promote aquatic and riparian habitat restoration within the Delta region, and implement practices that avoid or minimize negative impacts to salmon, steelhead, and sturgeon on all of their project sites within critical habitat.

2. Caltrans should provide fiscal and staffing support to anadromous salmonid and sturgeon monitoring programs throughout the Sacramento-San Joaquin Delta to improve the understanding of migration and habitat utilization by salmonids and sturgeon in this region.

In order for NOAA Fisheries to be kept informed of actions minimizing or avoiding adverse effects or benefitting listed species or their habitats, NOAA Fisheries requests notification of the

implementation of any conservation recommendations.

XII. REINITIATION NOTICE

This concludes formal consultation on the Antioch Bridge Seismic Retrofit 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, formal consultation shall be reinitiated immediately.

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Enclosure 2

Magnuson-Stevens Fishery Conservation and Management Act

ESSENTIAL FISH HABITAT CONSERVATION RECOMMENDATIONS

I. IDENTIFICATION OF ESSENTIAL FISH HABITAT

The Magnuson-Stevens Fishery Conservation and Management Act (MSA), as amended (U.S.C. 180 *et seq.*), requires that Essential Fish Habitat (EFH) be identified and described in Federal fishery management plans (FMPs). Federal action agencies must consult with NOAA's National Marine Fisheries Service (NMFS) on any activity which they fund, permit, or carry out that may adversely affect EFH. NMFS is required to provide EFH conservation and enhancement recommendations to the Federal action agencies.

EFH is defined as those waters and substrates necessary to fish for spawning, breeding, feeding, or growth to maturity. For the purposes of interpreting the definition of EFH, "waters" includes aquatic areas and their associated physical, chemical, and biological properties that are used by fish, and may include areas historically used by fish where appropriate; "substrate" includes sediment, hard bottom, structures underlying the waters, and associated biological communities; "necessary" means habitat required to support a sustainable fishery and a healthy ecosystem; and,
"spawning, breeding, feeding, or growth to maturity" covers all habitat types used by a species throughout its life cycle. The proposed project site is within the region identified as EFH for Pacific salmon in Amendment 14 of the Pacific Salmon FMP.

The Pacific Fishery Management Council (PFMC) has identified and described EFH, Adverse Impacts and Recommended Conservation Measures for salmon in Amendment 14 to the Pacific Coast Salmon FMP (PFMC 1999). Freshwater EFH for Pacific salmon in the California Central Valley includes waters currently or historically accessible to salmon within the Central Valley ecosystem as described in Myers *et al.* (1998), and includes the San Joaquin Delta (Delta) hydrologic unit (*i.e.*, number 18040003). Sacramento River winter-run Chinook salmon (*Oncorhynchus tshawytscha*), Central Valley spring-run Chinook salmon (*O. tshawytscha*), and Central Valley fall-/late fall-run Chinook salmon (*O. tshawytscha*) are species managed under the Salmon Plan that occur in the San Joaquin Delta hydrologic unit. The enclosed biological opinion (Enclosure 1) thoroughly addresses the species of Chinook salmon listed both under the Endangered Species Act (ESA) and the MSA which potentially will be affected by the proposed action. These include Sacramento River winter-run Chinook salmon and Central Valley spring-run Chinook salmon. Therefore, this EFH consultation will concentrate primarily on the Central Valley fall/late fall-run Chinook salmon which is covered under the MSA, although not listed under the ESA.

Factors limiting Chinook salmon populations in the San Joaquin River include periodic reversed flows due to high water exports (drawing juveniles into large diversion pumps), loss of fish into unscreened agricultural diversions, predation by introduced species, and reduction in the quality

and quantity of rearing habitat due to channelization, pollution, rip-rapping, *etc.* (Dettman *et al.* 1987; California Advisory Committee on Salmon and Steelhead Trout 1988, Kondolf *et al.* 1996a, 1996b).

A. Life History and Habitat Requirements

1. Pacific Salmon

General life history information for Central Valley fall-run Chinook salmon is summarized below. Further detailed information on the other Central Valley Chinook salmon Evolutionarily Significant Units (ESUs) are available in the enclosed biological opinion, the NMFS status review of Chinook salmon from Washington, Idaho, Oregon, and California (Myers *et al.* 1998), and the NMFS proposed rule for listing several ESUs of Chinook salmon (63 FR 11482).

Adult Central Valley fall-run Chinook salmon enter the Sacramento and San Joaquin Rivers from July through December and spawn from October through December while adult Central Valley late fall-run Chinook salmon enter the Sacramento and San Joaquin Rivers from October to March and spawn from January to March (U.S. Fish and Wildlife Service [FWS] 1998). Chinook salmon spawning generally occurs in clean loose gravel in swift, relatively shallow riffles or along the edges of fast runs (NMFS 1997).

Egg incubation occurs from October through April (Reynolds *et al.* 1993). Shortly after emergence from their gravel nests, most fry disperse downstream towards the Delta and into the San Francisco Bay and its estuarine waters (Kjelson *et al.* 1982). The remaining fry hide in the gravel or station in calm, shallow waters with bank cover such as tree roots, logs, and submerged or overhead vegetation. These juveniles feed and grow from January through mid-May, and emigrate to the Delta and estuary from mid-March through mid-June (Lister and Genoe 1970). As they grow, the juveniles associate with coarser substrates along the stream margin or farther from shore (Healey 1991). Along the emigration route, submerged and overhead cover in the form of rocks, aquatic and riparian vegetation, logs, and undercut banks provide habitat for food organisms, shade, and protect juveniles and smolts from predation. These smolts generally spend a very short time in the Delta and estuary before entry into the ocean. Whether entering the Delta or estuary as fry or larger juveniles, Central Valley Chinook salmon depend on passage through the Delta for access to the ocean.

II. PROPOSED ACTION

The proposed action is described in detail in section II (*Description of the Proposed Action*) of the enclosed biological opinion (Enclosure 1).

III. EFFECTS OF THE PROPOSED ACTION

The effects of the proposed action on salmonid habitat (*i.e.*, Central Valley steelhead) are described at length in *Effects of the Action* of the preceding biological opinion, and generally are expected to apply to Pacific salmon EFH.

Effects to EFH stemming from construction activities that may contribute sediment and increase turbidity will be avoided or minimized by meeting Regional Water Quality Board objectives, Caltrans water pollution specifications, implementing applicable BMPs, staging equipment outside of the riparian corridor, limiting the amount of riparian vegetation removal, and replacing (if any) lost riparian vegetation at the project site.

EFH will be adversely affected by the disturbance of up to 0.06 acres of riparian vegetation as a result of construction activities as well as the occupation of the riverbed and water column by temporary work trestles and the columns of the new bridge's substructure. The majority of these impacts are expected to be temporary, as all disturbed areas outside the actual footprint of the new bridge would be restored to preconstruction conditions and any areas of disturbed vegetation would be replanted with native riparian vegetation. Additionally, implementation of the proposed project would result in a permanent net increase of riverine habitat since this project would result in fewer piers being located within the channel.

These effects to EFH may result in a temporary redistribution of some individuals, primarily migrating adult and rearing juvenile salmonids, but, due to the temporary nature of these disturbances, the adverse effects that are anticipated to result from the proposed project are not of the type, duration, or magnitude that would be expected to adversely modify EFH to the extent that it could lead to an appreciable reduction in the function and conservation role of the affected habitat. NMFS expects that nearly all of the adverse effects to EFH from this project will be of a short term nature and will not affect future generations of Pacific salmon beyond the construction period of the project.

IV. CONCLUSION

Based on the best available information, and upon review of the effects of the proposed Antioch Bridge Seismic Retrofit project, NMFS believes that the construction and operation of the project features will have temporary adverse effects on EFH of Pacific salmon protected under MSA.

V. EFH CONSERVATION RECOMMENDATIONS

As the habitat requirements of Central Valley fall-run Chinook salmon within the action area are similar to those of the federally listed species addressed in the enclosed biological opinion, NMFS recommends that reasonable and prudent measures numbers 1 and 2 and their respective implementing terms and conditions listed in the incidental take statement prepared for Central Valley steelhead and the Southern DPS of North American green sturgeon in the associated biological opinion, be adopted as EFH conservation recommendations. Those terms and conditions which require the submittal of reports and status updates can be disregarded for the purposes of this EFH consultation as there is no need to duplicate those submittals.

VI. STATUTORY REQUIREMENTS

Section 305 (b) 4(B) of the MSA requires that the Federal lead agency provide NMFS with a detailed written response within 30 days, and 10 days in advance of any action, to the EFH

conservation recommendations, including a description of measures adopted by the lead agency for avoiding, minimizing, or mitigating the impact of the project on EFH (50 CFR '600.920[j]). In the case of a response that is inconsistent with our recommendations, the lead agency must explain its reasons for not following the recommendations, including the scientific justification for any disagreement with NMFS over the anticipated effects of the proposed action and the measures needed to avoid, minimize, or mitigate such effects.

VII. LITERATURE CITED

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UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Southwest Region
501 West Ocean Boulevard, Suite 4200
Long Beach, California 90802-4213

August 5, 2009

In response refer to:
2009/00173

Jeffery G. Jensen
Office Chief, Office of Biological Sciences and Permits
California Department of Transportation
111 Grand Avenue
P.O. Box 23660
Oakland, California 94623-0660

Dear Mr. Jensen:

This letter is regarding NOAA's National Marine Fisheries Service's biological and conference opinion (Opinion) for the proposed Antioch Bridge Seismic Retrofit project, which was issued to your agency on June 23, 2009. Enclosed please find an errata sheet to insert into the issued Opinion. We are issuing this errata sheet due to an administrative error made in processing the final Opinion. The errata sheet includes minor corrections to the text of the Opinion and to the terms and conditions of the Incidental Take Statement. However, these revisions do not change the basic analyses, findings, or the conclusion of the Opinion that the proposed project is not likely to jeopardize the continued existence of the listed species nor destroy or adversely modify designated or proposed critical habitat.

Please contact Monica Gutierrez at our Sacramento Area Office at (916) 930-3657, or via e-mail at Monica.Gutierrez@noaa.gov, if you have any questions regarding this errata sheet, or require additional information.

Sincerely,

for Rodney R. McInnis
Regional Administrator

Enclosures (2)

cc: Copy to file – ARN# 151422SWR2009SA00060
NMFS-PRD, Long Beach, CA

August 5, 2009

Errata Sheet
For

June 23, 2009 Antioch Bridge Seismic Retrofit Project

Pg 44-47. Effects of the Action. Replace section V.B.1., Pile Driving and Bridge Construction, with the following:

1. Pile Driving and Bridge Construction

The installation of steel piles with an impact hammer is expected to result in adverse effects to listed salmonids and green sturgeon due to high levels of underwater sound that will be produced. Although adverse effects to fish from high levels of underwater sound are well documented for explosives (Gaspin 1975; Keevin and Hempen 1997) and air guns (Pearson *et al.* 1992; Engas *et al.* 1996; McCauley *et al.* 2003; Popper *et al.* 2005), there is little information regarding the effects on fish from underwater sound pressure waves generated during the installation of piles (Caltrans 2001; Vagle 2003). Laboratory research on the effects of sound on fish has used a variety of species and sounds (Hastings *et al.* 1996; Popper and Clarke 1976; Scholik and Yan 2002; Turnpenny *et al.* 1994). Experimental data found in the literature concerning the effects of sound on aquatic animals are not reported in a consistent manner, and most of these studies did not examine the type of sound generated by pile driving. Thus, it is difficult to directly apply the results of those studies to pile driving effects on listed salmonids or green sturgeon. However, we do know that exposure of fish to high levels of underwater sound can cause injuries to their swimbladders and internal organs and temporary and permanent hearing damage. The degree to which normal behavior patterns are altered is less understood.

a. *Internal Injuries*

The degree to which an individual fish exposed to underwater sound will be affected (from a startle response to immediate mortality) is dependent on a number of variables such as the species of fish, size of the fish, presence of a swimbladder, sound pressure intensity and frequency, shape of the sound wave (rise time), depth of the water around the pile and the bottom substrate composition and texture. It has long been known that underwater explosives can cause injury and mortality to fish. The Department of the Navy conducted a series of experiments to determine the effects on fish from underwater explosions (Goertner *et al.* 1994; Gaspin 1975) which resulted in significant differences in effects to fish depending on whether or not they had swimbladders. Thus it is the swimbladder, inflated with gas, which expands rapidly as the pressure wave passes through the fish that likely causes the observed injuries to internal organs (Keevin and Hempen 1997). An important characteristic of the underwater sound that causes injury is the frequency. During pile installation, most energy is contained within the frequency range (100-1,000 Hertz) which results in reverberation of the swimbladder. Studies have shown that the most susceptible tissues that are injured during exposure to underwater sound produced from pile driving are the soft-tissue organs surrounding the swimbladder, such as the liver and kidney (Caltrans 2001; Abbott and Bing-Sawyer 2002; Caltrans 2003).

There are two types of swimbladders: physostomous, in which the organ is thin, membranous and connects to the esophagus through a pneumatic duct, and physoclistous, in which the organ is thick-walled and connected to the blood stream (Smith 1982). Salmonids and green sturgeon have physostomous swimbladders (Smith 1982; Lagler *et al.* 1977). As indicated by Keevin and Hempen (1997) fish with physoclistous swimbladders are believed to be most sensitive to blast pressures, however, species with both types of swimbladders are more susceptible to injury than fish with no swimbladders.

Although underwater sound pressure waves generated during pile driving are different in several ways from those generated during explosions, the mechanism of injury (*i.e.*, swimbladder expansion) may be similar. The most important differences between the two are the repetitive nature of pile driving and the overpressure-underpressure oscillations within the pile driving signal. When combined with the multiple strikes to which most fish will be exposed, these repetitive oscillations likely cause the swimbladder to act like a drum, and although any single pulse (depending on its magnitude) may not result in injury to the internal organs, the repetitive nature of the sound produced during pile driving is likely to result in injury.

In 2004, FHWA and Caltrans formed the Fisheries Hydroacoustic Working Group (FHWG) to address the issue of potential impacts to listed species from exposure to underwater sounds produced by pile driving. Caltrans contracted with prominent experts in the field of underwater acoustics to review existing literature on the effects of underwater sound on fish. The result of that effort (Hastings and Popper 2005) indicated that the use of the Sound Exposure Level (SEL) metric, which is expressed as decibels (dB) re one micropascal squared-second[1], would be a better metric to use to correlate physical injury to fish from underwater sound pressure produced during the installation of piles than peak sound pressure level (SPL) that was currently being used. The primary rationale for this new metric was the ability to sum the energy over multiple pulses, which cannot be accomplished with peak pressure. Using SEL, the exposure of fish to a total amount of energy (*i.e.* dose) can be used to determine a physical injury response.

A white paper written for the FHWG by Popper *et al.* (2006) proposed a dual metric approach, incorporating both SEL and peak pressure, in assessing potential physical injuries to fish from exposure to high levels of underwater sound produced during pile driving. The authors proposed interim single strike thresholds of 187 dB_{SEL} and 208 dB_{peak} re one micropascal[2]. In a critique of the white paper, NMFS scientists from the Northwest Fisheries Science Center in Seattle, Washington (Memorandum to Mr. Russ Strach and Mr. Mike Crouse, NMFS from Tracy Collier, NMFS, September 19, 2006) stated that exposure to multiple strikes must be considered in assessing impacts. They further stated that the method described in Hastings and Popper (2005) is appropriate. Specifically, to account for exposure to sound impulses generated by multiple hammer strikes, the single strike SEL at a given distance from the pile is added to 10*log(number of strikes). At a FHWG meeting in Vancouver, Washington in June 2008, an Agreement in Principle between NMFS, Caltrans and others was reached regarding the establishment of interim thresholds to be used to assess physical injury to fish exposed to underwater sound produced during pile driving. Specifically, this included a single strike peak

1 In the remainder of this document, SELs are referenced to one micropascal squared-second.
2 In the remainder of this document, peak SPLs are referenced to one micropascal.

In addition, elevated SPLs from impact and vibratory pile driving could conceivably delay the migration of fish and affect their foraging and migratory behavior.

To determine the level of underwater sound that would elicit a behavioral response, Turnpenny *et al.* (1994) exposed a variety of fish species to varying levels of sound and frequency. No significant avoidance was found for trout at exposure levels (metric not specified) of up to 150 dB, although a reaction threshold of around 170 dB was observed. The authors used pure tone bursts, which cause an effect at a lower sound pressure level due to the higher duty cycle of the signal.

In the early 1990s, pile driving operations in Puget Sound were reported to disrupt juvenile salmon behavior (Feist *et al.* 1992). Though no underwater sound measurements are available from that study, comparisons between juvenile salmon schooling behavior in areas subjected to pile driving/construction and other areas where there was no pile driving/construction indicate that there were fewer schools of fish in the pile-driving areas than in the non-pile driving areas. The results were not conclusive, but suggest that pile-driving operations may result in a disruption in normal migratory behavior.

During the construction of the Benicia-Martinez Bridge Project in April 2002, observations were made during pile driving that suggest small fish subject to the exposure of elevated underwater sound pressure levels can be vulnerable to predation. The stomach of a piscivorous striped bass (*Morone saxatilis*) killed by high underwater sound pressure levels was examined and found to contain several freshly consumed juvenile herring (R. Blizard, Caltrans, personal communication, May 2002). Although necropsies were not performed on the juvenile herring (*Clupea harengus*), the consensus of the biologists present at the site was that the striped bass was feeding heavily on killed, injured, or stunned herring as it also swam too close into the zone of lethal sound pressure levels.

There is uncertainty as to the behavioral response of fish to elevated levels of underwater sound produced when driving piles in or near water. Until new information indicates otherwise, NMFS believes a 150 dB_{rms} threshold for behavioral responses for salmonids is appropriate. Given the typical 15 decibel or so difference between peak SPL and rms, a value of 150 dB_{rms} is approximately equivalent to 165 dB_{peak} SPL.

d. *Pile Driving at the Antioch Bridge Project*

The proposed project includes installation of a temporary trestle (approximately 910 ft long) that will be constructed from the south end of the bridge. The proposed project will require two 24-in diameter steel shell piles for every 25 ft of trestle and around the piers. The driving of steel piles for the temporary trestle will occur in water less than 10 ft in depth. There will be approximately 160 piles driven to a depth of 50 ft to support the temporary trestle. Four to six piles supporting between two to three sections of the trestle will be installed per day. Water depths will range from the shore or mud during lower tides to about 10 ft (3 m). These piles will be vibrated in for approximately ten minutes per pile and one pile per each section (approximately 36 sections in total) will be driven with an impact hammer for approximately 20 strikes per pile to verify the load bearing capacity of the pile. This would equate to a maximum of 3,600 seconds of

vibratory pile installation and 60 hammer strikes per day. On a temporal scale, much more time will be spent using a vibratory hammer to install the piles. However, underwater sound levels generated when using a vibratory hammer (180 dB peak SPL and 166 dB SEL and RMS) are substantially less than when using an impact hammer on a similar size pile. For this project, NMFS estimates that sound levels during the use of a vibratory hammer will be below those considered to physical injure listed salmonids or green sturgeon, although fish within 117 m of the piles may respond behaviorally. Less time will be spent using an impact hammer, but the effect will be greater. Using single strike underwater sound estimates (based on 10 m from the pile) of 208 dB peak SPL, 194 dB rms, and 178 dB SEL, NMFS calculated the distances of 14 m for physical injury due to any single strike or 38 m for physical injury due to cumulative sound exposure, and 8,577 m for adverse behavioral response.

e. *Summary of Effects from Pile Driving*

The activities related to pile driving are temporary and will only last the duration of the in-water work activities. Both injurious and subinjurious effects to juvenile CV steelhead and green sturgeon, including altered behavior, auditory masking, temporary hearing threshold shifts, damage to the fish auditory system and internal organs, are expected and can affect their vulnerability to predation, foraging success, and other factors that influence survival and fitness. Pile driving will take place during each in-water work window during the bridge construction period (*i.e.*, concurrently with pile driving during temporary trestle installation and during removal of the temporary piles as elements of bridge construction are completed). Because daily pile driving activities will be separated by overnight rest periods when migration can proceed uninhibited, upstream and downstream migration of listed fish are not expected to be significantly delayed. The populations of these fish in the San Joaquin River represent a small number of the entire population in the Central Valley, and the action is expected to have little impact upon the entire DPS. There is potential for adult CV steelhead and green sturgeon to be adversely effected from pile driving activities, however, it is expected to be relatively low due to their larger bodies (above two grams) and pile driving activities occurring only in the daytime which would avoid crepuscular and nocturnal periods when steelhead and sturgeon migratory activity is highest.

Pg. 58. Under the first bullet of the Ecological Surrogates, replace letter a. with the following:

a. within 14 meters of the unattenuated impact pile driving necessary to establish the baseline SPLs for the monitoring, assuming that the peak underwater noise levels experienced by ESA listed fish within this area will exceed the 206 dB_{peak} injury threshold for a single pile strike (equivalent to no more than 208 dB_{peak} measured 10 meters from the pile);

Pg. 59. Under the first bullet of the Ecological Surrogates, replace letter b. with the following:

b. within 8,577 m of impact pile driving, where NMFS expects significant behavioral effects on ESA-listed fish due to SPLs in excess of 150 dB_{rms} (equivalent to 194 dBrms measured at 10 meters from each pile).

sound pressure level (SPL) of 206 dB and an accumulated SEL of 187 dB for fish greater than 2 grams or 183 dB for fish less than 2 grams. If either threshold is exceeded, then physical injury is assumed to occur. Because all ESA-listed fish in the action area during pile driving are expected to be larger than 2 grams, the threshold for accumulated SEL used in this analysis is 187 dB.

NMFS must make some assumptions as to the behavior of the fish in order to determine the response (*i.e.*, injury) of the fish. Sonalysts (1997) suggested that although fish (including Atlantic salmon) exhibit a startle response during the first few acoustic exposures, they do not move away from areas of very loud underwater sounds and can be expected to remain in the area unless they are carried away by currents or normal movement patterns. Generally, NMFS will assume that fish will remain in the vicinity of pile driving activities if occupied before pile driving commenced.

NMFS must also make some assumptions as to the recovery of tissue between pile strikes and between multiple piles being driven. It is not known whether there is recovery from any effects of pile driving in the intervals between strikes or, if there is recovery, how long between successive strikes is necessary for this to occur (Popper *et al.* 2006). Although mammalian auditory systems have been show to recover from trauma over periods of time between successive stimuli (Chen *et al.* 1999), if one pile driving strike is quickly followed by another, there is likely a cumulative effect since there may be little tissue recovery following the first strike. As noted in Popper *et al.* (2006) fish tissue is assumed to not recover within intervals on the order of a few seconds between hammer strikes (*e.g.*, they are essentially continuations of the same exposure).

Typically, several piles are installed on any given day, with tens of minutes or hours between the completion of one pile and the initial driving of the next. Recovery of fish tissue likely occurs if pile driving ceases for an extended period of time. At this time, there are no direct empirical data available to determine the conditions required for partial or full recovery of sensory function between exposures. Although there may be some tissue recovery between the completion of one pile and the beginning of pile driving at the next, given the level of uncertainty that exists, NMFS will sum the underwater sound energy produced during the installation of all piles on any given day (assuming pile driving ceases for at least 12 hours during the night) to determine potential physical effects to listed salmonids and green sturgeon (described below).

b. *Hearing Damage*

Sound is a major form of underwater communication for fish, so a functioning auditory system is essential for fish to survive. The structure of the fish inner ear is similar to that of other vertebrates: each ear has three semicircular canals and three otolithic organs, the utricle, saccule, and lagena. The semicircular canals and otolithic chambers are interconnected and filled with endolymphatic fluid. The swimbladder may act somewhat as an eardrum by responding to the sound pressure waves, depending on the species of fish. The motion of the swimbladder radiates a secondary signal to the inner ear. This provides the necessary particle movement for otolithic/auditory nervous stimulation, especially in species having the shortest distance between the swimbladder and the auditory apparatus (pars inferior).

High levels of underwater acoustic noises have been shown to have adverse impacts upon the auditory sensory organs of fish within close proximity of the noise source. The loss of hearing sensitivity may adversely affect a salmonids' ability to orient itself (*i.e.,* due to vestibular damage), detect predators, locate prey, or sense their acoustic environment. Chronic noise exposure can reduce a fish's ability to detect piscine predators either by reducing the sensitivity of the auditory response or by masking the noise of an approaching predator. Disruption of the exposed fish's ability to maintain position or swim with the school will enhance its potential as a target for predators. Unusual behavior or swimming characteristics single out an individual fish and allow a predator to focus its attack upon that fish more effectively.

The literature indicates damage to hearing by intense sound depends on auditory threshold and will vary from species to species (Popper and Fay 1973). Damage to hearing is normally measured in sound pressure levels expressed as root mean squared (RMS) decibels re 1 micropascal[3]. Some fish have hearing thresholds as low as 50 dB_{rms} while others have thresholds as high as 150 dB_{rms}. Enger (1981) exposed 26 cod (*Gadus morhua*) to continuous tones of 180 dB_{rms} at frequencies from 50 to 400 Hertz (Hz) for one to five hours and found destruction of auditory hair cells in the saccule. The cod has a hearing threshold of 75-80 dB_{rms} between 100 and 200 Hz (Chapman and Hawkins 1973), so 180 dB_{rms} is about 100 dB above threshold. For Atlantic salmon (*Salmo salar*), Hawkins and Johnstone (1978) reported a hearing threshold of 95-100 dB_{rms} between 100 and 200 Hz. Since the 100-200 Hz is the bandwidth of best sensitivity for both cod and Atlantic salmon, Hastings (2002) stated she would expect to see damage of auditory hair cells in salmon occurring with exposure to continuous sound at about 200 dB_{rms}. The peak pressure associated with a continuous sound of 200 dB_{rms} is equivalent to 203 dB_{peak}, thus Hastings (2002) concludes permanent hearing damage to the sensory hearing cells of salmonids onsets at a sound level of 203 dB_{peak}. Given the aforementioned discussion, it appears that physical damage to the auditory system of salmonids is likely to occur with continuous sound levels at or above 200 dB_{rms}. However, at this time unclear how auditory tissue cells are affected, either temporarily or permanently, by the repeated bursts of sound wave energy resulting from pile driving, as pure tone continuous sound cannot be correlated with broad frequency multiple impulse sound.

Sonalysts (1997) reported that they performed reaction testing with caged Atlantic salmon at a wide range of sound pressure levels and frequencies. They stated that although some avoidance was noted at certain specific levels and frequencies, no avoidance response was seen when the sound pressure levels (likely RMS) were over 180 dB. The report also included a brief discussion of previously unreported studies that show that beyond a brief startle response associated with the first few acoustic exposures, fish do not move away from areas of very loud noises and are expected to remain in the area unless they are carried away by currents.

c. *Modification to Behavior*

Behavioral responses to high noise levels can be in the form of a startled response, avoidance, agitation, etc. These behavioral responses can also lead to increased susceptibility to predation.

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3 In the remainder of this document, rms pressure levels are referenced to one micropascal.

Pg. 63. Reasonable and Prudent Measures. Replace section IX. C. 1 with the following:

1. Real time monitoring shall be conducted to ensure that underwater sound levels produced during impact pile driving and analyzed in this biological opinion (150 dB RMS at 8,577 m, 187 dB accumulated SEL at 38 m, and 206 dB peak SPL at 14 m from the piles being driven) are not exceeded.

Pg. 60. Terms and Conditions. Replace section IX. D. 1 a. with the following:

1. Real time monitoring shall be conducted to ensure that underwater sound levels produced during impact pile driving and analyzed in this biological opinion (150 dB RMS at 8,577 m, 187 dB accumulated SEL at 38 m, and 206 dB peak SPL at 14 m from the piles being driven) are not exceeded.

    a. Caltrans shall monitor underwater sound during all impact hammer pile driving activities on land or in water. If underwater sound exceeds 150 dB RMS at 8,577 m, 187 dB accumulated SEL at 38 m, and 206 peak SPL at 14 m from the piles being driven, then NMFS must be contacted within 24 hours.

DEPARTMENT OF THE ARMY
U.S. ARMY ENGINEER DISTRICT, SACRAMENTO
CORPS OF ENGINEERS
1325 J STREET
SACRAMENTO CA 95814-2922

REPLY TO
ATTENTION OF

August 20, 2009

Regulatory Division (SPK-2008-01340)

California Department of Transportation
Jeffery G. Jensen
Chief, Office of Biological Sciences and Permits
111 Grand Avenue
P.O. Box 23660
Oakland California 94623-0660

Dear Mr. Jensen:

We are responding to your April 10, 2009 request for a Department of the Army permit for the Antioch Bridge Seismic Retrofit project. This approximately 383-acre project involves activities, including discharges of dredged or fill material, in waters of the United States to retrofit selected marine footings, land piers, grade beam structures, and Bents 4-38, in the river channel and on Sherman Island. The project is located on or near San Joaquin River, in Sections 3, 4, 9, 10, 15, and 16, Township 2 North, Range 2 East, M.D.B.&M. Survey, Latitude 38° 2' 41.2", Longitude 121° 45' 5.9", Contra Costa and Sacramento Counties, California.

Based on the information you provided, the proposed activity in approximately 4.501 acres of waters of the United States, including wetlands, is authorized by Nationwide Permit Number 3, Maintenance. The proposed temporary impacts associated with this work include; approximately 0.011-acre of impacts to San Joaquin River and approximately 4.490 acres of impacts to wetlands abutting San Joaquin River. However, until Section 401 Water Quality Certification for the activity has been issued or waived, our authorization is denied without prejudice. Once you have provided us evidence of water quality certification, the activity is authorized and the work may proceed subject to the conditions of certification and the Nationwide Permit. Your work must comply with the general terms and conditions listed on the enclosed Nationwide Permit information sheets and the following special conditions:

1. To mitigate for the temporary loss of 4.501 acres of waters of the U.S. and abutting wetlands, you shall restore the 4.501 acres of waters of the U.S., including wetlands, back to their pre-existing condition. Upon completion of construction, you shall return the disturbed areas back to their per-construction elevation and grade. The temporarily affected areas shall be re-vegetated according to the document entitled *Antioch Bridge Seismic Retrofit Project NWP PCN Package*, dated April 2009.

2. To ensure mitigation success, you shall monitor the on-site re-establishment areas for one year. This period shall commence upon completion of the authorized fill activity, but not later than one year after the initiation of fill activity. You shall submit a monitoring report to this office at the end of the first-year monitoring period.

3. To ensure mitigation compliance, continued success of the re-establishment areas, without human intervention, must be demonstrated for one consecutive year. The mitigation will not be deemed successful until this criterion has been met. A final monitoring report shall be submitted at the end of the one year period demonstrating successful re-establishment of vegetation without human intervention. The primary focus of this monitoring shall be to assure that the temporary impact areas are successfully restored and maintained, and the integrity of water quality is maintained.

4. To document pre-project construction conditions, you shall submit numbered and dated pre-construction photos of waters of the U.S. (including wetlands) to be impacted within the project site.

5. To document post-project construction conditions, you shall submit numbered and dated post-construction photos of temporarily impacted waters of the U.S. (including wetlands) taken in approximately the same locations as the pre-project photos, within 30 days after project completion.

6. Your responsibility to complete the required compensatory mitigation as set forth in Special Condition 1 will not be considered fulfilled until you have demonstrated mitigation success and have received written verification from the U.S. Army Corps of Engineers.

7. This Corps permit does not authorize you to take an endangered species, in particular giant garter snake *(Thamnophis gigas)*, delta smelt *(Hypomesus transpacificus)*, longfin smelt *(Spirincus thaleichthys)*, Sacramento River winter-run Chinook salmon Evolutionary Significant Unit [ESU] *(Oncoryhynchus tshawytscha)*, Central Valley spring-run Chinook salmon ESU *(Oncoryhynchus tshawytscha)*, Central Valley steelhead Distinct Population Segment [DPS] *(Oncoryhynchus mykiss irideus)*, North American green sturgeon southern DPS *(Acipenser medirostris)*, or designated critical habitat. In order to legally take a listed species, you must have separate authorization under the Endangered Species Act (e.g., an Endangered Species Act Section 10 permit, or a Biological Opinion under Endangered Species Act Section 7, with "incidental take" provisions with which you must comply). The enclosed U.S. Fish and Wildlife Service Biological Opinion (Number 81420-2008-F-1537-3, dated August 14, 2009) and National Marine Fisheries Service Biological and Conference Opinion (Number 2009/00173, dated June 23, 2009 and errata sheet dated August 18, 2009), contains mandatory terms and conditions to implement the reasonable and prudent measures that are associated with "incidental take" that is also specified in the Biological and/or Conference Opinions. Your authorization under this Corps permit is conditional upon your compliance with all of the mandatory terms and conditions associated with "incidental take" of the attached Biological and/or Conference Opinions, which terms and conditions are incorporated by reference in this permit. Failure to comply with the terms and conditions associated with incidental take of the Biological/Conference Opinions, where a take of the listed species occurs, would constitute an unauthorized take, and it would also constitute non-compliance with your Corps permit. The Fish and Wildlife Service and/or National Marine Fisheries Service are the appropriate authorities to determine compliance with the terms and conditions of their Biological/Conference Opinions, and with the Endangered Species Act. The permittee must comply with all conditions of the Biological and/or Conference Opinions, including those ascribed to the Corps.

8. You shall design and construct all crossings of waters of the U.S. to retain a natural substrate and to accommodate all reasonably foreseeable fish passage, and expected high flows. Examples of water crossings include bridges, trestles, culverts, and pipes.

9. You shall follow the specifications and standards described in the Storm Water Pollution Prevention Plan (SWPPP) and/or Water Pollution Control Plan (WPCP), to prevent erosion and sedimentation during and after construction.

10. You shall employ Best Management Practices (BMP's) to avoid and minimize environmental impacts. Temporary fills must be removed in their entirety and the affected areas returned to preconstruction elevations and conditions. The affected areas must be re-vegetated with a weed-free native seed mix.

11. Excavated materials shall only be placed in upland locations. The upland disposal site(s) shall be delineated for waters of the U.S. and must be approved by the Corps of Engineers prior to disposal.

12. All equipment staging, including Temporary Construction Areas (TCA's), shall take place within Caltrans approved areas within the project boundary. Prior to construction implementation, you shall ensure all equipment staging, TCA's, demolition and disposal, excavation, off pavement detour, and borrow and fill areas, have been evaluated under National Environmental Policy Act (NEPA), Section 401 and 404 of the Clean Water Act, Section 7 of the Endangered Species Act and Section 106 of the National Historical Preservation Act and all required permits have been obtained.

13. You must allow representatives from the Corps of Engineers to inspect the authorized activity and any avoidance areas at any time deemed necessary to ensure that it is being or has been accomplished in accordance with the terms and conditions of your permit.

14. To prevent unauthorized fills and unforeseen impacts, you shall, prior to proceeding with any activity otherwise authorized by this permit, install high-visibility fencing and appropriate signage around the entire perimeter of avoided waters of the U.S. within the project area. To ensure fencing is installed in the appropriate locations, a qualified construction site monitor shall be present when fencing is erected. All fencing surrounding avoidance areas shall allow unrestricted visibility of these areas to discourage vandalism, destruction or disturbance.

15. You must install and maintain, at your expense, any safety lights and signals prescribed by the United States Coast Guard (USCG), through regulations or otherwise, on your authorized facilities.

Your use of the permitted activity must not interfere with the public's right to free navigation on all navigable waters of the United States.

You understand and agree, that, if future operations by the United States require the removal, relocation, or other alteration, of the structure or work herein authorized, or if, in the opinion of the Secretary of the Army or his authorized representative, said structure or work shall cause unreasonable obstruction to the free navigation of the navigable waters, you will be required, upon due notice from the Corps of Engineers, to remove, relocate, or alter the structural work or obstructions caused thereby, without expense to the United States. No claim shall be made against the United States on account of any such removal or alteration.

You must sign the enclosed Compliance Certification and return it to this office within 30 days after completion of the authorized work.

This verification is valid for two years from the date of this letter or until the Nationwide Permit is modified, reissued, or revoked, whichever comes first. Failure to comply with the General Conditions of this Nationwide Permit, or the project-specific Special Conditions of this authorization, may result in the suspension or revocation of your authorization.

We appreciate your feedback. At your earliest convenience, please tell us how we are doing by completing the customer survey on our website at: http://per2.nwp.usace.army.mil/survey.html.

Please refer to identification number SPK-2008-01340 in any correspondence concerning this project. If you have any questions, please contact Ms. Leah Fisher at our California North Branch Office, 1325 J Street, Room 1480, Sacramento, California 95814-2922 email *leah.m.fisher@usace.army.mil*, or telephone 916-557-6639. You may also use our website: *www.spk.usace.army.mil/regulatory.html*.

Sincerely,

Paul Maniccia

Paul M. Maniccia
Chief, California South Branch

Enclosure(s)

Copy furnished without enclosure(s)

Mr. William Marshall, Storm Water and Water Quality Certification Unit, Central Valley Regional Water Quality Control Board, 11020 Sun Center Drive #200, Rancho Cordova, California 95670-6114
Mr. Ryan Olah, Coast Bay-Delta Branch, Endangered Species Division, U.S. Fish and Wildlife Service, 2800 Cottage Way, Suite W2605, Sacramento, California 95825-3901
Mr. Chris States, California Department of Transportation, Division of Environmental Planning & Engineering, Mail Station 8E, P.O. Box 23660, Oakland California 94623-0660
Ms. Monica Gutierrez, National Marine Fisheries Service, 650 Capitol Mall, Suite 8-300, Sacramento California 95814

COMPLIANCE CERTIFICATION

Permit File Number: SPK-2008-01340, Antioch Bridge Seismic Retrofit Project

Nationwide Permit Number: 3, Maintenance

Permittee:
California Department of Transportation
Jeffery G. Jensen
Chief, Office of Biological Sciences and Permits
111 Grand Avenue
P.O. Box 23660
Oakland California 94623-0660

County: Sacramento

Date of Verification: August 20, 2009

Within 30 days after completion of the activity authorized by this permit, sign this certification and return it to the following address:

U.S. Army Corps of Engineers
Sacramento District, Regulatory Division
1325 J Street Room 1480
Sacramento, California 95814-2922
Fax: 916-557-6877

Please note that your permitted activity is subject to a compliance inspection by a U.S. Army Corps of Engineers representative. If you fail to comply with the terms and conditions of the permit your authorization may be suspended, modified, or revoked. If you have any questions about this certification, please contact the Corps of Engineers.

* * * * * * * * *

I hereby certify that the work authorized by the above-referenced permit, including all the required mitigation, was completed in accordance with the terms and conditions of the permit verification.

_____ _____
Signature of Permittee Date

United States Department of the Interior

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

In Reply Refer To:
81420-2008-F-1537-3

AUG 14 2009

Mr. James Richards
California Department Transportation
Division of Environmental Planning & Engineering
111 Grand Avenue
P.O. Box 23660
Oakland, California 94623-0660

Subject: Biological Opinion for the Antioch Bridge Seismic Retrofit Project in Contra Costa and Sacramento Counties, California (Caltrans EA 1A5210) on the Threatened Delta Smelt, the Threatened Giant Garter Snake, and Critical Habitat for the Delta Smelt

Dear Mr. Richards:

This is in response to your March 19, 2009, request for formal consultation with the U.S. Fish and Wildlife Service (Service) on the proposed Antioch Bridge Seismic Retrofit Project in Contra Costa and Sacramento Counties, California. Your letter was received in this office on March 23, 2009, and included the request for formal consultation on the threatened Delta smelt (*Hypomesus transpacificus*) and its critical habitat and the threatened giant garter snake (*Thamnophis gigas*). This document represents the Service's biological opinion on the effects of the proposed action on these listed species and the designated critical habitat. This document has been prepared in accordance with section 7 of the Endangered Species Act of 1973, as amended (16 U.S.C. § 1531 *et seq.*)(Act).

This biological opinion is based on: (1) a January 2009, Biological Assessment; (2) a July 16, 2008, field review; (3) revised compensation language provided on June 23, 2009; (4) Caltrans' July 14, 2009, response to the draft biological opinion; (5) miscellaneous correspondence and electronic mail (email) between the Service and the California Department of Transportation (Caltrans) from May 2008 to July 2009; and (6) other information available to the Service.

TAKE PRIDE IN AMERICA

Consultation History

July 16, 2008	The Service attended a field meeting with Caltrans. David Kelley of the Service told Caltrans that potential giant garter snake habitat was within the action area. Peter Johnsen of the Service explained that delta smelt could be found in the action area at any time of the year but the August 1 to November 30 work window would be optimal to minimize effects.
September 10, 2008	The Service attended a pre-consultation meeting with Caltrans and other resource agencies.
November 5, 2008	The Service attended a pre-consultation meeting with Caltrans and other resource agencies.
January 14, 2009	The Service attended a pre-consultation meeting with Caltrans and other resource agencies. During the meeting Caltrans issued a copy of the January 2009 Biological Assessment.
January 26, 2009	The Service received a letter from Caltrans dated January 22, 2009, requesting concurrence on a not likely to adversely affect determination for the delta smelt and the giant garter snake.
February 12, 2009	The Service received sent a letter to Caltrans expressing the inability to concur with their determination. The Service recommended that Caltrans enter into formal consultation for the delta smelt and its critical habitat and the giant garter snake.
March 23, 2009	The Service received a letter from Caltrans requesting initiation of formal consultation for the delta smelt and the giant garter snake. Caltrans concluded that the delta smelt was likely to be affected due to the presence in the action area and the hydro-acoustic sound levels from pile driving activities that are expected to exceed 183 decibel (db) Sound Exposure Level (SEL).
March 25, 2009	Caltrans requested the Service issue a draft biological opinion.
March 30, 2009	Caltrans informed the Service in an email message that the project description was based on 65% design. Caltrans does not anticipate the final design to change the limits of the action area or the effects described in their January 2009 Biological Assessment.

April 6, 2009 Caltrans informed the Service in an email message that the total acreage of delta smelt shallow water habitat in the action area is 38.194 acres. The total acreage under the temporary marine trestle is 0.952 acres.

April 7, 2009 Caltrans informed the Service in an email message that the total acreage of what they had incorrectly identified as non-shallow water habitat in the action area within the San Joaquin River is 304.451 acres. Therefore the Service calculated the total acreage within delta smelt critical habitat as 342.645 acres (304.451 + 38.194).

April 8, 2009 The Service informed Caltrans via an email message that the accurate definition of delta smelt shallow water (SWH) habitat as the top 10 feet of the water column. Due to the overlapping shading of the proposed temporary marine trestle and the existing Antioch Bridge over head, the Service agreed to limit the shading effects associated with the proposed project to the outer trestle platform. According to the Service's calculations the acreage for the 910 foot long and 25 foot wide trestle would be 0.522 acres.

April 9, 2009 The Service sent Caltrans an email message summarizing our calculations of effects based on our definitions of habitat for the delta smelt and the giant garter snake as shown below:

1. Total action area = 383.645 acres (land + water).
2. Action area within the San Joaquin River= 342.645 acres.
3. The shaded area from the trestle = 0.522 acres (910 feet long x 25 feet wide) = effects to delta smelt SWH due to shading.
4. Substrate area occupied by trestle piers within SWH = 0.002 acres.
5. Land action area = 41.0 acres (7.5 acres on south shore + 33.5 acres on north shore/Sherman Island).
6. Aquatic giant garter snake habitat directly affected in the action area = 0.
7. Upland giant garter snake habitat within 200 feet of aquatic (winter refugia) = 2.44 acres.
8. Total giant garter snake habitat (winter refugia + upland dispersal) = 33.5 acres.

The Service also provided Caltrans with a copy of standard avoidance and minimization measures for the giant garter snake to provide guidance for appropriate compensation to offset permanent and temporary habitat loss.

April 22, 2009 — The Service met with Caltrans and the California Department of Fish and Game to discuss the measures and conditions within the biological opinion that would be needed in order for the State to issue a consistency determination for the giant garter snake.

April 22, 2009 — The Service was copied on an email message from Caltrans to the California Department of Fish and Game in which Caltrans referred to seeking compensation credits for the delta smelt at the proposed Liberty Island Conservation Bank and for the giant garter snake at the proposed Ridge Cut Conservation Bank.

May 6, 2009 — The Service received a copy of a letter dated May 5, 2009, from Caltrans via an email message. In the letter, Caltrans agreed to accept the Service's definition of delta smelt SWH. However, Caltrans declined to modify their project description, effects analysis, or proposed compensation to reflect a correction of the inaccuracy.

Caltrans also confirmed that the construction within giant garter snake habitat would encompass at least three activity seasons (defined as the calendar year period between May 1 and October 1).

Caltrans has elected not to compensate for the effects to the listed snake as prescribed in the 1997 programmatic biological opinion (Service 1997).

May 11, 2009 — Caltrans stated in their May 5, 2009, letter that their calculation and assessment of effects to the delta smelt were incorrect but declined to revise or request revision of their project description to reflect the change. Caltrans suggested in their May 5, 2009, letter that any necessary changes needed to their project description be addressed in the *Terms and Conditions* section of this biological opinion rather than Caltrans revising their project description. The Service received an email message from Caltrans on May 11, 2009, stating that they planned to modify their May 5, 2009, response.

May 20, 2009 — The Service received an email message from Caltrans confirming that they reached an agreement with the California Department of Fish and Game that they would not pursue a consistency determination with this biological opinion. Instead Caltrans plans to seek a 2081 Incidental Take Permit with the State to address the California Department of Fish and Game's issues regarding the delta smelt and giant garter snake. This approach was also confirmed by Scott Wilson of the California Department of Fish and Game in a later email received on May 20, 2009.

May 20, 2009	The Service informed Caltrans that we were waiting for Caltrans' modified response, referenced on May 11, 2009, before continuing work on the draft biological opinion.
May 28, 2009	The Service received an email from Caltrans questioning their need to provide a modified response to their May 5, 2009, letter as they stated they would on May 11, 2009. In the May 28, 2009, email Caltrans referenced the Service's application of delta smelt SWH definition as an "alternative impact analysis assessment methodology." Caltrans incorrectly stated that all the necessary information needed to complete formal consultation was submitted on January 22, 2009. Caltrans' January 22, 2009, submittal included a request for informal consultation for both the delta smelt and the giant garter snake despite quantification of direct effects to both species and critical habitat for the delta smelt.
June 23, 2009	The Service received revised compensation language from Caltrans. The revised language was consistent with the guidance provided by the 1997 programmatic biological opinion for the giant garter snake and provided adequate compensation for the revised delta smelt shaded SWH value.
June 26, 2009	The Service issued a draft biological opinion (81420-2008-F-1537-2).
July 14, 2009	The Service received proposed conservation measures from Caltrans that addressed attenuation of hydroacoustic and turbidity effects on the delta smelt. The Service also received a request to finalize the biological opinion with the addition of these proposed measures.

BIOLOGICAL OPINION

Description of the Proposed Action

The following project description is based on information provided by Caltrans in their January 2009 Biological Assessment (Caltrans 2009). Caltrans and the Bay Area Toll Authority (BATA) propose a seismic safety retrofit of the Antioch Bridge crossing of the San Joaquin River on State Route 160 from north of the City of Antioch (Contra Costa County) to Sherman Island (Sacramento County). The affected roadway is roughly two miles long and connects the City of Antioch on the south bank of the San Joaquin River to Sherman Island on the north end. The bridge spans the 3,600-foot width of the San Joaquin River and over 4,000 feet of Sherman Island before touching down just north of Mayberry Slough. According to Caltrans, the project is intended to improve the seismic integrity of the Antioch Bridge by strengthening the bridge columns (or piers) and reducing the load of the roadway deck on those columns. The project is being conducted under the Caltrans Seismic Retrofit Program and will be referred to in the remainder of this biological opinion as the Antioch Bridge Seismic Retrofit Project.

According to a March 30, 2009 correspondence from Caltrans, the project description provided in the January 2009 Biological Assessment is based on 65% design. Caltrans will be required to reinitiate consultation when and if there are changes to the project description that exceed the effects described in this biological opinion.

Existing Infrastructure

Built in 1978, the Antioch Bridge is 9,437 feet long, and accommodates one lane of traffic in each direction and includes narrow accommodation for bicyclists and pedestrians. The bridge features two structural elements: the "Main Structure" and the "Slab Span Structure." The Main Structure is 8,650 feet long and consists of 40 spans (a section between two intermediate supports) varying in length from 135 to 460 feet. The superstructure of the Main Structure consists of a 43.5-foot wide concrete deck supported on two steel girders that vary in depth from 8 to 25 feet. The girders rest on concrete bent cap beams. Most of the bent cap beams are hollow. The columns are then supported on driven pile footings. The exterior piles are battered (installed at an angle) at a 3:1 inclination and the interior piles are vertical.

The Slab Span Structure is 787 feet long and consists of 30 spans supported by pile extensions with grade beams holding them at ground level. It extends north of Mayberry Slough to the point at which the bridge structure meets existing grade on Sherman Island. The sides of the structure in this area are enclosed with concrete slabs.

Construction Schedule

Construction is scheduled to begin in mid-2010 and end in late 2012.

Proposed Retrofit Elements and Construction Access

Proposed retrofit elements to the bridge include:

1. Installation of steel cross bracing between columns to stiffen the superstructure cross frames (Pier 12 to Pier 31).

2. Installation of bracing to existing cross frames at the bent caps (Pier 2 to Pier 40).

3. Replacement of the existing elastometric bearings with isolation bearings (Abutment 1 to Pier 41).

4. Removal of the existing curtain walls and retrofit of all the columns within the slab span structure (Bent 42 to Abutment 71).

Proposed construction access includes temporary upland access roads, barge access in the main channel of the San Joaquin River, and a temporary marine trestle on the south end as described below:

1. Construction of a temporary marine trestle to access the piers from the south shore of the San Joaquin River in Antioch to Pier 11.

2. Construction of a temporary access road on the south shore, which runs adjacent and parallel to the bridge, in order to access the temporary marine trestle.

3. Construction of a temporary access road from the southernmost bridge support on Sherman Island (Pier 22) to the last bridge support south of Mayberry Slough (Pier 38) to provide construction access for retrofit work.

4. Construction of temporary access roads parallel to the slab span structure on both sides, north of Mayberry Slough, to facilitate removal of the curtain walls from the slab span structure and reinforce existing columns and abutments.

5. Permanent widening of an existing access road along Mayberry Slough to access piers north of Mayberry Slough.

Action Area and Work Areas

The project limits, which include Caltrans right-of-way (ROW), the San Joaquin River, and temporary construction easements, cover approximately 383.645 acres, including 7.5 acres on the south shore of the San Joaquin River in Contra Costa County, 342.645 acres of the San Joaquin River, and 33.5 acres on Sherman Island in Sacramento County. The action area on Sherman Island utilized for proposed staging and access is owned and managed by the California Department of Water Resources (DWR). The action area, as defined in the January 2009, Biological Assessment, consists of the project's area of direct permanent and temporary effects including construction access, staging, and laydown areas. Caltrans does not anticipate areas of indirect effects. The action area also includes the project limit, plus an additional 285 feet around the temporary marine trestle, which represents the 183 decibel Sound Exposure Level (SEL) radius.

Proposed Terrestrial Work Areas

Temporary access roads. Temporary access roads are proposed in four locations: 1) one from Pier 22 to Pier 38 south of Mayberry Slough; 2) two north of Mayberry Slough on either side of the slab span structure; and 3) one on the south shore of the San Joaquin River to allow access to the south side of the trestle. In addition, two small trestles will be used to protect a drainage canal and drainage ditch as further described.

Caltrans plans to install a silt fence at the base of the temporary access roads as sediment control for the roadway, to minimize the potential for inadvertent encroachment of equipment and material into the surrounding area, and to minimize the potential for wildlife to enter the roadway. At completion of the project, the silt fence, geotextile fabric and crushed rock will be removed and the site will be restored to the preexisting condition.

Pier 22 to Pier 38: Caltrans has proposed a temporary access road within State ROW to provide access for work to all bridge columns south of Mayberry Slough (Pier 22 to Pier 38) on Sherman Island. The temporary access road will consist of placing geotextile fabric and an approximately 4 foot deep layer of crushed rock over the existing ground. The temporary access road will be approximately 24 feet wide along the travel surface, and will extend with 2:1 slopes to existing ground level. The base of the road will be approximately 40 feet wide at ground level and extend 3,300 feet, covering an estimated 4.45 acres. The temporary access road will stop at Mayberry Slough.

North of Mayberry Slough: Two additional temporary access roads, constructed of a 6 inch layer of crushed rock overlaying geotextile fabric, are proposed north of Mayberry Slough on both the west and east sides of the slab span structure. The access road on the west side will occupy 0.6 acres and will be 850 feet long by 36 feet wide; whereas, the access on the east side of the span will occupy 0.4 acres and be 850 feet long by 20 feet wide.

Small Trestles: Where the access road crosses the irrigation canal near Pier 32, a 24 foot wide temporary trestle will be installed to span the irrigation canal. The temporary trestle is intended to prevent additional load on the existing culvert and avoid the need for fill.

At the northern end of the bridge, a 24 foot wide temporary trestle will be installed to the west to span an irrigation/drainage ditch. The temporary trestle is intended to minimize disturbance to the existing irrigation ditch and wetland area.

Southern Access: On the south shore of the San Joaquin River at the south end of the temporary marine trestle, existing access roads and the Caltrans ROW will be utilized to access the trestle. The existing roads will require a widening from a 9 foot to a 24 foot width along a 650 foot length, and a 24 foot width extension along another 250 foot segment. The access preparation will be accomplished using a 6 inch layer of crushed rock overlaying geotextile fabric. The total expanded/extended area will be 0.364 acres. Caltrans plans to install an environmentally sensitive area fence along the west side of the access road to avoid effects to a drainage ditch that borders the ROW.

Temporary contractor staging and lay down area. Temporary staging areas include one main temporary staging and lay down area near the north end of the bridge; two staging areas between bridge piers on Sherman Island near Piers 29 and 30, and 31 north to the access road; and existing paved areas on the south side of the bridge.

Main staging and lay down area: Caltrans identified a temporary staging and lay down area north of Mayberry Slough, in a fallow upland field dominated by ruderal species. The staging area covers approximately 6 acres outside State ROW on the east side of the bridge. The area will be covered by a layer of crushed rock overlying geotextile fabric, approximately 6 inches thick, for drivability. Silt fence, fiber rolls and/or small earthen berms will be installed along the north and east side of the staging area to direct runoff away from the wetlands to the north and east. The staging and lay down areas will be kept 100 to 200 feet from the potential aquatic habitat for the giant garter snake habitat to the north and east. At the completion of the project, the silt fence, along with the environmentally sensitive area fencing, berm, crushed rocks, and geotextile fabric will be removed and the site will be restored to the existing condition.

Temporary staging areas between piers: Caltrans has identified two temporary contractor staging areas between bridge piers. One, located between Piers 29 and 30, will occupy approximately 0.17 acres and be 115 feet long by 65 feet wide. The other, on Sherman Island and between Pier 31 and the permanently extended access road, will occupy approximately 0.12 acres and be 81 feet long by 65 feet wide. The preparation of these temporary staging areas will consist of placing geotextile fabric and a crushed rock layer, approximately four feet in depth over the existing ground.

South side of the bridge: On the south end of the bridge, the contractor will use existing paved areas for staging. An environmentally sensitive area fence will be placed along the west side of the access road to protect the drainage ditch that borders the action area.

Permanent widening of access roads. The unpaved access road extending from the old Highway 84 to the staging area is currently 18 to 20 feet wide. Caltrans plans to widen this access road to 24 feet over a distance of approximately 1,200-feet in order to accommodate large construction equipment and trucks. Widening of this access road will include minor grading of the approximately 0.218 acre area and placing 6 inches of crushed rocks over the adjacent ground. The areas adjacent to this road currently consist of ruderal upland vegetation.

Proposed Aquatic Work Areas

Temporary marine trestle. A temporary marine trestle with an approximate length of 910 feet and a width of 25 feet will be constructed from the south bank of San Joaquin River to Pier 11 to allow construction access to the piers in the shallow water area. The trestle platform is expected to be approximately five feet above the Mean Higher-High Water.

Pile driving. The trestle will be constructed using approximately 160, 24-inch steel hollow shell piles that will be installed with a vibratory hammer. The design requires two 24-inch diameter steel shell piles of every 25 feet of trestle and around the piers. Caltrans estimates that the 160 piles will be driven to a depth of 50 feet and four to six piles and two to three sections of trestle would be installed per day. Water depths would range from the shore or mud during lower tides to approximately 10 feet. The piles would be vibrated in for approximately ten minutes per pile

and one pile each section will be driven with an impact hammer for approximately 20 blows per pile, to verify bearing capacity of the pile. This would equate to a maximum of 3,600 seconds of vibratory pile installation and 60 hammer strikes per day. Caltrans will proof test one pile per day using an impact hammer. At the completion of the project, the trestle along with the piles will be removed.

Barge work. Caltrans plans to use barges to retrofit Piers 12 to 21, which will include installation of mooring lines and temporary dolphins.

Proposed Superstructure Work

Superstructure work includes installation of steel cross bracings between columns, replacing the existing bearings with isolation bearings, and retrofitting the slab span columns as follows:

1. Installation of steel cross-bracing between columns to stiffen the superstructure from Pier 12 to Pier 31. Cross bracings will be anchored to the existing concrete columns with resin capsule anchors.

2. Installation of bracing to existing cross frames at the bents (Pier 2 to Pier 40).

3. Replacement of the existing elastometric bearings with isolation bearings (Abutment 1 to Pier 41).

4. Removal of the existing curtain walls and retrofitting of all the columns in the slab span structure by installing composite fiber jackets (Bent 42 to Abutment 71).

Caltrans will implement best management practices (BMPs) and exclusionary methods to prevent birds from nesting on the structure during construction. These may include exclusionary netting, potential hosing, and/or scheduling work around non-nesting periods.

Borrow and Disposal

According to Caltrans, the project will not require on-site borrow or disposal of excavated material. Gravel and rock will be imported for construction of the temporary access road and road widening. These materials will be removed upon completion of the project, and removal and disposal of this material will be implemented through contractors and subcontractors as part of the Caltrans standard BMPs and the Stormwater Pollution Prevention Plan (SWPPP). According to Caltrans, BMPs and SWPPP measures are a standard part of the plans and specifications for this project and are covered by the Regional Water Quality Control Boards' (RWQCB) 401 Water Quality Certification.

Proposed Avoidance and Minimization Measures

According to the January 2009 Biological Assessment and additional information provided on June 23, 2009, and July 14, 2009, Caltrans proposes to avoid, minimize, and compensate for effects to listed species by implementing the following measures:

Delta Smelt

1. In-water work will be restricted to the Service's recommended window of August 1 to November 30.

2. Caltrans will install all temporary piles for marine access with a vibratory hammer to minimize hydroacoustic effects. Maximum pile size will be limited to a 24-inch diameter.

3. Caltrans will proof-test one pile per day with an impact hammer. Daily proof-testing of piles will require 20 blows per day with an impact hammer. Caltrans will implement a sound pressure level attenuation system for all impact hammer pile driving activities. The attenuation system may include, but is not limited to one or a combination of the following methods:

    a. confined bubble-curtain,
    a. an unconfined bubble curtain,
    b. isolation casings, and/or
    c. wooden pile cushions.

    Caltrans will not begin pile driving until they have submitted and received approval for the final attenuation plan from the Service and the California Department of Fish and Game.

4. Turbidity levels produced by installation/removal of temporary piles will not exceed those permitted under the project SWPPP and construction activities will be halted if turbidity levels approach or exceed the acceptable criteria established by the RWQCB until turbidity levels return to within acceptable levels.

5. Compensation for the direct effects to 0.522 acres due to shallow water shading, substrate disturbance, and pile driving shall occur with either the purchase 1.57 acres of credit either through a Service and California Department of Fish and Game approved compensation bank, issuance of a letter of assurance indicating that sufficient funds have been set aside (such as in a separate EA) for future credit purchase, or an equivalent contribution to the Service in-lieu fund.

Giant Garter Snake

1. All ground-disturbing construction activity within giant garter snake habitat on Sherman Island will be conducted between May 1 and October 1. Given that all construction activity is confined to upland habitat (over-wintering and movement habitat), the laying of temporary access roads in giant garter snake habitat will occur during the snake's active season. Once the temporary access road is in place, no further ground disturbing activity will take place.

2. A qualified biologist will inspect construction-related activities at the proposed project site to ensure that no unauthorized take of federally listed species or destruction of their habitat occurs. The biologist will be available for monitoring throughout all phases of construction that may result in adverse effects to the giant garter snake. Additionally, if a giant garter snake is encountered during construction, the biologist will have the authority through communication with the resident engineer to stop construction activities in the immediate area until appropriate corrective measures have been completed, or until the snake is determined to be unharmed. Snakes encountered during construction activities will be allowed to move away from the area on their own volition. The biologist will notify the Service immediately if any listed species are found on-site, and will submit a report, including date(s), location(s), habitat description, and any corrective measures taken to protect the species found. The biologist will be required to report any take of listed species to the Service immediately by telephone at (916) 414-6600 and by email or written letter addressed to Chris Nagano, Division Chief, Endangered Species Program, within three (3) working days of the incident.

3. A Worker Environmental Awareness Training Program for construction personnel will be conducted by the Service-approved biologist for all construction workers, including contractors, prior to the commencement of construction activities. The program will provide workers with information on their responsibilities with regard to the giant garter snake, an overview of the life history of this species, information on take prohibitions; protections afforded this animal under the Act, and an explanation of the relevant terms and conditions of this biological opinion. Written documentation of the training will be submitted to the Sacramento Fish and Wildlife Office within 30 days of the completion of training.

4. At most, 24-hours prior to the commencement of construction activities, the Sherman Island portion of the project site will be surveyed for giant garter snake by a qualified biologist. The project area will be re-inspected by the monitoring biologist whenever a lapse in construction activity of two weeks or greater has occurred.

5. Aquatic habitat that will be disturbed or removed will be dewatered 15 days prior to the initiation of construction activities. If complete dewatering is not possible, potential

snake prey (i.e., fish and tadpoles) will be removed so that snakes and other wildlife are not attracted to the construction area.

6. BMPs, including a SWPPP, will be implemented to minimize effects to the snake during construction. Best management practices will be implemented to prevent sedimentation from entering environmentally sensitive areas and to reduce erosion, dust, noise, and other deleterious aspects of construction related activities. These BMPs may include, but are not limited to, silt fencing, temporary berms, restrictions on cleaning equipment in or near environmentally sensitive areas, installation of vegetative strips, and temporary sediment disposal. Runoff from dust control and hazardous materials will be retained on the construction site and prevented from flowing into the environmentally sensitive areas.

7. Tightly woven fiber netting or similar material will be used for erosion control and other purposes at the project site to minimize the likelihood that giant garter snakes would become trapped or become entangled. This limitation will be communicated to the contractor using special provisions included in the bid solicitation package.

8. During construction operations, the number of access routes, number and size of staging areas, and the total area of the proposed project activity will be limited to the minimum necessary. Routes and boundaries will be clearly demarcated. Movement of heavy equipment to and from the project site will be restricted to established roadways to minimize habitat disturbance. Project-related vehicles will observe a 20-mile-per-hour speed limit within construction areas, except on county roads and on state and federal highways. This is particularly important during periods when the snake may be sunning or moving on roadways. All heavy equipment, vehicles, and supplies will be stored at the designated staging area at the end of each work period.

9. During construction operations, stockpiling of construction materials, portable equipment, vehicles, and supplies will be restricted to the designated construction staging areas and exclusive of the environmentally sensitive areas. Caltrans will ensure that contamination of habitat does not occur during such operations.

10. All food-related trash items, such as wrappers, cans, bottles, and food scraps, will be disposed of in closed containers and removed at the end of each workday from the entire project site.

11. Prior to the commencement of construction activities, high visibility fencing will be erected within the action area to identify and protect these designated environmentally sensitive areas from encroachment of personnel and equipment. These areas will be avoided by all construction personnel. The fencing will be inspected before the start of each work day and maintained by the project proponents until completion of the project. The fencing may be removed only when the construction of the project is completed.

Fencing will be established at least 200-feet from the edge of potential aquatic habitat for the giant garter snake.

12. Signs will be posted every 50 feet along the edge of the environmentally sensitive areas, with the following information: "This area is habitat of federally-threatened and/or endangered species, and must not be disturbed. These species are protected by the Endangered Species Act of 1973, as amended. Violators are subject to prosecution, fines, and imprisonment." The signs will be clearly readable from a distance of 20 feet, and must be maintained for the duration of construction.

13. After construction activities are complete, any temporary fill or construction debris will be removed and disturbed areas restored to their pre-project conditions. An area subject to "temporary" disturbance includes any area that is disturbed during the project, but that, after project completion, will not be subject to further disturbance and has the potential to be re-vegetated. All giant garter snake habitats subject to temporary ground disturbances, including storage and staging areas and temporary roads, will be restored. These areas will be re-contoured, if appropriate, and re-vegetated with appropriate locally collected native plant species to promote restoration of the area to pre-project conditions. Appropriate methods and plant species used to re-vegetate such areas will be determined on a site-specific basis. Restoration work may include replanting emergent vegetation. Restoration will comply with the Service's *Guidelines for the Restoration and/or Replacement of Giant Garter Snake Habitat* (Service 1997). A written report will be submitted to the Service within ten (10) working days of the completion of construction at the project site.

14. Caltrans will restore the site to pre-construction conditions and monitor the project site for one (1) year following the completion of construction and restoration activities. Monitoring reports documenting the restoration effort will be submitted to the Service upon the completion of the restoration implementation and one (1) year after the restoration implementation. Monitoring reports will include photo-documentation, when restoration was completed, what materials were used, specified plantings, and justifications of any substitutions to the Service-recommended guidelines.

15. Compensation shall occur for permanent and temporary effects to the giant garter snake as prescribed in the programmatic biological opinion (Service 1997) in order to offset the permanent and temporal adverse effects to individual snakes.

    To be consistent with the programmatic, permanent effects to approximately 0.22 acres of upland giant garter snake habitat will be compensated with 0.66 acres of credit either through a Service and California Department of Fish and Game approved compensation bank or by providing a letter of assurance indicating that appropriate funds have been set aside (such as in a separate EA) for future credit purchase.

Restoration of the approximately 2.22 acres of direct effects from the temporary access roads and temporary contractor staging will be completed following three years of construction activities within the giant garter snake active season (May 1 to October 1). As prescribed by the programmatic, compensation for temporal effects shall occur with onsite restoration of the 2.22 acres along with 4.44 acres of off-site credit either through a Service and California Department of Fish and Game approved compensation bank or by providing a letter of assurance indicating that appropriate funds have been set aside (such as in a separate EA) for future credit purchase. If restoration of the 2.22 acres occurs in less than three active seasons, Caltrans will reinitiate consultation with the Service in order to compensate for temporal effects at the appropriate lower replacement ratio prescribed in the programmatic.

Restoration will be accomplished by removing the aggregate rock installed on top of geotextile fabric. The geotextile fabric will be removed and hydroseed mix will be applied to restore the ground cover vegetation. If the area has been substantially compacted, disking the top 4 to 6-inches of soil will be performed prior to applying the hydroseed mix.

Analytical Framework for the Jeopardy Determination

The following analysis relies on four components to support the jeopardy determination for the delta smelt and the giant garter snake: (1) the *Status of the Species*, which evaluates the species' rangewide condition, the factors responsible for that condition, and its survival and recovery needs; (2) the *Environmental Baseline*, which evaluates the condition of the species in the action area, the factors responsible for that condition, and the role of the action area in the species' survival and recovery; (3) the *Effects of the Action*, which determines the direct and indirect effects of the proposed Federal action and the effects of any interrelated or interdependent activities on the species; and (4) *Cumulative Effects*, which evaluates the effects of future, non-Federal activities in the action area on the species.

In accordance with the implementing regulations for section 7 and Service policy, the jeopardy determination is made in the following manner: the effects of the proposed Federal action are evaluated in the context of the aggregate effects of all factors that have contributed to the species' current status and, for non-Federal activities in the action area, those actions likely to affect the species in the future, 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 the species in the wild.

The following analysis places an emphasis on using the range-wide survival and recovery needs of the species and the role of the action area in providing for those needs 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.

Analytical Framework for the Adverse Modification Determination

This biological opinion does not rely on the regulatory definition of "destruction or adverse modification" of critical habitat at 50 CFR 402.02. Instead, we have relied upon the statutory provisions of the ESA to complete the following analysis with respect to delta smelt critical habitat.

The following analysis relies on four components to support the adverse modification determination: (1) the *Status of Critical Habitat*, which evaluates the range-wide condition of designated critical habitat for the delta smelt in terms of primary constituent elements (PCEs), the factors responsible for that condition, and the intended recovery function of the critical habitat overall, as well as the intended recovery function of discrete critical habitat units; (2) the *Environmental Baseline*, which evaluates the condition of the critical habitat in the action area, the factors responsible for that condition, and the recovery role of the critical habitat in the action area; (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 PCEs and how that will influence the recovery role of affected critical habitat unit; and (4) *Cumulative Effects*, which evaluates the effects of future, non-Federal activities in the action area on the PCEs and how that will influence the recovery role of affected critical habitat unit.

In accordance with Service policy and guidance, the adverse modification determination is made in the following manner: the effects of the proposed Federal action on critical habitat are evaluated in the context of the aggregate effects of all factors that have contributed to the current status of the critical habitat range-wide and, for non-Federal activities in the action area, those actions likely to affect the critical habitat in the future, to determine if the critical habitat would remain functional (or retain the current ability for the PCEs to be functionally established in areas of currently unsuitable but capable habitat) to serve the intended recovery role for the species with implementation of the proposed Federal action.

The following analysis places an emphasis on using the intended range-wide recovery function of delta smelt critical habitat and the role of the action area relative to that intended function as the context for evaluating the significance of effects of the proposed Federal action, taken together with cumulative effects, for purposes of making the adverse modification determination.

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 proposed action, the action area includes all land and water associated with the approximately 383.645 acre project footprint and roads (except for County roads, and State and Federal highways) and other areas accessed by project vehicles. This includes a 285-foot diameter around each temporary marine trestle to represent the 183 db SEL radius.

Status of the Species and Environmental Baseline

Delta Smelt

Delta smelt was federally listed as threatened on March 5, 1993, (58 FR 12854) (Service 1993a) and critical habitat was designated on December 19, 1994, (59 FR 65256) (Service 1994a). The delta smelt is included in the Sacramento-San Joaquin Delta Native Fishes Recovery Plan (Service 1996) and the Five Year Status Review for this species was completed on March 31, 2004 (Service 2004).

Delta smelt belong to the family Osmeridae, a more ancestral member of the order Salmoniformes which also includes the family Salmonidae (salmon, trout, whitefish, and graylings) (Moyle and Cech 1988). Delta smelt are slender-bodied fish with a small mouth and large eyes. Adults are typically 2.36–2.76 inches long (measured from tip of the snout to origin of the caudal fin) but can be up to 4.72 inches. Live delta smelt are nearly translucent with a steely-blue sheen to their sides. Some individuals have a chromatophore (cellular organelle containing pigment) between the mandibles. They have been described as unsteady, intermittent, slow speed swimmers that rely on a "stroke and glide" technique (Swanson and Cech 1995).

The delta smelt is a euryhaline fish (tolerate a wide range of salinities) endemic to the upper Sacramento-San Joaquin estuary. They occur in the Delta primarily downstream of Isleton on the Sacramento River, downstream of Mossdale on the San Joaquin River, and in Suisun Bay. They move into freshwater when spawning (ranging from January to July) and can occur in: (1) the Sacramento River as high as the confluence with the Feather River, (2) the Mokelumne River system, (3) the Cache Slough region, (4) the Delta, and, (5) Montezuma Slough, (6) Suisun Bay, (7) Suisun Marsh, (8) Carquinez Strait, (9) Napa River, (10) Napa Marsh, and 11) San Pablo Bay. It is not known if delta smelt in San Pablo Bay are a permanent population or if they are washed into the Bay during high outflow periods. Since 1982, the center of delta smelt abundance has been the northwestern Delta in the channel of the Sacramento River. In any month, two or more life stages (adult, larvae, and juveniles) of delta smelt have the potential to be present in Suisun Bay (California Department of Water Resources (DWR) and the Bureau of Reclamation (Reclamation) 1994; Moyle 1976; and Wang 1991). Delta smelt are also captured seasonally in Suisun Marsh.

Delta smelt of all sizes are found in the main channels of the Delta and Suisun Marsh and the open waters of Suisun Bay where the waters are well oxygenated and temperatures relatively cool, usually less than 68-71.6 Fahrenheit (°F) in summer. When not spawning, they tend to be concentrated near the zone where incoming salt water and out flowing freshwater mix. This rich productive area is referred to as the mixing zone, the 2 ppt isohaline, or X2. This area has the highest primary productivity and is where zooplankton populations (on which delta smelt feed) are usually most dense (Knutson and Orsi 1983; Orsi and Mecum 1986). At all life stages delta smelt are found in greatest abundance in the top 6.56 feet of the water column and usually not in close association with the shoreline.

The spawning season varies from year to year, and may occur from late winter (December) to early summer (July) and appears to peak in April and May (Wang 1991; Wang and Brown 1993 as cited in DWR and Reclamation 1994).

Delta smelt spawn in shallow, fresh, or slightly brackish water upstream of the mixing zone (Wang 1991). Most spawning occurs in tidally-influenced backwater sloughs and channel edgewaters (Moyle 1976, 2002; Wang 1986, 1991; Moyle et al. 1992). Although delta smelt spawning behavior has not been observed in the wild (Moyle et al. 1992), some researchers believe the adhesive, demersal eggs attach to substrates such as cattails, tules, tree roots, and submerged branches in shallow waters (Moyle 1976, 2002; Wang 1991).

Laboratory observations have indicated that delta smelt are broadcast spawners (DWR and Reclamation 1994) and eggs are demersal (sinks to the bottom) and adhesive, sticking to hard substrates such as: rock, gravel, tree roots or submerged branches, and submerged vegetation (Moyle 1976, 2002; Wang 1986). At 57.2-60.8 °F, embryonic development to hatching takes 9 -14 days and feeding begins 4-5 days later (R. Mager, UCD, unpublished data). Newly hatched delta smelt have a large oil globule that makes them semi-buoyant, allowing them to maintain themselves just off the substrate floor (R. Mager, UCD, unpublished data), where they feed on rotifers (microscopic crustaceans used by fish for food) and other microscopic prey. Once the swim bladder (a gas-filled organ that allows fish to maintain neutral buoyancy) develops, larvae become more buoyant and rise up higher into the water column. At this stage, 0.63-0.71 inches total length, most are presumably washed downstream until they reach the mixing zone or the area immediately upstream of it. Growth is rapid and juvenile fish are 1.57-1.97 inches long by early August (Erkkila et al. 1950; Ganssle 1966; Radtke 1966). By this time, young-of-year fish dominate trawl catches of delta smelt, and adults become rare. Delta smelt reach 2.17-2.76 inches standard length in 7-9 months (Moyle 1976, 2002). Growth during the next 3 months slows down considerably (only 0.12-0.35 inches total), presumably because most of the energy ingested is being directed towards gonadal development (Erkkila et al. 1950; Radtke 1966). There is no correlation between size and fecundity, and females between 2.32-2.76 inches standard lengths lay 1,200 to 2,600 eggs (Moyle et al. 1992). The abrupt change from a single-age, adult cohort during spawning in spring to a population dominated by juveniles in summer suggests that most adults die after they spawn (Radtke 1966 and Moyle 1976, 2002). However, in El Nino years when temperatures rise above 64.4 °F before all adults have spawned, some fraction of the unspawned population may also hold over as two-year-old fish and spawn in the subsequent year. These two-year-old adults may enhance reproductive success in years following El Nino events.

In a near-annual fish like delta smelt, a strong relationship would be expected between number of spawners present in one year and number of recruits to the population the following year. Instead, the stock-recruit relationship for delta smelt is weak, accounting for about a quarter of the variability in recruitment (Sweetnam and Stevens 1993). This relationship does indicate, however, that factors affecting numbers of spawning adults (e.g., entrainment, toxics, and predation) can have an effect on delta smelt numbers the following year.

Delta smelt feed primarily on (1) planktonic copepods (small crustaceans used by fish for food), (2) cladocerans (small crustaceans used by fish for food), (3) amphipods (small crustaceans used by fish for food) and, to a lesser extent, (4) on insect larvae. Larger fish may also feed on the opossum shrimp (*Neomysis mercedis*). The most important food organism for all sizes seems to be the euryhaline copepod (*Eurytemora affinis*) although in recent years the exotic species, *Pseudodiaptomus forbesi*, has become a major part of the diet (Moyle et al. 1992).

Delta smelt are a minor prey item of juvenile and subadult striped bass (*Morone saxatilis*), in the Sacramento-San Joaquin Delta (Stevens 1966). They also have been reported from the stomach contents of white catfish (*Ameiurus catus*) (Turner 1966 in Turner and Kelley (eds) 1966) and black crappie (*Pomoxis nigromaculatus*) (Turner 1966 in Turner and Kelley 1966) in the Delta.

Delta smelt were once one of the most common pelagic (living in open water away from the bottom) fish in the upper Sacramento-San Joaquin estuary, as indicated by its abundance in California Department of Fish and Game trawl catches (Erkkila et al. 1950; Radtke 1966; Stevens and Miller 1983). Since the 1850s, however, the amount and extent of suitable habitat for the delta smelt has declined dramatically due in large part to hydraulic mining, agricultural development in the Delta, agricultural practices, water diversion, and recreation.

In addition to the degradation and loss of estuarine habitat, delta smelt have been increasingly subject to entrainment, upstream or reverse flows of waters in the Delta and San Joaquin River, and constriction of low salinity habitat to deep-water river channels of the interior Delta (Moyle et al. 1992). These adverse conditions are primarily a result of the steadily increasing proportion of river flow being diverted from the Delta and occasional droughts (Monroe and Kelly 1992).

Reduced water quality from agricultural runoff, effluent discharge and boat effluent has the potential to harm the pelagic larvae and reduce the availability of the planktonic food source. When the mixing zone is located in Suisun Bay where there is extensive shallow water habitat within the euphotic zone (depths less than four meters), high densities of phytoplankton and zooplankton may accumulate (Arthur and Ball 1978, 1979, 1980). The introduction of the Asian clam (*Potamocorbula amurensis*), a highly efficient filter feeder, presently reduces the concentration of phytoplankton in this area.

Delta smelt abundance from year to year has fluctuated greatly in the past, but between 1982 and 1992 their population was consistently low. The decline became precipitous in 1982 and 1983 due to extremely high outflows and continued through the drought years 1987-1992 (Moyle et al. 1992). In 1993, numbers increased considerably, apparently in response to a wet winter and spring. During the period 1982-1992, most of the population was confined to the Sacramento River channel between Collinsville and Rio Vista (D. Sweetnam, CDFG unpublished data). This was still an area of high abundance in 1993, but delta smelt were also abundant in Suisun Bay. The abundance indices have shown a consistently low population for the last 10 years and a precipitous decline in the past few years (Stevens et al. 1990, Souza and Bryant 2002, CDFG 2001). The actual size of the delta smelt population is not known. However, the pelagic life

style of delta smelt, short life span, spawning habits, and relatively low fecundity indicate that a fairly substantial population probably is necessary to keep the species from becoming extinct. The health of the Delta and the declining delta smelt population has become a critical issue with wide ranging implications that have included proposals to up-list the species to endangered status.

Environmental Baseline

As a result of long-term monitoring in the Antioch area, delta smelt have been recorded in the San Joaquin River in close proximity to the action area as well as up and downstream of the action area. Therefore, the Service believes that the delta smelt is reasonably certain to occur within the action area given the biology and ecology of the animal, the presence of suitable habitat in and adjacent to the action area, as well as the recent records of this listed fish.

The Antioch Bridge crosses what is considered in the delta smelt programmatic as the "central delta smelt zone" (Service 2004). Adult delta smelt spawn in central Delta sloughs from February through August in shallow water areas having submersed aquatic plants and other suitable substrates and refugia. These shallow water areas have been identified in the Delta Native Fishes Recovery Plan (Service 1996) as essential to the long-term survival and recovery of delta smelt and other resident fish. A no net loss strategy of delta smelt population and habitat was proposed in this recovery plan.

More comprehensive information regarding the biology of the delta smelt and its current status (including abundance monitoring) are included in the species' five year review and in the biological opinion for the Operations Criteria and Plan (OCAP) for the continued operation of the Federal Central Valley Project (CVP) and State Water Project (SWP) on the Service's delta smelt recovery webpage (http://www.fws.gov/sacramento/es/delta_smelt.htm).

Delta Smelt Critical Habitat

In determining which areas to designate as critical habitat, the Service considers those physical and biological features that are essential to a species' conservation and that may require special management considerations or protection (50 CFR 424.12(b).

The Service is required to list the known primary constituent elements together with the critical habitat description. Such physical and biological features include, but are not limited to, the following:

1. Space for individual and population growth, and for normal behavior;

2. Food, water, air, light, minerals, or other nutritional or physiological requirements;

3. Cover or shelter;

4. Sites for breeding, reproduction, rearing of offspring, germination, or seed dispersal; and

5. Generally, habitats that are protected from disturbance or are representative of the historic geographical and ecological distributions of a species.

In designating critical habitat for the delta smelt, the Service identified the following primary constituent elements essential to the conservation of the species: physical habitat, water, river flow, and salinity concentrations required to maintain delta smelt habitat for spawning, larval and juvenile transport, rearing, and adult migration. These elements are organized by habitat conditions required for each life stage of the delta smelt and are further described as follows.

The spawning habitat element are described as shallow, fresh or slightly brackish backwater sloughs and edgewaters with suitable water quality and substrates for egg attachment to ensure egg hatching and larval viability. Specific areas that have been identified as important delta smelt spawning habitat include Barker, Lindsey, Cache, Prospect, Georgiana, Beaver, Hog, and Sycamore sloughs and the Sacramento River in the Delta, and tributaries of northern Suisun Bay.

The larval and juvenile transport element includes the ability to transport larvae from where they were hatched to shallow, productive rearing or nursery habitat. Adequate river flow is necessary to transport larvae from upstream spawning areas to rearing habitat in Suisun Bay and to ensure that rearing habitat is maintained in Suisun Bay. To ensure this, X2 (the 2 ppt isohaline mixing zone) must be located westward of the confluence of the Sacramento-San Joaquin Rivers, located near Collinsville (Confluence), during the period when larvae or juveniles are being transported, according to historical salinity conditions. X2 is important because the "entrapment zone" or zone where particles, nutrients, and plankton are "trapped," leading to an area of high productivity, is associated with its location. Habitat conditions suitable for transport of larvae and juveniles may be needed by the species as early as February 1 and as late as August 31, because the spawning season varies from year to year and may start as early as December and extend until July.

The rearing habitat element includes areas that support a food-rich environment that allow larval and juvenile delta smelt to mature into adulthood. An area extending eastward from Carquinez Strait, including Suisun, Grizzly, and Honker bays, Montezuma Slough and its tributary sloughs, up the Sacramento River to its confluence with Three Mile Slough, and south along the San Joaquin River including Big Break, defines the specific geographic area critical to the maintenance of suitable rearing habitat. Three Mile Slough represents the approximate location of the most upstream extent of historical tidal incursion. Rearing habitat is vulnerable to impacts of export pumping and salinity intrusion from the beginning of February to the end of August.

The adult migration element reflects the importance of providing unrestricted access to suitable spawning habitat. Adequate flow and suitable water quality is needed to attract migrating adults in the Sacramento and San Joaquin river channels and their associated tributaries, including Cache and Montezuma sloughs and their tributaries. These areas are vulnerable to physical disturbance and flow disruption during migratory periods.

The geographical boundaries of the designated critical habitat for the delta smelt includes all water and submerged lands below ordinary high water and the entire water column bounded by and contained in Suisun Bay (including Grizzly and Honker Bays); the length of Goodyear, Suisun, Cutoff, First Mallard (Spring Branch), and Montezuma sloughs; and the existing contiguous waters contained within the Delta.

Refer to the federal register announcement for additional information regarding these primary constituent elements and a map of the critical habitat (http://ecos.fws.gov/docs/federal_register/fr2751.pdf).

Delta smelt critical habitat has been affected by activities that destroy spawning and refugial areas and change hydrology patterns in Delta waterways. Critical habitat also has been affected by diversions that have shifted the position of X2 upstream of the confluence of the Sacramento and San Joaquin rivers. This shift has caused a decreased abundance of smelt. Existing baseline conditions and implementation of the Service's 1994 and 1995 biological opinions concerning the operation of the CVP and the SWP, provide a substantial part of the necessary positive riverine flows and estuarine outflows to transport smelt larvae downstream to suitable rearing habitat in Suisun Bay outside the influence of marinas, agricultural diversions, and Federal and State pumping plants.

The demands on surface water resources in the Central Valley have increased and there are several proposed diversion projects that would likely result in lower delta outflows and increased entrainment.

Environmental Baseline

The proposed Antioch Bridge Seismic Retrofit Project is within the designated critical habitat for the delta smelt. The action area spans the San Joaquin River from bank to bank and therefore has the potential to interrupt adult migration to suitable upstream spawning and larval/juvenile transport to rearing habitat in Suisun Bay.

Giant Garter Snake

The Service published a proposal to list the giant garter snake as an endangered species on December 27, 1991 (56 FR 67046). The Service reevaluated the status of the snake before adopting the final rule. The snake was listed as a threatened species on October 20, 1993 (58 FR 54053).

The giant garter snake is one of the largest garter snakes species reaching a total length of approximately 64 inches. Females tend to be slightly longer and proportionately heavier than males. The weight of adult female snakes is typically 1.1-1.5 pounds. Dorsal background coloration varies from brown to olive with a cream, yellow, or orange dorsal stripe and two light colored lateral stripes. Some individuals have a checkered pattern of black spots between the dorsal and lateral stripes. Background coloration and prominence of the checkered pattern and three yellow stripes are geographically and individually variable; individuals in the northern Sacramento Valley tend to be darker with more pronounced mid-dorsal and lateral stripes (Hansen 1980; Rossman et al. 1996). Ventral coloration is variable from cream to orange to olive-brown to pale blue with or without ventral markings (Hansen 1980).

Giant garter snakes formerly occurred throughout the wetlands that were extensive and widely distributed in the Sacramento and San Joaquin Valley floors of California (Fitch 1940; Hansen and Brode 1980; Rossman and Stewart 1987). The historical range of the snake is thought to have extended from the vicinity of Chico, Butte County, southward to Buena Vista Lake, near Bakersfield, in Kern County (Fitch 1940; Fox 1948; Hansen and Brode 1980; Rossman and Stewart 1987). Early collecting localities of the giant garter snake coincide with the distribution of large flood basins, particularly riparian marsh or slough habitats and associated tributary streams (Hansen and Brode 1980).

Loss of habitat due to agricultural activities and flood control have extirpated the listed snake from the southern one third of its range in former wetlands associated with the historic Buena Vista, Tulare, and Kern lake beds (Hansen 1980; Hansen and Brode 1980). By 1971, so much wetland habitat had been reclaimed, that the California Department of Fish and Game classified the giant garter snake as a rare animal and conducted a series of field surveys. The results of these surveys indicated that snake populations were distributed in marsh wetlands, tributary streams, and portions of the rice productions zones of the Sacramento Valley in Butte, Glenn, Colusa, Sutter, Yolo and Sacramento Counties, in the Delta region along the eastern fringes of the Sacramento-San Joaquin River Delta in Solano, Contra Costa, Sacramento, and San Joaquin Counties, and in the San Joaquin Valley in San Joaquin, Stanislaus, Merced, Mendota, and Fresno Counties (Hansen 1988; Hansen and Brode 1980).

Upon federal listing in 1993, the Service identified 13 separate populations of giant garter snakes, with each population representing a cluster of discrete locality records (Service 1993b). The 13 populations largely coincide with historical flood basins and tributary streams throughout the Central Valley: (1) Butte Basin, (2) Colusa Basin, (3) Sutter Basin, (4) American Basin, (5) Yolo Basin/Willow Slough, (6) Yolo Basin/Liberty Farms, (7) Sacramento Basin, (8) Badger Creek/Willow Creek, (9) Caldoni Marsh/White Slough, (10) East Stockton--Diverting Canal & Duck Creek, (11) North and South Grasslands, (12) Mendota, and (13) Burrel/Lanare.

A population is a group of organisms that interbreed and share a gene pool. The boundaries of a population, both in space and time, are generally not discrete and, in practice, as usually defined by the researcher (Krebbs 1994). The gene pool and breeding patterns of the 13 giant garter

snake populations identified in the final rule remain unstudied and unknown. What was described as "13 populations" should therefore be described more accurately as sub-populations and occurrences that note observations of individuals about which much remains unknown (Service 1999).

Surveys over the last 25 years suggest that sub-populations of giant garter snake in the northern parts of its range (i.e., Butte, Colusa, and Sutter Counties) are relatively large and stable (Wylie et al. 1997; Wylie et al. 2003a, 2004a). Habitat corridors connecting sub-populations, however, are either not present or not protected, and urban encroachment increases as a serious threat (Service 2003). Sub-populations in Yolo, Sacramento, Solano, and San Joaquin Counties areas are small, fragmented, and threatened by urbanization (Hansen 2004; Service 1999). Those sub-populations in the San Joaquin Valley, however, are most vulnerable having suffered near-devastating declines and possible extirpations over the last two decades (including populations in Stanislaus, Merced, Madera and Fresno Counties) (Dickert 2002, 2003; Hansen 1988; Williams and Wunderlich 2003). The southern sub-populations are extremely small, distributed discontinuously in isolated patches, and therefore are highly vulnerable to extinction by random environmental, demographic, and genetic processes (Goodman 1987).

Endemic to wetlands in the Sacramento and San Joaquin valleys, the giant garter snake inhabits marshes, sloughs, ponds, small lakes, low gradient streams, and other waterways and agricultural wetlands, such as irrigation and drainage canals, rice fields and the adjacent uplands (Service 1999). Essential habitat components consist of: (1) wetlands with adequate water during the snake's active season (early-spring through mid-fall) to provide food and cover; (2) emergent, herbaceous wetland vegetation, such as cattails and bulrushes, for escape cover and foraging habitat during the active season; (3) upland habitat with grassy banks and openings in waterside vegetation for basking; and (4) higher elevation uplands for over-wintering habitat with escape cover (vegetation, burrows) and underground refugia (crevices and small mammal burrows) (Hansen 1988). Snakes are typically absent from larger rivers and other bodies of water that support introduced populations of large, predatory fish, and from wetlands with sand, gravel, or rock substrates (Hansen 1988; Hansen and Brode 1980; Rossman and Stewart 1987). Riparian woodlands do not provide suitable habitat because of excessive shade, lack of basking sites, and absence of prey populations (Hansen 1988).

Giant garter snakes are the most aquatic garter snake species and are active foragers, feeding primarily on aquatic prey such as fish and amphibians (Fitch 1941). Historically, giant garter snake prey likely consisted of Sacramento blackfish (*Orthodon microlepidots*), thick-tailed chub (*Gila crassicauda*), and red-legged frog (*Rana aurora*) (Rossman et al. 1996; Service 1999). Because these prey species are no longer available (chub extinct, red-legged frog extirpated from the Central Valley, blackfish declining), other than Sierran treefrogs (*Pseudacris sierra*), the predominant food items are now introduced species such as carp (*Cyprinus carpio*), mosquito-fish (*Gambusia affinis*), and larval and sub-adult bullfrogs (*Rana catesbiana*) (Fitch 1941; Hansen and Brode 1993; Rossman et al. 1996).

The giant garter snake breeding season extends through March and April, and females give birth to live young from late July through early September (Hansen and Hansen 1990). Brood size is variable, ranging from 10 to 46 individual young, with a mean of 23 individuals (Hansen and Hansen 1990). At birth, young average about 8.1 inches snout-to-vent length and 0.10 to 0.18 ounces. Although growth rates are variable, young typically more than double in size by one year of age, and sexual maturity averages three years in males and five years for females (Service 1993b).

The giant garter snake is highly aquatic but also occupies a terrestrial niche (Service 1999; Wylie et al. 2004a). Aquatic habitat includes remnant native marshes and sloughs, restored wetlands, low gradient streams, and agricultural wetlands including rice fields and irrigation and drainage canals. Terrestrial habitat includes adjacent uplands which provide areas for basking, retreats, and over-wintering. Basking takes place in tules, cattails, saltbush, and shrubs over-hanging the water, patches of floating vegetation including waterweed, on rice checks, and on grassy banks (Service 1999). The snake typically inhabits small mammal burrows and other soil and/or rock crevices during the colder months of winter (i.e., October to April) (Hansen and Brode 1993; Wylie et al. 1996; Wylie et al. 2003a). It also uses burrows as refuge from extreme heat during its active period (Wylie et al. 1997; Wylie et al. 2004a). While individuals usually remain in close proximity to wetland habitats, the Biological Resource Division of the U.S. Geological Survey (BRD) has documented snakes using burrows as much as 165 feet away from the marsh edge to escape extreme heat and as far as 820 feet from the edge of marsh habitat for over-wintering habitat (Wylie et al. 1997). Snakes typically select burrows with sunny exposures along south and west facing slopes (Service 1993b).

In studies of marked snakes in the Natomas Basin, snakes moved about 0.25 to 0.5 miles per day (Hansen and Brode 1993). Home range (area of daily activity) averages about 0.1 mile^2 (25 hectares) in both the Natomas Basin and the Colusa National Wildlife Refuge (NWR) (Wylie 1998a; Wylie et al. 2002). Total activity, however, varies widely between individuals; individual snakes have been documented to move up to 5 miles over a few days in response to dewatering of habitat (Wylie et al. 1997) and to use up to more than 8 miles of linear aquatic habitat over the course of a few months, and to have a home range as large as 14.5 miles (Wylie and Martin 2004).

In agricultural areas, snakes were documented using rice fields in 19-20 percent of the observations, marsh habitat in 20-23 percent of observations, and canal and agricultural waterway habitats in 50-56 percent of the observations (Wylie 1998b). In the Natomas Basin, habitat used consisted almost entirely of irrigation ditches and established rice fields (Wylie 1998a; Wylie et al. 2004b). In the Colusa NWR, snakes were regularly found on or near edges of wetlands and ditches with vegetative cover (Wylie et al. 2003a). Telemetry studies also indicate that active snakes use uplands extensively; more than 31 percent of observations were in uplands (Wylie 1998b). Snakes observed in uplands during the active season were consistently near vegetative cover, particularly where cover exceeded 50 percent in the area within 1.6 feet of the snake (Wylie 1998b).

Giant garter snakes have been documented moving into restored habitat after two years. At the Colusa NWR, after two years, restoration area population estimates increased from 30 snakes per kilometer to 59-95 snakes per kilometer (Wylie et al. 2004a). At the Colusa Basin Drainage Canal, of the three available upland restoration treatments, 1) soil planted with native grasses over rock riprap, 2) soil planted with native grasses without rock, and 3) rock riprap only; giant garter snakes were most commonly found at the soil over rock riprap treatment (Wylie and Martin 2004).

Giant garter snakes are eaten by a variety of predators, including raccoons (*Procyon lotor*), striped skunks (*Mephitis mephitis*), opossums (*Didelphis virginiansa*), bull frogs, hawks (*Buteo* sp.), egrets (*Casmerodius albus*, *Egretta thula*), and great blue herons (*Ardea herodias*) (Dickert 2003; Service 1999; Wylie et al. 2003c). Many areas supporting snakes have been documented to have abundant predators; however, predation does not seem to be a limiting factor in areas that provide abundant cover, high concentrations of prey items, and connectivity to a permanent water source (Hansen and Brode 1993; Wylie et al. 1996).

The current distribution and abundance of the giant garter snake is much reduced from former times (Service 1999). Less than 10 percent, or approximately 319,000 acres, of the historic 4.5 million acres of Central Valley wetlands remain (U.S. Department of Interior 1994), of which very little provides habitat suitable for the giant garter snake. Loss of habitat due to agricultural activities and flood control have extirpated the snake from the southern one-third of its range in former wetlands associated with the historic Buena Vista, Tulare, and Kern lakebeds (Hansen 1980; Hansen and Brode 1980). These lakebeds once supported vast expanses of ideal snake habitat, consisting of cattail and bulrush dominated marshes (Service 1999). Cattail and bulrush floodplain habitat also historically typified much of the Sacramento Valley (Hinds 1952). Prior to reclamation activities beginning in the mid- to late-1800s, about 60 percent of the Sacramento Valley was subject to seasonal overflow flooding providing expansive areas of snake habitat (Hinds 1952). Valley flood wetlands are now subject to cumulative effects of upstream watershed modifications, water storage and diversion projects, as well as urban and agricultural development.

The CVP is the largest water management system in California and the historic water development activities that preceded it have not only resulted in the loss of all but approximately 10 percent of wetlands, they have created an ecosystem altered to such an extent that remaining wetlands, like agriculture, depend on managed water (U.S. Department of Interior 1994). The historic disturbance events associated with seasonal inundation that occur naturally in dynamic riverine, riparian, and wetland ecosystems have been largely eliminated. In addition to the highly managed water regimes, implementation of CVP has resulted in conversion of native habitats to agriculture, and has facilitated urban development through the Central Valley (Service, unpublished). In 1992, Congress enacted the Central Valley Project Improvement Act (CVPIA), the concerns of which include pricing and management of Central Valley water and attempting to mitigate for project impacts on fish, wildlife, and associated habitat. CVPIA, however, has been largely ineffective thus far, addressing primarily only the water needs of publicly-owned

wetlands, which account for less than one-fourth of the wetlands in the Central Valley (Service, unpublished).

Residential and commercial growth within the Central Valley is consuming an estimated 15,000 acres of Central Valley farmland each year (American Farmland Trust 1999). In the future, this transformation is expected to accelerate. Rice fields have become important habitat for giant garter snakes, particularly associated canals and their banks for both spring and summer active behavior and winter hibernation (Hansen 2004). While within the rice fields, snakes forage in the shallow water for prey, utilizing rice plants and vegetated berms dividing rice checks for shelter and basking sites (Hansen and Brode 1993). The loss of rice land resulting from residential and commercial growth compounds the adverse effect of direct habitat loss resulting from development itself.

Ongoing maintenance of aquatic habitats for flood control and agricultural purposes eliminates or prevents the establishment of habitat characteristics required by the giant garter snake (Hansen 1988). Such practices can fragment and isolate available habitat, prevent dispersal of snakes among habitat units, and adversely affect the availability of the snake's food items (Hansen 1988; Brode and Hansen 1992). For example, tilling, grading, harvesting and mowing may kill or injure giant garter snakes (Service 1999; Wylie et al. 1997). Biocides applied to control aquatic vegetation reduce cover for the snake and may harm prey species (Wylie et al. 1996). Rodent control threatens the snake's upland estivation habitat (Wylie et al. 1996; Wylie et al. 2004a). Restriction of suitable habitat to water canals bordered by roadways and levee tops renders snakes vulnerable to vehicular mortality (Wylie et al. 1997). Materials used in construction projects (e.g., erosion control netting) can entangle and kill snakes (Stuart et al. 2001; Barton and Kinkead 2005). Livestock grazing along the edges of water sources degrades water quality and can contribute to the elimination and reduction of available quality snake habitat (Hansen 1988). Fluctuation in rice and agricultural production affects stability and availability of habitat (Wylie and Casazza 2001; Wylie et al. 2003b, 2004b).

Other land use practices also currently threaten the survival of the giant garter snake. Nonnative predators, including introduced predatory game fish, bullfrogs, and domestic cats, can threaten snake populations (Dickert 2003; Wylie et al. 1996; Wylie et al. 2003c). Nonnative competitors, such as the introduced water snake (*Nerodia fasciata*) in the American River and associated tributaries near Folsom, may also threaten the giant garter snake (Stitt et al. 2005). Recreational activities, such as fishing, may disturb snakes and disrupt basking and foraging activities. While large areas of seemingly suitable snake habitat exist in the form of duck clubs and waterfowl management areas, water management of these areas typically does not provide the summer water needed by the species. Degraded water quality continues to be a threat to the species both on and off refuges.

The disappearance of giant garter snakes from much of the west side of the San Joaquin Valley was approximately contemporaneous with the expansion of subsurface drainage systems in this area, providing circumstantial evidence that the resulting contamination of ditches and sloughs

with drainwater constituents (principally selenium) may have contributed to the demise of giant garter snake populations. Dietary uptake is the principle route of toxic exposure to selenium in wildlife, including giant garter snakes (Beckon et al. 2003). Many open ditches in the northern San Joaquin Valley carry subsurface drainwater with elevated concentrations of selenium. Green sunfish (*Lepomis cyanellus*) in this drainwater have been found to have concentrations of selenium ranging from 12 to 23 µp/g (Saiki 1998), within the range of concentrations associated with adverse affects on predator aquatic reptiles (Hopkins et al. 2002). Since 1996, subsurface drainwater has been discharged, via the Grassland Bypass Project into Mud Slough North, where selenium concentrations in small fish, including mosquito fish, frequently reach 10-15 µp/g (Beckon et al. 2003).

The Central Valley and Delta region contains a number of endangered ecosystems due to its fertile soils, amiable climates, easy terrains, and other factors that historically have encouraged human settlement and exploitation. Environmental impacts associated with urbanization include loss of biodiversity and habitat, alternation of natural fire regimes, fragmentation of habitat from road construction, and degradation due to pollutants (Service 1999).

Environmental Baseline

The action area is located near the western extent of this species' recognized distribution in the Delta region and is included in the Mid Valley Recovery Unit identified in the 1999 draft recovery plan for the giant garter snake (Service 1999). Little is known about the listed snake's distribution in the Antioch area but a giant garter snake has been documented in the action area (Hansen 1987) and the Service identified the levee banks of Mayberry Slough and the interconnecting drainage ditches in the and around the action area as suitable giant garter snake habitat during a July 16, 2008, field visit. The action area contains habitat components that can be used by the snake for feeding, resting, mating, and other essential behaviors, as well as for a movement corridor. Proposed access roads cross aquatic habitat for the snake. The proposed access roads, laydown, and work areas are also located in areas that provide likely upland basking and winter refugia habitat within 200 feet of aquatic habitat. The surrounding uplands are utilized for grazing and therefore are not subject to regular disking or other intense agricultural maintenance that are more detrimental to the listed snake. Snakes have been documented to move up to 5 miles over a few days in response to dewatering of habitat (Wylie et al. 1997) and to use up to more than 8 miles of linear aquatic habitat over the course of a few months, and to have a home range as large as 14.5 miles (Wylie and Martin 2004). Therefore, there is a potential to encounter dispersing giant garter snakes throughout Sherman Island. Because of the biology and ecology of the snake, the presence of suitable habitat within the proposed project, and observations of the species, the Service has determined that the snake is reasonably certain to occur within the Sherman Island portion of the action area.

Effects of the Proposed Action

Delta Smelt

Installation of trestles on the south shoreline of the San Joaquin River could detrimentally affect delta smelt by increasing turbidity, pile driving, increasing noise, reducing water quality, creating predator habitat, restricting channels, and changing water velocities. Re-suspended sediments may contain toxic substances which may interfere with the development of young delta smelt. The vegetation upon which delta smelt may depend for egg attachment and refugia may become silted over or removed by the proposed actions.

Caltrans has estimated that the action area includes approximately 342.645 acres of surface water within the San Joaquin River. The Service considers the top 10 feet of the water column throughout the action area within the San Joaquin River to be SWH for the delta smelt. The action area is wider on the south shore due to the area needed to install the approximately 910-foot long, 0.952-acre temporary marine trestle. The action area includes work space for barge activities in deeper water (>10 feet) along with adequate space near the south shore for the trestle and the additional work space needed to construct the trestle. The completed trestle structure will result in direct effects to approximately 0.522 acres of SWH due to shading and 0.002 acres of substrate within the SWH due to pile driving and installation of temporary piers. This shading could decrease productivity in SWH and enhance habitat for predators of the delta smelt. The Service did not include the trestle shading that extends around the existing Antioch Bridge piers because this area is already significantly shaded by the overhead bridge. Activities within the remaining action area within the San Joaquin River will be limited to boat/barge use and is unlikely to have a measureable effect on the delta smelt.

As SWH is removed and turbidity increased, the delta smelt's feeding, breeding, and sheltering would likely be reduced as food sources associated with the aquatic plants and found in the water column is destroyed, and habitat used for spawning substrate and refugia is eliminated. Habitat for predatory fish will also be enhanced by the shaded water area. The trestle will eventually be removed after approximately 2.5 years. Removal of the trestle will result in additional disturbance to the substrate that could affect the delta smelt.

The above effects are greatly reduced by the restriction of in-water work to time periods when delta smelt eggs, larvae, and juveniles are not present and delta smelt adults are rarely present or present in low numbers. The potential adverse effects associated with pile driving will likely be reduced by the use of a vibratory hammer along with the implementation of one or more of Caltran's proposed hydroacoustic attenuation methods. Adverse effects associated with increased turbidity will likely be limited due to the proposed methodology along with monitoring and compliance with the conditions of the RWQCB. The trestle structure will be installed under the existing Antioch Bridge structure and will therefore be a limited addition (to be removed after approximately 2.5 years) to an existing situation. In addition, the above shading effects to 0.522

acres of delta smelt habitat are minimized by the preservation, creation, or restoration of shallow water habitat at 3:1.

Critical Habitat for the Delta Smelt

The proposed project includes 342.645 acres of critical habitat for the delta smelt, which includes all water and all submerged lands below ordinary high water within the action area.

The proposed project would affect feeding, breeding, and sheltering for the delta smelt within critical habitat. Direct effects to critical habitat PCEs would likely be limited to the 0.522 acres of habitat associated with the trestle installation and shading on the south shore of the San Joaquin River. Although it is unclear what long-term effects the installation of the trestle will have on the PCEs, the trestle structure will be completely removed within approximately 2.5 years of its installation.

The above effects to the PCEs are likely reduced based on the location relative to the existing Antioch Bridge, the eventual removal of the trestle, and the commitment for the preservation, creation, or restoration of shallow water habitat lost or shaded at 3:1. Therefore proposed project is not expected to diminish the long-term value of the critical habitat for the delta smelt, or prevent critical habitat from sustaining its role in the conservation and recovery of the species.

Giant Garter Snake

The direct effects of the project to the giant garter snake are likely limited to activities on the north side of the San Joaquin River on Sherman Island where the proposed project would result in adverse effects to approximately 2.44 acres of giant garter snake upland habitat within 200 feet of giant garter snake aquatic habitat. These effects include approximately 1.10 acres of upland habitat due to temporary access roads, approximately 0.22 acres of upland habitat due to permanent access road widening, and approximately 1.12 acres of upland habitat due to equipment staging. According to Caltrans, no aquatic habitat for the giant garter snake would be directly affected. Therefore, snakes in the action area are most likely to be encountered basking or foraging. Snakes in underground refugia may be unearthed, crushed, or buried, decreasing the chances for detection. Other than the 0.22 acres of permanent road widening the use of the other access roads and staging areas will be limited to the approximately 2.5-year duration of the project. Caltrans plans to restore these areas to their former function following use and they will continue to be managed by DWR and will not be incorporated into the Caltrans right-of-way. These effects will likely be further offset by compensation that is consistent with the 1997 programmatic biological opinion. Access to the Sherman Island work area is limited by a locked gate and is not open to the public. The project, including the permanent road widening, is not expected to result in increased use or disturbance to the area following completion of the Antioch Bridge Seismic Retrofit Project.

Construction activities associated with the project occurring in snake upland habitat may harm, harass, injure, or kill giant garter snakes. The proposed project has been designed to avoid initial ground-disturbing activities associated with the establishment of the staging areas and the improvement of access roads within the active period for the snake (May 1 – October 1), resulting in a decreased risk of direct mortality. The Service believes that after October 1, snakes are more likely to be dispersing into the uplands in search of overwintering hibernacula and prey, and could be subject to mortality from the ground disturbing activities. Snakes have been observed traveling greater than 200 feet from aquatic habitat into the uplands; therefore ground disturbing activity throughout the approximately 33.5-acre action area on Sherman Island could result in direct effects to this species. The construction would remove vegetation cover and basking sites, fill or crush burrows or crevices, obstruct snake movement, and result in the death/removal of potential non-aquatic the prey, and may result in the direct disturbance, displacement, injury, and/or mortality of snakes. Snakes may disperse across or may bask on existing roads, and thus may be killed or injured by construction equipment or other vehicles accessing the project site. As evidenced by the CNDDB record, this species has been claimed as roadkill in the action area before (CNDDB 2009). Silting, fill, or spill of oil or other chemicals could cause loss of prey items in Mayberry Slough and the surrounding interconnecting drainage ditches.

Indirect effects of the proposed project on the giant garter snake include temporary displacement and reduction of prey (both aquatic and terrestrial); and increased sedimentation, oils, and other hazardous materials from access roads and staging areas which could wash into drainages. Roads and parking/staging areas may affect chemical signals, which serve as sensory mechanisms of intraspecific communication and prey detection. The ability to detect odors and phermones plays a role in the detection of cues to locate mates (Le Master et al. 2001), prey items (Chiszar et al. 1990), and ambush sites (Clark 2004) in reptiles. Phermone scent trailing, observed in a variety of reptilian species, could be altered by contaminants running off of roads (Klauber 1931) or road substrate type (Shine et al. 2004). Giant garter snakes may be adversely affected by all of these factors.

Disturbance during construction activities may also cause giant garter snakes to move into or across areas of unsuitable habitat where they may be prone to higher rates of mortality from vehicles and predation. The proposed project may also result in increased disturbances to snakes due to traffic, predation, and increases in pollution (i.e. stormwater runoff into the receiving ditches) once the proposed staging areas are established.

Giant garter snakes may be attracted to gravel surfaces of the staging areas and widened access roads as basking habitat, and may be injured or killed by vehicles driving and parking in the proposed staging area. Research has found that some snake species may be attracted to road surfaces to thermoregulate (Klauber 1939; Sullivan 1981; Ashley and Robinson 1996). Depending on air and surface temperatures, snakes may not be able to move quickly enough to avoid being injured or killed by vehicles or equipment in these staging areas.

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.

Delta Smelt and its Critical Habitat

Cumulative effects on the delta smelt and its designated critical habitat include the adverse effects associated with point and non-point source chemical contaminant discharges. These contaminants include selenium and numerous pesticides and herbicides associated with discharges related to agricultural and urban activities. Implicated as potential sources of mortality for delta smelt, these contaminants may adversely affect delta smelt reproductive success and survival rates. Spawning habitat may also be affected if submersed aquatic plants used as substrates for adhesive egg attachment are lost due to toxic substances.

Additional cumulative effects may result from any continuing or future non-Federal diversions of water that may entrain adult or larval fish or that may decrease outflows incrementally, thus shifting the position of the delta smelt's preferred habitat upstream. Water diversions through intakes serving numerous small, private agricultural lands and duck clubs in the Delta, upstream of the Delta, and in Suisun Bay contribute to these cumulative effects. These diversions also include municipal and industrial uses, as well as providing water for power plants. State or local levee maintenance may also destroy or adversely modify critical habitat by disturbing spawning or rearing habitat and release contaminants into the water.

The introduction of exotic species may occur when levees are breached or when separate creeks or river systems are reconnected during various projects. Several exotic species may adversely affect the smelt, including the Asian clam and three non-native species of euryhaline copepods. The Asian clam could play an important role in affecting the phytoplankton dynamics. The exotic copepods may displace native species and at least one species of copepods (*Sinocalanus doerri*) is difficult for larval fishes to catch because of its fast swimming and effective escape response. Reduced feeding efficiency and ingestion rates weaken and slow the growth of young and make them more vulnerable to starvation and predation.

Giant Garter Snake

The overall status of the giant garter snake has not improved since its listing. Based on scarcity of suitable habitat and limited population size, at listing, threats to the Delta Basin population were considered imminent (Service 1993b). The status of the Delta Basin sub-population has been, and continues to be, adversely affected by past and present Federal, state, private, and other human activities.

The Federal Highway Administration/Caltrans and/or the Corps have consulted with the Service on the issuance of wetland fill permits for several transportation-related projects within the Delta Basin that affected snake habitat. The direct effect of these projects is often small and localized, but the effects of transportation projects, which improve access and therefore indirectly affect snakes by facilitating further development of habitat in the area and by increasing snake mortality via vehicles, are not quantifiable.

The global average temperature has risen by approximately 0.6 degrees centigrade during the 20th Century (International Panel on Climate Change 2001, 2007; Adger et al 2007). There is an international scientific consensus that most of the warming observed has been caused by human activities (International Panel on Climate Change 2001, 2007; Adger et al. 2007), and that it is "very likely" that it is largely due to increasing concentrations of greenhouse gases (carbon dioxide, methane, nitrous oxide, and others) in the global atmosphere from burning fossil fuels and other human activities (Cayan et al. 2005, EPA Global Warming webpage http://yosemite.epa.gov; Adger et al. 2007). Eleven of the twelve years between 1995 and 2006 rank among the twelve warmest years since global temperatures began in 1850 (Adger et al. 2007). The warming trend over the last fifty years is nearly twice that for the last 100 years (Adger et al. 2007). Looking forward, under a high emissions scenario, the International Panel on Climate Change estimates that global temperatures will rise another four degrees centigrade by the end of this Century; even under a low emissions growth scenario, the International Panel on Climate Change estimates that the global temperature will go up another 1.8 degrees centigrade (International Panel on Climate Change 2001).

The increase in global average temperatures affects certain areas more than others. The western United States, in general, is experiencing more warming than the rest of the Nation, with the 11 western states averaging 1.7 degrees Fahrenheit warmer temperatures than this region's average over the 20th Century (Saunders et al. 2008). California, in particular, will suffer significant consequences as a result of global warming (California Climate Action Team 2006). In California, reduced snowpack will cause more winter flooding and summer drought, as well as higher temperatures in lakes and coastal areas. The incidence of wildfires in the Golden State also will increase and the amount of increase is highly dependent upon the extent of global warming. No less certain than the fact of global warming itself is the fact that global warming, unchecked, will harm biodiversity generally and cause the extinction of large numbers of species. If the global mean temperatures exceed a warming of two to three degrees centigrade above pre-industrial levels, twenty to thirty percent of plant and animal species will face an increasingly high risk of extinction (International Panel on Climate Change 2001, 2007).

The mechanisms by which global warming may push already imperiled species closer or over the edge of extinction are multiple. Global warming increases the frequency of extreme weather events, such as heat waves, droughts, and storms (International Panel on Climate Change 2001, 2007; California Climate Action Team 2006; Lenihan et al. 2003). Extreme events, in turn may cause mass mortality of individuals and significantly contribute to determining which species will remain or occur in natural habitats. As the global climate warms, terrestrial habitats are

moving northward and upward, but in the future, range contractions are more likely than simple northward or upslope shifts. Ongoing global climate change (Anonymous 2007; Inkley et al. 2004; Adger et al. 2007; Kanter 2007) likely imperils the giant garter snake and the resources necessary for its survival. Since climate change threatens to disrupt annual weather patterns, it may result in a loss of their habitats and/or prey, and/or increased numbers of their predators, parasites, and diseases. Where populations are isolated, a changing climate may result in local extinction, with range shifts precluded by lack of habitat.

Conclusion

After reviewing the current status of the delta smelt and its critical habitat, the environmental baseline, the effects of the project, and the cumulative effects, it is the Service's biological opinion that the proposed Antioch Bridge Seismic Retrofit Project is not likely to jeopardize the continued existence of the delta smelt, or result in the destruction or adverse modification of its critical habitat. We base this determination on the nature of the effects; the restriction of in-water work to times when delta smelt are less likely to be present; implementation of required noise attenuation during pile driving, and the preservation of shallow water habitat lost or shaded at 3:1.

It is also the Service's biological opinion that the project, as proposed, is not likely to jeopardize the continued existence of the giant garter snake. This determination is based on the nature of the effects; the restriction of upland ground disturbance on Sherman Island to when giant garter snakes are less likely to be in underground winter refugia; proposed restoration of areas of temporal effects, and Caltrans' commitment to compensate for the effects to this listed snake as outlined in the Service's 1997 programmatic biological opinion.

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 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

The Service anticipates that incidental take of delta smelt will occur. However, the Service anticipates that any take of delta smelt will be difficult to detect and quantify because they have a relatively small body size; they are relatively secretive; their presence in the Delta and associated areas coincides with relatively turbid conditions, which makes their detection difficult; and their presence in aquatic vegetation makes them difficult to detect. Therefore, it is not possible to provide precise numbers of delta smelt that could be injured, harassed, harmed, or killed due to the proposed action. Accordingly, the Service anticipates that all delta smelt within the approximately 0.522 acres of delta smelt habitat that will be affected by the project due to shading. Low mortality is anticipated because of the work restriction windows and implementation of required noise attenuation during pile driving. Because the species is wide-ranging and its distribution varies from one year to the next, take may vary from year to year. Additionally, losses of the species may be masked by seasonal fluctuations in numbers. Upon implementation of the following reasonable and prudent measures, incidental take associated with the Antioch Bridge Seismic Retrofit Project in the form of harm, harassment, injury, or mortality to delta smelt will become exempt from the prohibitions described under section 9 of the Act.

The Service anticipates that incidental take of the giant garter snake will be difficult to detect or quantify because giant garter snakes are cryptically colored, secretive, and known to be sensitive to human activities. Snakes may avoid detection by retreating to burrows, soil crevices, vegetation, and other cover. Individual snakes are difficult to detect unless they are observed, undisturbed, at a distance. Most close-range observations represent chance encounters that are difficult to predict. It is not possible to make an accurate estimate of the number of snakes that would be harassed or harmed during construction activities, including use of staging areas and access roads. In instances when take is difficult to detect, the Service may estimate take in numbers of individuals per acre of habitat lost or degraded as a result of the action. The Service anticipates that all giant garter snakes within the approximately 2.44 acres of upland habitat within 200 feet of giant garter snake aquatic habitat on Sherman Island may be subject to harassment and harm as a result of habitat modification and degradation due to the proposed project. Snakes in this area are likely to encountered basking or foraging above ground or unearthed from or crushed in underground refugia. The Service is also issuing incidental take for giant garter snakes within the remaining 31.06 acres of upland habitat within the action area on Sherman Island. The snakes within this area are likely to be encountered during dispersal and

may be subject to harassment and harm due to staging and mobilization and use of the access roads.

Upon implementation of the following reasonable and prudent measures incidental take associated with the proposed action described above for the delta smelt and giant garter snake will become exempt from the prohibitions described under section 9 of the Act.

Effect of the Take

The Service has determined that this level of anticipated take is not likely to result in jeopardy to the delta smelt or adverse modification or destruction of its critical habitat. The Service has also determined that the level of anticipated take for is not likely to jeopardize the continued existence of the giant garter snake.

Reasonable and Prudent Measures

The following reasonable and prudent measures are necessary and appropriate to minimize the effect of the proposed action on the delta smelt and its critical habitat and the giant garter snake. Caltrans will be responsible for implementation of and compliance with these measures:

1. Caltrans shall implement the conservation measures in the project description as described in the January 2009, Biological Assessment and this biological opinion.

2. Caltrans shall minimize adverse effects to the delta smelt and giant garter snake. Take in the form of harassment, harm, or mortality of delta smelt and harassment and/or harm of the giant garter snake during construction activities and associated with implementing the project shall be minimized.

3. Caltrans shall ensure their compliance with this biological opinion.

Terms and Conditions

In order to be exempt from the prohibitions of section 9 of the Act, Caltrans shall ensure compliance with the following terms and conditions, which implement the reasonable and prudent measures described above. These terms and conditions are nondiscretionary.

1. The following Terms and Conditions implement Reasonable and Prudent Measure one (1):

    a. Caltrans shall minimize the potential for harm, harassment, or killing of federally listed fish and wildlife species resulting from project related activities by implementation of the conservation measures as described in the January 2009,

Biological Assessment and appearing in the *Project Description* of this biological opinion.

b. 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. In addition, Caltrans shall educate and inform contractors involved in the project as to the requirements of the biological opinion.

2. The following Terms and Conditions implement Reasonable and Prudent Measure two (2):

a. Prior to ground-breaking (including site preparation or grading) on any component of the proposed project, Caltrans shall provide the Service with written documentation that they have satisfied their proposed compensation for the delta smelt and the giant garter snake. If the banks identified for credit purchase have not been approved to sell credits prior to ground-breaking, Caltrans will provide evidence that the necessary funds have been set aside in a secure account. If the approval to sell credits for the species has been denied by the Service, then Caltrans shall reinitiate consultation with the Service.

b. The applicants shall include a copy of this biological opinion within its solicitations for design and construction of the proposed project making the primary contractor responsible for implementing all requirements and obligations included within the biological opinion, and to educate and inform all other contractors involved in the project as to the requirements of the biological opinion. A copy of the solicitations containing the biological opinion also will be provided to Coast-Bay Branch Chief at the Sacramento Fish and Wildlife Office.

c. A Worker Environmental Awareness Training Program for all construction personnel prior to their involvement in work activities. The program shall include discussion of the delta smelt and the giant garter snake including an overview of their life history and take prohibitions outlined in the biological opinion. The program shall focus on the conservation measures that are relevant to employee's personal responsibility. Distributed materials should include wallet-sized cards with a distinctive photograph of the giant garter snake, compliance reminders, and relevant contact information. Documentation of the training, including individual signed affidavits, shall be submitted to the Service with the annual compliance report described in the *Reporting Requirements* beginning on page 41 of this biological opinion. An outline of the program shall be submitted to Chris Nagano, Division Chief, Endangered Species Program within twenty (20) working days prior to the initial onset of construction activities. As needed, training shall be conducted in Spanish for Spanish language speakers. Documentation of the training, including individual signed affidavits, shall be kept on file and available on request.

d. Project employees shall be provided with written guidance governing vehicle use, speed limits on unpaved roads, fire prevention, and other hazards.

e. Only Service-approved biological monitors shall implement the monitoring duties outlined in this biological opinion including delivery of the Worker Environmental Awareness Training Program.

f. At least 30 calendar days prior to initiating construction activities, the project proponents shall submit the names and qualifications of the biological monitor(s) for the proposed project for Service approval.

g. The Resident Engineer or their designee shall be responsible for implementing the conservation measures and Terms and Conditions of this biological opinion and shall be the point of contact for the project. The Resident Engineer or their designee shall maintain a copy of this biological opinion onsite whenever construction is taking place. Their name and telephone number shall be provided to the Service at least thirty (30) calendar days prior to groundbreaking at the project. Prior to ground breaking, the Resident Engineer must submit a letter to the Service verifying that they posses a copy of this biological opinion and have read the Terms and Conditions.

h. A Service-approved biologist(s) shall be onsite during any ground disturbing activities on Sherman Island. Prior to approval, the biologist(s) must submit a letter to the Service verifying that they possess a copy of this biological opinion and understand its Terms and Conditions. The biologist(s) will keep a copy of this biological opinion in their possession when onsite. The biologist(s) shall have the authority to stop any work, through communication with the Resident Engineer or their designee that may result in the take of a listed species. If the biologist(s) exercises this authority, the Service and the California Department of Fish and Game shall be notified by telephone and email within one (1) working day. The Service contact is Chris Nagano, Division Chief, Endangered Species Program at the Sacramento Fish and Wildlife Office at telephone (916) 414-6600 or by an email message at Chris_Nagano@fws.gov.

i. A Service-approved biological monitor(s) shall be onsite to monitor the initial ground disturbance activities on Sherman Island. The biological monitor shall perform a clearance survey immediately prior to the initial ground disturbance. The biological monitor shall also investigate areas of disturbed soil for signs of listed species within 30 minutes following the initial disturbance of that given area.

j. The biological monitor shall be required to report any take to the Service immediately by telephone at (916) 414-6600 and by email or written letter addressed to Chris Nagano, Division Chief, Endangered Species Program, within one (1) working day of the incident.

k. The Service considers all of the 33.5-acre action area on Sherman Island to be giant garter snake habitat. All ground-disturbing activities (including grubbing, clearing, and site compaction) occurring on Sherman Island shall be conducted between May 1 and October 1. If it appears that ground disturbing activity on Sherman Island may go beyond October 1, the project proponents shall contact the Service as soon as possible, but not later than September 15 of the year in question, to determine if additional measures are necessary to minimize take.

l. Giant garter snakes encountered in active construction areas shall be allowed to leave on their own volition. Caltrans shall contact the Service and the California Department of Fish and Game for direction if a giant garter snake does not leave on its own within one working day.

m. Runoff from dust control and oil and other chemicals used in other construction activities shall be retained in the construction site and prevented from flowing into areas containing giant garter snake habitat. The runoff shall be retained in the construction areas by creating small earthen berms, installing silt fences or hay-bale dikes, or implementing other measures on the construction site to prevent runoff from entering the habitat of the snake.

n. Any dewatered habitat shall remain dry for at least 15 consecutive days after April 15 and prior to excavating or filling of the dewatered habitat.

o. Erosion control structures will be installed concurrently with road construction. Erosion control structures will be constructed so runoff will be directed away from sensitive habitats. Tightly woven fiber netting (mesh size less than 0.25 inches) or similar material shall be used for erosion control or other purposes at the project site to minimize the potential for giant garter snakes from being trapped by the erosion control material. Coconut coir matting is an acceptable erosion control material. No plastic mono-filament matting shall be used for erosion control. The edge of the material shall be buried in the ground to prevent giant garter snakes from crawling underneath the material. Erosion control measures shall direct water flow into existing drainages or disperse water across vegetated areas in order to avoid concentrating water.

p. To the extent feasible, the project proponents shall confine clearing of vegetation and scraping, or digging, of soil to the minimal area necessary to facilitate construction activities.

q. To the maximum extent possible, night-time construction should be minimized.

3. The following Terms and Conditions implement Reasonable and Prudent Measure three (3):

   a. The following shall be implemented for staging, storage sites, vehicle parking areas, and access associated with the project:

      1. Contractors may independently seek off-site staging locations. Offsite staging locations will be subject to the requirements of resource agencies and permits will be the responsibility of the contractor.

      2. Caltrans will require as part of the construction contract that all contractors comply with the Act in the performance of the work as described in the project description of this biological opinion and conducted within the action area.

      3. If a staging, storage, access, or vehicle parking area that is in compliance with the Act is not available, the agency with jurisdiction and the contractor would be responsible for compliance with the Act.

   b. If requested, before, during, or upon completion of ground breaking and construction activities, Caltrans shall allow access by Service and/or California Department of Fish and Game personnel to the project site to inspect project effects to the delta smelt and giant garter snake, and their habitats.

Reporting Requirements

Observations of delta smelt, giant garter snakes, or of any listed or sensitive animal species shall be reported to the California Natural Diversity Data Base (CNDDB).

Any salvaged delta smelt specimens taken shall be properly preserved in accordance with the Natural History Museum of Los Angeles County's policy of accessioning (10% formalin in a quart jar or freezing). Information concerning how the specimen was taken, length of the interval between death and preservation, the environmental conditions, the incidental take permit number (81420-2008-F-1537), and any other relevant information shall be written on 100% rag content paper, with indelible ink, and included in the container with the specimen. Preserved specimens shall be delivered to the Service's Division of Law Enforcement at 2800 Cottage Way, Room W-2928, Sacramento, California 95825, (916) 414-6660.

Injured giant garter snakes shall be cared for by a licensed veterinarian or other qualified person such as the on-site biologist; dead individuals must be placed in a sealed plastic bag with the date, time, location of discovery, and the name of the person who found the animal; the carcass should be kept in a freezer; and held in a secure location. The Service and the California Department of Fish and Game will be notified within one (1) working day of the discovery of death or injury to a giant garter snake that occurs due to project related activities or is observed at

the project site. Notification will include the date, time, and location of the incident or of the finding of a dead or injured animal clearly indicated on a USGS 7.5 minute quadrangle and other maps at a finer scale, as requested by the Service, and any other pertinent information. The Service contacts are Chris Nagano, Division Chief, Endangered Species Program at the Sacramento Fish and Wildlife Office (916) 414-6600, and Dan Crum, Resident Agent-in-Charge of the Service's Law Enforcement Division at (916) 414-6660. The California Department of Fish and Game contact is Mr. Scott Wilson at telephone (707) 944-5563. Sightings of any listed or sensitive animal species should be reported to the California Natural Diversity Database of the California Department of Fish and Game

Caltrans shall submit a post-construction compliance report prepared by the on-site biologist to the Sacramento Fish and Wildlife Office within 60 calendar days following each year of construction or within 60 calendar days of any break in construction activity lasting more than 60 calendar days. This report shall detail (i) dates that construction occurred; (ii) pertinent information concerning the success of the project in meeting compensation and other conservation measures; (iii) an explanation of failure to meet such measures, if any; (iv) known project effects on the delta smelt and giant garter snake, if any; (v) occurrences of incidental take of either of these species; (vi) documentation of employee environmental education; and (vii) other pertinent information. The reports shall be addressed to the Coast-Bay Branch Chief of the Endangered Species Program, Sacramento Fish and Wildlife Office.

Caltrans shall report to the Service any information about take or suspected take of listed wildlife species not authorized by this biological opinion. Caltrans must notify the Service via email and telephone within 24 hours of receiving such information. Notification must include the date, time, location of the incident or of the finding of a dead or injured animal, and photographs of the specific animal. The individual animal shall be preserved, as appropriate, and held in a secure location until instructions are received from the Service regarding the disposition of the specimen or the Service takes custody of the specimen. The Service contacts are Chris Nagano, Division Chief, Endangered Species Program, Sacramento Fish and Wildlife Office at (916) 414-6600, and Resident Agent-in-Charge Dan Crum of the Service's Law Enforcement Division at (916) 414-6660.

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 that can be implemented to further the purposes of the Act, such as preservation of endangered species habitat, implementation of recovery actions, or development of information and data bases. We propose the following conservation recommendations:

1. Caltrans should assist the Service in implementing recovery actions identified in the recovery plan for the Sacramento-San Joaquin Delta native fishes.

2. Caltrans should consider participating in the planning for a regional habitat conservation plan for the delta smelt, giant garter snake, other listed species, and sensitive species.

3. Caltrans should consider establishing functioning preservation and creation conservation banking systems to further the conservation of the delta smelt, giant garter snake, and other listed species. It is possible that such banking systems could be utilized for other required mitigation (i.e., seasonal wetlands, riparian habitats, etc.) where appropriate. Efforts should be made to preserve habitat along roadways in association with wildlife crossings.

4. Roadways can constitute a major barrier to critical wildlife movement. Therefore, Caltans, should incorporate culverts, tunnels, or bridges on highways and other roadways that allow safe passage by giant garter snakes and other listed animals. Photographs, plans, and other information should be included in biological assessments if "wildlife friendly" crossings are incorporated into projects. Efforts should be made to establish upland culverts designed specifically for wildlife movement rather than accommodations for hydrology. Transportation agencies should also acknowledge the value of enhancing human safety by providing safe passage for wildlife in their early project design.

5. Caltrans should continue to pursue multifaceted compensation packages such as the one developed for the proposed U.S. Interstate 580/Isabel Avenue Interchange Construction Project (Service File # 1-1-07-F-0280) on future formal consultations with the Service.

6. Caltrans should continue to develop and implement their Early Statewide Biological Mitigation Planning Project that has been developed by the University of California at Davis, Road Ecology Center through Caltrans funding.

7. Caltrans should examine the use of natural fiber check dams enhanced with polyacrylamide as a BMP to control sediment discharge.

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

REINITIATION--CLOSING STATEMENT

This concludes formal consultation on the proposed Antioch Bridge Seismic Retrofit Project, Contra Costa and Sacramento Counties, California. As provided in 50 CFR §402.16 and in the terms and conditions of this biological opinion, reinitiation of formal consultation is required where discretionary Federal agency involvement or control over the action has been maintained (or is authorized by law) and if: (1) the final project design exceeds the described action area in the January 2009, Biological Assessment; (2) the amount or extent of incidental take is exceeded; (3) 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; (4) the agency action is

subsequently modified in a manner that causes an effect to the listed species or critical habitat that was not considered in this opinion; or (5) 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 operations causing such take must cease pending reinitiation.

If you have questions concerning this opinion on the proposed Antioch Bridge Seismic Retrofit Project, Contra Costa and Sacramento Counties, California, please contact John Cleckler or Ryan Olah at the letterhead address or at (916) 414-6600.

Sincerely,

for Susan K. Moore
Field Supervisor

cc:
Christopher States, Stuart Kirkham, California Department of Transportation, Oakland, CA
Scott Wilson, Melissa Escaron, California Department of Fish and Game, Yountville, CA
Carl. T. Hausner, David. H. Sulouff, Eleventh Coast Guard District, Alameda, CA
Dannas Berchtold, Greg Vaughn, Central Valley Regional Water Quality Control Board, Rancho Cordova, CA
Douglas Hampton, Monica Gutierrez, National Marine Fisheries Service, Sacramento, CA
Erin Foresman, Carolyn Mulvihill, U.S. Environmental Protection Agency, San Francisco, CA
Paul M. Maniccia, U.S. Army Corps of Engineers, Sacramento, CA

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FOUNDATION ANALYSIS REPORT
ANTIOCH BRIDGE SEISMIC RETROFIT PROJECT

Prepared for:
Bay Area Toll Authority (BATA)
and
CALIFORNIA DEPARTMENT OF TRANSPORTATION

Submitted by:

EARTH MECHANICS, INCORPORATED

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1.0 INTRODUCTION

This project was conducted under a contract (contractually known as Dumbarton and Antioch Toll Bridge Geotechnical Investigation) with the Bay Area Toll Authority (BATA), while the California Department of Transportation (Caltrans) provided technical oversight. The geotechnical investigation was conducted for the Dumbarton Toll Bridge and Antioch Toll Bridge separately, and a number of reports were prepared for each of the two bridges.

This report presents the results of foundation analyses undertaken by Earth Mechanics, Inc. (EMI) as part of larger geotechnical investigation for the seismic evaluation of the Antioch Toll Bridge in the San Joaquin/Sacramento River Delta of California. The materials covered in this report are primarily related to foundation evaluation, pile capacity estimates, and soil-structure interaction. While geology, subsurface conditions, and ground motion study are briefly discussed in this report, two separate reports have been prepared to document these subjects in details.

1.1 Background

The Antioch Bridge (officially named as the Senator John A. Nejedly Bridge) crosses the San Joaquin River linking the City of Oakley (southern) and the Sherman Island (northern), California. This 1.8 mile long bridge is signed as part of State Route 160. The location of the Antioch Bridge and photograph of the structure are shown in Figure 1-1. The bridge is formerly known as the San Joaquin River Bridge.

The current Antioch Toll Bridge was designed in the middle 1970's and the construction was completed in 1978, replacing the original 1926-era lift span structure. The bridge consists of the Main Channel crossing, South and North Approaches, and a slab structure in the north end. Unlike the other toll bridges in California, the Antioch Bridge has only one lane going in each direction. It has bicycle and pedestrian access. The superstructure is comprised of two steel girders resting on a concrete bent cap supported on two hollow concrete columns. While the Antioch Toll Bridge construction incorporated seismic resistant features as required by the post-1971 San Fernando earthquake codes, recent significant changes in seismic design practice prompted Caltrans to initiate vulnerability studies in 2004 (Caltrans, 2005). The studies were unable to conclusively determine the performance of the bridge during a design earthquake normally adopted for this kind of bridge. The studies found that a comprehensive geotechnical study was necessary to determine whether seismic retrofit work is needed for the bridge, thus initiating the onset of this project. The findings from this project provide necessary geotechnical data for the development of seismic retrofit strategy finalized in early 2009.

1.2 Scope of Work

The overall geotechnical investigation program conducted by EMI consists of the following three major elements for the Antioch Toll Bridge:

Geotechnical Site Characterization: A number of soil borings (both marine and on-land), CPT soundings (marine and on-land), geophysical measurements, in-situ testing, laboratory testing, subsurface interpretation, and characterization of engineering properties of soils are performed. Faulting study was also conducted to clarify the existence of Antioch Fault and the possibility of surface fault rupturing. The operation of the field program, findings from the in-situ and laboratory testing, Logs-of-Test Borings (LOTBs), the interpreted subsurface conditions and the faulting study are documented in an EMI report entitled "Geotechnical Site Characterization for Antioch Bridge Seismic Retrofit Project."

Ground Motion Study: The ground motion study includes probabilistic and deterministic seismic hazard analyses incorporating the 2007 Delta Risk Management Study by URS, development of reference rock motion criteria for the Safety Evaluation Earthquake (SEE), generation of spectrum compatible time histories for site response analyses, and kinematic soil-structure interaction analyses to develop ARS (Acceleration Response Spectrum) design curves and pier-specific kinematic time histories. The findings are documented in an EMI report is entitled "Ground Motion Study for Antioch Bridge Seismic Retrofit Project."

Foundation Analysis: Detailed analyses of the foundations are conducted. The analyses include characterizations of lateral soil supports (*p*-*y* curves), and axial soil supports (*t*-*z* and *q*-*u* curves) along the pile. Pile capacity evaluations are conducted by performing axial and lateral load-deformation analyses on a single pile. The pile groups are characterized by linearized 6×6 stiffness and mass matrices to be used in a global bridge model for seismic response evaluation. Liquefaction potential and associated settlement is also evaluated at susceptible locations. The results are provided in this report entitled "Foundation Analysis for Antioch Bridge Seismic Retrofit Project."

1.3 Organization of the Report

In addition to this introductory section, the report has been organized into the following sections:

- Section 2 – Local geology and geotechnical conditions are briefly described including idealized subsurface conditions along the bridge alignment and the soil profile and geotechnical soil parameters at individual pier locations;
- Section 3 – Site ground motion study is briefly summarized, which includes: development of ARS design curves, site response analyses and kinematic motions analyses for selected piers;
- Section 4 – The foundation system of the existing bridge is described, and its foundation performance is evaluated in terms of axial loading conditions and lateral

loading conditions. Liquefaction potential and associated settlement is evaluated at locations where loose sands are encountered. Soil support curves (*p-y*, *t-z*, and *q-u* curves) and pile capacities are provided;

- Section 5 – The condensed stiffness and mass matrices for each pier are presented according to soil-structure interaction analysis, and a verification study of our sub-structuring scheme on a selected pier is included;
- Section 6 – Our main conclusions are summarized.

FIGURE 1-1: LOCATION AND PHOTO OF ANTIOCH TOLL BRIDGE

2.0 SUBSURFACE CONDITIONS

This section presents a brief summary of local geology, idealized subsurface conditions, and soil strata for each pier location according to site investigation results along the bridge alignment in order to support the foundation analyses of the Antioch Bridge. Detailed descriptions for the field program including soil boring, geophysical testing, laboratory testing, geotechnical interpretation, and logs of test boring, are provided in a dedicated report entitled "Geotechnical Site Characterization for Antioch Bridge Seismic Retrofit Project."

2.1 Local Geology

The Antioch Toll Bridge spans the San Joaquin River along the eastern margin of the California Coast Range, a geomorphic province characterized by northwest-southeast trending ranges and valleys formed as a result of ongoing motion along the Pacific-North American plate boundary. The San Joaquin River flows north from its headwaters in the southern Sierra Nevada range and turns to the west where it joins the Sacramento River, 4 miles west of the bridge. The uplifted Coast Ranges west of the San Joaquin/Sacramento River confluence have created a unique topographic condition resulting in an inverted delta, a deposit fan forming as the river drops much of its sediment in a low-lying inland valley. The bedrock in the Antioch Bridge vicinity includes folded and faulted late Jurassic to Tertiary-aged rocks of the Great Valley Group (east) and the Franciscan Complex (west). The bedrock is overlain by channelized sands and gravels eroded from underlying bedrock, fine-grained deltaic sediments at the channel base, and up to 40' of peaty deposits north of the channel.

The Antioch Toll Bridge is located in the northeast corner of the San Francisco Bay region, whose seismicity is controlled by the northwest trending, right-lateral San Andreas fault system, comprised of several major and minor fault strands as shown in Figure 2-1 (source: http://sfgeo.wr.usgs.gov). A total of 15 earthquakes of moment magnitude (M) $\geq$ 6.0 occurring in this area from 1850 to present are associated with the San Andreas fault system. The sub-parallel San Andreas and Hayward fault zones strike ~N35°W to N37°W and cut through the crust at variably high angles. The San Andreas fault on the San Francisco Peninsula is relatively young strand that has undergone ~15 miles of right-lateral offset in the past 3.3-1.3 Ma. The Hayward fault system, including the Hayward, Calaveras, Rodgers Creek, and Healdsburg faults, has undergone ~ 65 miles of cumulative offset in the past 12 Ma.

Seismicity of the Antioch Toll Bridge is also affected by smaller local faults such as the Greenville, the Pittsburg/Kirby Hills, and the Midland faults. A more detailed description about the seismic source of the site can be found in Section 3.1. The seismic sources considered in the seismic hazard study do not include Antioch fault as it is not considered active by several researchers. The Antioch fault has been removed from Alquist-Priolo Special Studies Zone, and Caltrans has removed the Antioch fault from the updated seismic hazard map. Fault rupturing across the Antioch Bridge was evaluated, and it was determined that possibility of this event is highly unlikely.

2.2 Idealized Subsurface Conditions

As part of the geotechnical investigation program, EMI conducted extensive site explorations in the marine and on-land areas for the Antioch Bridge, with borings and CPT probing penetrating to depths of about 210 ft below the modern San Joaquin channel. A number of earlier investigations were also conducted prior to EMI's exploration program. A separate site characterization report has been prepared for the project documenting geology, site investigation, field and laboratory testing, and interpretation of geotechnical conditions along the bridge. The materials and sediments underlying the bridge, which belong to the late Pleistocene to Holocene deposition, is a typical of the San Joaquin/Sacramento River Delta geology. According to the current investigation results and previous work, the in-situ lithological units can be interpreted and grouped into the following principal strata:

- Artificial Fill – Approximately 30 feet of loose, fine-grained, well-graded sand present at the top of the south side of the bridge;
- Loose Sand – Loose silty sand and sand with peat existing in the southern channel area from elevation +5 to -50 ft;
- Clayey Peat – Laterally continuous soft clay and peat present north of the main channel from elevation +5 to -60 ft;
- Medium Sand – Laterally continuous, medium dense, poorly-graded sand present about at the elevation -80 ft in the main channel and -20 ft in the south approach and the north end of slab bridge span, with thickness varying from 10 to 60 feet ;
- Stiff Clay – Discontinuous thin lenses of interbedded firm to stiff, plastic clay and medium dense, clayey sand extending laterally from the southern abutment structure to the vicinity of Piers 17 and 18 from elevation -30 to -40 ft;
- Dense Sand – Laterally continuous, dense to very dense interbedded sands, gravelly sands and sandy gravels present from elevation -20 to -100 ft;
- Hard Clay – Hard to stiff, yellowish brown to olive gray silty clay (Montezuma Formation) found continuously below the elevation of -100 to -120 ft with thickness greater than 100 feet;

Figure 2-2 presents the idealized subsurface soil profile developed along the bridge. Within the limits of the bridge alignment, the subsurface conditions underlying the site are rather uniform and flat-lying in the region north of the main channel, with considerable variation in the area beneath the South Approach span.

2.3 Liquefaction Potential

Liquefaction is defined as the transformation of a geo-medium from a solid to a liquefied state due to increased pore water pressure and reduced shear strength. Liquefaction often takes place in loose to medium silty sands or sands capped by impermeable sediment seams below water table and at the relatively shallow depth (< 50 ft), when subjected to strong vibrations such as earthquakes. The denseness of a granular material can be easily identified by the SPT or CPT sounding. As referred to the idealized soil stratification profile of Figure 2-2, the liquefaction susceptible regions are

located at the southern part of the bridge from Abutment 1 to Pier 19 as well as near the northern half of the slab bridge span from Pier 47 to Abutment 71. Liquefaction assessment is performed for these pier locations, and the analysis results are presented in Section 4.2.

2.4 Idealized Soil Strata and Property Data for Each Pier

As described in the following sections, various foundation analyses were conducted along the bridge, which required the idealized soil profile and engineering property data at each pier location. Table 2-1 presents the idealized soil properties adopted for the different lithological units at the site. The idealized soil strata at all Antioch Bridge and slab bridge piers are presented in Appendix A, in which engineering soil properties used and foundation data are also included.

TABLE 2-1: IDEALIZED SOIL PROPERTIES ALONG THE BRIDGE

Soil Profile I: South Approach: Abutment P01 (Sta. 134+00)

Soil Layer	Top Elevation (ft)	γ (pcf)	c (psf)	ε_{50}	ϕ (°)	k (pci)	V_s (fps)
Fill (Sand)	+20	115	-	-	32	70[1]	350~450
Medium Sand	+5	120	-	-	33	90[1]/60[2]	450~800
Dense Sand	-35	125	-	-	36	90[2]	800~1000
Hard Clay	-103	125	4000	0.005	-	-	1000~1200

Note: [1] above GWT; [2] below GWT.

Soil Profile II: South Approach: Pier P02 ~ Pier P07 (Sta. 135+00 ~ 146+00)

Soil Layer	Top Elevation (ft)	γ (pcf)	c (psf)	ε_{50}	ϕ (°)	k (pci)	V_s (fps)
Loose Sand[3]	+8 ~ +10	115	-	-	30	45[1]	300~400
Medium Sand[4]	+2	120	-	-	32	70[1]/50[2]	400~500
Soft Clay	-10 ~ +2	115	600	0.015	-	-	300~400
Medium Sand[5]	-26 ~ -12	120	-	-	33	60[2]	400~700
Dense Sand[6]	-48 ~ -34	125~128	-	-	36~38	90~115[2]	700~1000
Hard Clay	-103 ~ -102	125	4000	0.005	-	-	1000~1200

Note: [1] above GWT; [2] below GWT; [3] disappears near Pier 07; [4] only apperas near Pier 02;
[5] a soft clay sub-layer 3'~5' thick appears between Pier 02 and Pier 05 ;
[6] a firm clay sub-layer 4'~14' thick appears between Pier 05 and Pier 07 (See below for their properties).

Soil Profile III: South Approach: Pier P08 ~ Pier P16 (Sta. 147+00 ~ 164+00)

Soil Layer	Top Elevation (ft)	γ (pcf)	c (psf)	ε_{50}	ϕ (°)	k (pci)	V_s (fps)
Loose Sand	-27 ~ -16	115	-	-	30	33	300~450
Medium Sand	-37 ~ -18	120	-	-	33	60	450~700
Firm Clay	-48 ~ -28	120	1000	0.01	-	-	500~600
Dense Sand	-54 ~ -43	128	-	-	38	115	600~1000
Hard Clay	-120 ~ -98	125	4000	0.005	-	-	1000~1200

Soil Profile IV: South Approach: Pier P08 ~ Pier P16 (Sta. 147+00 ~ 164+00)

Soil Layer	Top Elevation (ft)	γ (pcf)	c (psf)	ε_{50}	ϕ (°)	k (pci)	V_s (fps)
Loose Sand	-40 ~ -34	115	-	-	30	33	300~400
Medium Sand	-60 ~ -37	120	-	-	34	70	400~700
Dense Sand	-86 ~ -72	128	-	-	38	115	600~1000
Hard Clay	-117 ~ -107	125	4000	0.005	-	-	1000~1200

Soil Profile V: Main Channel Pier P20 ~ North Approach Pier 40 (Sta. 175+00 ~ 219+00)

Soil Layer	Top Elevation (ft)	γ (pcf)	c (psf)	ε_{50}	ϕ (°)	k (pci)	V_s (fps)
Soft Clay	-46 ~ -9	110	300	0.02	-	-	250~450
Medium Sand	-79 ~ -63	120	-	-	34	70	500~700
Dense Sand[1]	-101 ~ -78	125~128	-	-	36~38	90~115	700~1000
Hard Clay	-115 ~ -98	125	4000	0.005	-	-	900~1200

Note: [1] does not appear between Pier 27 and Pier 31.

TABLE 2-1: IDEALIZED SOIL PROPERTIES ALONG THE BRIDGE (Cont.)

Soil Profile VI: North Approach Abutment 41 ~ Slab Bridge Pier 56 (Sta. 220+00 ~ 224+50)

Soil Layer	Top Elevation (ft)	γ (pcf)	c (psf)	ε_{50}	ϕ (°)	k (pci)	V_s (fps)
Soft Clay[1]	-11 ~ -7	110	300	0.02	-	-	250~450
Medium Sand	-69 ~ -30	120	-	-	34	70	500~700
Dense Sand	-85 ~ -81	128	-	-	38	115	700~900
Hard Clay	-109 ~ -100	125	4000	0.005	-	-	900~1200

Note: [1] a medium sand pocket 8' thick appears between Pier 47 and Pier 50.

Soil Profile VII: Slab Bridge: Pier 57 ~ Abut 71 (Sta. 224+50 ~ 228+00)

Soil Layer	Top Elevation (ft)	γ (pcf)	c (psf)	ε_{50}	ϕ (°)	k (pci)	V_s (fps)
Soft Clay	-13 ~ -12	110	300	0.02	-	-	250~350
Medium Sand[1]	-25 ~ -23	120	-	-	34	70	400~700
Dense Sand	-80 ~ -77	128	-	-	38	115	700~900
Hard Clay	-108 ~ -100	125	4000	0.005	-	-	900~1200

Note: [1] a soft clay pocket 5' thick appears between Pier 57 and Pier 58.

FIGURE 2-1: MAJOR FAULT SYSTEM IN SAN FRANCISCO BAY AREA

FIGURE 2-2: IDEALIZED SOIL PROFILE ALONG ANTIOCH BRIDGE

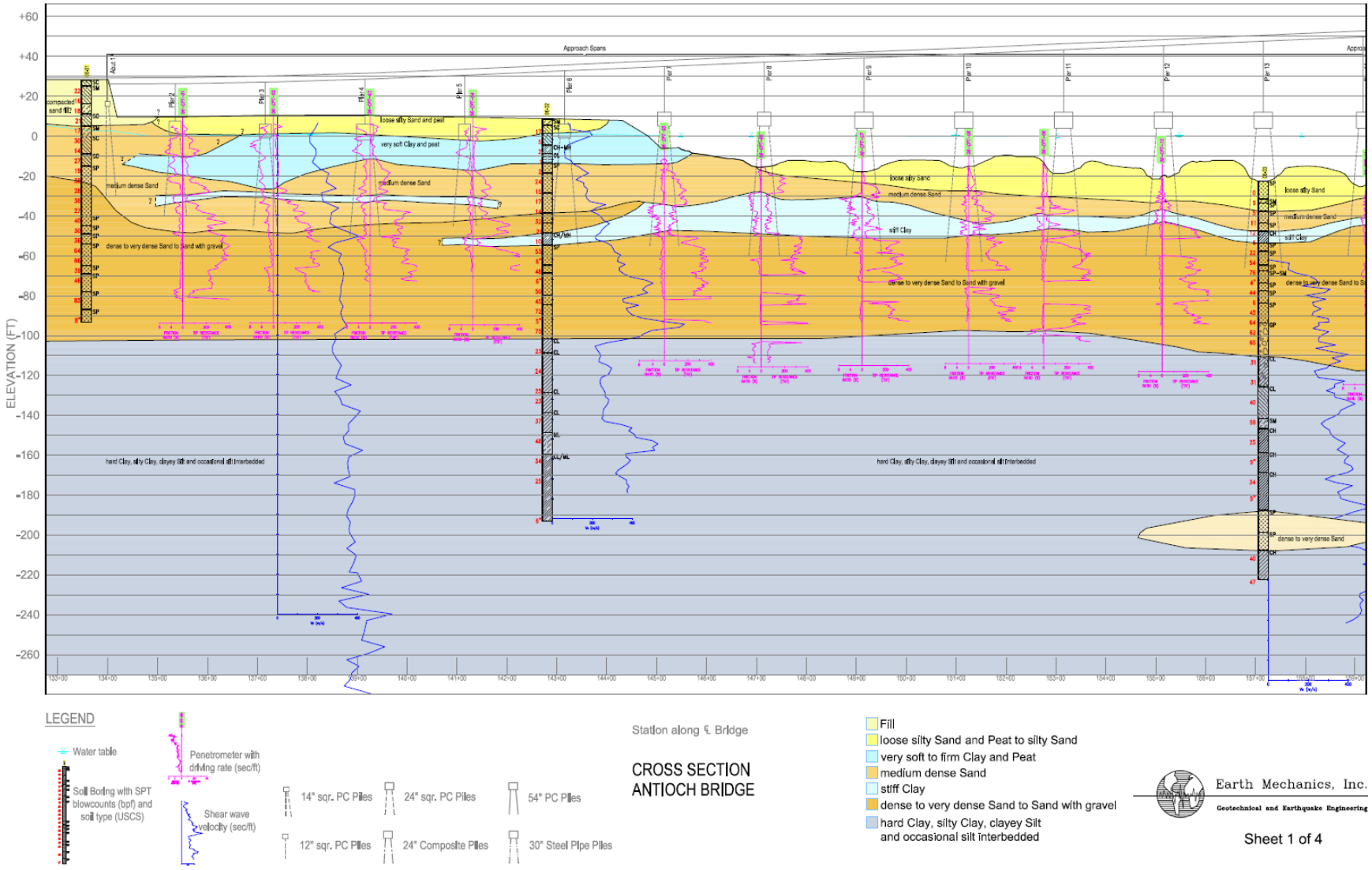


FIGURE 2-2: IDEALIZED SOIL PROFILE ALONG ANTIOCH BRIDGE (Cont.)

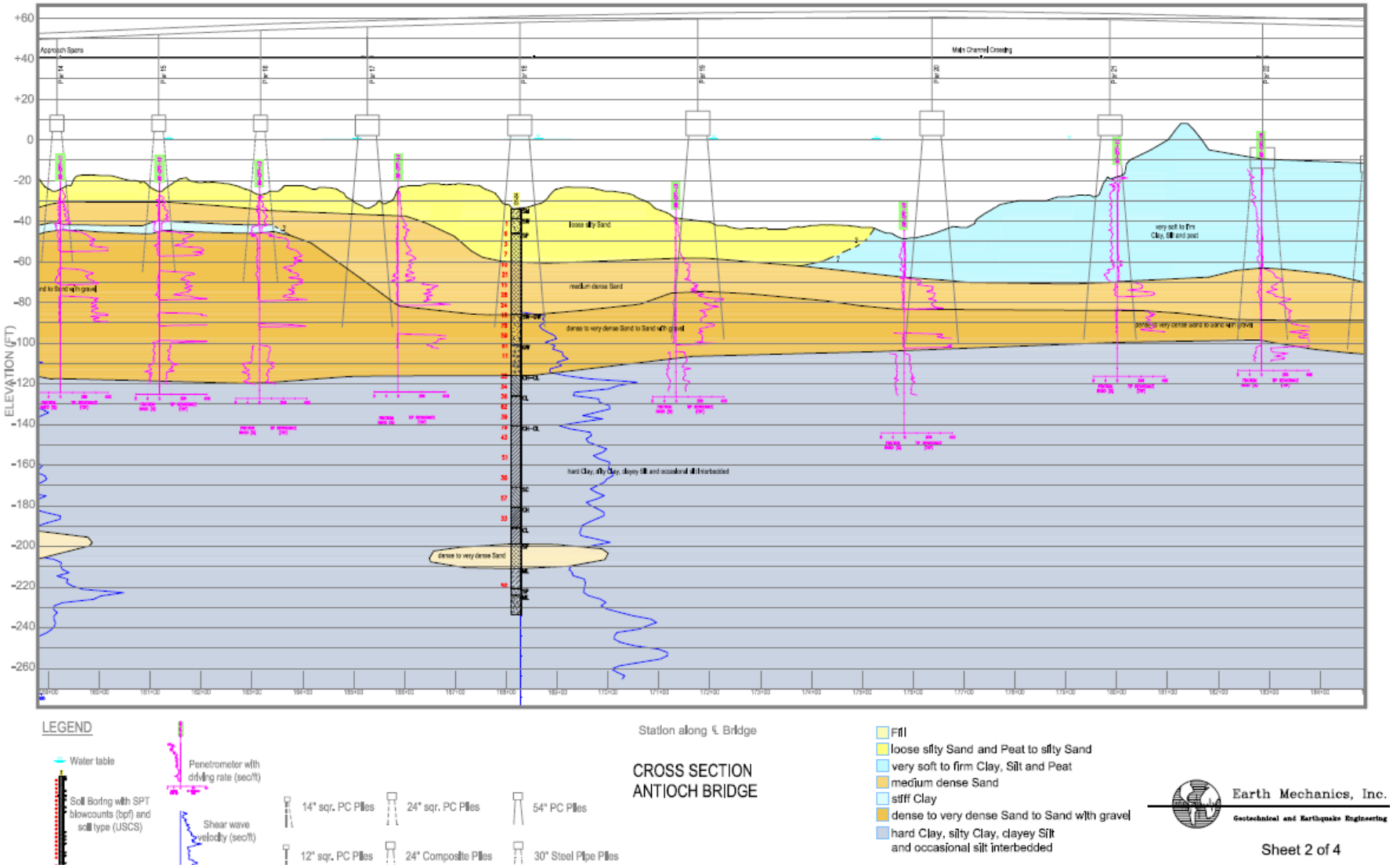


FIGURE 2-2: IDEALIZED SOIL PROFILE ALONG ANTIOCH BRIDGE (Cont.)

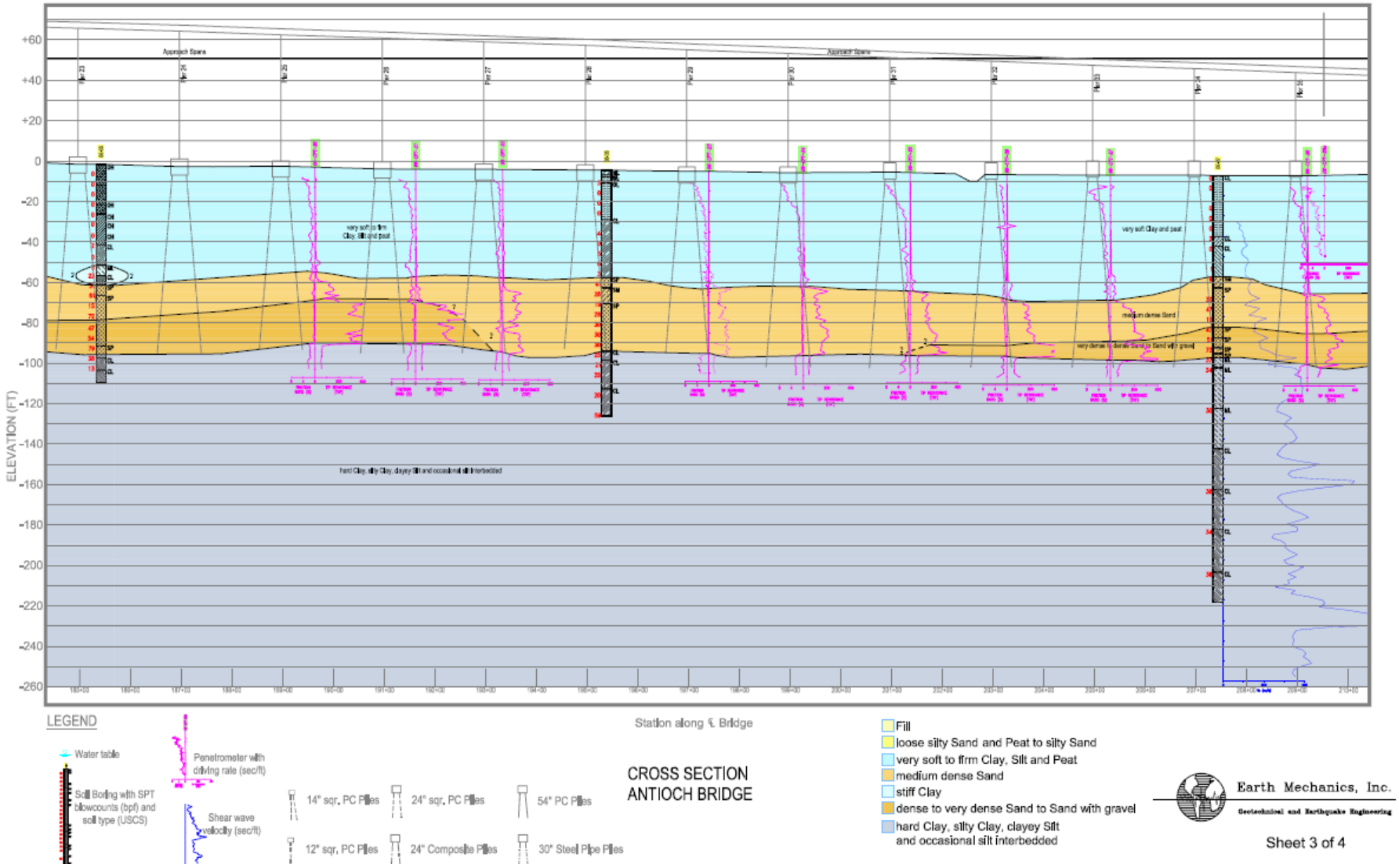
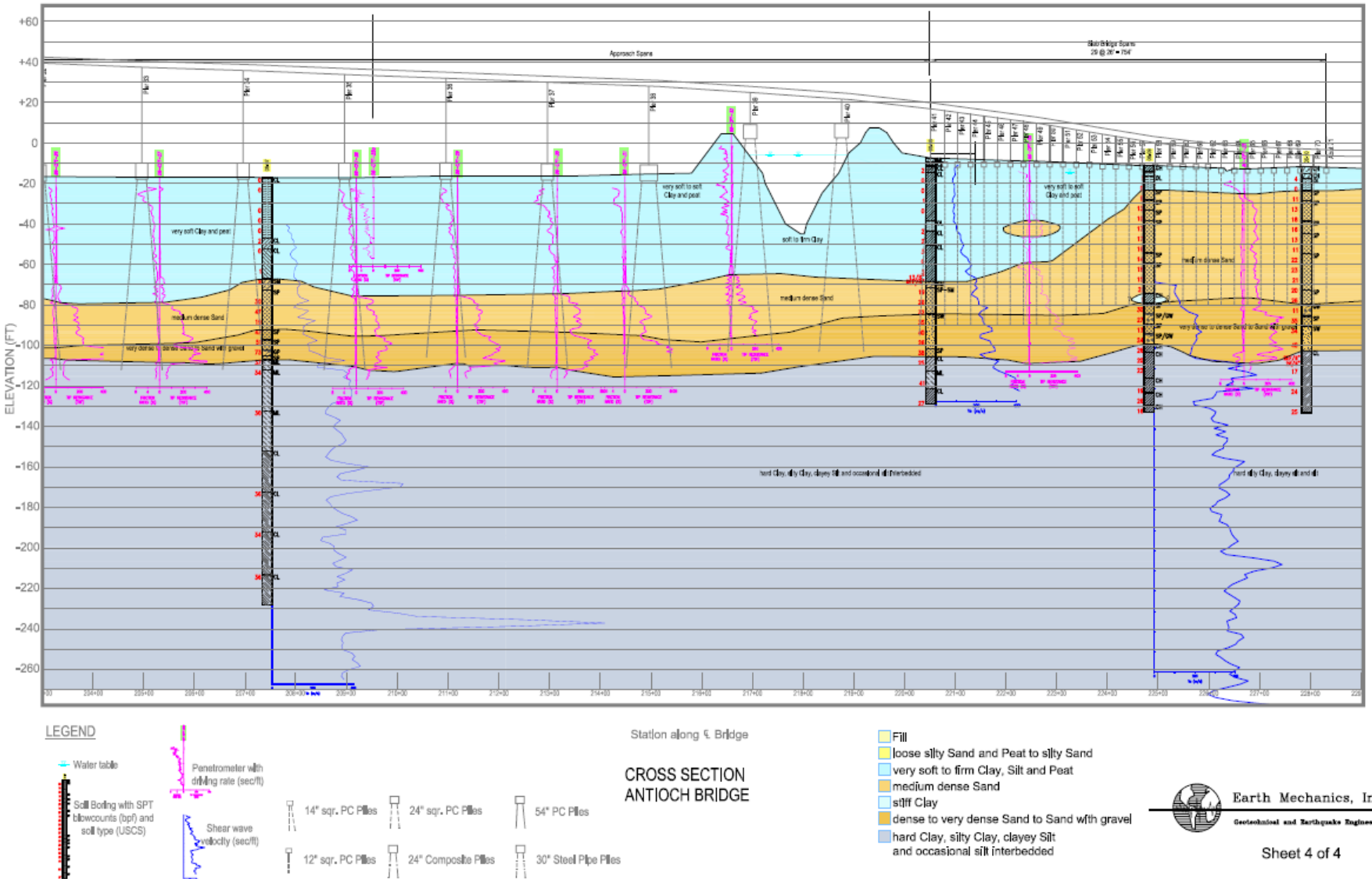


FIGURE 2-2: IDEALIZED SOIL PROFILE ALONG ANTIOCH BRIDGE (Cont.)



3.0 GROUND MOTIONS

This section presents a brief summary of ground motion study work. Details can be found in a separate ground motion report entitled "Ground Motion Study for Antioch Bridge Seismic Retrofit Project," which has been prepared for documenting probabilistic and deterministic seismic hazard study, spectrum-compatible earthquake time histories, site response analysis, and soil-structure interaction analysis in depth with supporting tables and illustrations.

3.1 Seismic Hazard Study

The analytical technique adopted for the probabilistic seismic hazard analysis (PSHA) follows the original work developed by Cornell (1968), except with the extension considering both the aleatory variability and the epistemic uncertainty of ground motion prediction. The site relative to the major faults in the region is shown in Figure 3-1, and the local seismic sources in the delta area are shown in Figure 3-2. The bridge is located about 74 km east of the San Andreas fault, 16 km east of the Greenville fault, and 15 km east of the Pittsburg/Kirby Hills fault. The Midland fault dips toward the site, with the shortest distance to the site at 11 km. For the delta region, the source characterization developed by URS (2007) for the Delta Risk Management Study was adopted, while for the other major faults, the seismic source characterization was based on the 2003 USGS Working Group on Earthquake Probabilities in Northern California (WG 2003).

For the magnitude density function describing how the fault slip-rate is distributed in different size earthquakes, the characteristic model (Youngs and Coppersmith 1995) was used for major faults, and Y&C model with a weight of 0.7 and a normal distribution with a weight of 0.3 was adopted for the faults in the delta region. The rupture dimension model is based on the relations for fault area and fault width (Wells and Coppersmith 1994) for all source types. Five attenuation relationships developed as part of PEER Next Generation Attenuation (NGA) program were used in the probabilistic seismic hazard analysis. These attenuation relations were made for a spectral damping of 5% and adjusted to account for near-fault directivity effects. The near-fault directivity effects were based on a modified form of the Somerville et al. (1997) fault-rupture directivity model (as described in Abrahamson, 2000), comprising two period-dependent scaling factors: one dealing with the increase in shaking intensity in the average horizontal component and another reflecting the directional nature of the shaking intensity.

Uniform hazard spectra (UHS) at six return periods (100-, 300-, 475-, 1,000-, 1,500- and 2,000-years) were then computed, including the fault normal (FN) and fault parallel (FP). Figure 3-3 shows a series of uniform hazard spectra for the FN component, as well as the result of deterministic analyses conducted for the Southern Midland fault using 50th percentile (mean) and 84th percentile (mean plus one standard deviation). Vertical spectrum was developed from a V/H ratio applied to the average of the fault normal and fault parallel components.

From several discussions with Caltrans and the Seismic Peer Review Panel for the toll bridges, the 1,000-year return period ground motion was considered appropriate and selected as the Safety Evaluation Earthquake (SEE) for seismic retrofit evaluation of the Antioch Bridge. Figure 3-4 presents the reference rock spectra for the SEE scenario showing the fault normal (FN), fault parallel (FP), and vertical components.

3.2 Spectrum Compatible Time Histories

Seven sets of spectrum compatible time histories were developed by modifying seed motions (usually actual earthquake records) so that their spectra are similar to the SEE reference rock spectra. Various methods have been developed to perform the spectrum matching. A commonly used method adjusts the Fourier amplitude spectrum based on the ratio of the target response spectrum to the time history response spectrum while keeping the Fourier phase of the reference history fixed. An alternative approach adjusts the time history in the time domain by adding wavelets to the reference time history which used in this project.

As part of the spectral matching procedure, a baseline correction was also applied to the ground motions in acceleration, velocity, and displacement. The baseline is computed by fitting the displacement time history to a high order polynomial (order 4 to 7) and excluding the constant and linear terms. The second derivative of this displacement baseline is computed and it is subtracted from the acceleration ground motion.

The following are a summary of seven seed motions that have been used to generate spectrum-compatible time histories:

- Set 1: 1989 Loma Prieta Earthquake (M=6.9), Saratoga – Aloha Ave at 13.0 km
- Set 2: 1987 Superstition Hill Earthquake (M=6.3), Wildlife Liquefaction Array at 24.7 km
- Set 3: 1987 Whittier Earthquake (M=6.0), Northridge-Saticoy St. at 39.8 km
- Set 4: 1979 Imperial Valley Earthquake (M=6.5), EC CO Center FF at 7.6 km
- Set 5: 1979 Imperial Valley Earthquake (M=6.5), Calexico Fire Station at 10.6 km
- Set 6: 1994 Northridge Earthquake (M=6.7), Century City, LACC at 25.7 km
- Set 7: 1981 Taiwan Earthquake (M=6.3), SMART1 M07 at 21.0 km

3.3 Seismic Response and Kinematic SSI Analysis

For the development of ARS design criteria, six representative piers were selected to conduct site response and kinematic soil-pile interaction analyses. The six selected piers are: South Approach Piers 03 and 12 (20"×20" square concrete piles, the former with a buried pile cap and the latter with a cantilevered one); Main Channel Piers 19 and 21 (54-inch diameter concrete hollow piles with a long cantilever pile length above mud-line); North Approach Piers 30 (20"×20" square concrete

piles with a buried pile cap) and Pier 39 (30-inch steel pipe piles with a cantilevered portion above mud-line). The exterior piles for each of the six selected piers are highly battered outward.

Small-strain shear modulus G_{max} is best estimated from shear wave velocity values that are measured in the field and by using the relationship of $G_{max} = \rho V_s^2$, where ρ is mass density and V_s is shear wave velocity. Soil dynamic properties in terms of normalized shear modulus and damping curves have been studied by many researchers. For the site response analyses, we adopted the Seed et al. (1986) relationship for sand and the Vucetic and Dobry (1991) relationship for clays. To deal with potential variations in the determination of in situ soil properties, the following parametric studies were considered: 1) the best-estimate case established from the down-hole shear wave velocity measurements; 2) a lower bound case; and 3) an upper bound case. Scaling factors of 0.75 and 1.25 were used as multiplication factors on the best-estimate shear-wave velocity for lower and upper bound scenarios.

Site response analyses were conducted using the computer program SHAKE91 (Idriss and Sun, 1992), an equivalent linear analysis. The program SHAKE91 has been used for solving one-dimensional shear wave propagation problems for three decades. Engineers have accumulated knowledge from the performance of SHAKE in predicting ground response during earthquakes. To avoid an unrealistic prediction of free-field motion for a long soil column, a relatively short soil column was used for our site response analyses. A transmitting boundary was selected near Elevation (El.) -200 feet where an average shear wave velocity of 1200 feet per second (366 m/sec) is anticipated, which was a controlling parameter in the NGA attenuation models.

To rigorously develop the design response spectra for the pile-supported structure, soil-pile interaction was considered. The method is based on a linear theory making use of the sub-structuring procedure (see Section 5 for detail). The first step involved linearization of *p-y* curves by performing a lateral pushover analysis of a single pile to a representative displacement level expected during the earthquake. A pile foundation model was then created in which each pile was supported on elastic soil springs that were excited by depth-varying, free-field motions computed from the site response analyses. Sub-structuring was performed to compute resultant forces acting at the pile-cap level. The resultant forces were divided by the foundation stiffness to result in so-called kinematic motions. The kinematic motions formed the basis for development of ARS design curves for the bridge structure. The kinematic motion is calculated at the pile cap level and implicitly contains the statically condensed forces transmitted from the ground to the superstructure along the entire embedded pile length. Therefore, the effects of the depth-varying shaking intensity in the soil column, the depth-varying soil stiffnesses, and the pile properties are included in the solution. The following pile properties were used in conducting kinematic soil-pile interaction analyses (also see Section 5.3):

- 54-inch diameter concrete piles (Main Channel Piers 17 ~ 21)
  Effective pile EI = 8.47×10^{11} lb-in^2. (Infilled section)
  Effective pile EI = 6.44×10^{11} lb-in^2. (Hollow section)
- 30-inch diameter steel pipe piles (Piers 39,40)
  Effective pile EI = 2.35×10^{11} lb-in^2.
- 14-inch square concrete piles (Abutment 1 and Pier 41)
  Effective pile EI = 6.95×10^{9} lb-in^2.

- 24-inch square concrete piles (the rest of bridge piers)
  Effective pile EI = 6.07×10^{10} lb-in^2.
- 12-inch square concrete piles (slab bridge piers)
  Effective pile EI = 3.11×10^{9} lb-in^2.

A fixed pile head condition was assumed in all the cases. The analyses were conducted with the in-house computer program KIPS, which is dedicated to performing kinematic soil-pile interaction analyses (Earth Mechanics, Inc., 1999). Considering seven motion sets and three levels of shear wave velocity, 21 kinematic spectra (spectral accelerations and displacements) for each selected pier were computed, from which their mean and mean plus one standard deviation spectra were then obtained.

3.4 ARS Design Curves

The shape of response spectra as obtained from the kinematic soil-pile interaction analyses sometimes contains multiple peaks and valleys. For practical use and simplicity for the design process, it was decided that the final ARS recommendations should be constrained by a well-behaved ARS curve shape for both spectral acceleration and displacement (i.e., the final ARS curves should be smoothed-out). Discussions with the structural designers led to a decision to keep a minimum number of ARS design curves for the response spectrum analyses. From a review of the kinematic spectra from the six piers, it appears that three sets of ARS curves would be adequate to cover horizontal seismic loading for the entire bridge:

- ARS Curve 1: Recommended for design of the South Approach piers (1~16), or the entire Antioch Bridge at all piers as the most simplified but the most conservative design basis
- ARS Curve 2: Recommended for designing the Main Channel piers (17~21), representing 54-inch diameter concrete hollow piles with a long cantilever pile extending above mud-line
- ARS Curve 3: Recommended for designing the North Approach piers (22~41) founded on smaller piles driven through the very soft peat layer

For the vertical spectrum, we recommend using the reference vertical motion spectrum from PSHA without further site response analysis. The recommended SEE design spectra for 5 percent damping are presented on Figure 3-5.

FIGURE 3-1: FAULT MAP AROUND PROJECT SITE (RED STARS FOR THE SITE)

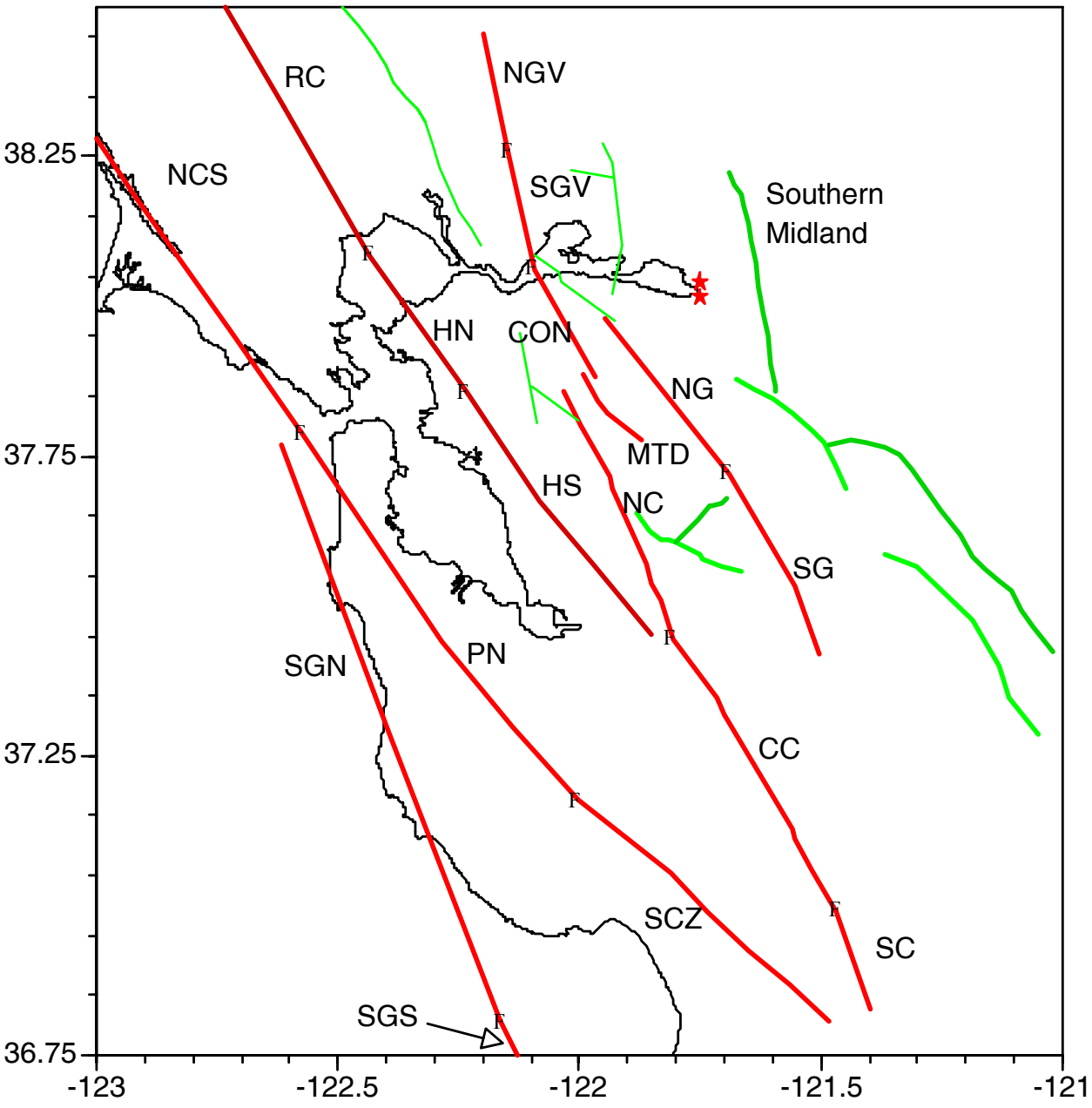


FIGURE 3-2: SEISMIC SOURCES IN THE DELTA REGION (RED FAULTS-WG03; OTHERS- URS,2007)

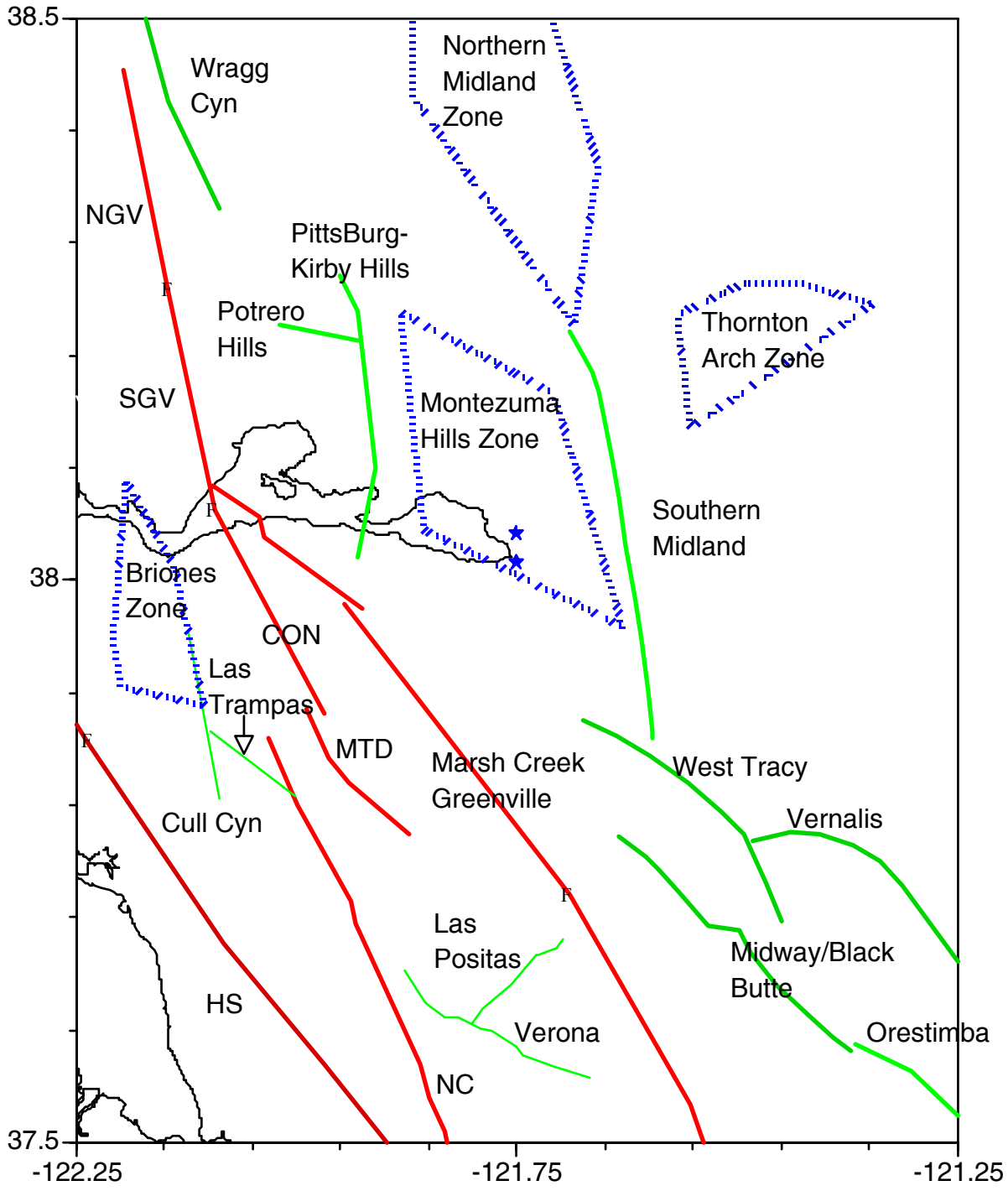


FIGURE 3-3: UNIFORM HAZARD SPECTRA AND MCE SPECTRA (SPECTRAL ACCELERATION)

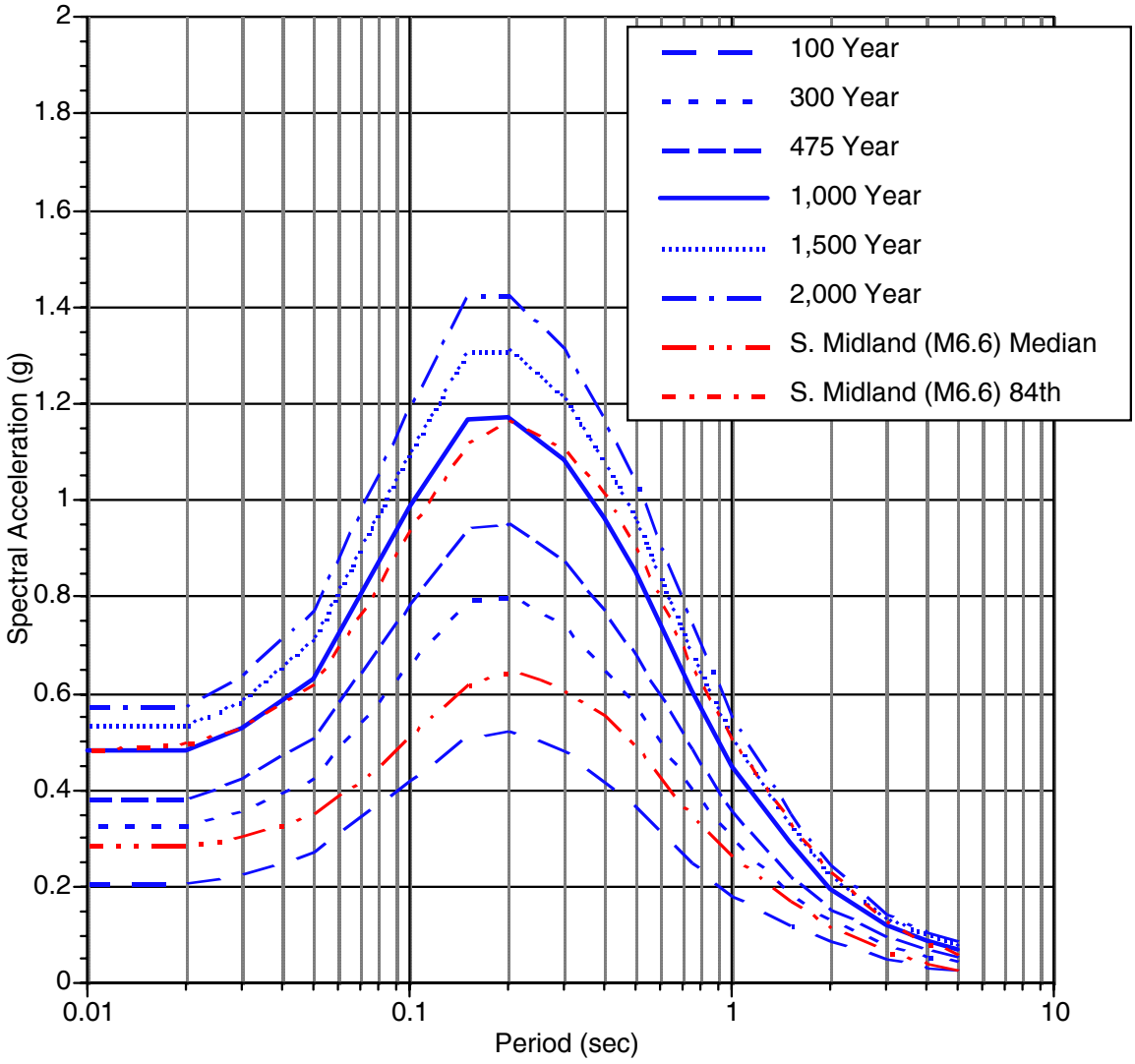


FIGURE 3-4: REFERENCE ROCK SPECTRA FOR THE SAFETY EVALUATION EARTHQUAKE

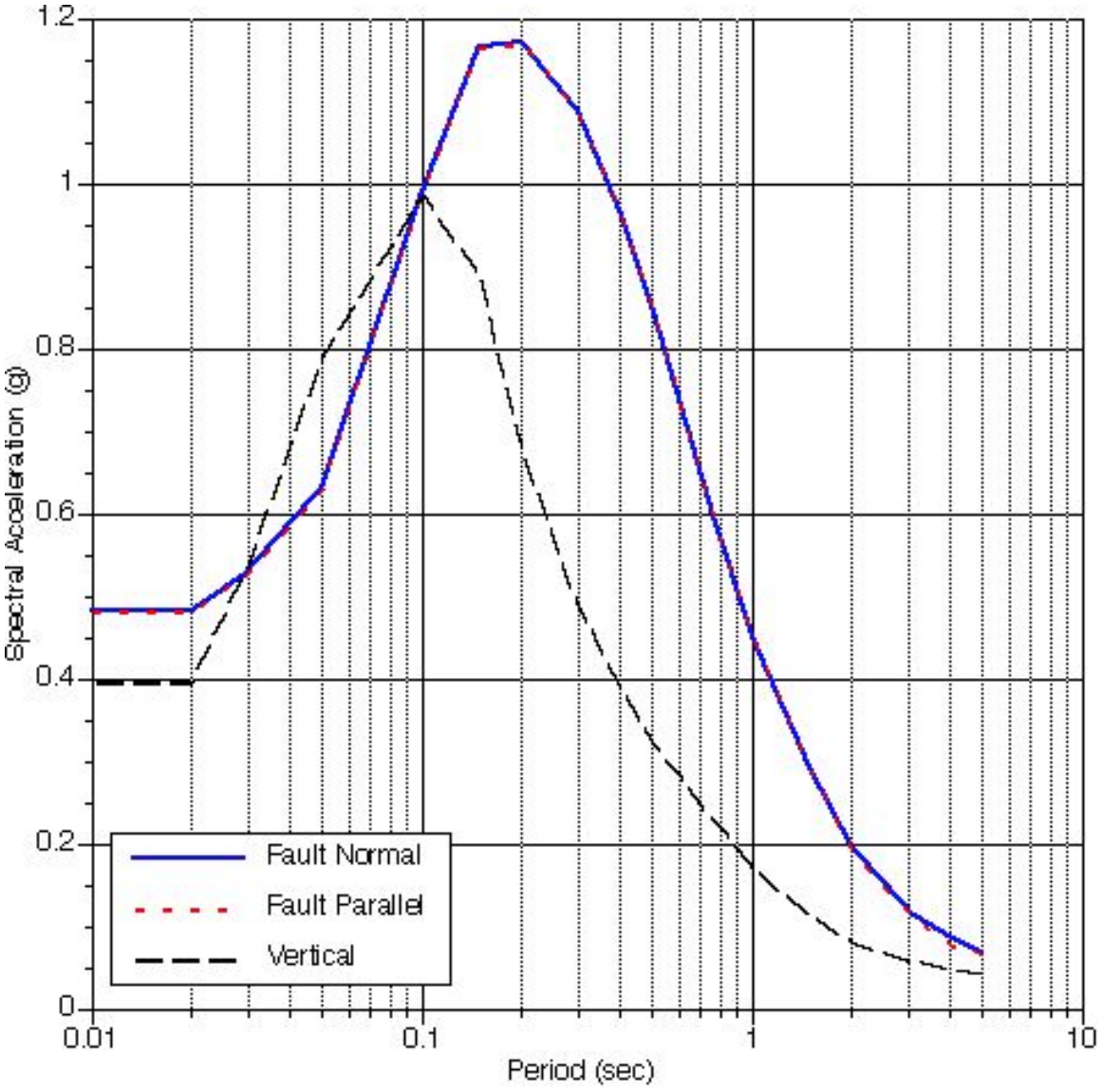
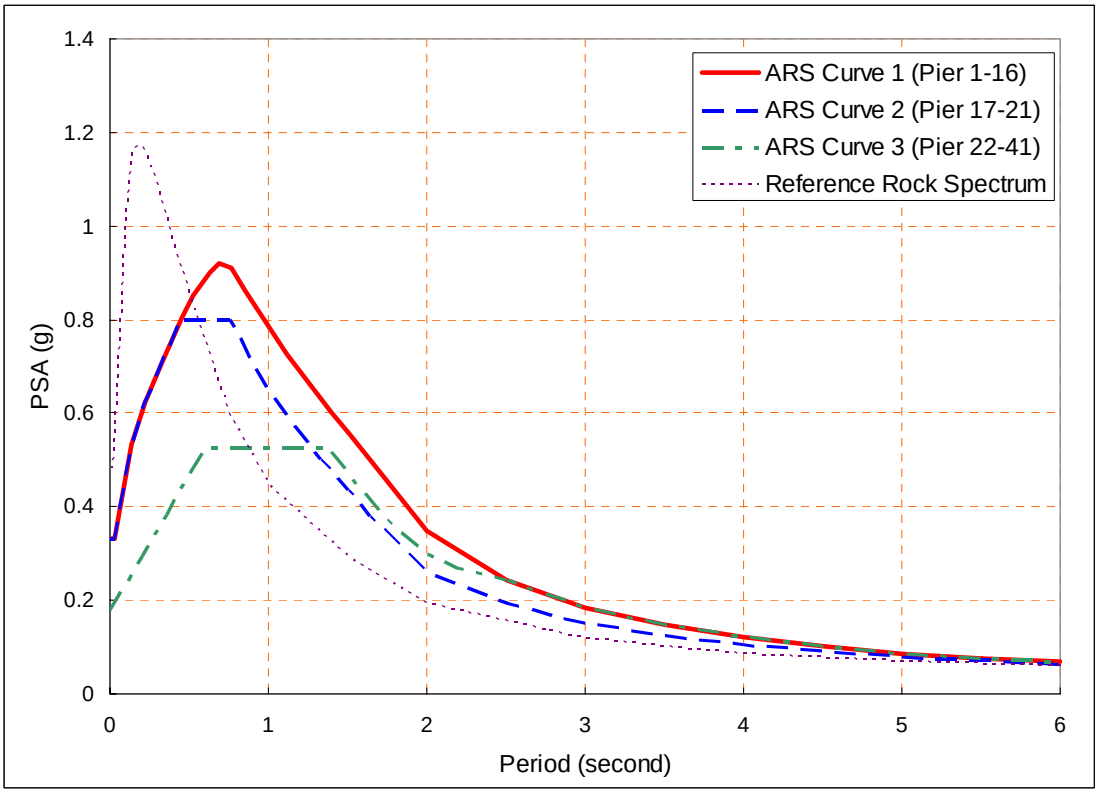
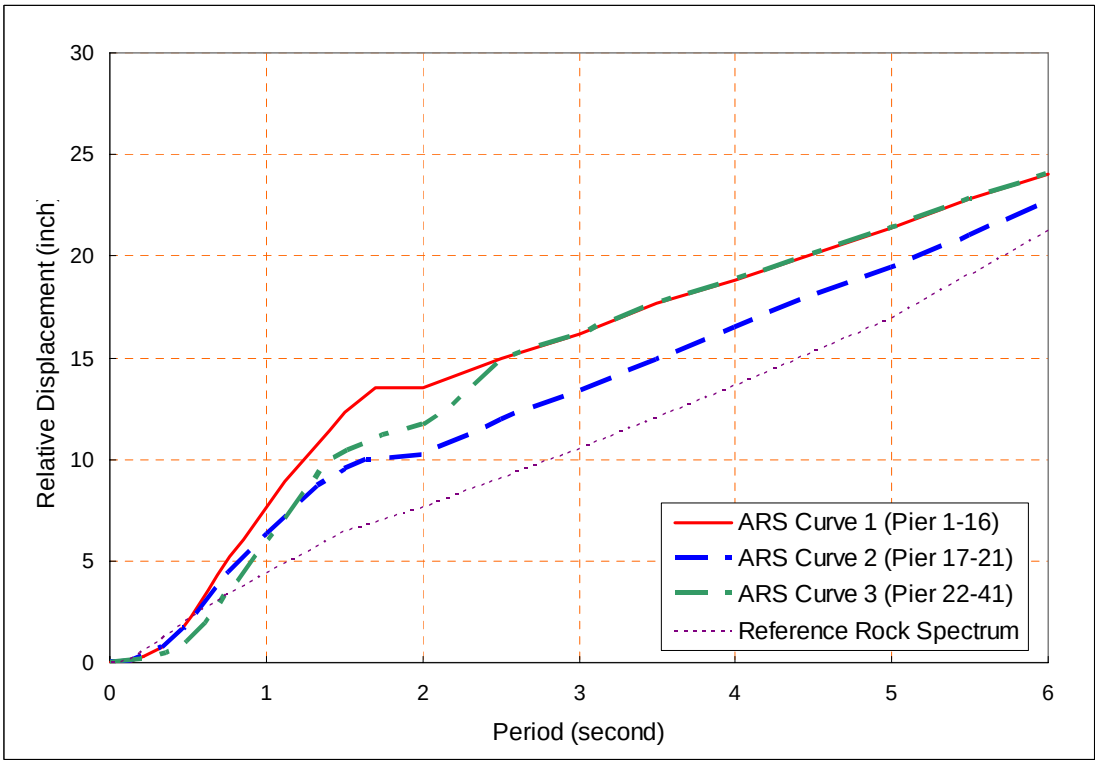


FIGURE 3-5: ARS DESIGN CURVES FOR SAFETY EVALUATION EARTHQUAKE (SEE)





4.0 FOUNDATION EVALUATION

This section presents the description of foundations along the bridge, and the important issues on evaluation of these foundations in terms of axial loading conditions and lateral loading conditions. Liquefaction potential and associated settlement is evaluated at potentially susceptible locations. In addition, soil support characteristics depicting *p-y*, *t-z*, and *q-u* curves for individual pile are tabulated which can be used for pushover analyses and estimating pile capacities. To assist modeling of the foundations in the global bridge models for seismic response evaluation, foundation stiffness, mass, and damping matrices are provided in Section 5.3.

4.1 Foundation Description

The entire existing bridge is composed of Main Channel, South and North Approaches, and a slab structure in the north end; all supported on pile foundations (see Figure 4-1). Tables 4-1 and 4-2 summarize the number of piles per bent, pile top and pile tip elevations, pile group layout, pile type and size, and design load of the pile for Antioch Bridge and slab bridge piers.

The South Approach consists of Abutment 1 and Pier 2 through Pier 16, with Abutment 1 founded on 14-inch square concrete piles and Piers 2 to 16 on 24-inch square concrete piles. Abutment 1 and Pier 2 through Pier 6 have buried pile caps and the remaining piers have pile caps cantilevered above the mud-line with cantilever height varying from 15 to 28 ft. The Main Channel span contains Piers 17 to 21, each supported on 54-inch diameter concrete hollow piles with a pile cap cantilevered 27 to 52 ft above the mud-line. The North Approach consists of Piers 22 through 41, with Pier 22 through Pier 38 supported on 24-inch square concrete piles, Piers 39 and 40 on 30-inch diameter steel pipe piles in-filled with concrete, and Pier 41 founded on 14-inch square concrete piles. Piers 39 and 40 have pile caps cantilevered 10 to 20 ft above the mud-line, and the remaining piers have embedded pile caps. The design load of a single 54-inch diameter concrete hollow pile is 500 tons. The design load of a single 24-inch square or 30-inch diameter pile is 250 tons, and that of a single 14-inch square pile is 100 tons.

All the pile caps of Antioch Bridge piers are rectangular-shaped on a plan view. The cap width varies from 24 to 48 feet, the cap length varies from 39 to 56 feet, and the cap thickness is between and 7 and 11 feet. Pier 19 in the middle of main crossing channel has the largest cap dimension. The number of piles per pier varies from 12 to 30. The exterior piles for each Antioch Bridge pier (except Abutment 1 and Pier 41) are highly battered outward with angle 1 (horizontal) to 3 (vertical), for providing higher lateral resistance. The elevation of pile top is between -21 and +5 feet, while that of pile tip is between -112 and -40 feet. The elevation of mud-line varies from -46 to 10 feet, with the lowest value near Pier 20.

The slab structure at the end of the North Approach is composed of 30 piers (Pier 42 through Pier 70 and Abutment 71), each supported on extensions of four 12-inch square concrete vertical piles

with a slender cap-beam near the mud-line elevation. The design load of a single 12-inch square pile is 70 tons. The pile layout for each pier can be also found in Appendix A.

4.2 Liquefaction Assessment

The adopted procedure of quantitative liquefaction evaluation is mainly based on the collaborative work of Youd and others (2001), which provides the state-of-the-art summary of consensus recommendations on the extensive developments, after the "simplified procedure" for evaluating soil liquefaction resistance pioneered by Seed and Idriss in 1964. The following briefly describes the definition of safety factor and the criteria based on standard penetration and cone penetration tests. Further details can be found in their original paper.

The factor of safety against liquefaction of a soil sub-layer (FS) is defined by the ratio of soil cyclic resistance ratio (CRR) to soil cyclic stress ratio (CSR), as follows:

$$FS = \frac{CRR}{CSR} = \frac{CRR_{7.5} \cdot MSF \cdot K_{\sigma} \cdot K_{\alpha}}{CSR}$$

in which $CRR_{7.5}$ is the cyclic resistance ratio for magnitude 7.5 earthquake, MSF is the magnitude scaling factor, K_{σ} is the correction factor for high overburden pressure, K_{α} is the correction factor for sloping ground, and CSR can be expressed by the ratio of average shear stress (τ_{av}) to effective overburden pressure (σ'_{v0}), as follows:

$$CSR = \frac{\tau_{av}}{\sigma'_{v0}} = 0.65 \cdot \frac{a_{\max}}{g} \cdot \frac{\sigma_{v0}}{\sigma'_{v0}} \cdot r_d$$

in which a_{max} is the peak horizontal acceleration at ground surface, σ_{v0} is the total overburden pressure, and r_d is the stress reduction coefficient, as function of depth.

For the standard penetration tests (SPT), $CRR_{7.5}$ can be statistically approximated by

$$CRR_{7.5} = \frac{1}{34 - (N_1)_{60cs}} + \frac{(N_1)_{60cs}}{135} + \frac{50}{\left(10 \cdot (N_1)_{60cs} + 45\right)^2} - \frac{1}{120}$$

in which $(N_1)_{60cs}$ is the clean-sand SPT blow count normalized to an overburden pressure of 100kPa (1tsf) and a hammer energy ratio of 60%, and equals to:

$$(N_1)_{60cs} = \alpha + \beta (N_1)_{60} = \alpha + \beta \cdot N_m \cdot C_N \cdot C_E \cdot C_B \cdot C_R \cdot C_S$$

where α and β are correction coefficients for fine content, N_m is the measured SPT blow count and C_N, C_E, C_B, C_R and C_S are SPT correction coefficients for overburden pressure, energy ratio, borehole diameter, rod length and sampling method, respectively.

For the cone penetration tests (CPT), $CRR_{7.5}$ can be approximated by

$$\begin{cases} (q_{c1N})_{cs} < 50 & CRR_{7.5} = 0.833 \cdot \dfrac{(q_{c1N})_{cs}}{1000} + 0.05 \\ 50 \le (q_{c1N})_{cs} < 160 & CRR_{7.5} = 93 \cdot \left(\dfrac{(q_{c1N})_{cs}}{1000} \right)^3 + 0.08 \end{cases}$$

in which $(q_{c1N})_{cs}$ is the clean-sand cone penetration resistance normalized to an overburden pressure of 100kPa, and equals to:

$$(q_{c1N})_{cs} = K_c \cdot (q_{c1N}) = K_c \cdot C_Q \cdot \frac{q_c}{p_a}$$

where K_c is the correction factor for grain characteristics, C_Q is a normalizing factor, q_c is the field cone penetration resistance at tip, and p_a is 1atm of pressure.

The results of liquefaction assessment conducted on Abutment 1 through Pier 19 at the southern segments of the bridge and 4 selected piers near the northern half of the slab bridge span are summarized in Table 4-3. The SPT or CPT soundings nearest to each of these piers were chosen for performing analysis, providing the representative results to these pier locations. The peak ground acceleration (a_{max}) of each pier location was computed from the SHAKE runs of the seven input motion sets. A moment magnitude of 6.6 was adopted for the site. When a soil layer has a FS less than unity, it is classified as liquefiable; several successive liquefiable layers make up a potential liquefaction zone. Individual liquefiable layers are identified in Table 4-3. From evaluation of these results, the following observations and recommendations can be made:

- The soil strata at the southern end of the bridge span (from Abutment 1 to Pier 4) are generally non-liquefiable, because none or only few thin liquefiable zones exists for these pier locations;
- On the other hand, the subsoil at the remaining portion of south bridge span and the northern half of the slab bridge span contains liquefiable zone(s) with total thickness varying from 20 to 45 feet; these liquefiable zones might be continuous or localized along these regions;
- The influence of these liquefiable zones on foundation performance is examined in Section 4.6.

4.3 Axial Loading Conditions

Vertical loads on the foundation are resisted by the underlying piles which are axially loaded. The pile resistance is developed when there is relative movement between the pile and the surrounding soil. The load-displacement relation between the pile shaft and soil is characterized by the so-called *t-z* curve, while that between the pile tip and soil represents the *q-u* curve. For a well-designed pile, the soil adjacent to the pile should provide a sufficient capacity to withstand the applied load

without bearing failure so that the pile does not undergo exceeding settlement under the working load condition. In this section, the *t-z* and *q-u* curves of all Antioch Bridge and slab bridge piers are presented, their axial load-deformation (Q-δ) curves in terms of pile head load versus pile head displacement relationship are developed, and their ultimate bearing capacity values computed using CPT data are compared with the capacity estimated from the conventional pile capacity calculations.

4.3.1 *t-z* and *q-u* Curves

Determination of the ultimate skin friction resistance (t_{max}) and end bearing capacity (q_{max}) as well as development of the *t-z* and *q-u* curves are described in this section. The developed *t-z* and *q-u* curves are used in the following section for generating Q-δ curves (pile head load vs. pile head deformation), in the soil-structure interaction analysis for forming 6×6 condensed matrices and kinematic motions (see Section 5-3), and in the finite element analysis of the bridge model for simulating the nonlinear soil springs distributed along the piles.

The ultimate skin friction resistance (t_{max}) in the *t-z* curve can be obtained by multiplying a unit skin friction of soil (f_s) with the pile circumference, and therefore the *t-z* curves are developed per a linear pile length basis. The general formula for soil unit skin friction (f_s) is given in the following equation, depending upon the soil type:

$$\begin{aligned} sand: \quad & f_s = K\sigma_v' \tan\delta \\ clay: \quad & f_s = \alpha\, c \end{aligned}$$

where K is the lateral earth pressure coefficient whose value depends on the pile installation method, σ_v' is the effective overburden pressure, δ is the friction angle between the pile material and the soil as function of soil internal friction angle (ϕ'), c is the undrained shear strength, and α is the adjustment factor depending on (c, σ_v'). In the project, K=1.0 and δ=0.75ϕ' were adopted for sand layers, and α varying from 0.8 to 1.0 was used for clays. The real shape of in-situ *t-z* curves is affected by the pile installation method, the roughness of pile surface, soil type and depth. The *t-z* curve adopted in the project is based on the work developed by Vijayvergiya in 1977, as shown in the following equation in a normalized form:

$$\frac{t}{t_{\max}} = A_0 \sqrt{\frac{z}{z_c}} - B_0 \frac{z}{z_c}$$

where t is the actual skin resistance, (A_0, B_0) are empirical coefficients, z is the actual relative displacement between the pile surface and soil, and z_c is the ultimate relative displacement between the pile surface and soil. It is noted that the skin friction behavior becomes purely plastic when z exceeds z_c. In the project, we adopted A_0=2 and B_0=1 for both sand and clay, z_c=0.2 inch for sand and z_c=0.01D (where D is pile diameter) for clay. Accordingly, the normalized *t-z* curves for both sand and clay can be approximated by the following table and plotted in Figure 4-2:

t/t_{max}	z/z_c
0.000	0.000
0.397	0.050
0.532	0.100
0.694	0.200
0.795	0.300
0.865	0.400
0.949	0.600
1.000	1.000
1.000	∞

The ultimate end bearing force (q_{max}) in the *q-u* curve can be obtained by multiplying a unit end bearing capacity at the pile tip (q_t) with the pile-tip area (A). The general formula for soil end bearing capacity (q_t) is presented in the following equation, also depending upon the soil type:

$$sand: \quad q_t = N_q \sigma_v'$$
$$clay: \quad q_t = N_c \, \bar{c}$$

where (N_q, N_c) are bearing capacity factors depending on ϕ', failure mode and pile geometry, σ_v' is the effective overburden pressure at tip, and $\bar{c}$ is the average undrained shear strength beneath the tip. Figure 4-3 depicts several bearing capacity factor N_q versus internal friction angle relationships (Fang, 1991). It can be seen that there are appreciable variations among different theories in determining the end bearing capacity factors. The uncertainty is compounded by different pile installation methods. In the project, N_q varying from 25 to 105 was adopted for sand layers and N_c=9 was used for clays. The shape of in-situ *q-u* curves is affected by the pile installation method, the pile tip geometry, soil type and depth. The *q-u* curve adopted in the project is also based on the work developed by Vijayvergiya in 1977, as shown in the following equation:

$$\frac{q}{q_{\max}} = \begin{cases} \left(\dfrac{u}{u_c}\right)^{C_0} & u < u_c \\ 1 & u \geq u_c \end{cases}$$

where q is the actual end bearing resistance, C_0 is an empirical coefficient, u is the actual end settlement at the tip, and u_c is the ultimate end settlement. It is also observed that the end bearing behavior becomes purely plastic when u exceeds u_c. In the project, we adopted C_0=1/3 and u_c=0.1D for both sand and clay. Note that since the displacement for mobilizing full end bearing is relatively large compared to skin friction, the contribution of end bearing resistance will be small during load transfer analyses. The normalized *q-u* curves for both sand and clay can be approximated by the following table and also plotted in Figure 4-2:

q/q_{max}	u/u_c
0.00	0.00
0.45	0.10
0.63	0.25
0.79	0.50
1.00	1.00
1.00	∞

In order to compute the *t-z* curves along an in-situ pile and *q-u* curve at its tip, the following parameters are required, namely, pile diameter *D*, pile circumference and tip area, a series of selected depth values from pile top to tip, (γ, *c*) of soft clay, and (γ, ϕ) of sand. All these values can be found in Table 2-1 and in the generalized soil profiles provided in Appendix A. The coordinates of *t-z* and *q-u* curves of all Antioch Bridge and slab bridge piers developed using these parameters are listed in Appendix B. These *t-z* and *q-u* curves are applicable for both the vertical pile and battered pile as long as they are aligned along the pile axis. Also, the presented data are for loading in compression only, whereas a scale factor of 0.75 can be applied on soil skin resistance (*t*) for tensile loading and there is no end bearing resistance in tension.

4.3.2 Axial Load versus Deformation Analysis

From the complete axial pile-head load versus pile-head deformation (Q-δ) curve of a pile, one can readily find the pile head settlement for any axial load being applied at the pile top, and vice versa. Once the *t-z* and *q-u* curves of a pile are developed and its cross-section area (*A*) and Young's modulus (*E*) are given, the Q-δ curve of the soil-pile system can be generated. Figure 4-4a shows a schematic of an embedded pile, and the pile top is subjected to a boundary condition of prescribed load or displacement (Q_1 or δ_1). Figure 4-4b depicts that this soil-pile system is modeled as a series of nodes (from 1 to N) connected by N-1 sets of elastic axial springs (stiffness=$EA/\Delta l_i$), with N sets of *t-z* soil springs attached at the pile nodes and one *q-u* soil spring at the tip node. Because of the nonlinear nature of *t-z* and *q-u* curves, iterative solution schemes are usually adopted. This kind of boundary value problem can be readily solved using most modern computer codes.

In this project, the BMCOL program developed by Matlock et al. (1981) in the axial mode was used to compute the Q-δ curves of the piles of Antioch Bridge and slab bridge piers. The input data required include: the pile geometry and deformability, a series of *t-z* curves along the pile, one *q-u* curve at the tip, and a series of desired prescribed settlements δs at pile top. For all piles investigated, the prescribed δs are -3, -2, -1, -0.5, -0.25, -0.1, 0, 0.1, 0.25, 0.5, 1, 2, 3, 4, and 6 inches. The complete Q-δ curves of all Antioch Bridge and slab bridge piers developed using these parameters are presented in Appendix C. These Q-δ curves represent the pile behavior along the pile axis regardless of the plumb pile or battered pile. The following pile properties were used in conducting the axial load versus deformation analyses:

- 54-inch diameter concrete piles (Main Channel Piers 17 ~ 21)

Pile AE = 8.62×10^9 lb. (Infilled section)
Pile AE = 4.47×10^9 lb. (Hollow section)

- 30-inch diameter steel pipe piles (Piers 39,40)
  Pile AE = 3.77×10^9 lb.
- 14-inch square concrete piles (Abutment 1 and Pier 41)
  Pile AE = 8.1×10^8 lb.
- 24-inch square concrete piles (the rest of bridge piers)
  Pile AE = 2.44×10^9 lb.
- 12-inch square concrete piles (slab bridge piers)
  Pile AE = 5.19×10^8 lb.

4.3.3 Pile Capacity Evaluation

Design Load: As summarized in Tables 4.1 and 4.2, five types of piles are used: 54-inch diameter concrete hollow pile, 30-inch diameter steel pile, 14-inch square concrete pile, 24-inch square concrete pile, and 12-inch square concrete pile. The design loads of these piles as documented on the as-built drawings are 500 tons, 250 tons, 100 tons, 250 tons, and 70 tons, respectively. The prevailing pile design practice in the U.S. requires a minimum static factor of safety of 2.0 and therefore these piles should have ultimate geotechnical capacities of 1000 tons, 500 tons, 200 tons, 500 tons, and 140 tons, respectively, as minimum values.

During construction of the bridge, a pile load testing program was undertaken to verify the ultimate pile capacities. The load testing was conducted on production piles at the following locations:

South Approach: 24-inch square piles at Pier 5
Main Channel: 54-inch diameter piles at Pier 19
North Approach: 24-inch square piles at Piers 28 and 37

Ultimate Pile Capacity: To estimate long term ultimate capacities of the piles, conventional pile capacity evaluation was made which generally involves summing of the skin friction resistance and end bearing resistance. While summation of t_{max} (peak value of *t-z* curves) multiplied by its tributary length along the pile plus q_{max} (peak value of *q-u* curves) at the tip yields some measures of the static ultimate bearing capacity of a single pile, we elected to use the load resistance at a pile-head displacement of 3 inches from the Q-δ curve as the ultimate pile capacity. This explicitly considered displacement compatibility between skin friction and end bearing. The estimated ultimate pile capacity along with the design load for each pile is presented in Figure 4-5. The ultimate pile capacities estimated from the Q-δ curve have been compared with results from a computer program, APILE, and the comparison is found to be in agreement (the solution from APILE are not included in this report). In addition, following the discussions with the Peer Review Panel members, CPT data were used directly to estimate the pile capacities for comparison with the conventional pile design practice. In the following, a brief description of the CPT-based pile capacity calculation method is provided.

As depicted in Figure 2-2, the Antioch Bridge has one CPT probing conducted at every pier for most cases. The CPT sounding provides soil properties on a continuous basis, which has greater

advantage over conventional soil borings using SPT samplings with a 5-foot interval. When foundation soils are stratified with thin beds of different soil types, the CPT-based pile capacity method can capture the variations within short distances. For this purpose, the computer program CPeT-IT was used, which was recently developed by GeoLogismiki (http://www.geologismiki.gr) in collaboration with Peter Robertson of Gregg Drilling & Testing Inc.

The program CPeT-IT is coded to follow a LCPC method (Bustamante and Gianeselli, 1982), which is based on the analysis of 197 pile load tests with a wide range of foundation and soil types. This partly explains the reportedly good results with the LCPC method. The program also provides simple guidance to account for different pile installations. In this method, the pile unit end bearing, q_p, is calculated from the equivalent average cone resistance, q_{ca}, multiplied by an end bearing coefficient, k_c, whereas the pile unit side friction, f_p, is calculated from measured q_c values divided by a friction coefficient, α, as shown in the following equations:

$$q_p = k_c q_{ca}; f_p = q_c/\alpha$$

Selection of these coefficients (k_c,α) and the limiting value of unit side friction (f_p) depends upon the soil and pile type, and their recommended values are listed in Table 4-4, which was developed on the basis of calibration with the pile load test results with variety of pile types and soil conditions. To evaluate the pile unit end bearing, equivalent average cone resistance (q_{ca}) is taken as the mean value of the cone tip resistance within one pile diameter (D) zone around the pile tip (0.5D above and 0.5D below the pile tip). Only the measured q_c is used for the estimation of both side friction and pile end bearing resistance. This is considered an advantage by many due to the difficulties associated in interpreting sleeve friction (f_s) in CPT data. However, both sleeve friction and tip resistance are used for interpretation of soil behavior which proves to be an important parameter for selection of the friction and end bearing coefficients. Figure 4-6 shows the illustration of sample pile capacity calculation at Pier 04 using the CPT data (S03). The ultimate pile capacities estimated using CPT data for all piers are also shown on Figure 4-5 for comparison.

4.4 Lateral Loading Conditions

During an earthquake, lateral loading of a deep foundation is resisted by flexural properties of the pile and lateral soil supports along the pile. The lateral soil supports to the pile is mobilized when there is a relative displacement between the pile and the surrounding soil according to the deflection profile of the pile. This lateral load-deflection relation between the pile and soil is generally known as *p-y* curve. In this section, the lateral soil support (*p-y*) curves of all Antioch Bridge and slab bridge piers are developed, and the response results of the piles subjected to lateral push-over loading are presented.

4.4.1 *p-y* Curves

Determination of the ultimate lateral bearing capacity (p_u) and the lateral soil support (*p-y*) curves of a pile in soils is mainly based on the API Recommended Practice 2A-WSD (1993). The

developed *p-y* curves are used in the soil-structure interaction analysis for forming 6×6 condensed stiffness matrices and kinematic motions (also see Section 5-3), and in the finite element analysis of the bridge for simulating the nonlinear soil springs attached to the piles. The following briefly describes the elements of soil support behaviors for clayey and sandy soils. For the static loads, the ultimate lateral bearing capacity (p_u) for piles in soft clay at a certain depth below soil surface (X), increases from $3c$ to $9c$ as X increases from 0 to X_R, according to:

$$p_u = \begin{cases} 3cD + \gamma XD + JcX & \text{for } X < X_R \\ 9cD & \text{for } X \geq X_R \end{cases}$$

where p_u is ultimate lateral bearing capacity (in unit of force per pile length), c is the undrained shear strength, D is the pile diameter, γ is the effective soil unit weight, J is the dimensionless empirical constant varying from 0.25 to 0.5 (usually taken as 0.5), and X_R is the critical depth equal to $6D/(J+\gamma D/c)$. Note that consistent units should be used for the parameters in the above equation. The lateral soil resistance-deflection relationships for piles in soft clay are generally non-linear. The normalized *p-y* curves of soft clay for the short-term static load case can be represented by the following table:

p/p_u	y/y_u
0.000	0.000
0.250	0.016
0.500	0.125
0.720	0.375
1.000	1.000
1.000	∞

where p is the actual lateral resistance, y is the actual lateral deflection, and y_u is the ultimate lateral deflection when p_u takes place (which equals to 20 times ε_{50}, the strain occurring at 50% the maximum stress on laboratory undrained compression tests of undisturbed soil samples). On the other hand, the ultimate lateral bearing capacity (p_u) for piles in sand may be assigned as the smaller one of the following two equations:

$$p_{us} = (C_1 X + C_2 D)\gamma X; \; p_{ud} = C_3 D\gamma H$$
$$p_u = \min(p_{us}, p_{ud})$$

where (γ, D, X) are defined as above, and (C_1, C_2, C_3) are the empirical coefficients as function of soil internal friction angle (ϕ), as shown in Figure 4-7. The lateral soil resistance-deflection relationships for sand are also non-linear and in the absence of more defining information may be approximated by the following expression:

$$p = Ap_u \tanh\left(\frac{kX}{Ap_u} y\right) \text{ or } \frac{p}{(Ap_u)} = f\left(\frac{y}{y_u}\right)$$

where (p, y) are defined as above, and A is the loading factor which is 0.9 for cyclic loading and 3.0-0.8X/D for static loading, k is the initial modulus of subgrade reaction as function of ϕ' (also see Figure 4-7), f represents the corresponding normalized function, and y_u is the ultimate lateral deflection approximated by $3Ap_u/(kX)$. The normalized p-y curves of sand can be represented by the following table:

p/p_u	y/y_u
0.00	0.00
0.10	0.03
0.46	0.17
0.76	0.33
0.91	0.50
1.00	1.00
1.00	∞

Figure 4-2 also depicts the normalized p-y curves of soft clay and sand used in the project. In order to compute the p-y curves along an in-situ pile, the following parameters are required, namely, pile diameter D, a series of selected depth X values from pile top to tip, (γ, J, c, ε_{50}) of soft clay, and (γ, ϕ', k) of sand. All these values can be found in Table 2-1 and in the generalized soil profiles provided in Appendix A. A p-multiplier of 0.5 was applied for p_u to collectively account for potential soil cyclic softening and pile group effect for the main bridge and approach piers. For the slab bridge, a p-multiplier of 1.0 may be used for larger pile spacing. The coordinates of p-y curves of all Antioch Bridge and slab bridge piers developed using these parameters are listed in Appendix D. No differentiation on the p-y curves is made between the vertical pile and battered pile since the p-y curves describe the soil behavior perpendicular to the pile axis. The same sets of p-y curves should be attached normal to the pile axis for the plumbed pile and battered pile.

4.4.2 Lateral Push-Over Analysis

In this project, the LPILE^{plus} 5.0 program developed by Ensoft, Inc. (2004) was used to perform the lateral push-over analyses of the piles of Antioch Bridge and slab bridge piers. The input data included the pile flexural properties, soil properties, and a series of desired prescribed boundary conditions at pile top. Fixed-head condition at the pile top (y=prescribed,θ=0) is used, and the prescribed y's are 1, 2, 3, 4, 5 and 6 inches for all the Antioch piles (the lateral displacements are prescribed perpendicular to the pile axis). The resultant depth-varying deflection, moment, and shear diagrams along the pile as well as pile top moment and shear versus pile top deflection curves are included in Appendix E. The following flexural properties were used for the single pile lateral push-over analyses:

- 54-inch diameter concrete piles (Main Channel Piers 17 ~ 21)
  Effective pile EI = 8.47×10^{11} lb-in^2. (Infilled section)
  Effective pile EI = 6.44×10^{11} lb-in^2. (Hollow section)
- 30-inch diameter steel pipe piles (Piers 39,40)
  Effective pile EI = 2.35×10^{11} lb-in^2.
- 14-inch square concrete piles (Abutment 1 and Pier 41)

Effective pile EI = 6.95×10^{9} lb-in^2.
- 24-inch square concrete piles (the rest of bridge piers)
  Effective pile EI = 6.07×10^{10} lb-in^2.
- 12-inch square concrete piles (slab bridge piers)
  Effective pile EI = 3.11×10^{9} lb-in^2.

4.5 Nonlinear Soil Springs for Pile Cap

The pile caps for much of the approach foundations are buried in the soils. For these piers, in addition to the piles, the pile caps would also offer additional resistance against lateral movement derived from passive pressure in the soil. The recommendations for pile cap springs are presented in this section. The estimated values of passive soil resistance depend largely on the undrained shear strength of the soil, and to some extent on the pile cap configuration, i.e., the contact dimension for longitudinal and transverse loading directions. The reaction of soil passive resistance can be modeled as two soil springs attached to the pile cap; one in the longitudinal direction, and one in the transverse direction. For this purpose, tri-linear soil springs were developed, and their coordinates are tabulated in Table 4-5.

4.6 Liquefaction-induced Settlement

The results of liquefaction assessment discussed in Section 4.1 indicate the existence of fairly thick liquefiable zones beneath a large portion of southern segments of the bridge span and the northern half of the slab bridge span. In order to investigate the effect on foundation performance, evaluation of liquefaction-induced ground settlement as well as pile settlement was made. Prediction of liquefaction-induced ground settlement was mainly based on the empirical work of Tokimatsu and Seed (1987), and Ishihara and Yoshimine (1992), in which post-liquefaction volumetric strain was estimated from cyclic shear strain, standard penetration resistance, or safety factor against liquefaction. The computed values of ground settlement are presented in the last column of Table 4-3, which represents ground surface settlement of a free-field condition (without pile). Depending on the thickness of the liquefied soil and the portion of pile length in the liquefied soil, the pile settlement is expected to be much smaller than the free-field soil settlement.

To estimate the pile settlement resulting from the liquefaction-induced free-field ground settlement, a down-drag analysis was conducted at selected locations (Piers 10, 11, 17, 18, 19, 64, and 69). The down drag behavior was performed for two cases; one without the down drag mechanism and one with the down drag mechanism. Comparison between the two cases enables determination of additional settlement due to the down-drag loading. The BMCOL program with the axial mode was used to compute the Q-δ curves for the two cases. In the case without the down drag mechanism, one end of the *t-z* curves is fixed before the pile is loaded axially resulting in a load-deformation (Q-δ) curve that is normally observed. A separate analysis with the down drag mechanism is simulated by pulling down the *t-z* curves, according to applicable ground settlement profile, followed by gradually increasing axial loads on the pile top.

The difference in pile settlements with and without the down drag mechanism at the service load level yields the liquefaction induced foundation settlement. Foundation settlements on the order of 0.2 to 0.4 inches were estimated from the analyses; the results are provided in Appendix F. However, since the mechanism used to study the pile settlement is an extremely ideal case, these foundation settlements computed from the down-drag analysis should be regarded as qualitative assessment.

The performance criterion adopted for the Antioch Bridge is based on a no-collapse scenario for the Safety Evaluation Earthquake representing a 1,000-year return period ground motion. Judging from the down-drag analysis results and the project-specific design criteria, the performance of foundation for liquefaction-induced settlement is acceptable.

TABLE 4-1: SUMMARY OF FOUNDATION INFORMATION FOR BRIDGE PIERS

Pier Number	Pile Top Elevation (ft)	Pile Tip Elevation (ft)	ML Elevation (ft)	Pile Group Layout	Number of Piles	Pile Type	Pile Dimension	Design Load (ton)
Abut 1	15.00	-30.00	20.00	$5+6_{bN}$ [1]	11	Square Concrete	14"×14"	100.00
2	0.50	-40.00	9.00	$3_b \times 4_b$ [2]	12	Square Concrete	24"×24"	250.00
3	-1.00	-45.00	10(8)	$3_b \times 4_b$	12	Square Concrete	24"×24"	250.00
4	-2.00	-50.00	10.00	$5_b \times 4_b$	20	Square Concrete	24"×24"	250.00
5	-2.00	-45.00	9.00	$3_b \times 5_b$	15	Square Concrete	24"×24"	250.00
6	-1.00	-55.00	8.00	$3_b \times 4_b$	12	Square Concrete	24"×24"	250.00
7	5.00	-55.00	-6.00	$3_b \times 4_b$	12	Square Concrete	24"×24"	250.00
8	5.00	-60.00	-16.00	$3_b \times 4_b$	12	Square Concrete	24"×24"	250.00
9	4.00	-60.00	-18.00	$5_b \times 5_b$	25	Square Concrete	24"×24"	250.00
10	4.00	-63.00	-16.00	$5_b \times 5_b$	25	Square Concrete	24"×24"	250.00
11	4.00	-63.00	-19.00	$5_b \times 4_b$	20	Square Concrete	24"×24"	250.00
12	4.00	-60.00	-20(-19)	$5_b \times 4_b$	20	Square Concrete	24"×24"	250.00
13	4.00	-66.00	-23(-22)	$5_b \times 4_b$	20	Square Concrete	24"×24"	250.00
14	4.00	-60.00	-25(-20)	$3_b \times 6_b$	18	Square Concrete	24"×24"	250.00
15	4.00	-65.00	-25(-24)	$3_b \times 6_b$	18	Square Concrete	24"×24"	250.00
16	4.00	-70.00	-27(-26)	$3_b \times 6_b$	18	Square Concrete	24"×24"	250.00
17	2.00	-92.00	-34.00	$5_b \times 5_b$	25	Prestr. concrete hollow	54"ϕOD,40"ϕID	500.00
18	2.00	-92.00	-34.00	$5_b \times 5_b$	25	Prestr. concrete hollow	54"ϕOD,40"ϕID	500.00
19	2.00	-98.00	-40.00	$5_b \times 6_b$	30	Prestr. concrete hollow	54"ϕOD,40"ϕID	500.00
20	2.00	-100.00	-46(-44)	$5_b \times 6_b$	30	Prestr. concrete hollow	54"ϕOD,40"ϕID	500.00
21	2.00	-98.00	-19(-20)	$5_b \times 5_b$	25	Prestr. concrete hollow	54"ϕOD,40"ϕID	500.00
22	-14.00	-98.00	-9.00	$7_b \times 7_b$	49	Square Concrete	24"×24"	250.00
23	-16.00	-103.00	-12.00	$5_b \times 4_b$	20	Square Concrete	24"×24"	250.00
24	-17.00	-105.00	-13.00	$5_b \times 4_b$	20	Square Concrete	24"×24"	250.00
25	-18.00	-103.00	-13.00	$5_b \times 4_b$	20	Square Concrete	24"×24"	250.00
26	-18.50	-105.00	-13.00	$5_b \times 6_b$	30	Square Concrete	24"×24"	250.00
27	-19.50	-105.00	-14.00	$5_b \times 6_b$	30	Square Concrete	24"×24"	250.00
28	-20.00	-103.00	-14.00	$4_b \times 6_b$	24	Square Concrete	24"×24"	250.00
29	-21.00	-105.00	-15.00	$4_b \times 6_b$	24	Square Concrete	24"×24"	250.00
30	-21.00	-112.00	-16.00	$4_b \times 6_b$	24	Square Concrete	24"×24"	250.00
31	-19.00	-112.00	-16.00	$3_b \times 6_b$	18	Square Concrete	24"×24"	250.00
32	-19.00	-112.00	-17.00	$3_b \times 6_b$	18	Square Concrete	24"×24"	250.00
33	-19.00	-112.00	-17.00	$3_b \times 6_b$	18	Square Concrete	24"×24"	250.00
34	-18.00	-112.00	-17.00	$3_b \times 5_b$	15	Square Concrete	24"×24"	250.00
35	-18.00	-112.00	-17.00	$3_b \times 5_b$	15	Square Concrete	24"×24"	250.00
36	-18.00	-106.00	-17.00	$3_b \times 5_b$	15	Square Concrete	24"×24"	250.00
37	-18.50	-111.00	-16.00	$3_b \times 6_b$	18	Square Concrete	24"×24"	250.00
38	-19.00	-111.00	-15.00	$5_b \times 4_b$	20	Square Concrete	24"×24"	250.00
39	2.00	-103.00	-7(-10)	$3_b \times 4_b$	12	Steel Pipe	30"ϕ	250.00
40	2.50	-103.00	-12.00	$3_b \times 4_b$	12	Steel Pipe	30"ϕ	250.00
41	-13.00	-95.00	-7.00	2×6	14	Square Concrete	14"×14"	100.00

Note: [1] two rows of piles with 5 piles in the south row and 6 battered piles in the north row;
[2] 3 piles in the longitudinal direction and 4 piles in the transverse direction with subscript b for the exterior piles battered at 1/3 slope.

TABLE 4-2: SUMMARY OF FOUNDATION INFORMATION FOR SLAB BRIDGE PIERS

Pier Number	Pile Top Elevation (ft)	Pile Tip Elevation (ft)	ML Elevation (ft)	Pile Group Layout	Number of Piles	Pile Type	Pile Dimension	Design Load (ton)
42	-12.00	-90.00	-13.00	1×4[1]	4	Square concrete	12"×12"	70.00
43	-12.00	-90.00	-13.00	1×4	4	Square concrete	12"×12"	70.00
44	-12.00	-90.00	-13.00	1×4	4	Square concrete	12"×12"	70.00
45	-12.00	-90.00	-12.00	1×4	4	Square concrete	12"×12"	70.00
46	-12.00	-90.00	-13.00	1×4	4	Square concrete	12"×12"	70.00
47	-12.00	-90.00	-13.00	1×4	4	Square concrete	12"×12"	70.00
48	-12.00	-90.00	-13.00	1×4	4	Square concrete	12"×12"	70.00
49	-12.00	-90.00	-13.00	1×4	4	Square concrete	12"×12"	70.00
50	-12.00	-90.00	-13.00	1×4	4	Square concrete	12"×12"	70.00
51	-12.00	-90.00	-13.00	1×4	4	Square concrete	12"×12"	70.00
52	-12.00	-85.00	-13.00	1×4	4	Square concrete	12"×12"	70.00
53	-12.00	-85.00	-13.00	1×4	4	Square concrete	12"×12"	70.00
54	-13.00	-80.00	-13.00	1×4	4	Square concrete	12"×12"	70.00
55	-13.00	-80.00	-13.00	1×4	4	Square concrete	12"×12"	70.00
56	-13.00	-80.00	-13.00	1×4	4	Square concrete	12"×12"	70.00
57	-13.00	-80.00	-13.00	1×4	4	Square concrete	12"×12"	70.00
58	-13.00	-80.00	-13.00	1×4	4	Square concrete	12"×12"	70.00
59	-13.00	-80.00	-13.00	1×4	4	Square concrete	12"×12"	70.00
60	-13.00	-80.00	-13.00	1×4	4	Square concrete	12"×12"	70.00
61	-13.00	-80.00	-13.00	1×4	4	Square concrete	12"×12"	70.00
62	-13.00	-80.00	-13.00	1×4	4	Square concrete	12"×12"	70.00
63	-15.00	-80.00	-13.00	1×4	4	Square concrete	12"×12"	70.00
64	-15.00	-80.00	-13.00	1×4	4	Square concrete	12"×12"	70.00
65	-15.00	-80.00	-13.00	1×4	4	Square concrete	12"×12"	70.00
66	-15.00	-80.00	-13.00	1×4	4	Square concrete	12"×12"	70.00
67	-15.00	-80.00	-13.00	1×4	4	Square concrete	12"×12"	70.00
68	-15.00	-80.00	-13.00	1×4	4	Square concrete	12"×12"	70.00
69	-15.00	-80.00	-13.00	1×4	4	Square concrete	12"×12"	70.00
70	-15.00	-80.00	-13.00	1×4	4	Square concrete	12"×12"	70.00
Abut 71	-13.00	-80.00	-7.00	1×4	4	Square concrete	12"×12"	70.00

Note: [1] 1 pile in the longitudinal direction and 4 piles in the transverse direction.

TABLE 4-3: SUMMARY OF LIQUEFACTION ANALYSES

Location	Sounding	Mudline Elevation (ft)	Tip Elevation (ft)	a_{max} (g)	Potential Liquefaction Zones Elevations (ft)	Seismic Settlement (in)
Abut 1	B-06-01	28.7	-30.0	0.417	Not Significant in 50 feet depth	0.1
Pier 2	06-CPT-1	9.6	-40.0	0.430	-17.1 to -19.8, -34.2 to -36.2	2.2
Pier 3	06-CPT-2	10.4	-45.0	0.399	Not Significant in 50 feet depth	0.5
Pier 4	06-CPT-3	10.5	-50.0	0.394	-9.4 to -10.2, -11.3 to -14.1	1.4
Pier 5	06-CPT-4	9.5	-45.0	0.442	-17.9 to -42.2	6.2
Pier 6	B-06-02	8.7	-55.0	0.393	-13.0 to -40.0	5.6
Pier 7	06-CPT-5	-2.5	-55.0	0.426	-5.7 to -12.9, -14.6 to -15.9, -34.9 to -44.4	5.2
Pier 8	06-CPT-6	-12.0	-60.0	0.432	-16.2 to 19.8, -34.9 to -49.0	4.8
Pier 9	06-CPT-7	-15.0	-60.0	0.474	-22.1 to -29, -44.8 to -52.0, -54.9 to -56.3	8.5
Pier 10	06-CPT-8	-8.5	-63.0	0.507	-14.0 to -36.0, -41.6 to -50.7, -55.7 to -60.3	8.1
Pier 11	06-CPT-9	-10.5	-63.0	0.522	-14.4 to -37.0, -39.6 to -41.3, -42.9 to -47.8, -51.4 to -54.4	10.0
Pier 12	06-CPT-10	-15.0	-60.0	0.428	-22.1 to -38.8, -43.8 to -46.4	6.8
Pier 13	B-06-03	-13.1	-66.0	0.500	-30.0 to -55.0, -57.5 to -62.5	8.8
Pier 14	06-CPT-11	-18.0	-60.0	0.483	-22.5 to -42.8	5.9
Pier 15	06-CPT-12	-20.0	-65.0	0.473	-26.2 to -40.6, -43.5 to -44.5	5.0
Pier 16	06-CPT-13	-21.0	-70.0	0.488	-25.8 to -40.3	5.1
Pier 17	06-CPT-14	-22.0	-92.0	0.474	-27.2 to -72.4	11.9
Pier 18	B-06-04	-19.6	-92.0	0.387	-52 to -69.6	16.2
Pier 19	06-CPT-15	-39.0	-98.0	0.504	-43.5 to -80.2	9.7
Pier 49	06-CPT-34	-8.0	-90.0	0.357	-14.6 to -23.1, -34.1 to -45.9	3.8
Pier 57	B-06-09	-11.3	-80.0	0.366	-28.0 to -64.0	7.1
Pier 64	06-CPT-35	-8.0	-80.0	0.378	-19.7 to -58.0	10.3
Pier 69	B-06-10	-11.8	-80.0	0.384	-29.0 to -64.0	9.6

TABLE 4-4: END BEARING AND FRICTIONAL FACTORS (K_C,α) USED IN THE LCPC METHOD

Nature of soil	q_c (MPa)	Factor, k_c	
		Group I	Group II
Soft clay and mud	< 1	0.40	0.50
Moderately compact clay	1 to 5	0.35	0.45
Silt and loose sand	≤ 5	0.40	0.50
Compact to stiff clay and compact silt	> 5	0.45	0.55
Soft chalk	≤ 5	0.20	0.30
Moderately compact sand and gravel	5 to 12	0.40	0.50
Weathered to fragmented chalk	> 5	0.20	0.40
Compact to very compact sand and gravel	> 12	0.30	0.40

Group I: plain bored piles; mud bored piles; micro piles (grouted under low pressure); cased bored piles; hollow auger bored piles; piers; barrettes.
Group II: cast screwed piles; driven precast piles; prestressed tubular piles; driven cast piles; jacked metal piles; micropiles (small diameter piles grouted under high pressure with diameter < 250mm); driven grouted piles (low pressure grouting); driven metal piles; driven rammed piles; jacket concrete piles; high pressure grouted piles of larger diameter.

Nature of soil	q_c (MPa)	Category									
		Coefficient, α				Maximum limit of f_p (MPa)					
		I		II		I		II		III	
		A	B	A	B	A	B	A	B	A	B
Soft clay and mud	< 1	30	90	90	30	0.015	0.015	0.015	0.015	0.035	
Moderately compact clay	1 to 5	40	80	40	80	0.035 (0.08)	0.035 (0.08)	0.035 (0.08)	0.035	0.08	≥0.12
Silt and loose sand	≤ 5	60	150	60	120	0.035	0.035	0.035	0.035	0.08	-
Compact to stiff clay and compact silt	> 5	60	120	60	120	0.035 (0.08)	0.035 (0.08)	0.035 (0.08)	0.035	0.08	≥0.12
Soft chalk	≤ 5	100	120	100	120	0.035	0.035	0.035	0.035	0.08	-
Moderately compact sand and gravel	5 to 12	100	200	100	200	0.08 (0.12)	0.035 (0.08)	0.08 (0.12)	0.08	0.12	≥0.12
Weathered to fragmented chalk	> 5	60	80	60	80	0.12 (0.15)	0.08 (0.12)	0.12 (0.15)	0.12	0.15	≥0.12
Compact to very compact sand and gravel	> 12	150	300	150	200	0.12 (0.15)	0.08 (0.12)	0.12 (0.15)	0.12	0.15	≥0.12

Category - IA: plain bored piles; mud bored piles; hollow auger piles; micropiles (grouted under low pressure); cast screwed piles; piers; barrettes. IB: cased bored piles; driven cast piles. IIA: driven precast piles; prestressed tubular piles; jacket concrete piles. IIB: driven metal piles; jacked metal piles. IIA: driven grouted piles; driven rammed piles. IIIB: high pressure grouted piles of larger diameter > 250mm; micropiles (grouted under high pressure).
Note: Maximum limit skin friction, f_p: bracket values apply to careful execution and minimum distance of soil due to construction.

TABLE 4-5: TRI-LINEAR SOIL SPRINGS FOR PILE CAPS

Pier Number	Soil Spring Elevation (ft)	Longitudinal Direction						Transverse Direction					
		Point 1		Point 2		Point 3		Point 1		Point 2		Point 3	
		Δ_1 (in)	P_1 (kips)	Δ_2 (in)	P_2 (kips)	Δ_3 (in)	P_3 (kips)	Δ_1 (in)	P_1 (kips)	Δ_2 (in)	P_2 (kips)	Δ_3 (in)	P_3 (kips)
1	16.25	0.00	0.0	0.20	59.3	2.64	118.5	0.00	0.0	0.20	275.6	2.64	551.3
2	4.00	0.00	0.0	0.30	424.6	4.87	849.3	0.00	0.0	0.30	690.0	4.87	1380.1
3	2.50	0.00	0.0	0.59	152.6	9.52	305.1	0.00	0.0	0.59	247.9	9.52	495.9
4	2.00	0.00	0.0	0.28	699.0	6.48	1398.0	0.00	0.0	0.28	832.7	6.48	1665.3
5	2.00	0.00	0.0	0.30	557.4	6.06	1114.8	0.00	0.0	0.30	975.5	6.06	1951.0
6	2.50	0.00	0.0	0.30	290.0	5.06	579.9	0.00	0.0	0.30	471.2	5.06	942.3
7	5.00	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0
8	5.00	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0
9	4.00	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0
10	4.00	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0
11	4.00	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0
12	4.00	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0
13	4.00	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0
14	4.00	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0
15	4.00	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0
16	4.00	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0
17	2.00	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0
18	2.00	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0
19	2.00	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0
20	2.00	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0
21	2.00	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0
22	-11.50	0.00	0.0	0.61	98.2	6.00	196.4	0.00	0.0	0.61	98.2	6.00	196.4
23	-14.00	0.00	0.0	0.58	54.1	4.80	108.2	0.00	0.0	0.58	64.4	4.80	128.9
24	-15.00	0.00	0.0	0.58	54.1	4.80	108.2	0.00	0.0	0.58	64.4	4.80	128.9
25	-15.50	0.00	0.0	0.61	69.5	6.00	139.1	0.00	0.0	0.61	92.0	6.00	184.1
26	-15.75	0.00	0.0	0.62	77.3	6.60	154.6	0.00	0.0	0.62	93.2	6.60	186.4
27	-16.75	0.00	0.0	0.62	77.3	6.60	154.6	0.00	0.0	0.62	93.2	6.60	186.4
28	-17.00	0.00	0.0	0.63	82.6	7.20	165.1	0.00	0.0	0.63	102.6	7.20	205.2
29	-18.00	0.00	0.0	0.63	82.6	7.20	165.1	0.00	0.0	0.63	102.6	7.20	205.2
30	-18.50	0.00	0.0	0.61	67.5	6.00	135.0	0.00	0.0	0.61	83.9	6.00	167.7
31	-17.50	0.00	0.0	0.54	27.4	3.60	54.8	0.00	0.0	0.54	52.5	3.60	105.0
32	-18.00	0.00	0.0	0.47	19.6	2.40	39.1	0.00	0.0	0.47	37.5	2.40	75.0
33	-18.00	0.00	0.0	0.47	19.6	2.40	39.1	0.00	0.0	0.47	37.5	2.40	75.0
34	-17.50	0.00	0.0	0.34	6.8	1.20	13.5	0.00	0.0	0.34	11.8	1.20	23.6
35	-17.50	0.00	0.0	0.34	6.8	1.20	13.5	0.00	0.0	0.34	11.8	1.20	23.6
36	-17.50	0.00	0.0	0.34	6.8	1.20	13.5	0.00	0.0	0.34	11.8	1.20	23.6
37	-17.25	0.00	0.0	0.51	22.0	3.00	44.1	0.00	0.0	0.51	42.2	3.00	84.5
38	-17.00	0.00	0.0	0.58	54.1	4.80	108.2	0.00	0.0	0.58	64.4	4.80	128.9
39	2.00	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0
40	2.50	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0
41	-11.50	0.00	0.0	0.32	11.6	6.07	23.1	0.00	0.0	0.32	61.9	6.07	123.9

FIGURE 4-1: ANTIOCH BRIDGE PIERS

FIGURE 4-2: NORMALIZED *t-z*, *q-u* AND *p-y* CURVES FOR SOFT CLAY AND SAND

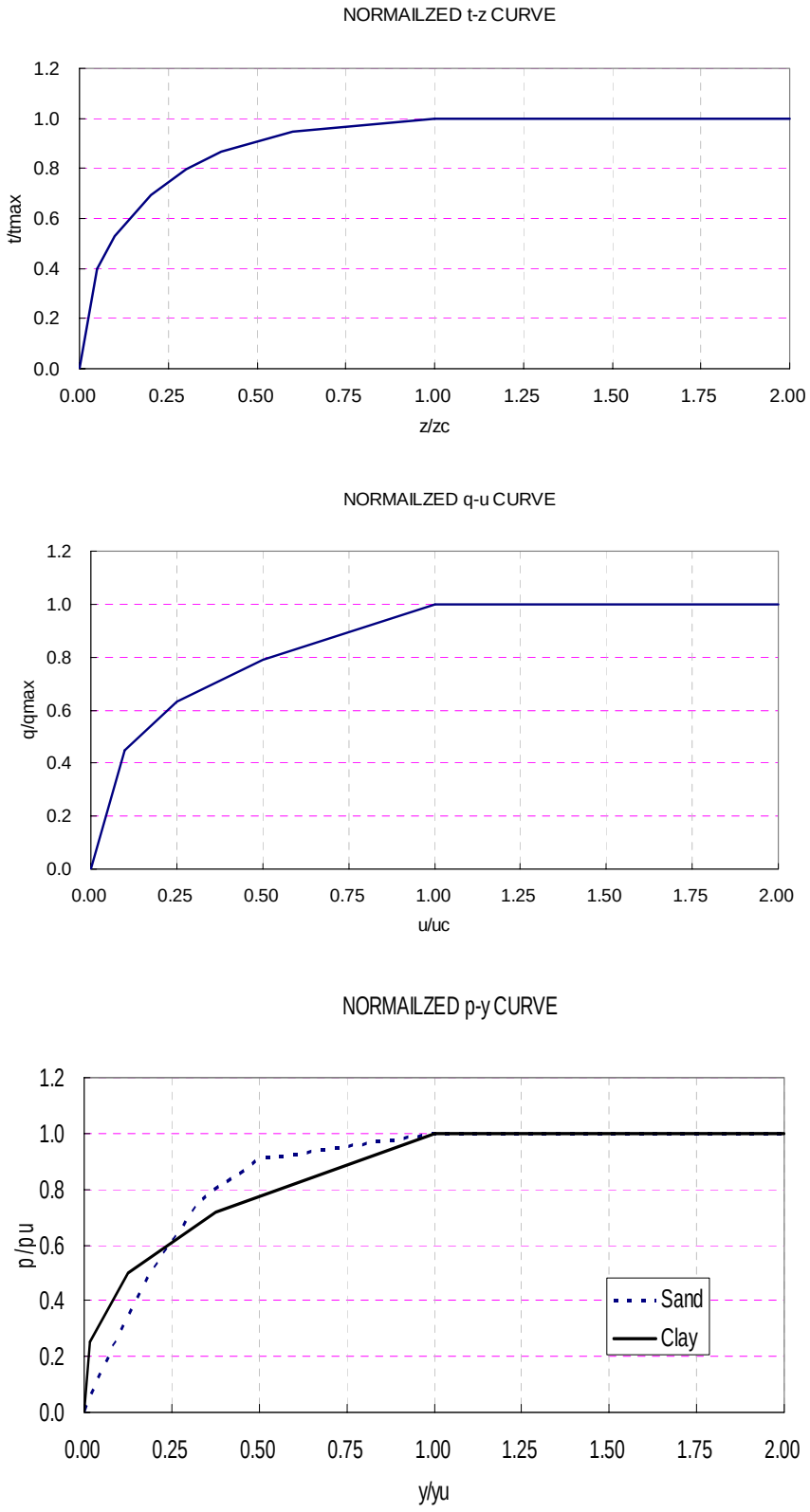


FIGURE 4-3: BEARING CAPACITY FACTOR N_q VERSUS INTERNAL FRICTION ANGLE

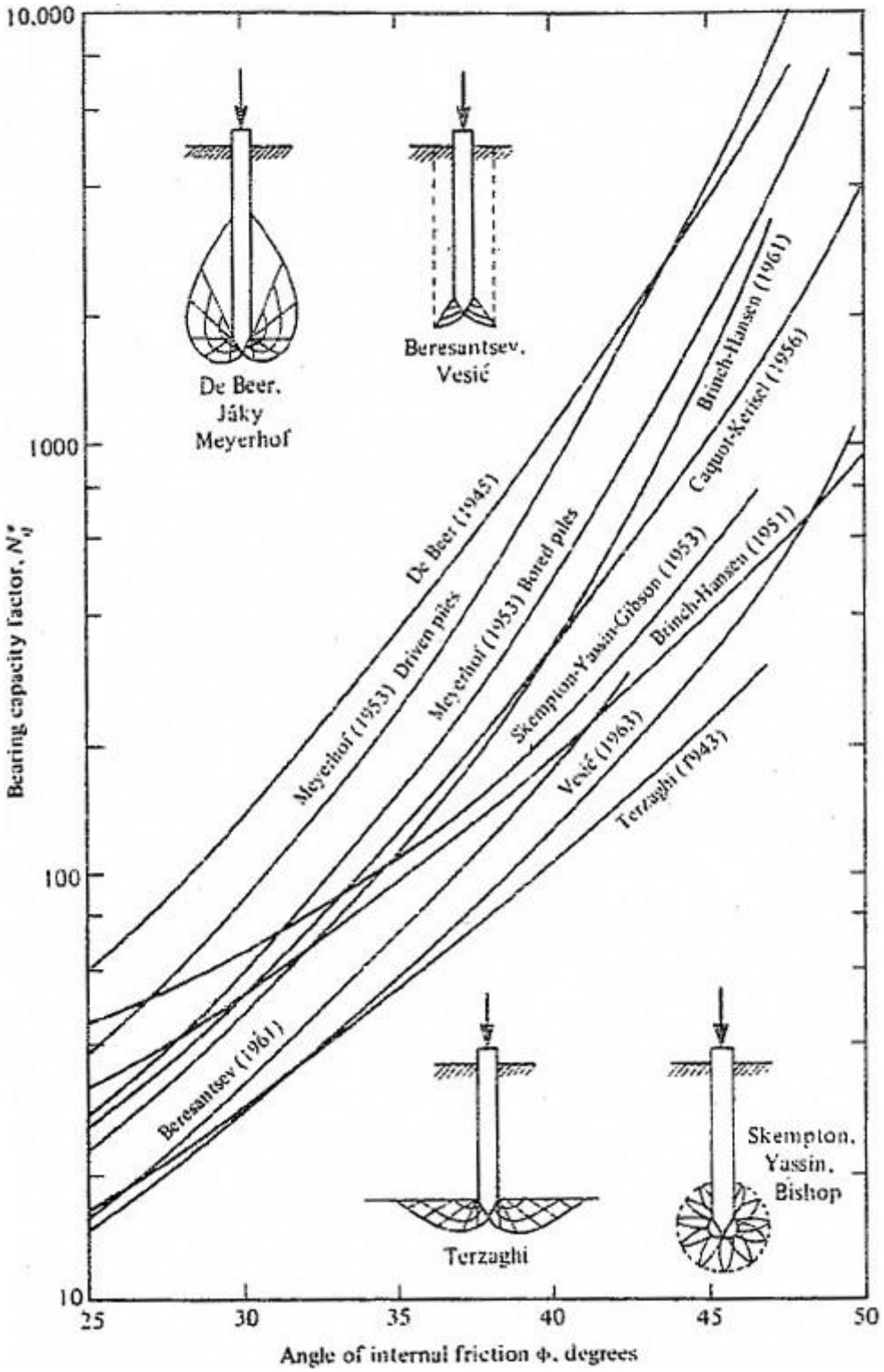


FIGURE 4-4: MODELLING OF AXIAL LOAD VERSUS DEFORMATION BEHAVIOR

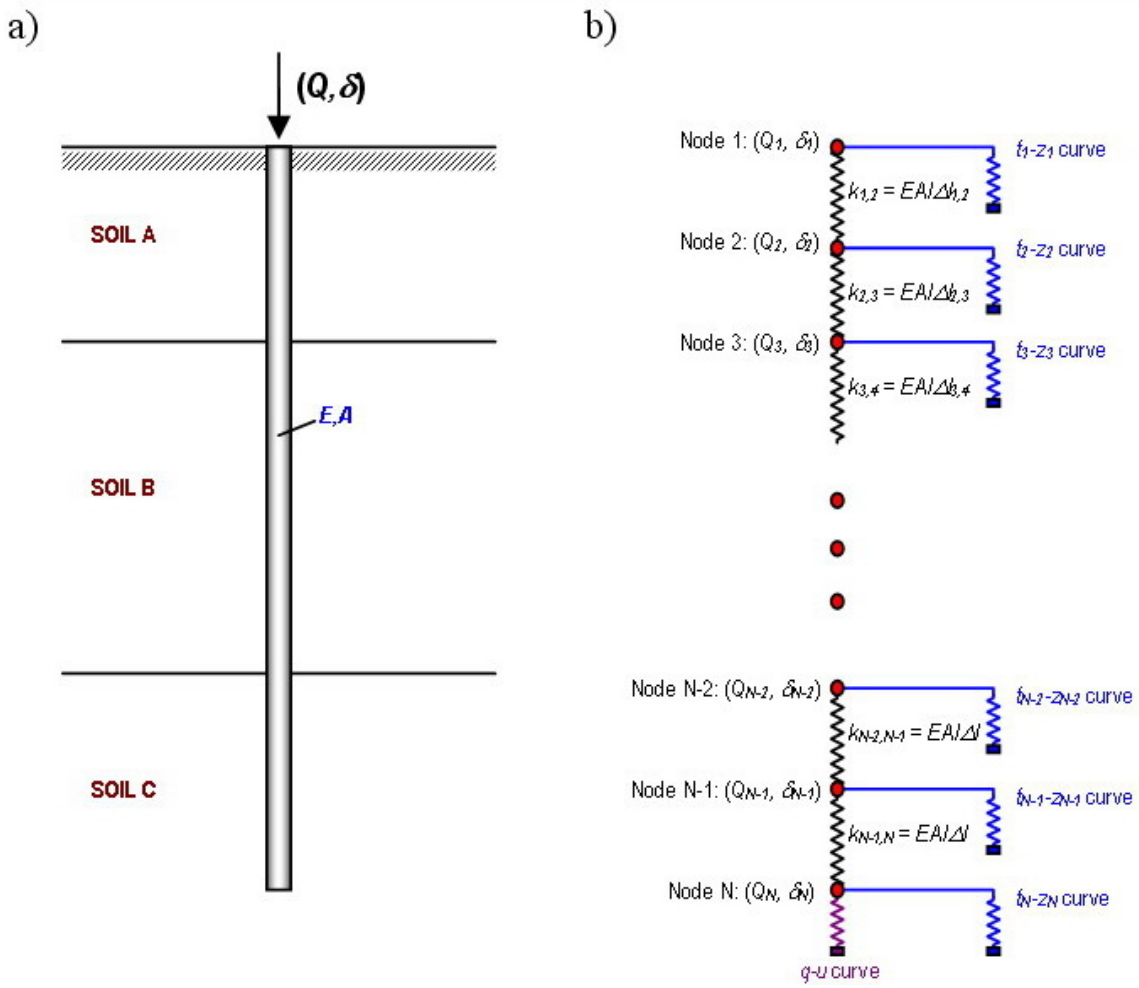


FIGURE 4-5: AXIAL PILE CAPACITY VERSUS PIER NUMBER OF ANTIOCH PIERS

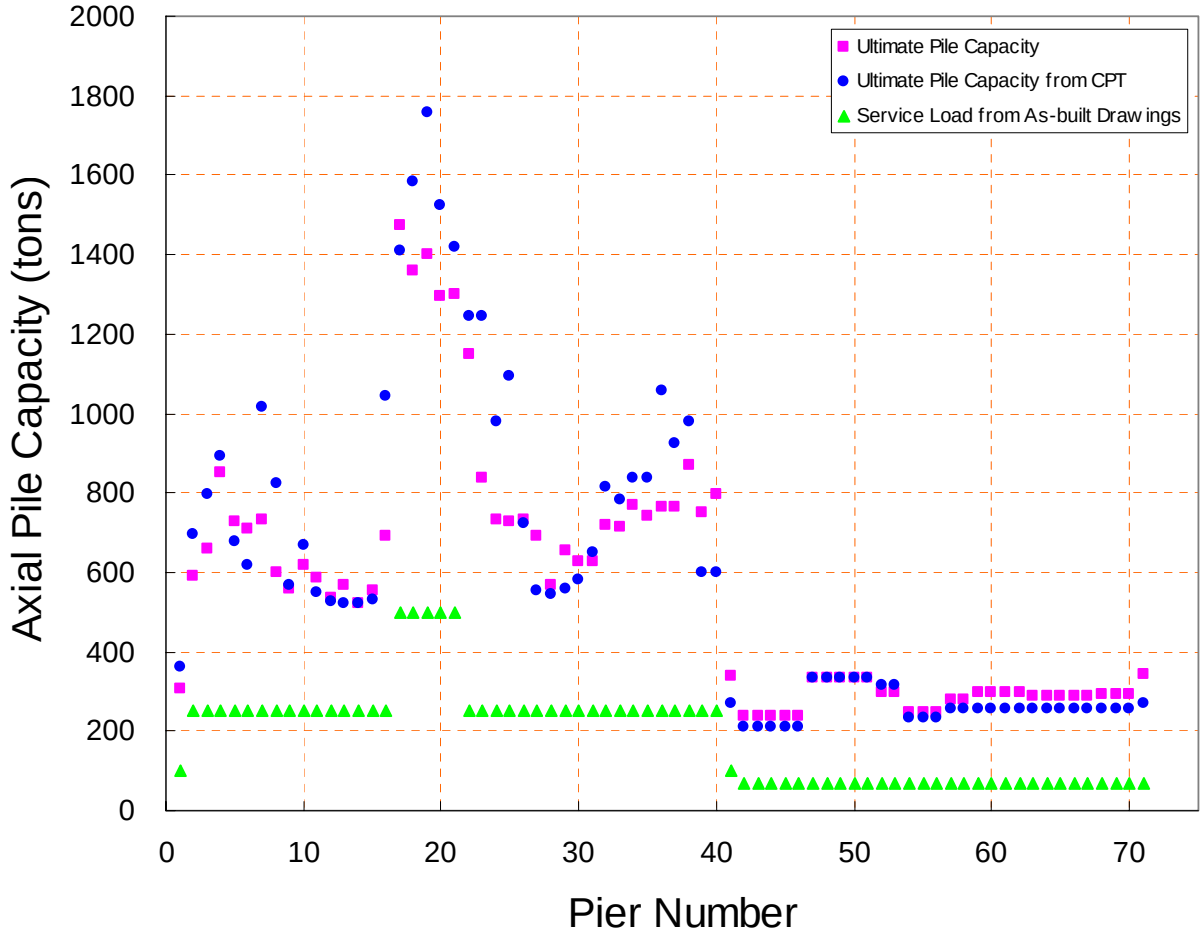


FIGURE 4-6: CALCULATION RESULTS OF PILE BEARING CAPACITY BY CPeT-IT (S03)

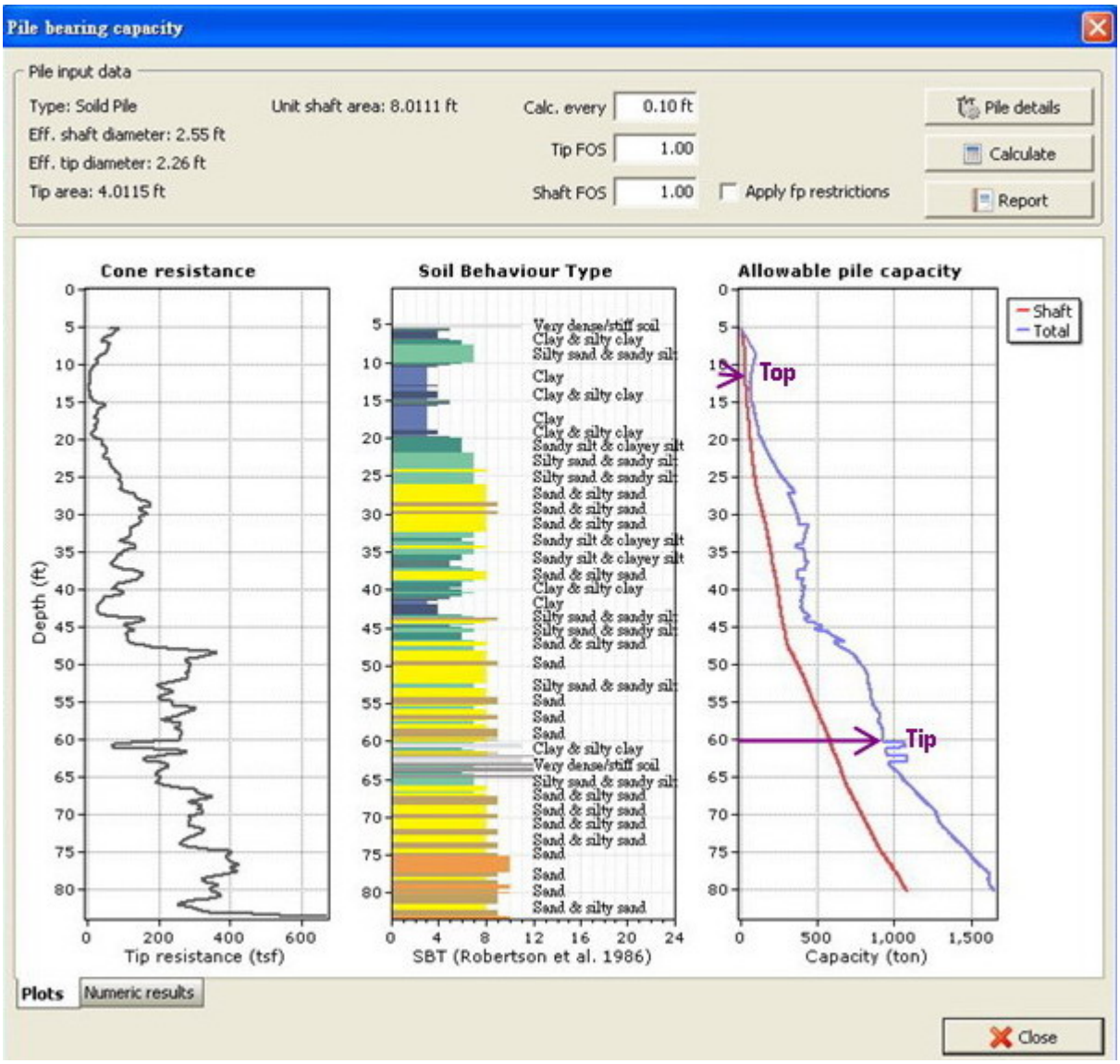
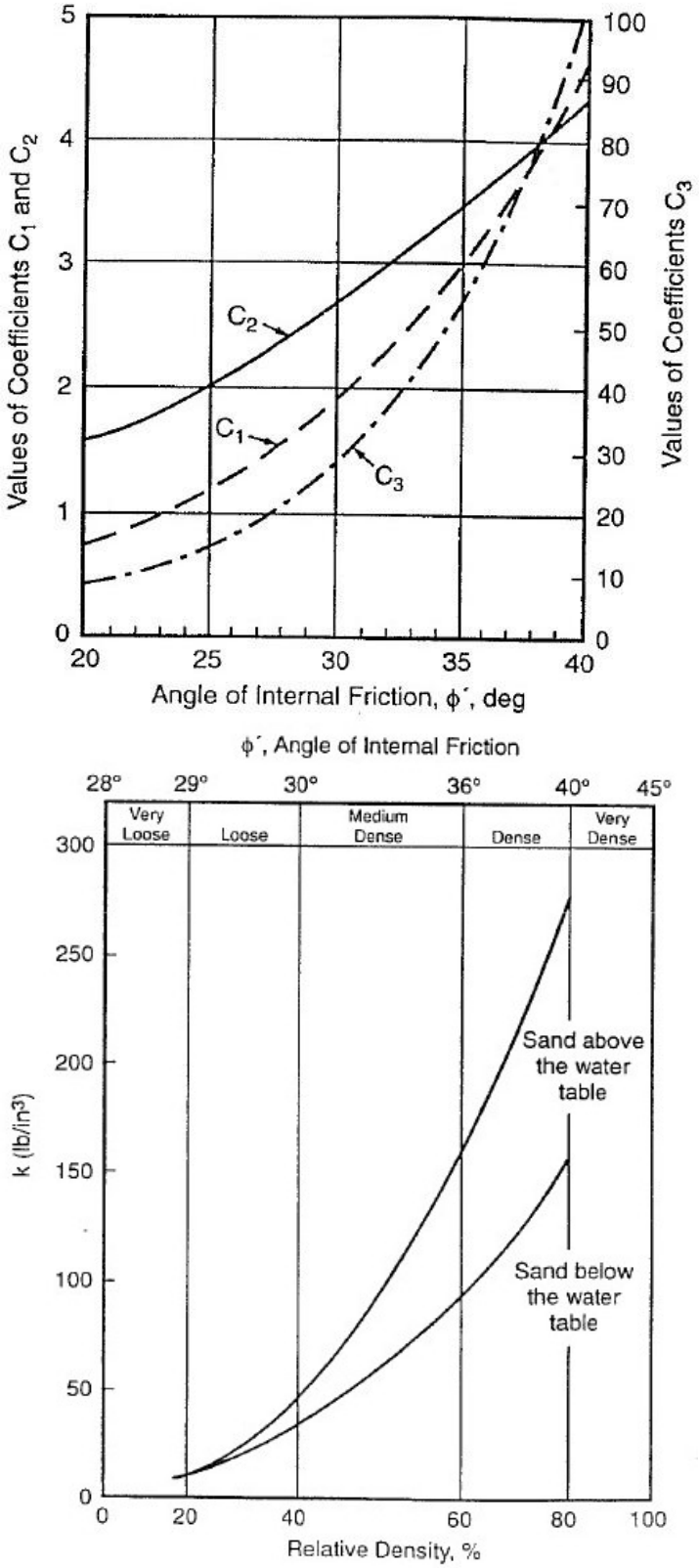


FIGURE 4-7: COEFFICIENTS (C_1, C_2, C_3) AND INITIAL MODULUS (K) AS FUNCTION OF ϕ'



5.0 SOIL-STRUCTURE INTERACTION

Pile foundations supporting a bridge can be modeled in several ways for seismic response evaluation. Figure 5-1 illustrates some of the modeling approaches adopted in the Toll Bridge Seismic Retrofit Program; namely, Complete Model, Sub-structure Model 1 and Sub-structure Model 2. They all offered satisfactory results depending on the objectives of the global bridge model. The Complete Model includes all foundation members in the global bridge model, in which the piles are explicitly modeled with beam elements and *t-z* and *p-y* soil springs distributed along each pile. Then, depth-varying free field motions are used to excite the foundation. On the other hand, Sub-structure Model 1 and Sub-structure Model 2 involve a cut-off line at convenient interface and the structure immediately above the interface line is subjected to some kind of equivalent stiffness matrix and kinematic motion to represent the contribution of the sub-structure (foundation) below. In this project, the Sub-structure Model 2 with the cut-off line at pile cap was adopted for primary design. As such, the entire pile-foundation below the pile-cap was represented by 6×6 stiffness, mass, and damping matrices, and kinematic motion to excite the global bridge structure. A special study was also conducted on a stand-alone pier to check validity of the models shown in Figure 5-1.

The sections that follow describe the formulation of foundation stiffness matrix using the sub-structuring approach. A more detailed formulation of kinematic motion and its discussion can be found in an MCEER report (Lam and Law, 2000). A set of stiffness matrices were developed at the pile-cap level to represent the entire pile group of each Antioch Bridge pier. Other than foundation stiffness matrices, we also provided mass matrices, damping matrices and kinematic motions (forcing functions) for seismic response analyses.

5.1 Method of Sub-structuring

To develop a foundation stiffness matrix and kinematic motion (forcing function) for a substructure system, we consider a global structural model (total system) consisting of superstructure, pile-cap, and pile-foundation, as shown in Figure 5-2. For the purpose of discussion, we neglect the damping term and assume a lumped mass system. The global bridge structure is excited by depth-varying input ground motions $\{x_g(t)\}$ along the pile length, and the equations of motion can be written as,

$$\begin{bmatrix} [m_s] & & \\ & [m_c] & \\ & & [m_p] \end{bmatrix} \begin{Bmatrix} \{\ddot{x}_s\} \\ \{\ddot{x}_c\} \\ \{\ddot{x}_p\} \end{Bmatrix} + \begin{bmatrix} [K_{ss}] & [K_{sc}] & \\ [K_{cs}] & [K_s]+[K_{cc}] & [K_{cp}] \\ & [K_{pc}] & [K_{pp}] \end{bmatrix} \begin{Bmatrix} \{x_s\} \\ \{x_c\} \\ \{x_p\} \end{Bmatrix} = \begin{Bmatrix} 0 \\ 0 \\ [K_g]\{x_g\} \end{Bmatrix}$$

where $\{x_s\}$, $\{x_c\}$ and $\{x_p\}$ are displacement vectors of the superstructure, pile-cap, and pile degrees of freedom, respectively relative to the earth inertia reference frame (i.e, total displacements). The pile-cap would have 6 degrees of freedom (three translations, and three rotations). We assume that mass of the pile is small, and can be ignored, i.e, $[m_p]=0$. Typically, this is the case because inertial forces of the piles are relatively small in relation to the more massive

superstructure and therefore, neglecting the foundation inertial effect does not normally cause significant error. Then the system of equations becomes

$$\begin{bmatrix} [m_s] & & \\ & [m_c] & \\ & & [0] \end{bmatrix} \begin{Bmatrix} \{\ddot{x}_s\} \\ \{\ddot{x}_c\} \\ \{\ddot{x}_p\} \end{Bmatrix} + \begin{bmatrix} [K_{ss}] & [K_{sc}] & \\ [K_{cs}] & [K_s]+[K_{cc}] & [K_{cp}] \\ & [K_{pc}] & [K_{pp}] \end{bmatrix} \begin{Bmatrix} \{x_s\} \\ \{x_c\} \\ \{x_p\} \end{Bmatrix} = \begin{Bmatrix} 0 \\ 0 \\ [K_g]\{x_g\} \end{Bmatrix}$$

With the pile mass assumed to be zero, static condensation can be conducted to eliminate the pile degrees of freedom. Dynamic response analysis in the time domain can be conducted via the following equation derived from the first two sets of the above equation:

$$\begin{bmatrix} [m_s] & \\ & [m_c] \end{bmatrix} \begin{Bmatrix} \{\ddot{x}_s\} \\ \{\ddot{x}_c\} \end{Bmatrix} + \begin{bmatrix} [K_{ss}] & [K_{sc}] \\ [K_{cs}] & [K_s]+[K] \end{bmatrix} \begin{Bmatrix} \{x_s\} \\ \{x_c\} \end{Bmatrix} = \begin{Bmatrix} 0 \\ \{f\} \end{Bmatrix}$$

which only involves the superstructure $\{x_s\}$ and the pile cap variables $\{x_c\}$, and where [K] and $\{f\}$ in the above equation are defined as:

$$[K] = [K_{cc}] - [K_{cp}][K_{pp}]^{-1}[K_{pc}]$$
$$[f] = -[K_{cp}][K_{pp}]^{-1}[K_g]\{x_g\}$$

It is noted that the resultant dynamic equations of motion contain only pile-cap and superstructure degrees of freedom, and in fact the solutions to these equations are what the structure engineers are seeking, which represent demands for the superstructure and the pile-cap. The original global structural model is now reduced to a system of the superstructure and pile-cap which is connected with the ground by an equivalent stiffness matrix of [K] and is subjected to an equivalent force of $\{f\}$, as shown Figure 5-3a. This transformation of the original problem into the substructure system consisting only of superstructure and pile-cap is entirely based on classical static condensation. The stiffness and loading of pile foundation appear in the form of 6×6 condensed stiffness matrix [K] and a 6×1 time-series forcing function $\{f\}$ applied at the pile-cap level. Both the stiffness matrix [K] (which is constant with time) and the forcing $\{f\}$ (which is time dependent related to the time histories of the depth-varying free-field input ground motion $\{x_g(t)\}$) can be pre-calculated without knowledge of the response of the superstructure or the pile cap. Instead of using the forcing function $\{f\}$ explicitly on the right hand side of the equations, we introduce a 6×1 vector {X}, such that

$$\{f\} = [K]\{X\}$$

From the above equation, it can be noted that loading from ground excitation is introduced into the overall structure as a right hand vector in a form of a displacement vector {X} times the foundation stiffness [K]

$$\begin{bmatrix} [m_s] & \\ & [m_c] \end{bmatrix} \begin{Bmatrix} \{\ddot{x}_s\} \\ \{\ddot{x}_c\} \end{Bmatrix} + \begin{bmatrix} [K_{ss}] & [K_{sc}] \\ [K_{cs}] & [K_s]+[K] \end{bmatrix} \begin{Bmatrix} \{x_s\} \\ \{x_c\} \end{Bmatrix} = \begin{Bmatrix} 0 \\ [K]\{X\} \end{Bmatrix}$$

Upon inspection of the above reduced equations of motion, {X} represents some form of rigid-base motion. The system becomes the superstructure and pile cap, connected with the ground by the stiffness matrix [K], and the ground is subjected to the rigid-base motion of {X}, as shown Figure 5-3b. This six-component motion {X} is termed "kinematic motion", and is a major element in defining ARS design criteria.

It is interesting to note the form of stiffness matrix. For a vertical pile group, the form of pile group stiffness matrix is identical to that of a single pile, and has the following terms for a fixed head condition

$$[K] = \begin{bmatrix} k_x & 0 & 0 & 0 & -k_{x\theta y} & 0 \\ 0 & k_y & 0 & k_{y\theta x} & 0 & 0 \\ 0 & 0 & k_z & 0 & 0 & 0 \\ 0 & k_{y\theta x} & 0 & k_{\theta x} & 0 & 0 \\ -k_{x\theta y} & 0 & 0 & 0 & k_{\theta y} & 0 \\ 0 & 0 & 0 & 0 & 0 & k_{\theta z} \end{bmatrix}$$

in which k_x, k_y, k_z and $k_{\theta x}$, $k_{\theta y}$, $k_{\theta z}$ are stiffness coefficients corresponding to translational and rotational degrees of freedom associated with the X ,Y and Z axes, respectively. The X- and Y-coordinates are taken as horizontal axes, and the Z-coordinate is the vertical axis. For a bettered pile group, the off-diagonal terms of the pile group stiffness matrix could become opposite sign from the vertical pile group.

$$[K] = \begin{bmatrix} k_x & 0 & 0 & 0 & k_{x\theta y} & 0 \\ 0 & k_y & 0 & -k_{y\theta x} & 0 & 0 \\ 0 & 0 & k_z & 0 & 0 & 0 \\ 0 & -k_{y\theta x} & 0 & k_{\theta x} & 0 & 0 \\ k_{x\theta y} & 0 & 0 & 0 & k_{\theta y} & 0 \\ 0 & 0 & 0 & 0 & 0 & k_{\theta z} \end{bmatrix}$$

Changes in the signs of the off-diagonal terms can be explained by rotation of the pile cap as depicted in Figure 5-4. Since the axial pile stiffness is generally an order of magnitude greater than the lateral stiffness, a small battered angle of the piles could lead to back-ward rotation of the pile cap.

5.2 Treatment of Mass and Damping

The substructuring approach using static condensation, as mentioned above, provides rigorous solutions for massless piles. However for piles with some limited mass, the method is only approximate and the error depends on the relative magnitude of the pile mass to the superstructure mass. The solution can be greatly improved by implementing a condensed mass in the foundation substructure, which can be derived from a free vibration system of pile-cap and piles as shown in Figure 5-5. This is to maintain the fundamental mode of vibration of the entire foundation system in the condensed substructure which consists of 6 degrees of freedom (3 translation and 3 rotational modes) at the pile cap. One approach would be based on computation of Eigen values for the soil-pile system representing the entire foundation. The condensed mass, [M], can be approximated by

$$[\mathrm{M}] = \frac{1}{\omega^2}[\mathrm{K}]$$

where [K] is the condensed stiffness matrix (6×6) obtained from static condensation and ω is an angular frequency. The value for ω is often chosen as the fundamental frequency (1st mode) for each of the six axes (3 translation and 3 rotation) of the entire foundation. By doing so, the condensed model consisting of 6×6 mass matrix [M] and 6×6 stiffness matrix [K] would reproduce the same 6 fundamental modes of vibration as the original foundation prior to adding the superstructure. In fact, matching of six modes of vibration is the best one can achieve for a condensed system that has only six degrees of freedom. It is not feasible to have more than six vibration modes for a six-d.o.f system.

In many cases, however, computation of natural frequencies and mode shapes for a large pile group can be time consuming. A method similar to static condensation can be employed to reduce the number of degrees of freedom for a dynamic system which reduces the expense of computing Eigen value and Eigen vector. This condensation algorithm is known in the literature as Guyan reduction, mass condensation, dynamic condensation, or Eigen value economization. In the context of pile foundation, free vibration characteristics of the pile-cap/pile system can be expressed as,

$$\left(\begin{bmatrix}[\mathrm{K_{cc}}] & [\mathrm{K_{cp}}]\\ [\mathrm{K_{pc}}] & [\mathrm{K_{pp}}]\end{bmatrix} - \omega^2\begin{bmatrix}[\mathrm{m_c}] & \\ & [\mathrm{m_p}]\end{bmatrix}\right)\begin{Bmatrix}\{\mathrm{x_c}\}\\ \{\mathrm{x_p}\}\end{Bmatrix} = \begin{Bmatrix}0\\0\end{Bmatrix}$$

where the subscript c denotes the pile-cap d.o.f and the subscript p denotes the pile d.o.f. In order to obtain a relation between $\{x_c\}$ and $\{x_p\}$, we temporarily ignore all the mass, and the above equation reduces to

$$\begin{Bmatrix}\{\mathrm{x_c}\}\\ \{\mathrm{x_p}\}\end{Bmatrix} = [\mathrm{T}]\{\mathrm{x_c}\}$$

where

$$[\mathrm{T}] = \begin{Bmatrix}\mathrm{I}\\ -[\mathrm{K_{pp}}]^{-1}[\mathrm{K_{pc}}]^{\mathrm{T}}\end{Bmatrix}$$

Substituting the above equation into the free-vibration Eigen value equation and pre-multiplying by $[T]^T$ yields the condensed Eigen-value problem as follows

$$([K]-\omega^2[M])\{x_c\}=0$$

where the reduced stiffness and mass matrices are symmetric and are given by

$$[K]=[T]^T\begin{bmatrix}[K_{cc}] & [K_{cp}]\\ [K_{pc}] & [K_{pp}]\end{bmatrix}[T]$$

and

$$[M]=[T]^T\begin{bmatrix}[m_c] & \\ & [m_p]\end{bmatrix}[T]$$

It can be seen that [T] plays a similar role as Ritz vectors in the Raleigh-Ritz method. Furthermore, it is noted the condensed mass [M] is banded and is a combination of both mass and stiffness coefficients. If the piles carry no mass, then [K] is the same matrix as produced by static condensation. If damping matrix appears in the equation of motion, the same principle can be employed to obtain a condensed damping matrix [C] as

$$[C]=[T]^T\begin{bmatrix}[C_{cc}] & [C_{cp}]\\ [C_{pc}] & [C_{pp}]\end{bmatrix}[T]$$

However, in typical seismic response analysis of global bridge foundation damping is not used explicitly. Global damping parameters such as those based on Raleigh damping coefficients are generally used.

5.3 Foundation Stiffness, Mass and Damping

The method of sub-structuring is an approach based on a linear theory, and it provides approximate solutions to the problems with non-linear foundation behavior. Though *p-y* and *t-z* curves are highly non-linear, the overall behavior of foundation system, which consists of pile and soil supports, is mildly non-linear within the range of seismic loading.

The first step towards developing the foundation stiffness matrix involved linearization of the *p-y* curves by performing lateral pushover analysis of the single pile to a representative displacement level expected during the earthquake. The structural engineers provided their initial estimates on peak foundation displacements, while we used 65% of the peak displacement values as representative displacement levels. Once the *p-y* curves were linearized on the basis of lateral pushover analysis, the problem became beams on elastic springs, and the method of sub-structuring was applied to obtain the condensed stiffness matrix. These stiffness matrices were then used in the next round of the global analysis to compute displacement demands. Iteration was adopted to ensure that the displacements used to linearize the soil stiffness were compatible with the seismic demands.

Stiffness matrices were developed at the bottom of the pile cap (equivalent to Sub-structure Model

2 depicted in Figure 5-1) for all Antioch Bridge and slab bridge piers, presuming a fixed head condition. The stiffness matrices are listed in Appendix G. The coordinate system adopted for the stiffness calculation is such that the X-direction is along the bridge axis, Y-direction is transverse to the bridge axis, and Z-direction is vertical. The mass matrices and damping matrices are also provided in the same tables. Formulation of the mass matrix follows the procedure based on Guyan reduction discussed above, and therefore the condensed mass matrix is fully populated; however for simplicity, the off-diagonal terms have been neglected. Using the stiffness matrix and the mass matrix, a damping matrix was developed assuming a 5% damping ratio for all six modes of vibration (3 translation and 3 rotation). Computation of the above condensed matrices were also conducted with the in-house computer program KIPS.

5.4 Comparison Study of Different Foundation Modeling

At the onset of seismic response analyses of the bridge, the structural designers evaluated the most appropriate foundation model to be used for the primary design of bridge. To assist the decision making, two of the four models shown in Figure 5-1 were studied using Pier 17 as a stand alone bent without adjacent piers (see Figure 5-6).

The first model was a complete SSI model considering all piles as structure members with non-linear soil springs attached to the piles. Free-field motions provided depth-varying ground excitation. The second model was Sub-structure Model 2, adopting a cut-off line at the pile-cap and a 6×6 stiffness matrix to represent the entire pile group.

The Office of Earthquake Engineering conducted the time history analyses of the Pier 17 stand - alone models with the two foundation representations. The superstructure response of the bridge from each of the model is shown in Figure 5-7. The solutions are shown to be very comparable; the minor variations are attributed to non-linear springs used in some of the foundation models.

5.5 Nonlinear Pushover Analyses

Static nonlinear pushover analyses were conducted at three piers to assist Caltrans structural designers for the independent check of displacement capacities, and to evaluate whether foundation stiffnesses used for the seismic analyses were consistent with the displacement demands. Piers 11, 19 and 30 were selected; 24” x 24” square concrete piles are used at Piers 11 and 30, and 54” diameter hollow concrete pile at Pier 19. The pushover analyses involved modeling the pile/footing connection with a non-linear moment-rotation spring, characterizing the pre-stressed pile section with a moment-curvature relationship, and representing the soil supports with non-linear p-y curves. Findings from the single pile and limited pile-group push-over analyses are provided in Appendix H.

Dr. Nigel Priestley provided the characterizations of the pile/footing connection (moment-rotation spring) and pre-stressed pile section (moment-curvature relationship) for a typical 24” x 24” square concrete pile, and a 54 inch diameter prestressed concrete pile. For each pile type, three different axial loads were examined. Priestley’s report describing limit states and the level of strains used are also included in Appendix H.

FIGURE 5-1: FOUNDATION MODELING SCHEMES FOR SOIL-STRUCTURE INTERACTION

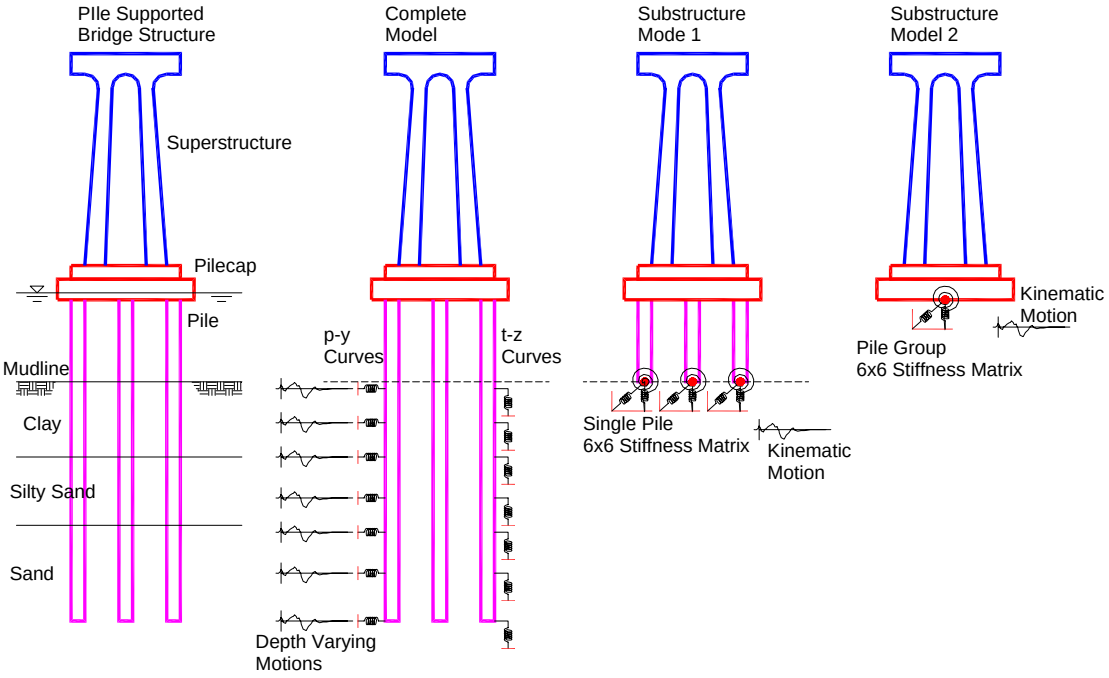


FIGURE 5-2: COMPLETE MODEL FOR SOIL-STRUCTURE INTERACTION

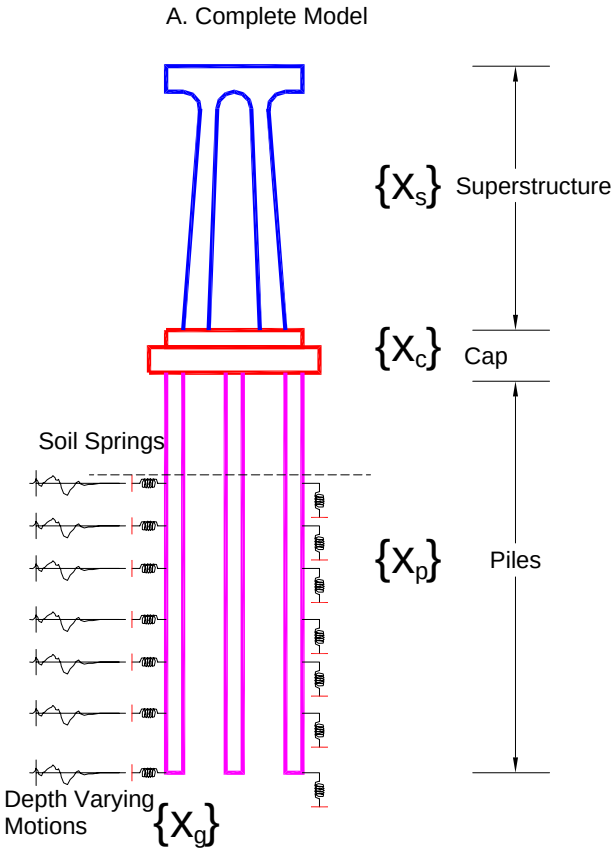


FIGURE 5-3: SUBSTRUCTURE MODEL 2 FOR SOIL-STRUCTURE INTERACTION

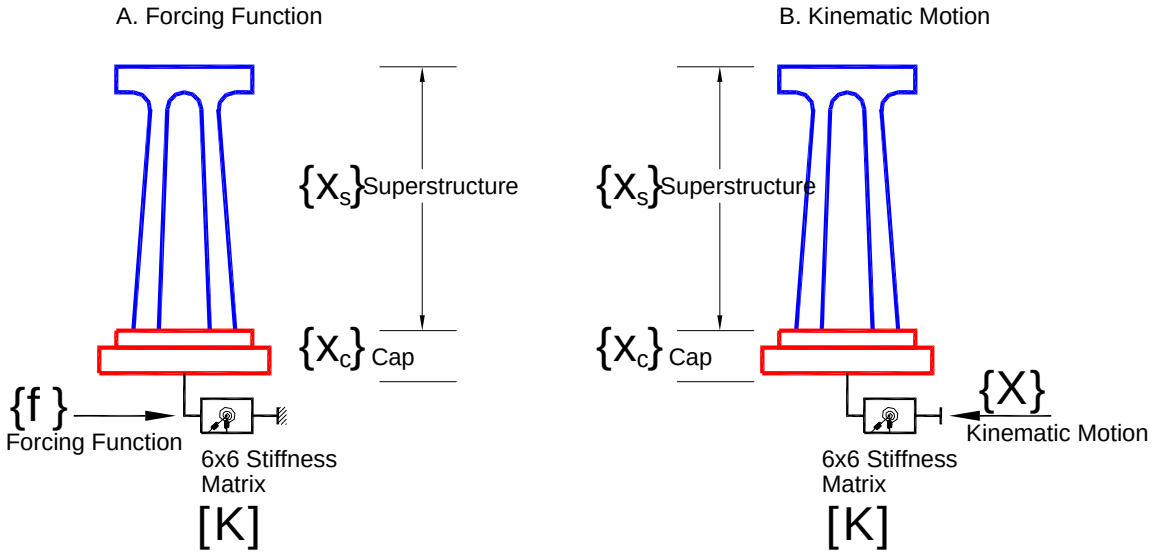
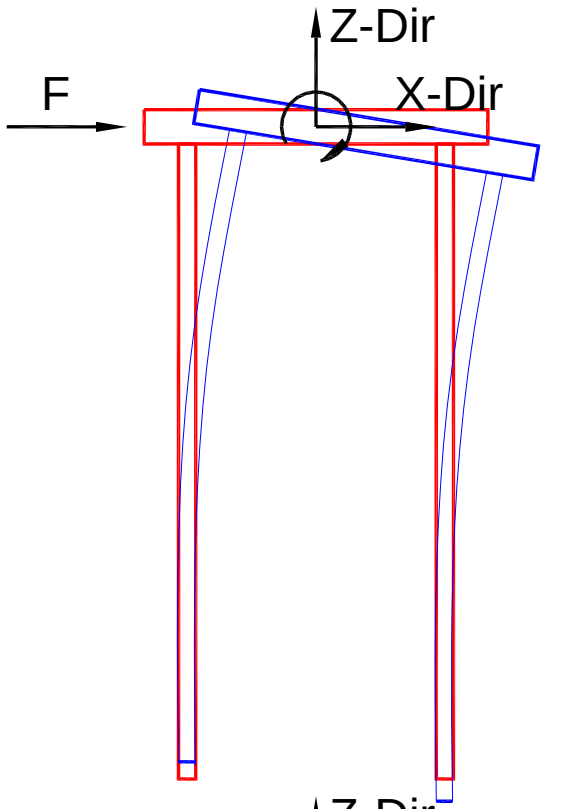
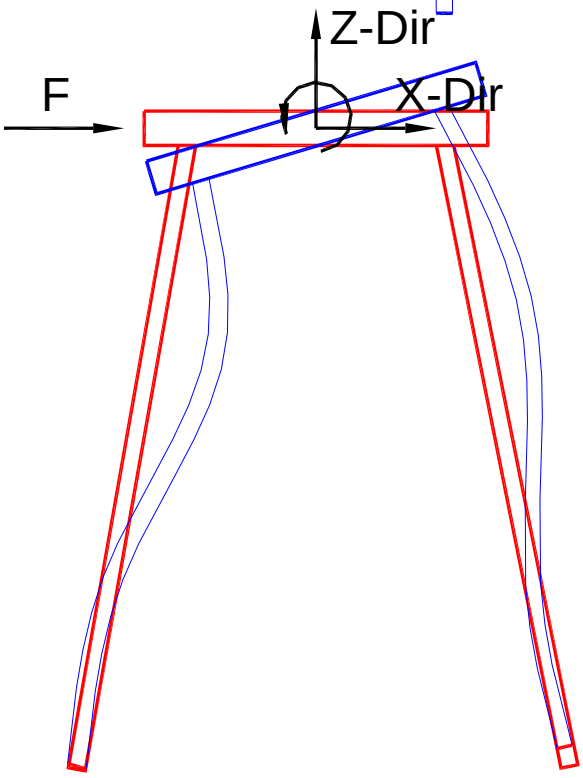


FIGURE 5-4: ROTATION OF A PILECAP SUBJECTED TO HORIZONTAL LOADING



$$[\mathrm{K}] = \begin{bmatrix} k_x & 0 & 0 & 0 & -k_{x\theta y} & 0 \\ 0 & k_y & 0 & k_{y\theta x} & 0 & 0 \\ 0 & 0 & k_z & 0 & 0 & 0 \\ 0 & k_{y\theta x} & 0 & k_{\theta x} & 0 & 0 \\ -k_{x\theta y} & 0 & 0 & 0 & k_{\theta y} & 0 \\ 0 & 0 & 0 & 0 & 0 & k_{\theta z} \end{bmatrix}$$



$$[\mathrm{K}] = \begin{bmatrix} k_x & 0 & 0 & 0 & k_{x\theta y} & 0 \\ 0 & k_y & 0 & -k_{y\theta x} & 0 & 0 \\ 0 & 0 & k_z & 0 & 0 & 0 \\ 0 & -k_{y\theta x} & 0 & k_{\theta x} & 0 & 0 \\ k_{x\theta y} & 0 & 0 & 0 & k_{\theta y} & 0 \\ 0 & 0 & 0 & 0 & 0 & k_{\theta z} \end{bmatrix}$$

FIGURE 5-5: MODEL FOR FOUNDATION MASS

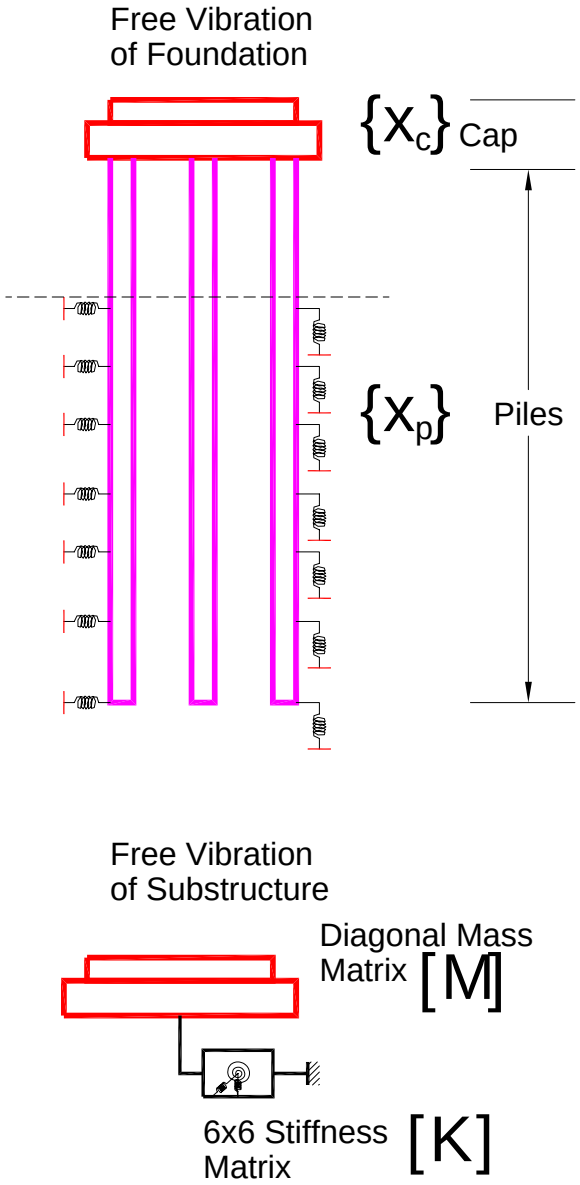
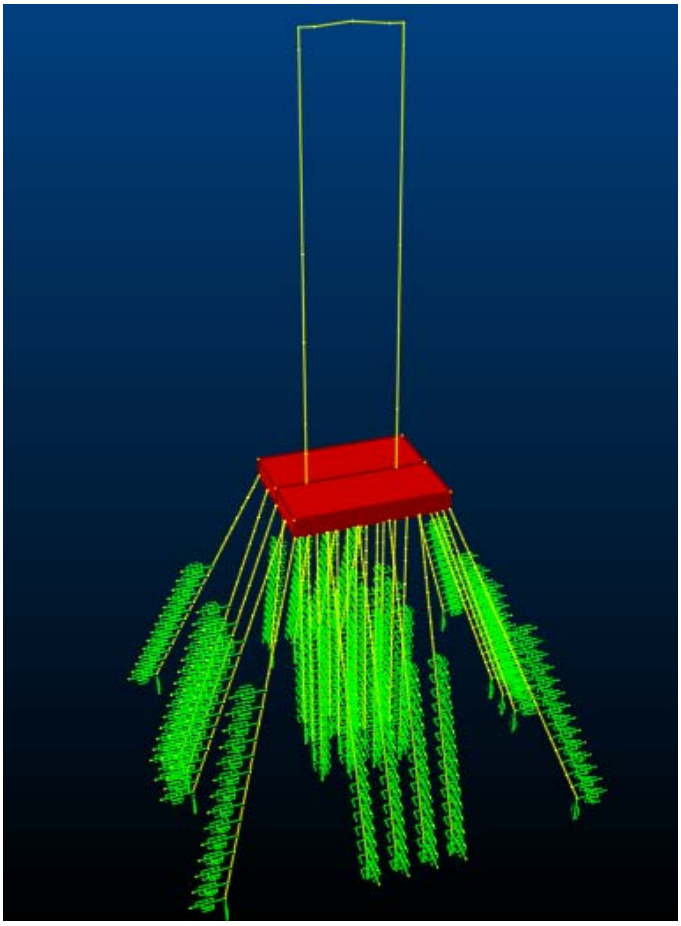


FIGURE 5-6: TWO SSI MODELS USED FOR ANTIOCH PIER 17

a) Complete Model



b) Subs-structure Model 2

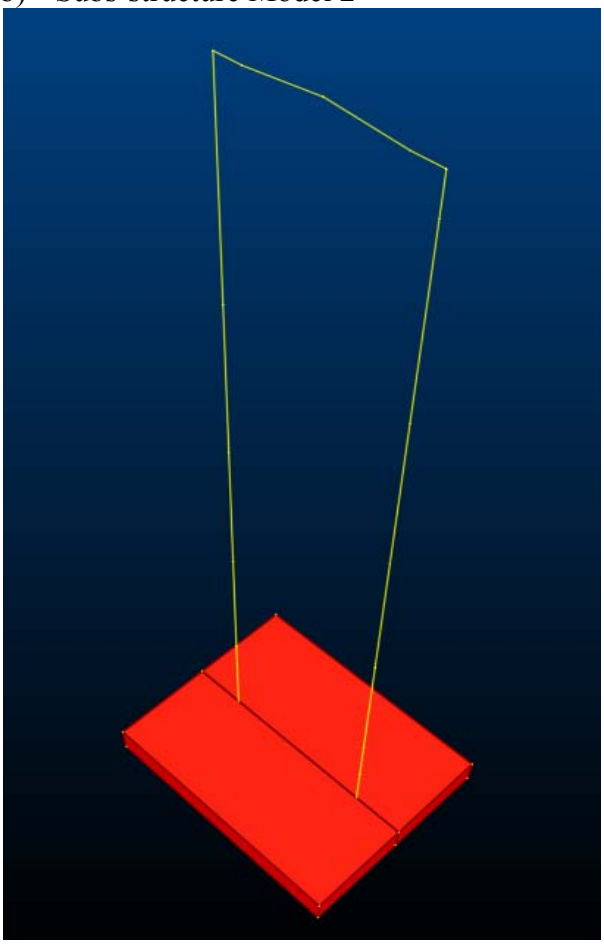
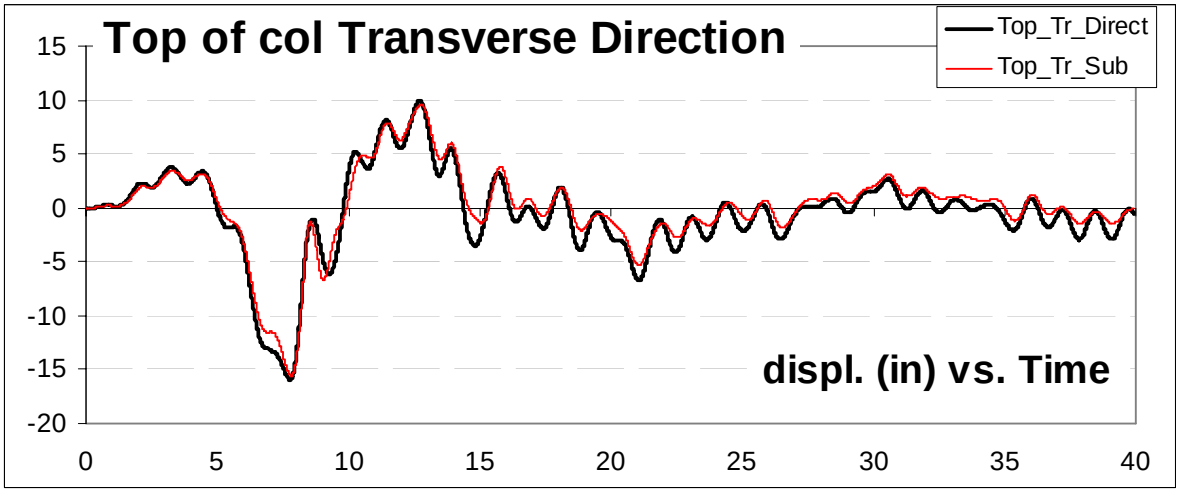
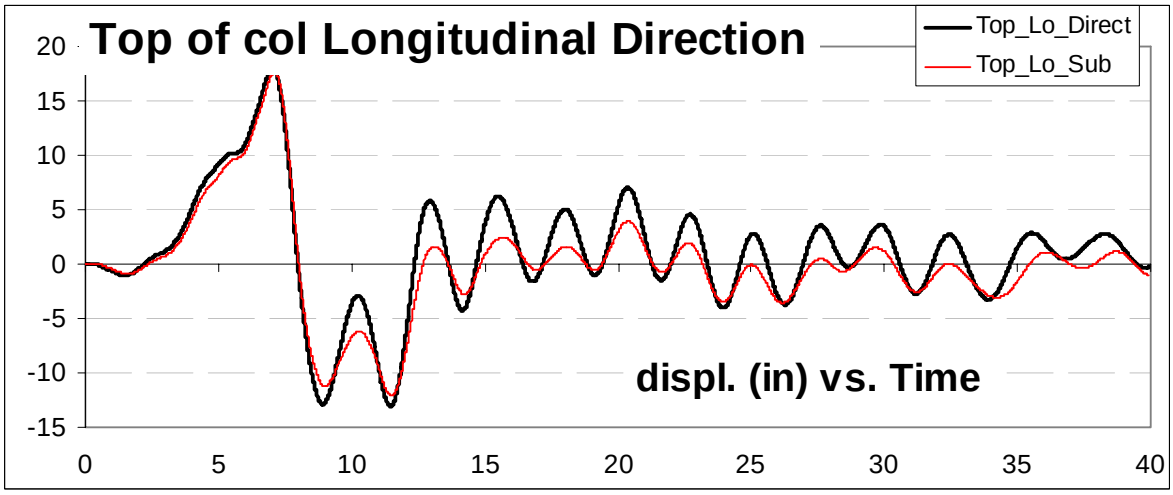


FIGURE 5-7: COMPARATIVE STUDY RESULTS FOR ANTIOCH PIER 17

a) Transverse Direction



b) Longitudinal Direction



6.0 CONCLUSIONS

This report presents foundation analysis works conducted for the existing Antioch Toll Bridge, with emphasis on the foundation design and modeling issues. The following are a summary of materials discussed in the report:

(1) The subsurface conditions underlying the site are typical of the San Joaquin/Sacramento River Delta geology and mainly composed of sand (loose to dense), clayey peat, and clay (stiff to hard). The engineering properties of these soil units are provided at all piers along the bridge.

(2) The seismicity is controlled by local faults in the delta region. The seismic study incorporated the 2007 Delta Risk Management Study by URS. Reference rock spectra corresponding to the 1,000-year return period ground motions were selected as the Safety Evaluation Earthquake (SEE) for seismic retrofit evaluation, based on a probabilistic approach.

(3) The Antioch fault is believed to be inactive. Hazards arising from fault rupturing are determined to be remote possibilities.

(4) Three sets of ARS curves for the SEE event are developed for three groups of piers along the bridge alignment, based on the results of seismic response and SSI analyses conducted at six representative piers with seven spectrum-compatible motions.

(5) Liquefaction potential and associated settlement are evaluated at susceptible locations.

(6) Soil supports in terms of *t-z* curves along the pile and the end bearing *q-u* curves at pile tip for all bridge piers and trestle bents are provided. They were used in pile capacity analyses, development of foundation stiffness matrix, and direct modeling of soil springs in the complete foundation model.

(7) The axial pile-head load versus pile-head deformation (Q-δ) curves are evaluated. Design loads and ultimate pile capacities are discussed including results from conventional pile capacity calculations, and findings from a CPT-based pile capacity method.

(8) The lateral soil supports (*p-y* curves) along the pile and the results of the lateral push-over analyses on a single pile are presented. The development of *p-y* curves is based on API code; however a *p*-multiplier of 0.5 was adopted for seismic design; it is intended to collectively account for cyclic degradation and pile group effects.

(9) Modeling approaches used in the Toll Bridge Program are discussed, and mathematical derivation of 6×6 foundation stiffness, mass and damping matrices is presented. The foundation stiffness matrices, mass matrices, and damping matrices are provided for all bridge piers and trestle bents in the seismic response analyses of the global bridge model.

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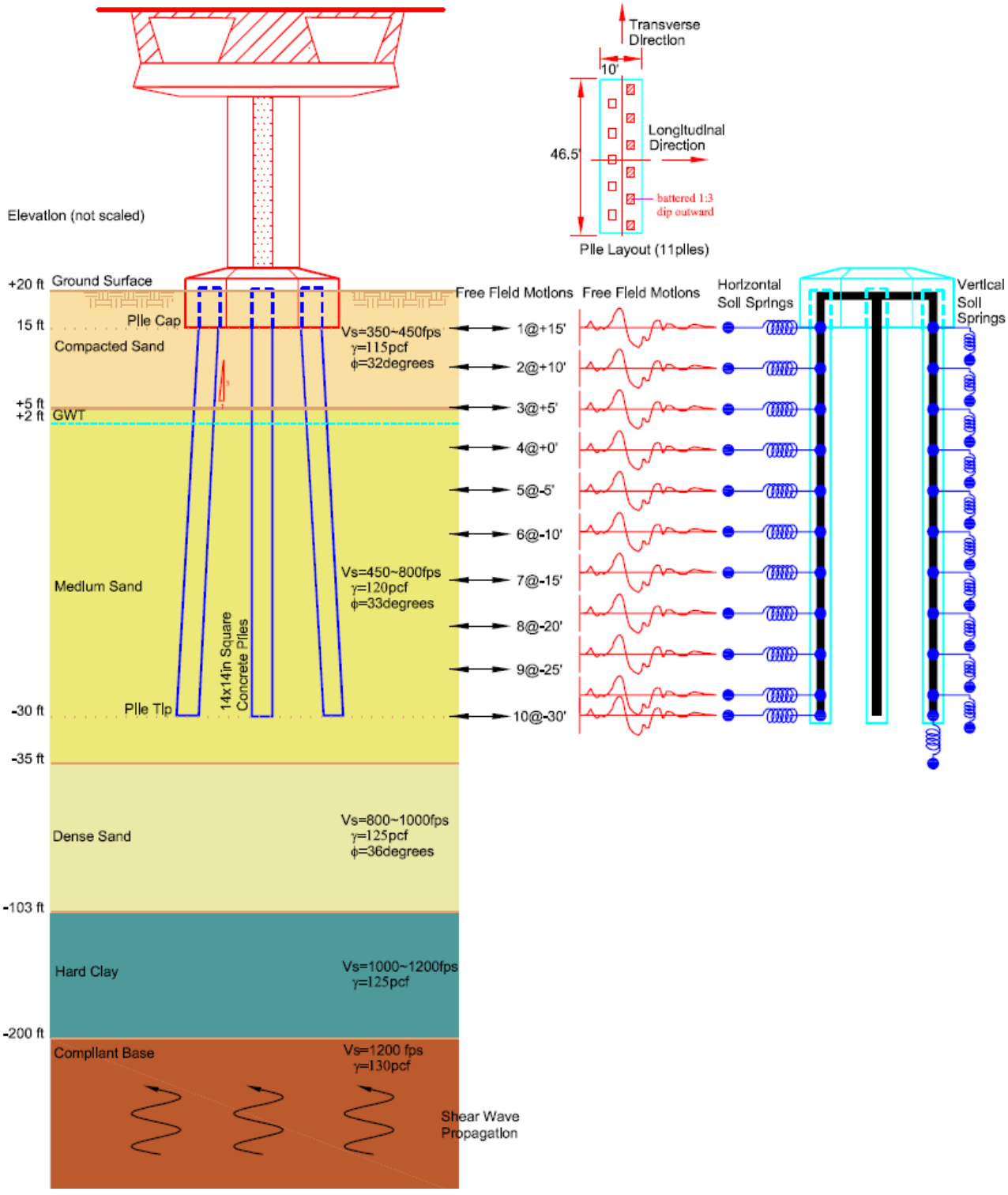
8.0 APPENDIX A: IDEALIZED SOIL CONDITIONS AND FOUNDATION DATA

FIGURE A-1. IDEALIZED SOIL CONDITIONS AND FOUNDATION DATA AT ABUTMENT 1


Transverse Direction
10'
46.5'
Longitudinal Direction
battered 1:3 dip outward
Pile Layout (11piles)
Elevation (not scaled)
+20 ft
Ground Surface
15 ft
Pile Cap
Compacted Sand
Vs=350~450fps
γ=115pcf
ϕ=32degrees
+5 ft
+2 ft
GWT
Medium Sand
Vs=450~800fps
γ=120pcf
ϕ=33degrees
14x14in Square Concrete Piles
-30 ft
Pile Tip
-35 ft
Dense Sand
Vs=800~1000fps
γ=125pcf
ϕ=36degrees
-103 ft
Hard Clay
Vs=1000~1200fps
γ=125pcf
-200 ft
Compliant Base
Vs=1200 fps
γ=130pcf
Shear Wave Propagation
Free Field Motions
Free Field Motions
1@+15'
2@+10'
3@+5'
4@+0'
5@-5'
6@-10'
7@-15'
8@-20'
9@-25'
10@-30'
Horizontal Soil Springs
Vertical Soil Springs

9.0 APPENDIX B: *T-Z* AND *Q-U* CURVES

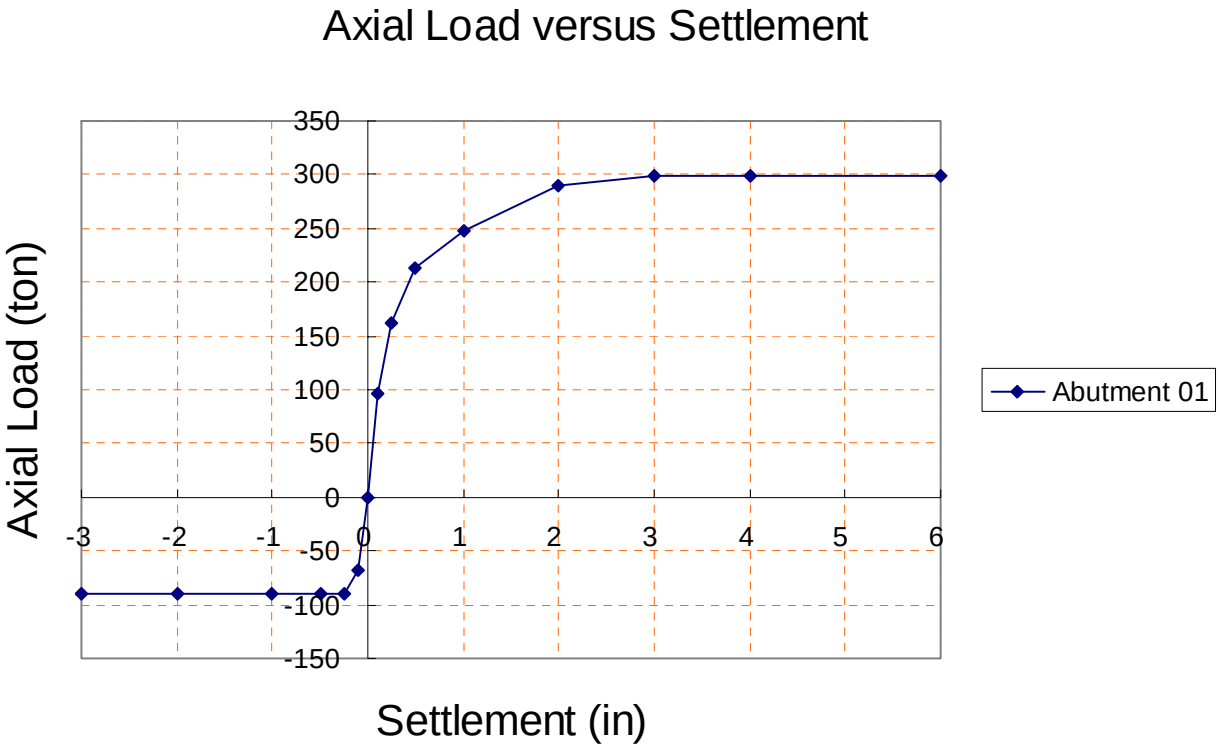
TABLE B-1: ABUTMENT 1 - *t-z* AND *q-u* CURVES

Node #	Elevation	Soil	t_{max}	z_c	t_1	z_1	t_2	z_2	t_3	z_3	t_4	z_4	t_5	z_5	t_6	z_6	t_7	z_7
	(ft)	Type	(lb/in)	(in)	(lb/in)	(in)	(lb/in)	(in)	(lb/in)	(in)	(lb/in)	(in)	(lb/in)	(in)	(lb/in)	(in)	(lb/in)	(in)
1	1.5	Clay	314.2	0.20	124.7	0.01	167.1	0.02	218.0	0.04	249.8	0.06	271.7	0.08	298.1	0.12	314.2	0.20
2	-1.0	Clay	314.2	0.20	124.7	0.01	167.1	0.02	218.0	0.04	249.8	0.06	271.7	0.08	298.1	0.12	314.2	0.20
3	-4.0	Clay	222.5	0.20	88.3	0.01	118.4	0.02	154.4	0.04	176.9	0.06	192.5	0.08	211.2	0.12	222.5	0.20
4	-8.0	Clay	130.9	0.20	52.0	0.01	69.6	0.02	90.8	0.04	104.1	0.06	113.2	0.08	124.2	0.12	130.9	0.20
5	-13.0	Clay	130.9	0.20	52.0	0.01	69.6	0.02	90.8	0.04	104.1	0.06	113.2	0.08	124.2	0.12	130.9	0.20
6	-18.0	Clay	130.9	0.20	52.0	0.01	69.6	0.02	90.8	0.04	104.1	0.06	113.2	0.08	124.2	0.12	130.9	0.20
7	-23.0	Clay	130.9	0.20	52.0	0.01	69.6	0.02	90.8	0.04	104.1	0.06	113.2	0.08	124.2	0.12	130.9	0.20
8	-28.0	Clay	130.9	0.20	52.0	0.01	69.6	0.02	90.8	0.04	104.1	0.06	113.2	0.08	124.2	0.12	130.9	0.20
9	-33.0	Clay	130.9	0.20	52.0	0.01	69.6	0.02	90.8	0.04	104.1	0.06	113.2	0.08	124.2	0.12	130.9	0.20
10	-38.0	Clay	130.9	0.20	52.0	0.01	69.6	0.02	90.8	0.04	104.1	0.06	113.2	0.08	124.2	0.12	130.9	0.20
11	-43.0	Clay	130.9	0.20	52.0	0.01	69.6	0.02	90.8	0.04	104.1	0.06	113.2	0.08	124.2	0.12	130.9	0.20
12	-48.0	Clay	350.4	0.20	139.1	0.01	186.4	0.02	243.2	0.04	278.6	0.06	303.1	0.08	332.6	0.12	350.4	0.20
13	-53.0	Sand	600.9	0.20	238.6	0.01	319.7	0.02	417.1	0.04	477.7	0.06	519.8	0.08	570.3	0.12	600.9	0.20
14	-58.0	Sand	662.9	0.20	263.2	0.01	352.7	0.02	460.1	0.04	527.0	0.06	573.4	0.08	629.1	0.12	662.9	0.20
15	-63.0	Sand	724.9	0.20	287.8	0.01	385.6	0.02	503.1	0.04	576.3	0.06	627.0	0.08	687.9	0.12	724.9	0.20
16	-68.0	Sand	786.9	0.20	312.4	0.01	418.6	0.02	546.1	0.04	625.5	0.06	680.6	0.08	746.7	0.12	786.9	0.20

q_{max}	u_c	$_{q1}$	u_1	q_2	u_2	q_3	u_3	q_4	u_4
(kips)	(in)	(kips)	(in)	(kips)	(in)	(kips)	(in)	(kips)	(in)
359.0	2.00	161.6	0.20	226.2	0.50	283.6	1.00	359.0	2.00

10.0 APPENDIX C: *Q*-δ CURVES

TABLE C-1: ABUTMENT 1 - *Q*-δ CURVES



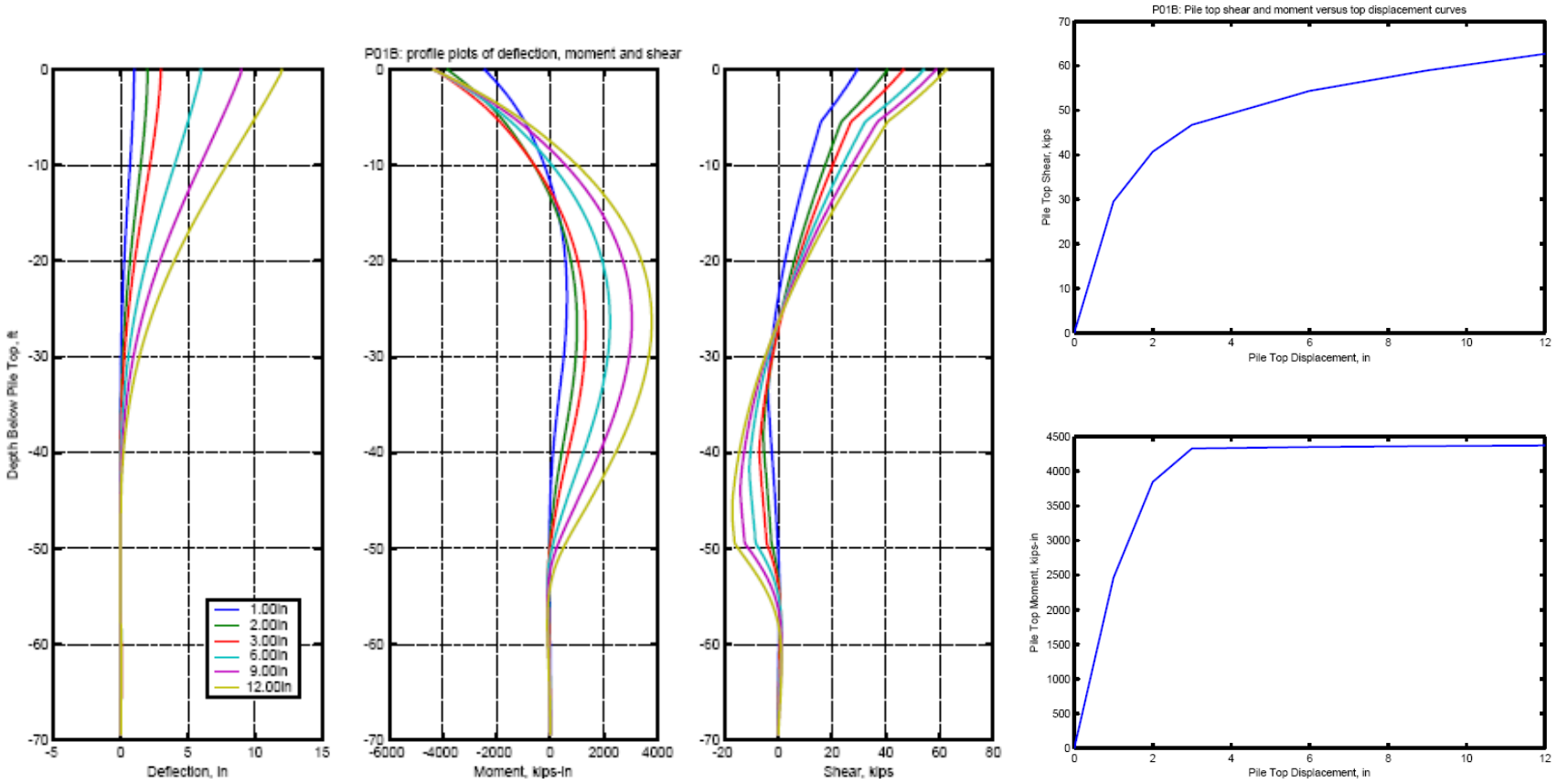
11.0 APPENDIX D: *P-Y* CURVES

TABLE D-1: ABUTMENT 1 - *p-y* CURVES

Node #	Elevation	Soil	p_u	y_u	p_1	y_1	p_2	y_2	p_3	y_3	p_4	y_4	p_5	y_5
	(ft)	Type	(lb/in)	(in)	(lb/in)	(in)	(lb/in)	(in)	(lb/in)	(in)	(lb/in)	(in)	(lb/in)	(in)
1	1.5	Clay	276.0	4.00	69.0	0.06	138.0	0.50	198.7	1.50	276.0	4.00	276.0	8.00
2	-1.0	Clay	332.5	4.00	83.1	0.06	166.3	0.50	239.4	1.50	332.5	4.00	332.5	8.00
3	-4.0	Clay	288.3	6.00	72.1	0.10	144.2	0.75	207.6	2.25	288.3	6.00	288.3	12.00
4	-8.0	Clay	187.5	8.00	46.9	0.13	93.8	1.00	135.0	3.00	187.5	8.00	187.5	16.00
5	-13.0	Clay	187.5	8.00	46.9	0.13	93.8	1.00	135.0	3.00	187.5	8.00	187.5	16.00
6	-18.0	Clay	187.5	8.00	46.9	0.13	93.8	1.00	135.0	3.00	187.5	8.00	187.5	16.00
7	-23.0	Clay	187.5	8.00	46.9	0.13	93.8	1.00	135.0	3.00	187.5	8.00	187.5	16.00
8	-28.0	Clay	187.5	8.00	46.9	0.13	93.8	1.00	135.0	3.00	187.5	8.00	187.5	16.00
9	-33.0	Clay	187.5	8.00	46.9	0.13	93.8	1.00	135.0	3.00	187.5	8.00	187.5	16.00
10	-38.0	Clay	187.5	8.00	46.9	0.13	93.8	1.00	135.0	3.00	187.5	8.00	187.5	16.00
11	-43.0	Clay	187.5	8.00	46.9	0.13	93.8	1.00	135.0	3.00	187.5	8.00	187.5	16.00
12	-48.0	Clay	4336.4	4.49	1084.1	0.07	2168.2	0.56	3122.2	1.68	4336.4	4.49	4336.4	8.98
13	-53.0	Sand	9460.3	1.00	946.0	0.03	4351.7	0.17	7189.8	0.33	8608.9	0.50	9460.3	1.00
14	-58.0	Sand	10435.3	1.02	1043.5	0.03	4800.2	0.17	7930.8	0.34	9496.1	0.51	10435.3	1.02
15	-63.0	Sand	11410.2	1.03	1141.0	0.03	5248.7	0.18	8671.8	0.34	10383.3	0.52	11410.2	1.03
16	-68.0	Sand	12385.2	1.05	1238.5	0.03	5697.2	0.18	9412.7	0.35	11270.5	0.52	12385.2	1.05

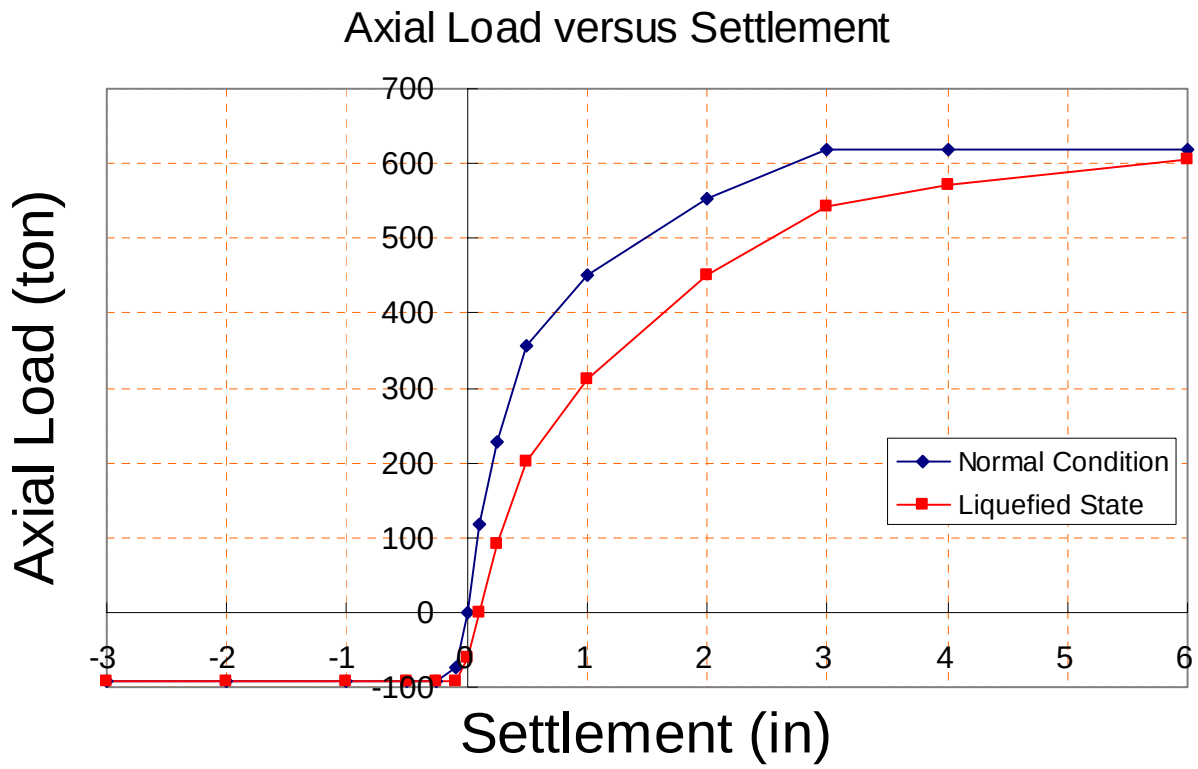
12.0 APPENDIX E: LATERAL PUSH-OVER CURVES

FIGURE E-1: ABUTMENT 1 – LATERAL PUSH-OVER CURVES



13.0 APPENDIX F: *Q*-δ CURVES AT LIQUEFIED STATE

TABLE F-1: PIER 10 - *Q*-δ CURVES AT LIQUEFIED STATE



14.0 APPENDIX G: 6×6 MATRICES

TABLE G-1: ABUTMENT 1A - PILE GROUP CONDENSED MATRICES AT PILE-CAP

6x6 Stiffness Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
1.4110E+05	0.0000E+00	0.0000E+00	0.0000E+00	-1.6750E+07	0.0000E+00
0.0000E+00	1.4110E+05	0.0000E+00	1.6750E+07	0.0000E+00	-1.9540E+05
0.0000E+00	0.0000E+00	5.1920E+06	0.0000E+00	7.1890E+06	0.0000E+00
0.0000E+00	1.6750E+07	0.0000E+00	4.6930E+11	0.0000E+00	-2.3190E+07
-1.6750E+07	0.0000E+00	7.1890E+06	0.0000E+00	5.7860E+09	0.0000E+00
0.0000E+00	-1.9540E+05	0.0000E+00	-2.3190E+07	0.0000E+00	1.2690E+10

6x6 Mass Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
1.8870E+02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	1.8870E+02	0.0000E+00	0.0000E+00	0.0000E+00	-2.6130E+02
0.0000E+00	0.0000E+00	7.3890E+02	0.0000E+00	1.0230E+03	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	6.6200E+07	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	1.0230E+03	0.0000E+00	2.3940E+05	0.0000E+00
0.0000E+00	-2.6130E+02	0.0000E+00	0.0000E+00	0.0000E+00	1.6970E+07

6x6 Damping Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
1.0244E+03	0.0000E+00	0.0000E+00	0.0000E+00	-1.1848E+05	0.0000E+00
0.0000E+00	1.0244E+03	0.0000E+00	1.1848E+05	0.0000E+00	-1.4187E+03
0.0000E+00	0.0000E+00	3.6829E+04	0.0000E+00	5.0995E+04	0.0000E+00
0.0000E+00	1.1848E+05	0.0000E+00	3.3289E+09	0.0000E+00	-1.6404E+05
-1.1848E+05	0.0000E+00	5.0995E+04	0.0000E+00	4.0961E+07	0.0000E+00
0.0000E+00	-1.4187E+03	0.0000E+00	-1.6404E+05	0.0000E+00	9.2134E+07

Note: units = lb,in,sec; Stiffness (translation=lb/in, rotation=lb-in/rad), mass (translation=lb-sec^2/in, rotation=lb-in-sec^2/rad), Damping (translation=lb-sec/in, rotation=lb-in-sec/rad).

15.0 APPENDIX H: NONLINEAR PUSHOVER ANALYSES

8.0 APPENDIX A: IDEALIZED CONDITIONS AND FOUNDATION DATA

FIGURE A-1: IDEALIZED SOIL CONDITIONS AND FOUNDATION DATA AT ABUTMENT 1

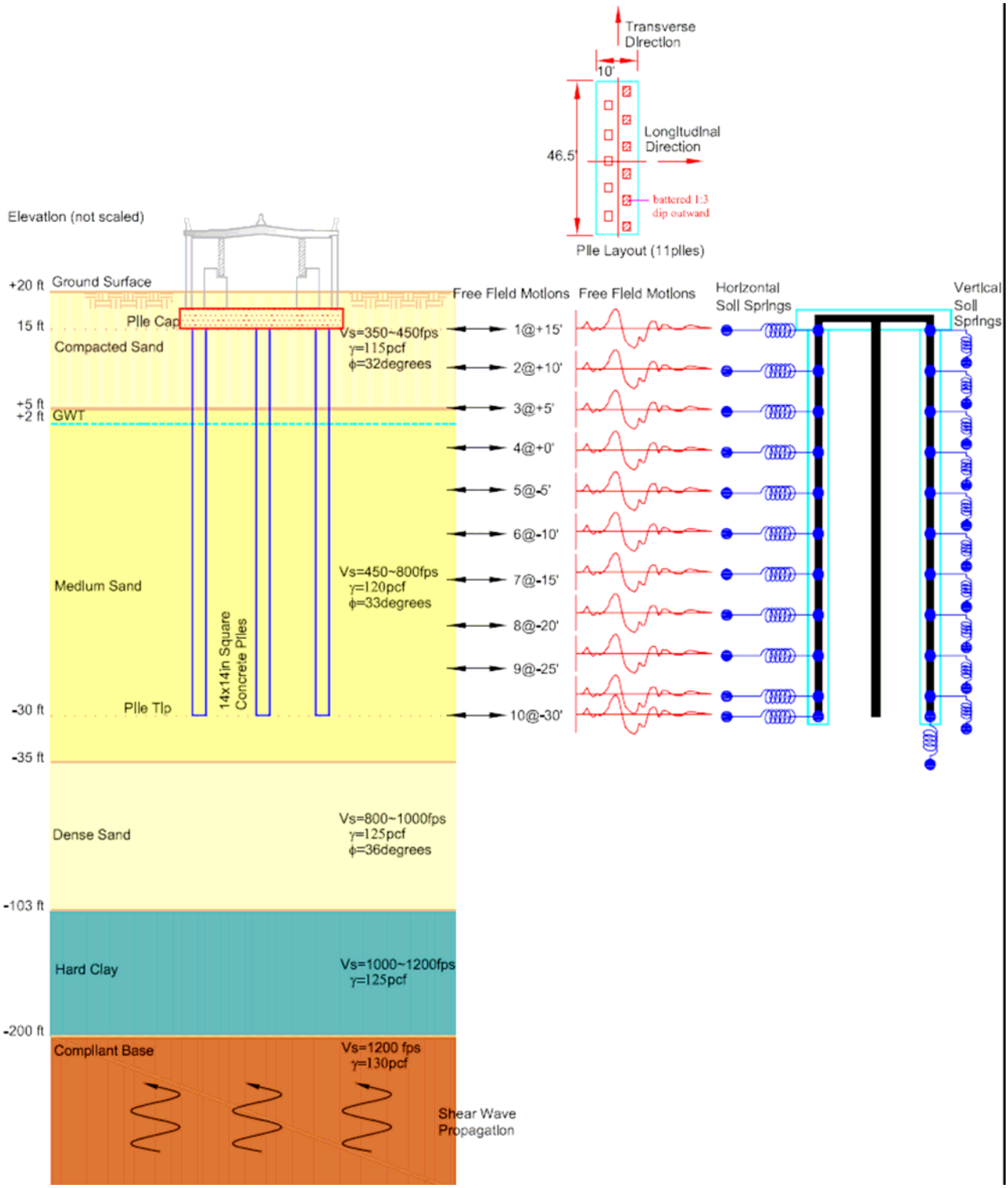


FIGURE A-2: IDEALIZED SOIL CONDITIONS AND FOUNDATION DATA AT PIER 2

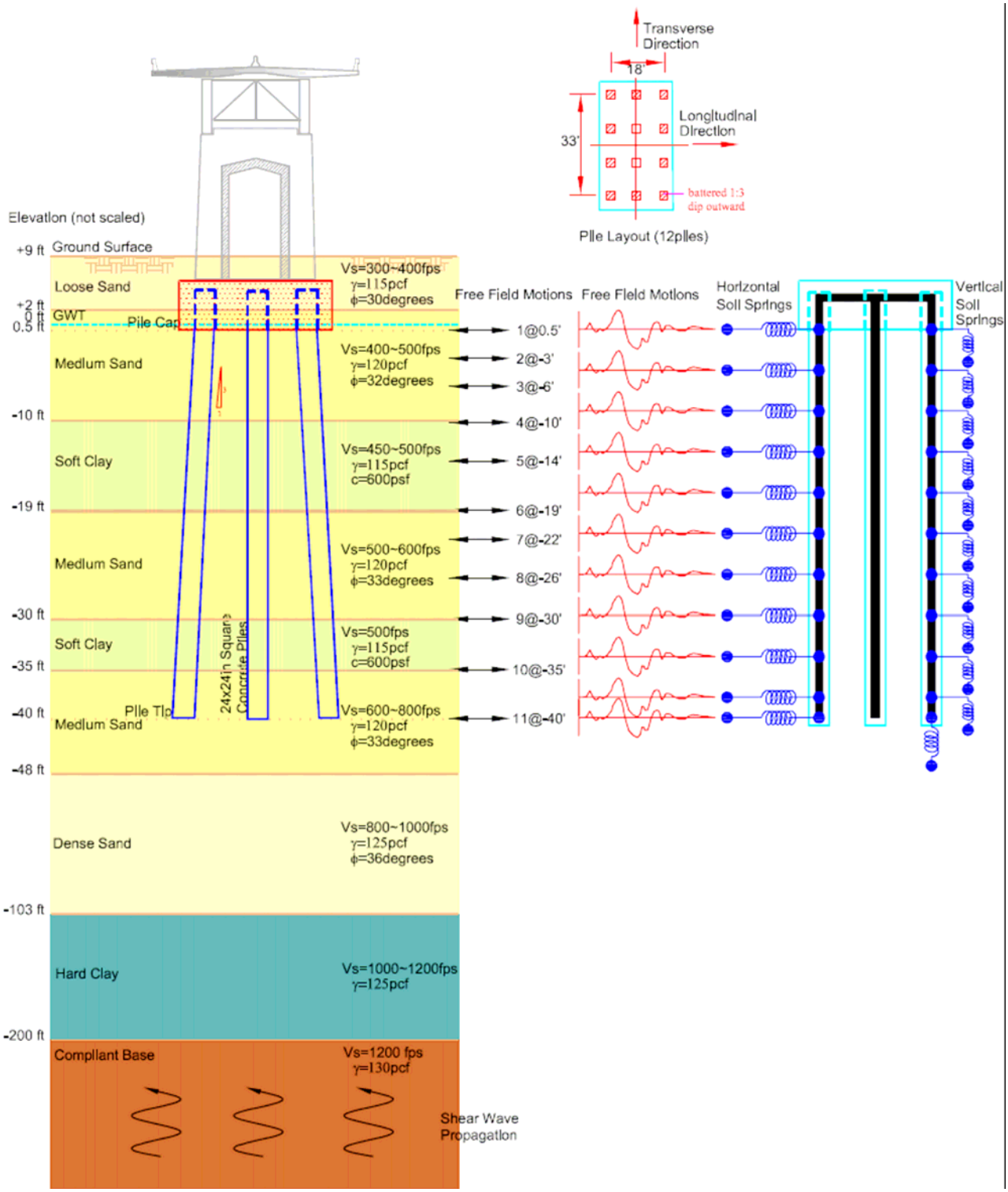


FIGURE A-3: IDEALIZED SOIL CONDITIONS AND FOUNDATION DATA AT PIER 3

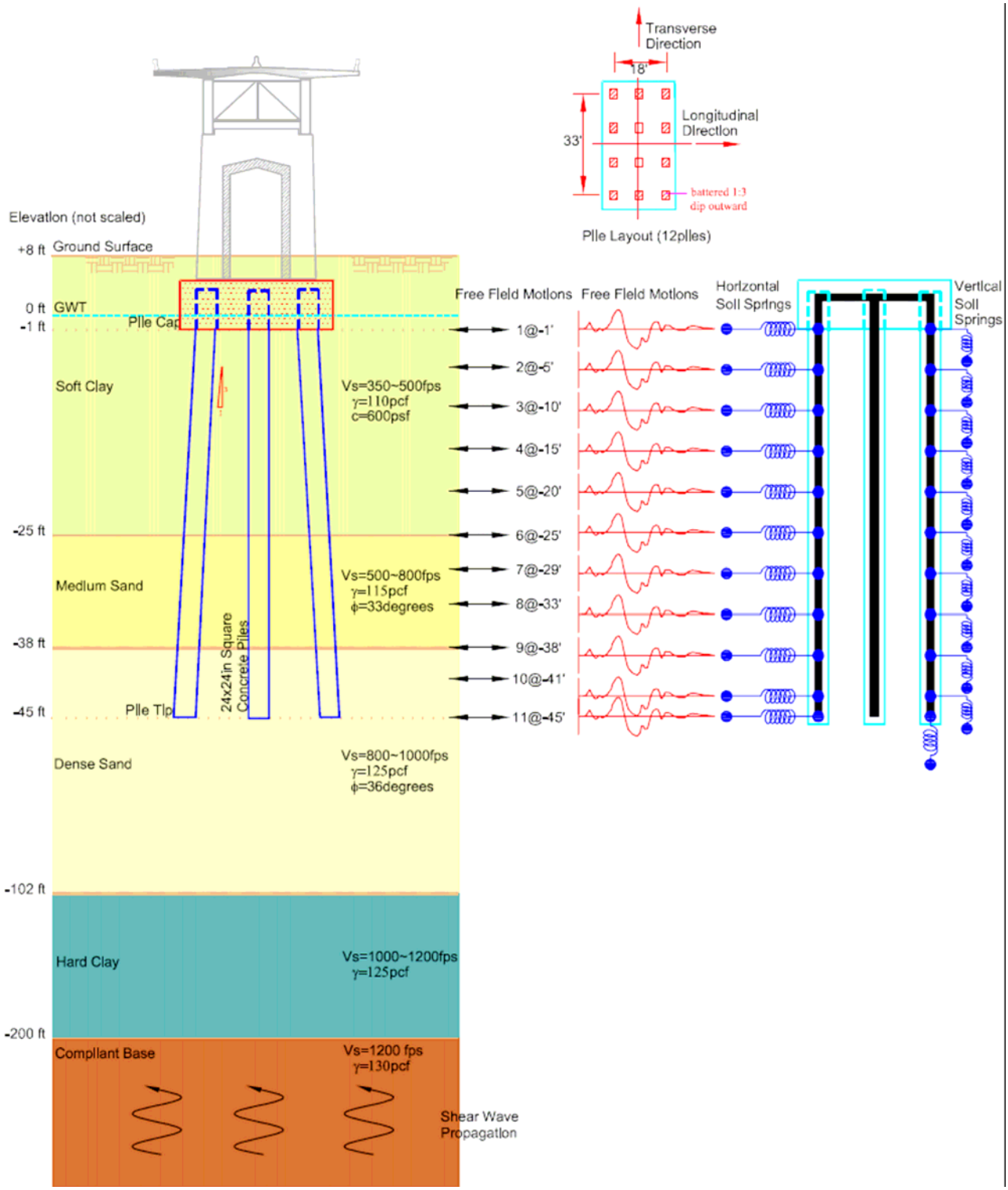


FIGURE A-4: IDEALIZED SOIL CONDITIONS AND FOUNDATION DATA AT PIER 4

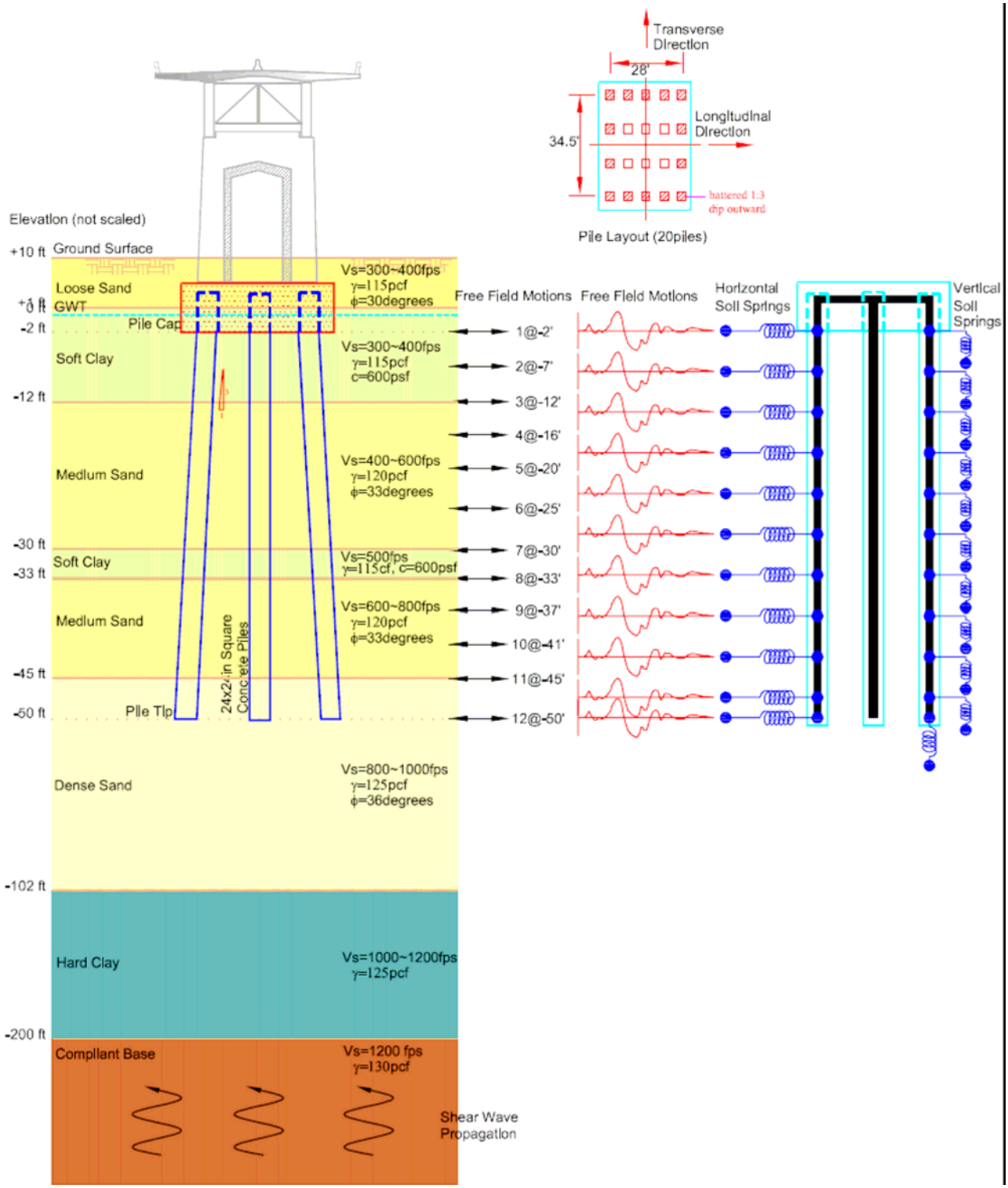


FIGURE A-5: IDEALIZED SOIL CONDITIONS AND FOUNDATION DATA AT PIER 5

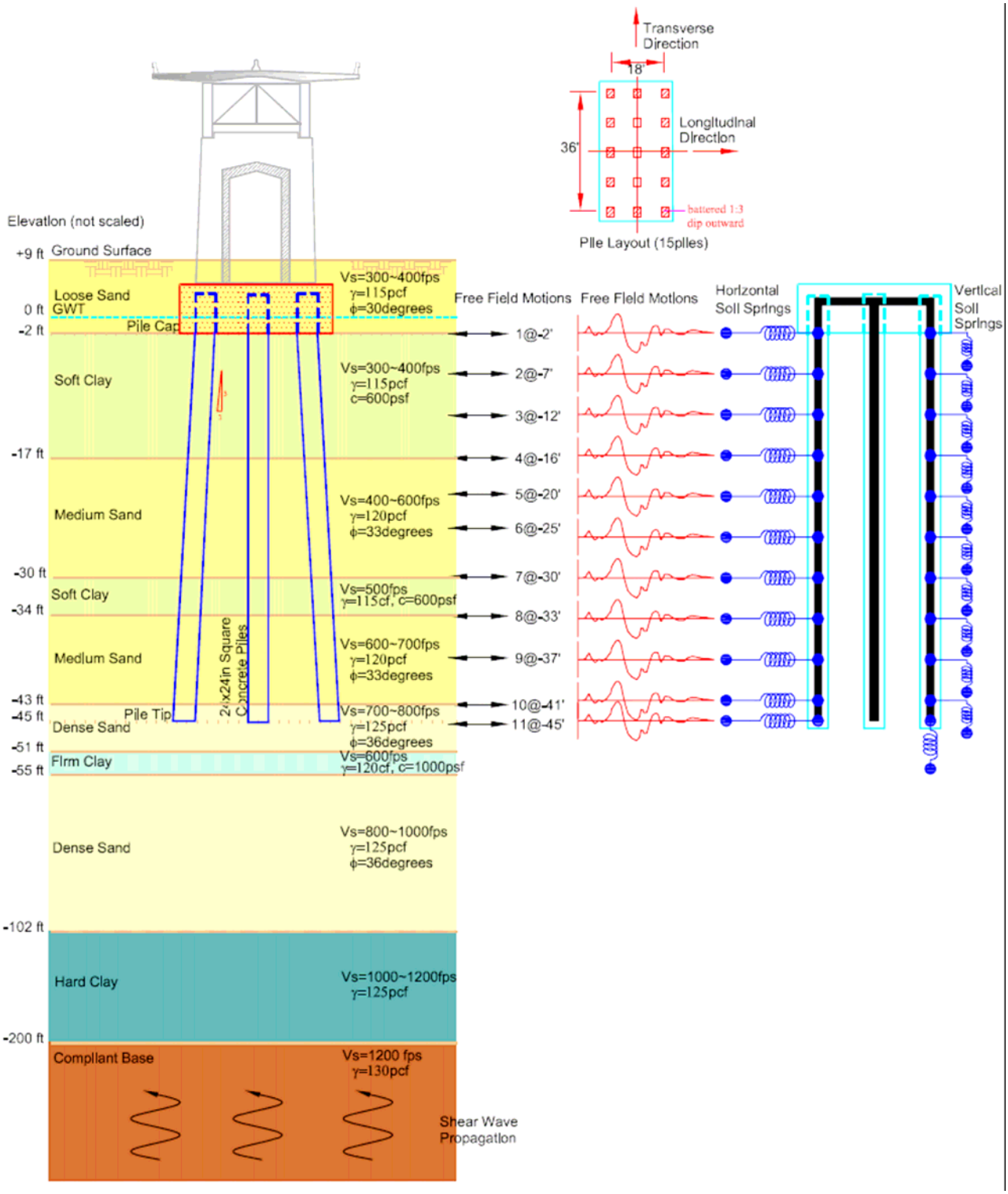


FIGURE A-6: IDEALIZED SOIL CONDITIONS AND FOUNDATION DATA AT PIER 6

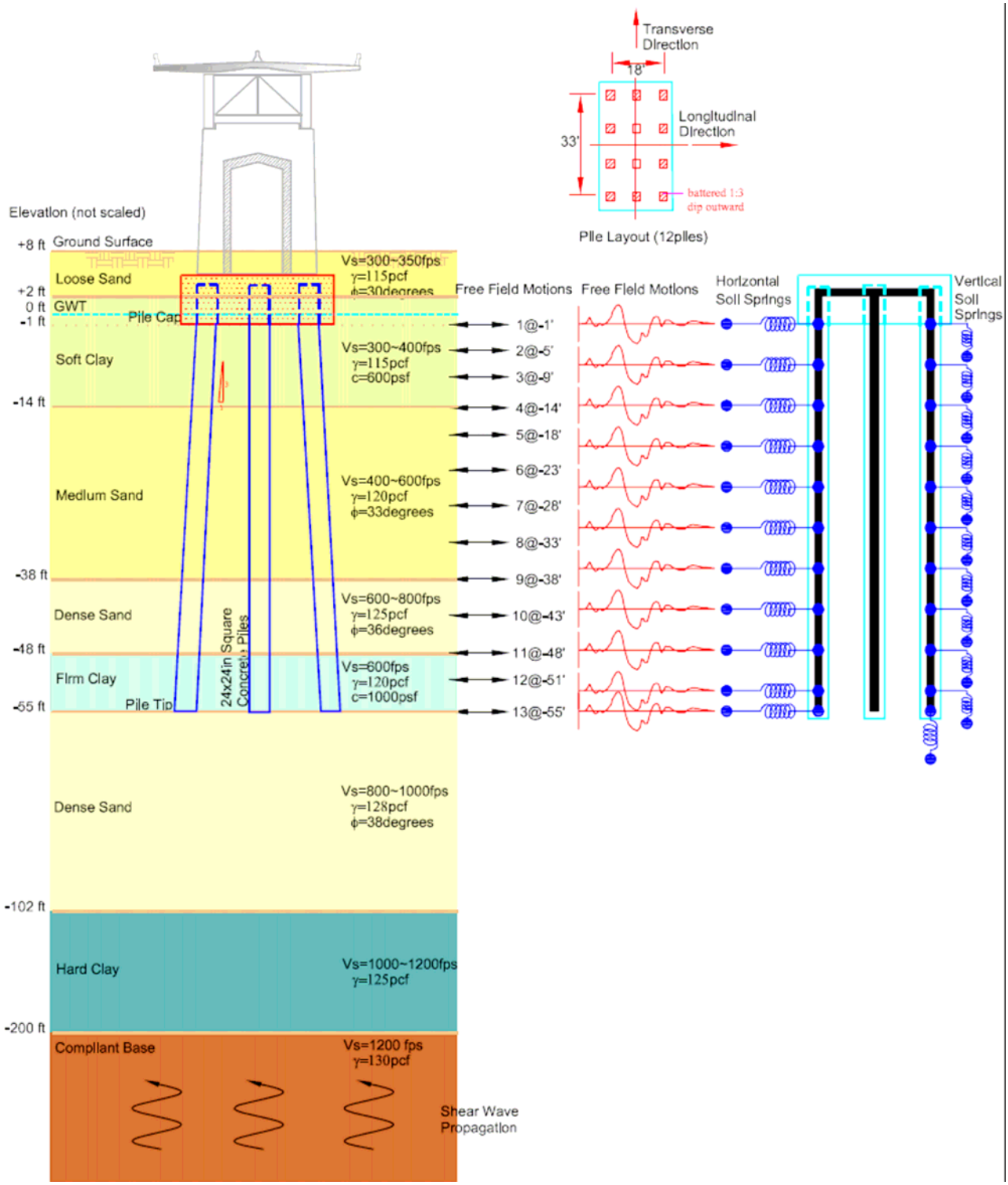


FIGURE A-7: IDEALIZED SOIL CONDITIONS AND FOUNDATION DATA AT PIER 7

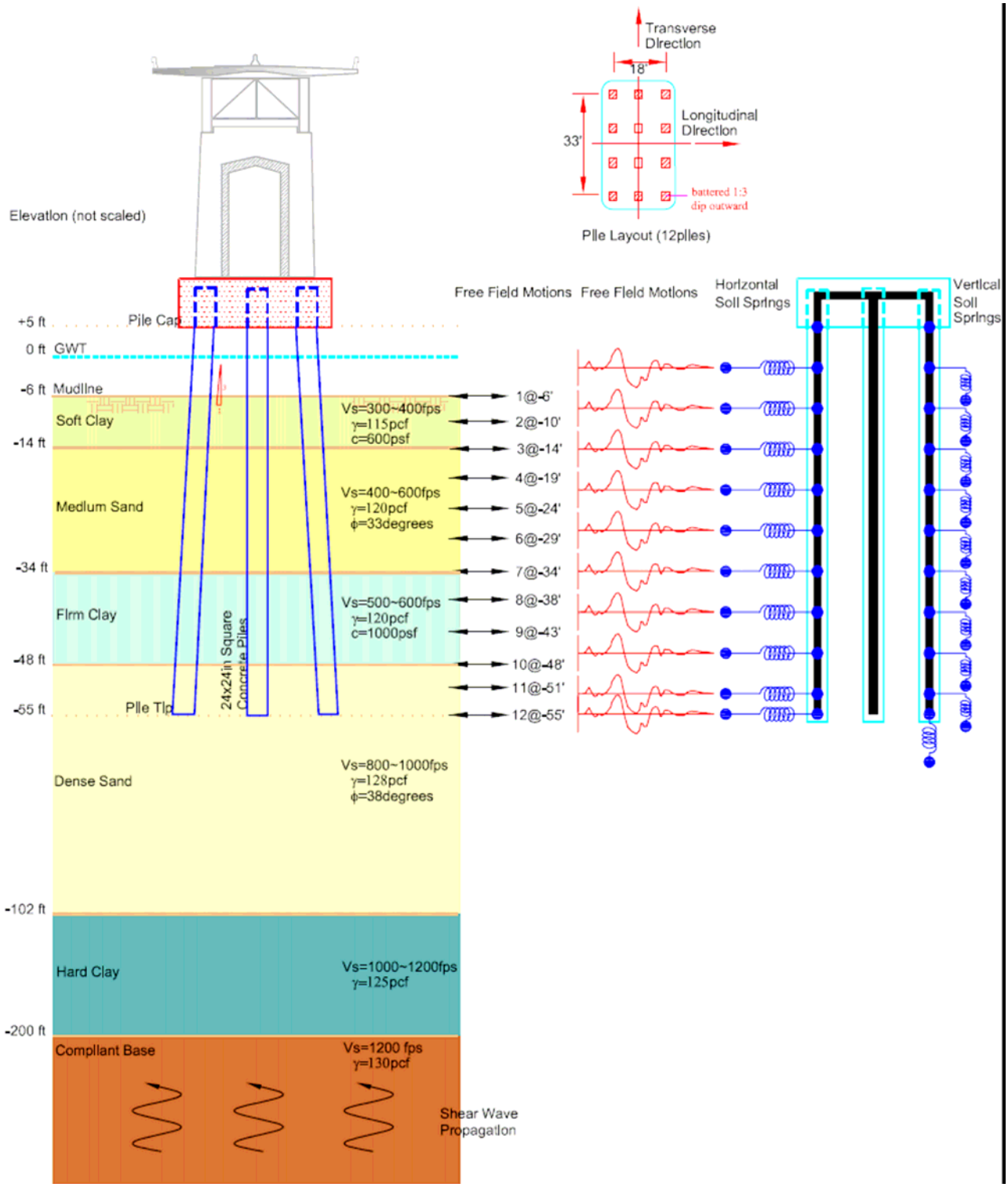


FIGURE A-8: IDEALIZED SOIL CONDITIONS AND FOUNDATION DATA AT PIER 8

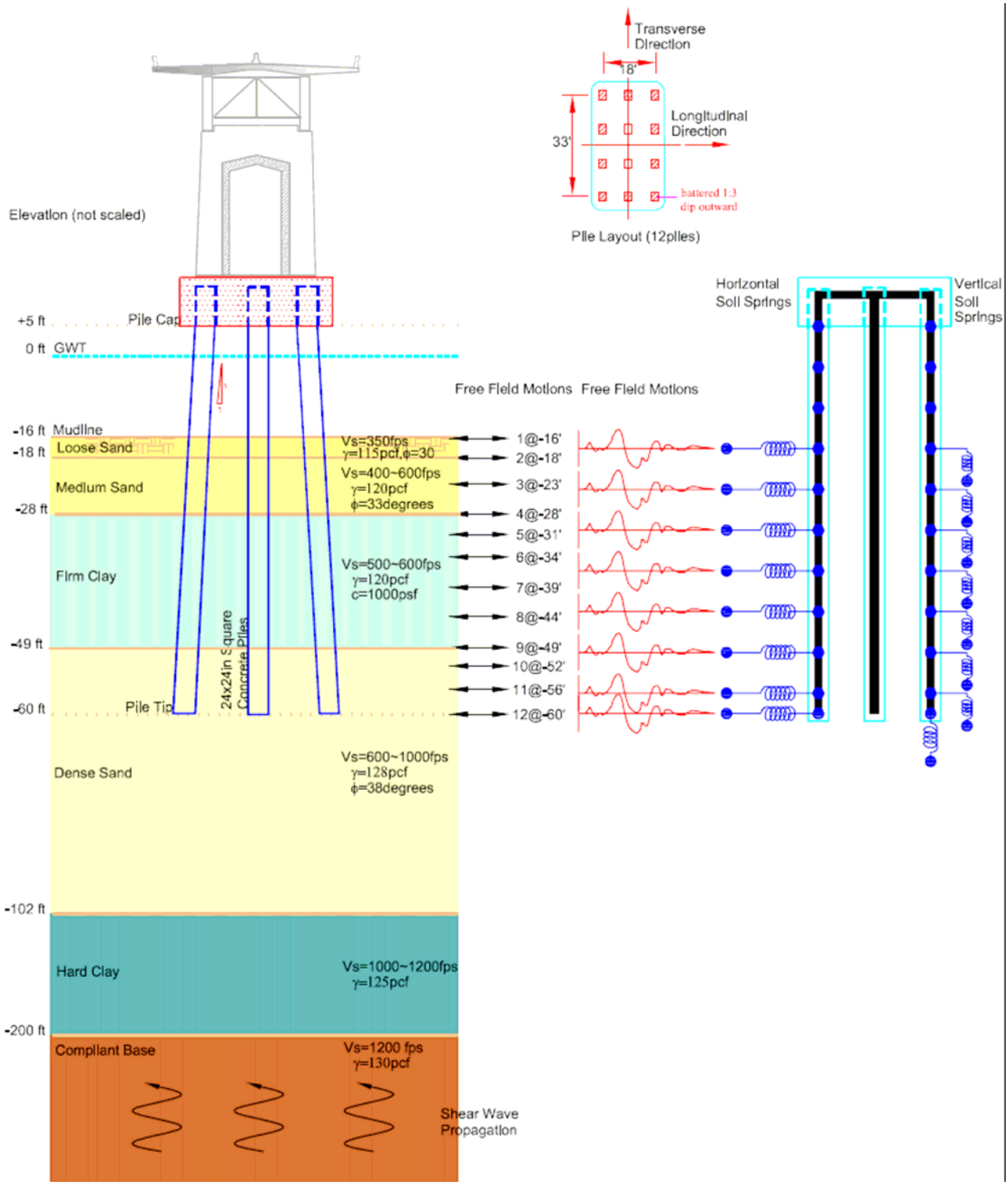


FIGURE A-9: IDEALIZED SOIL CONDITIONS AND FOUNDATION DATA AT PIER 9

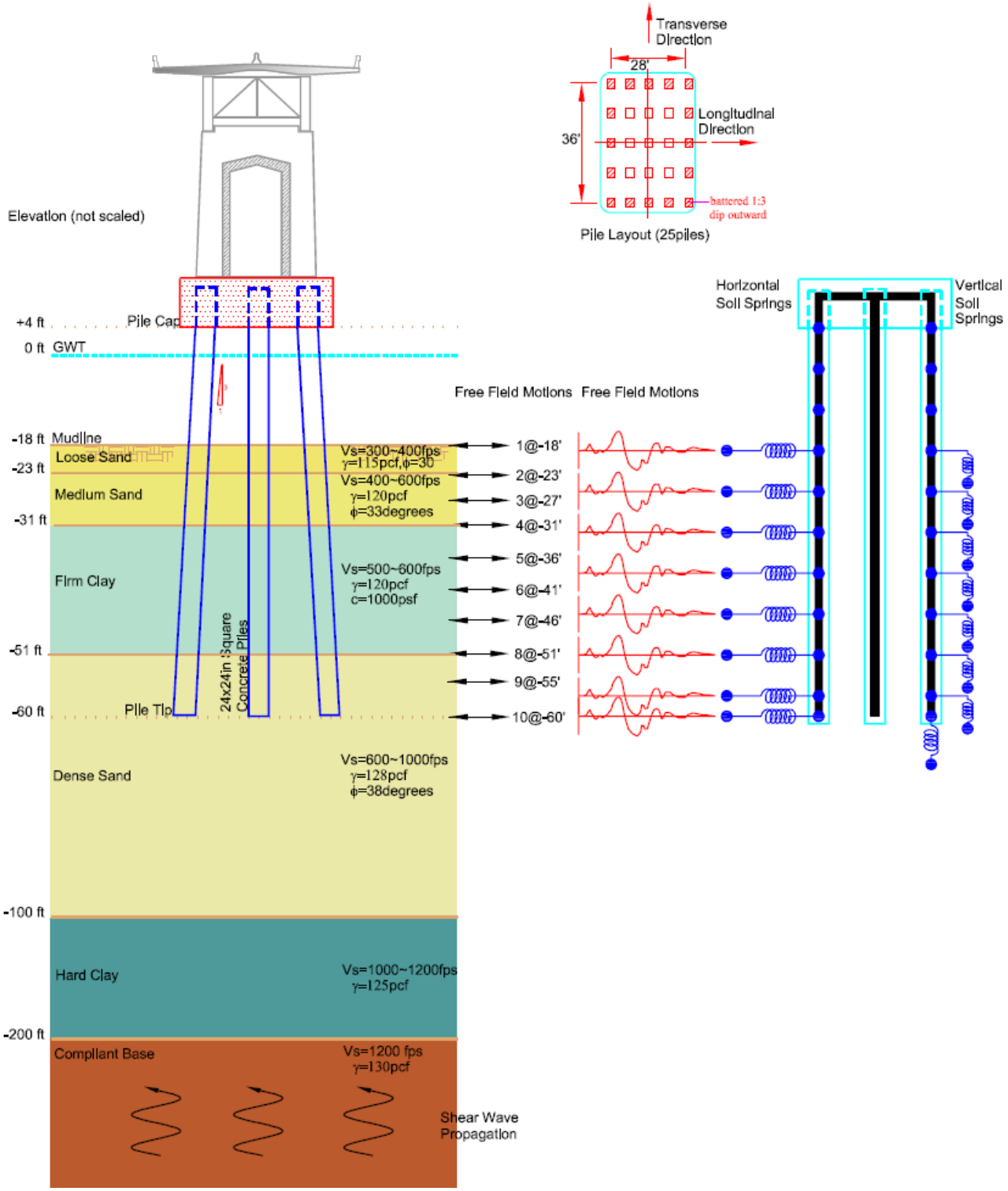


FIGURE A-10: IDEALIZED SOIL CONDITIONS AND FOUNDATION DATA AT PIER 10

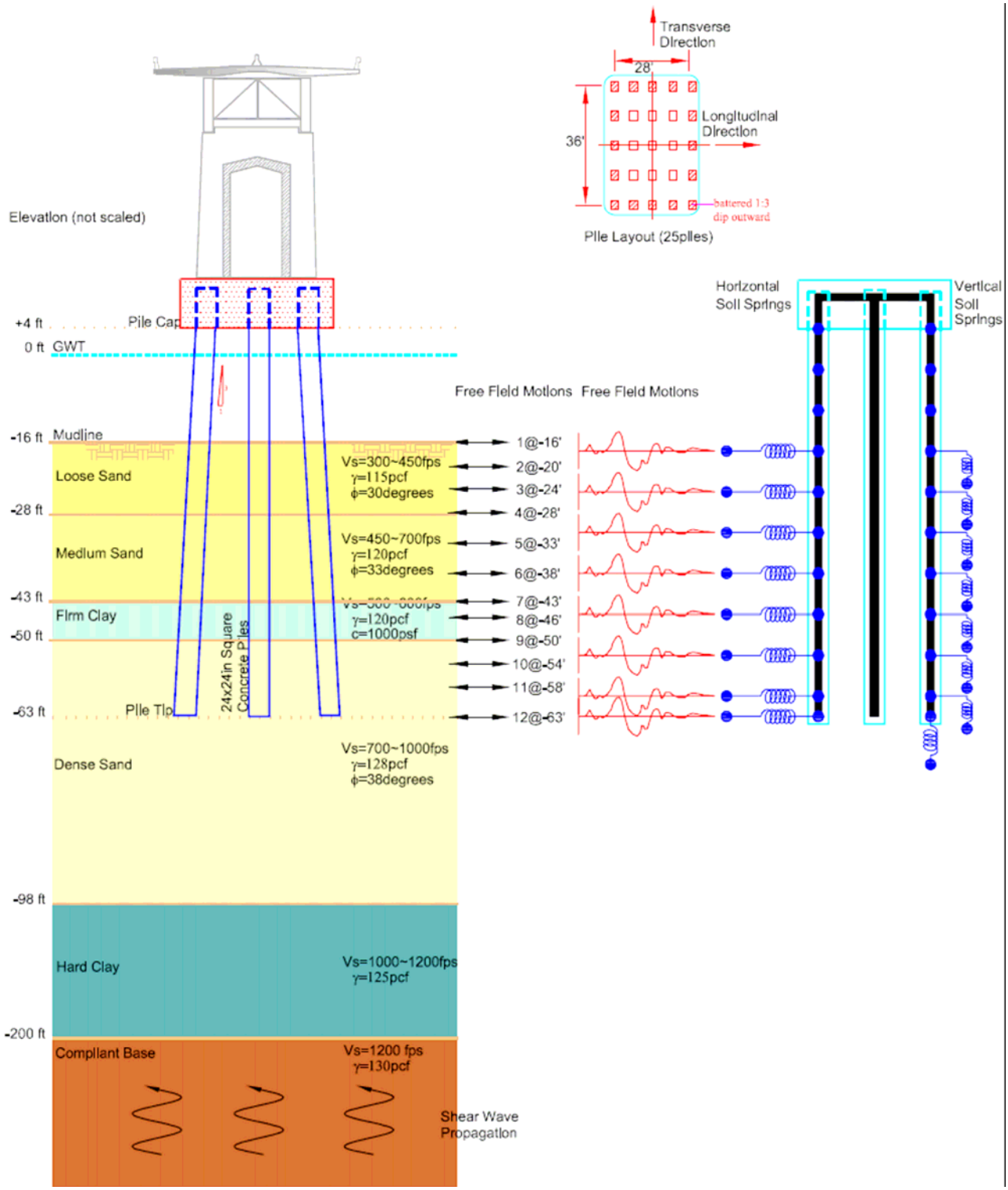


FIGURE A-11: IDEALIZED SOIL CONDITIONS AND FOUNDATION DATA AT PIER 11

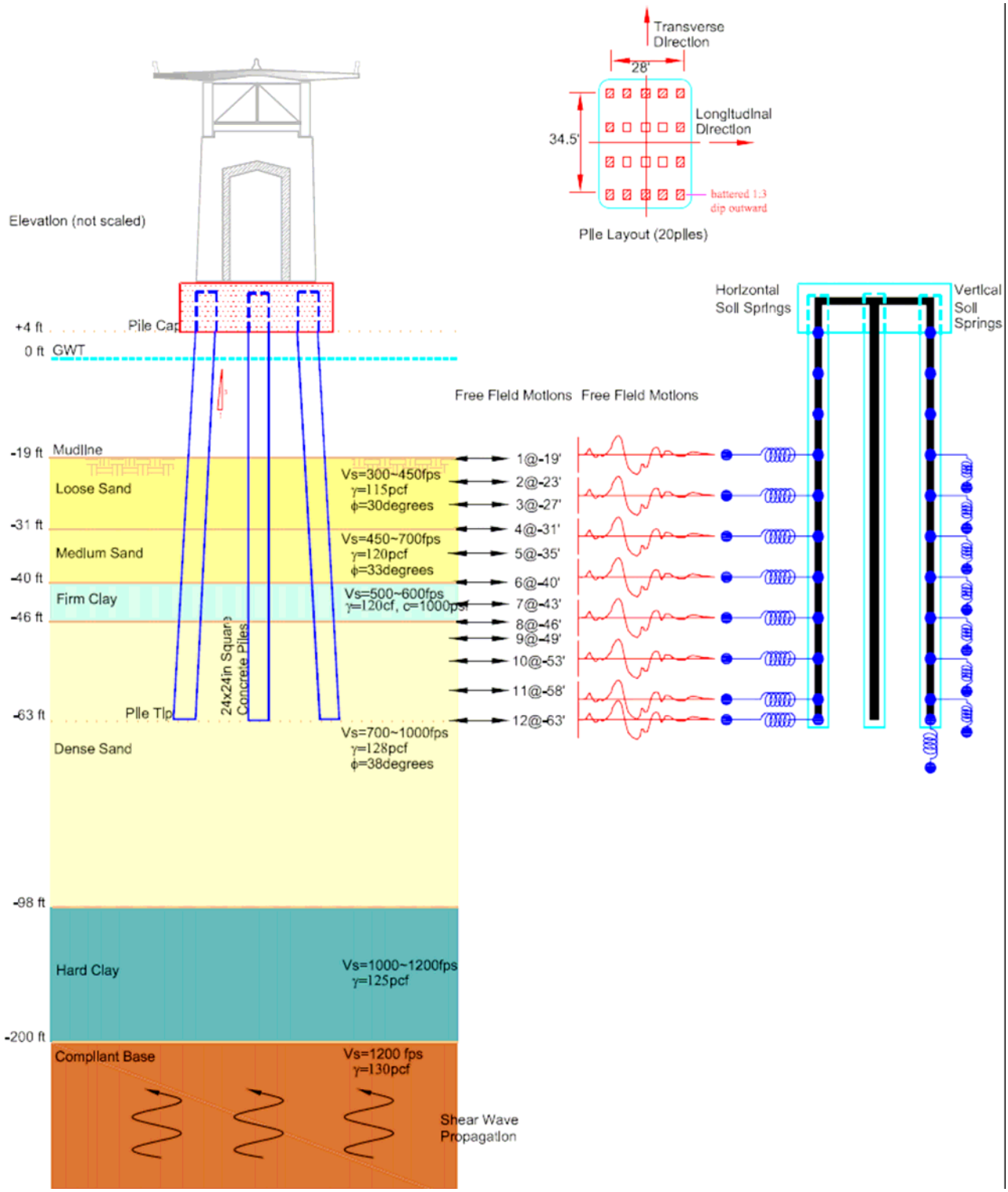


FIGURE A-12: IDEALIZED SOIL CONDITIONS AND FOUNDATION DATA AT PIER 12

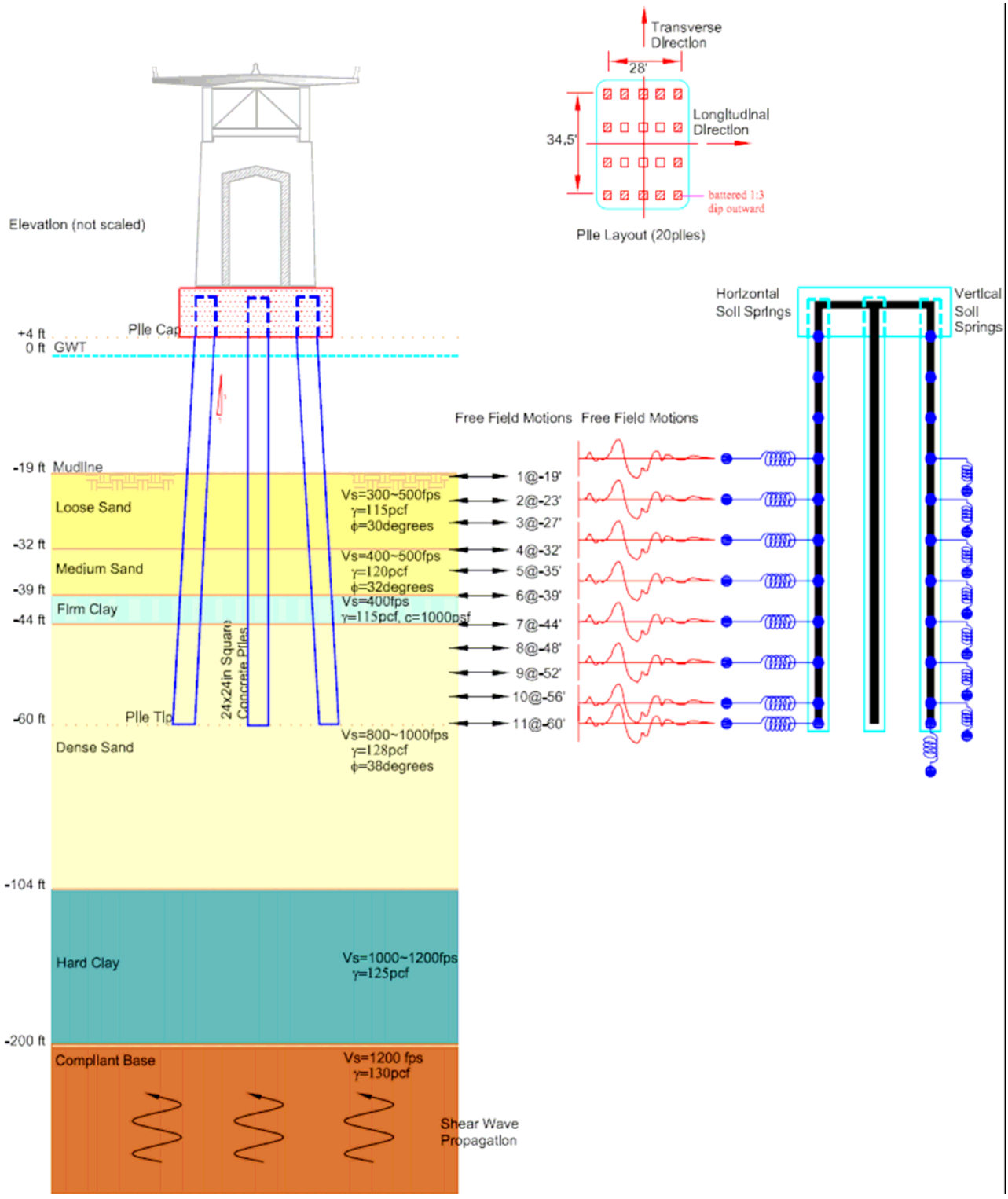


FIGURE A-13: IDEALIZED SOIL CONDITIONS AND FOUNDATION DATA AT PIER 13

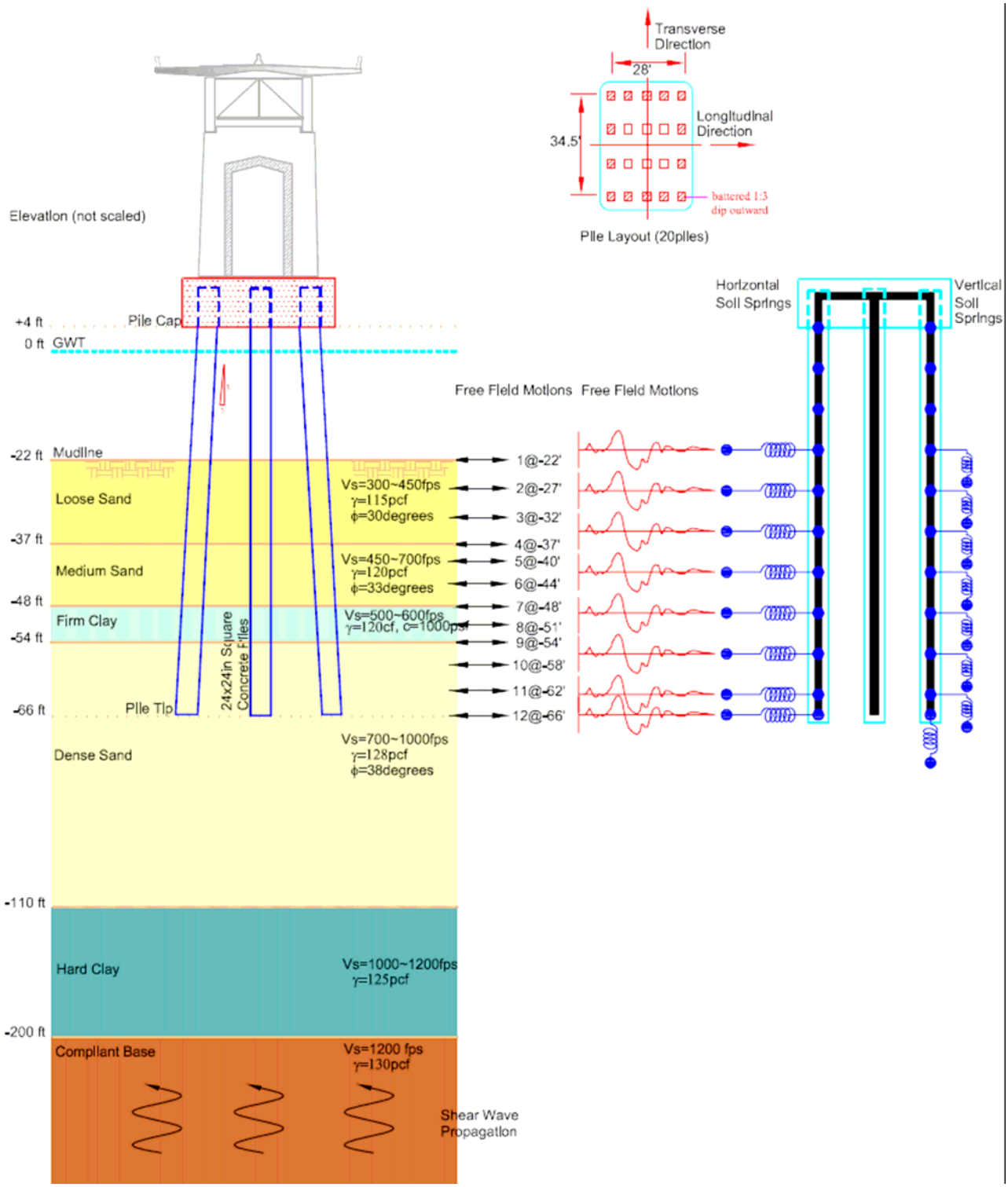


FIGURE A-14: IDEALIZED SOIL CONDITIONS AND FOUNDATION DATA AT PIER 14

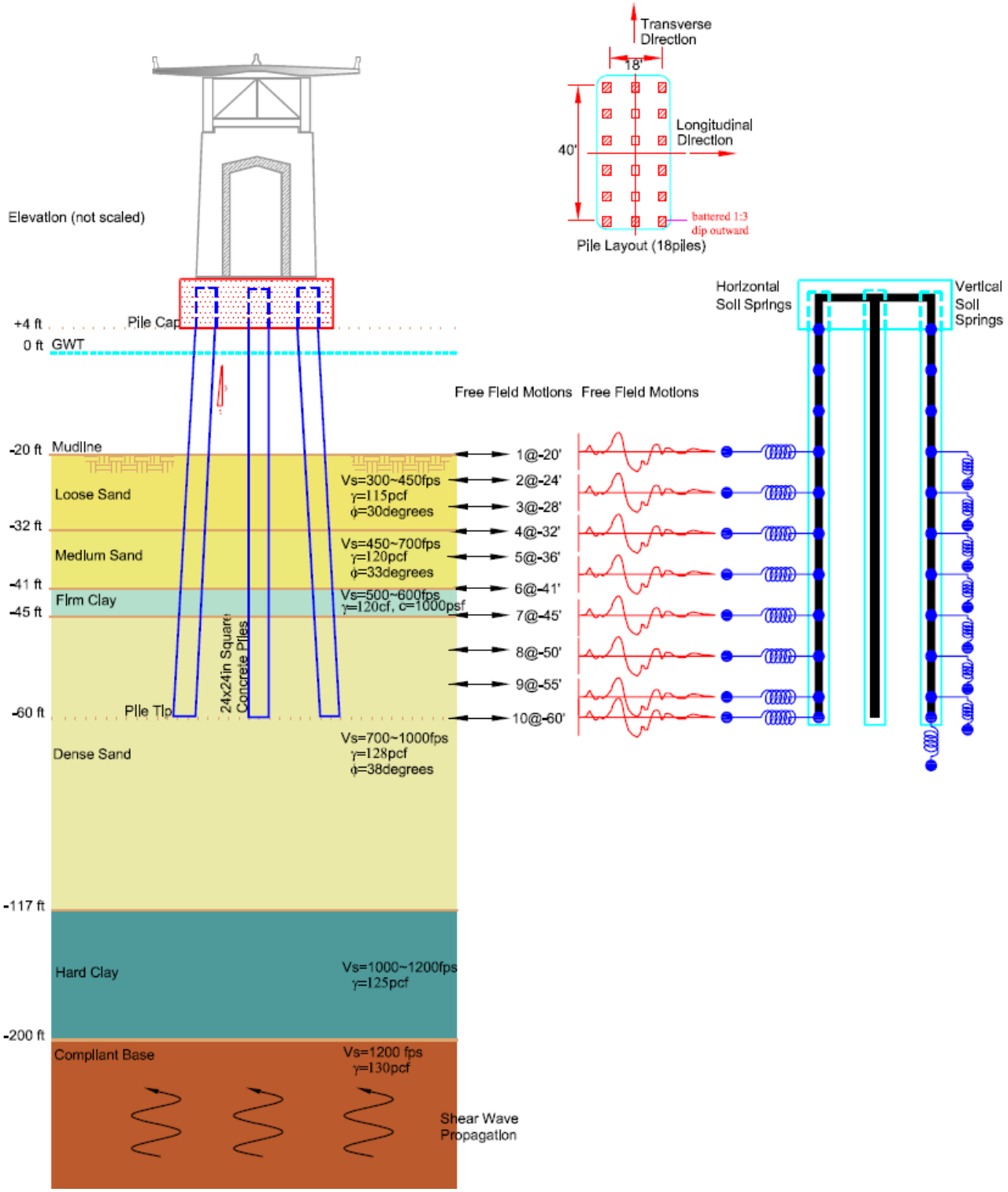


FIGURE A-15: IDEALIZED SOIL CONDITIONS AND FOUNDATION DATA AT PIER 15

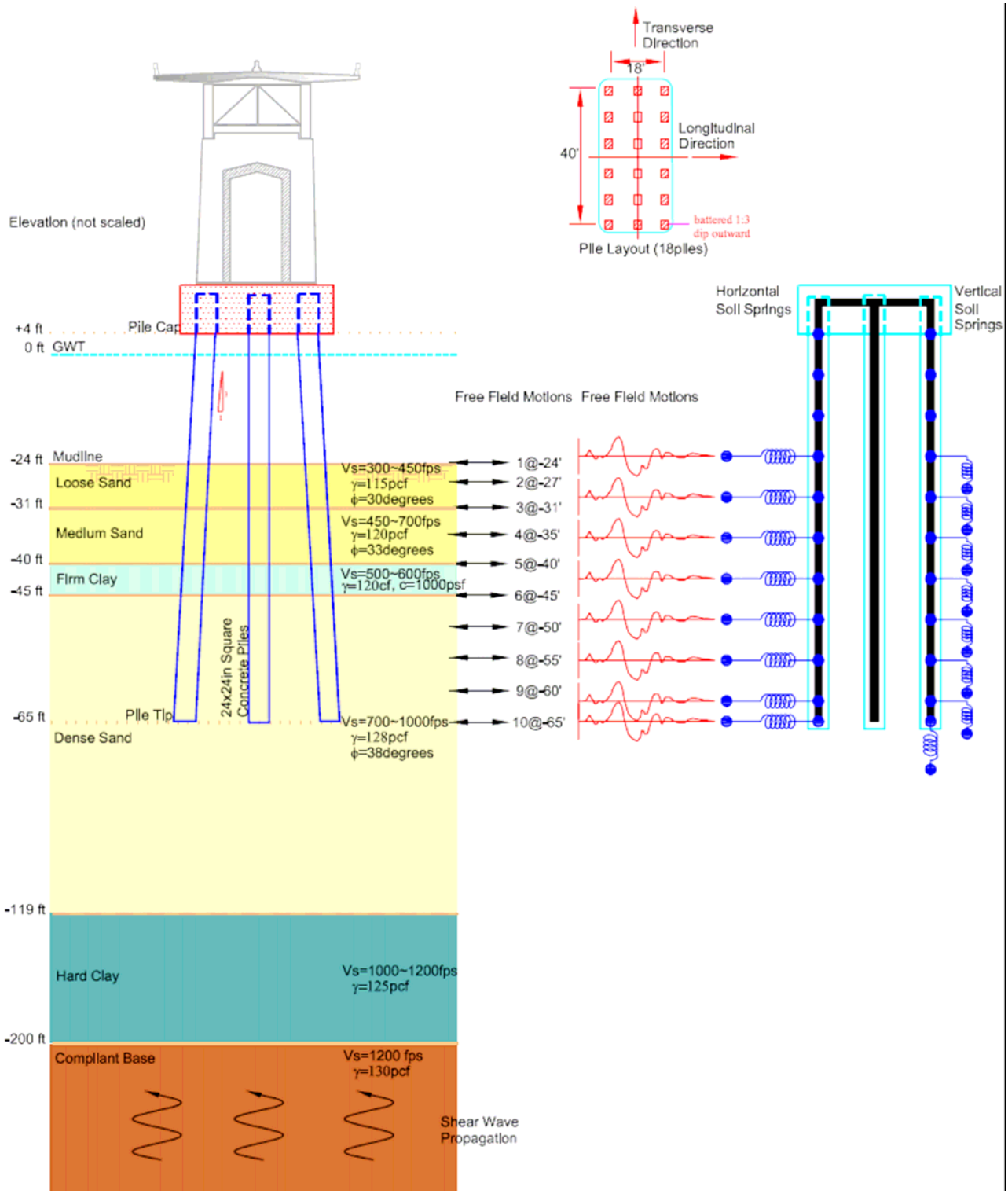


FIGURE A-16: IDEALIZED SOIL CONDITIONS AND FOUNDATION DATA AT PIER 16

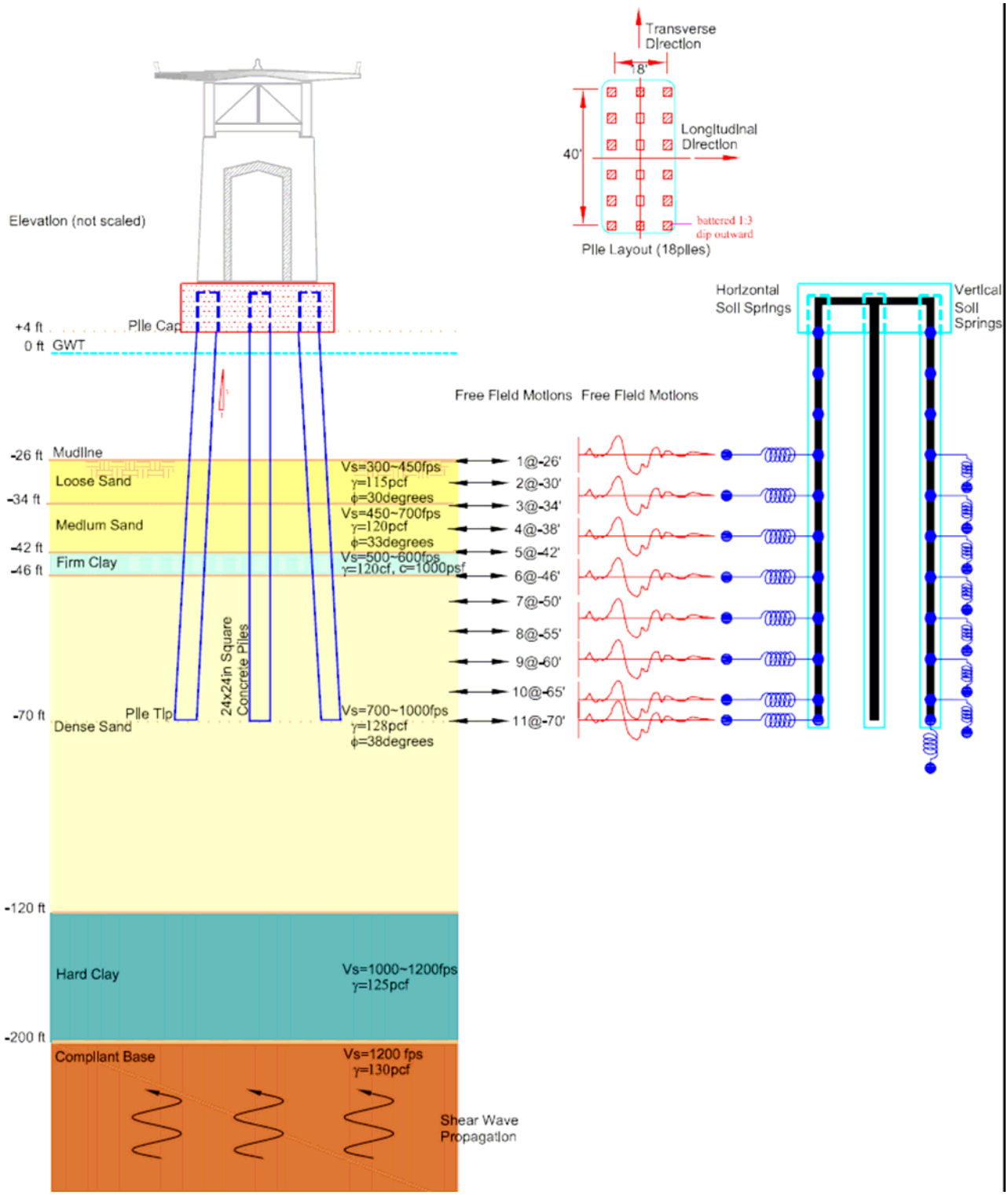


FIGURE A-17: IDEALIZED SOIL CONDITIONS AND FOUNDATION DATA AT PIER 17

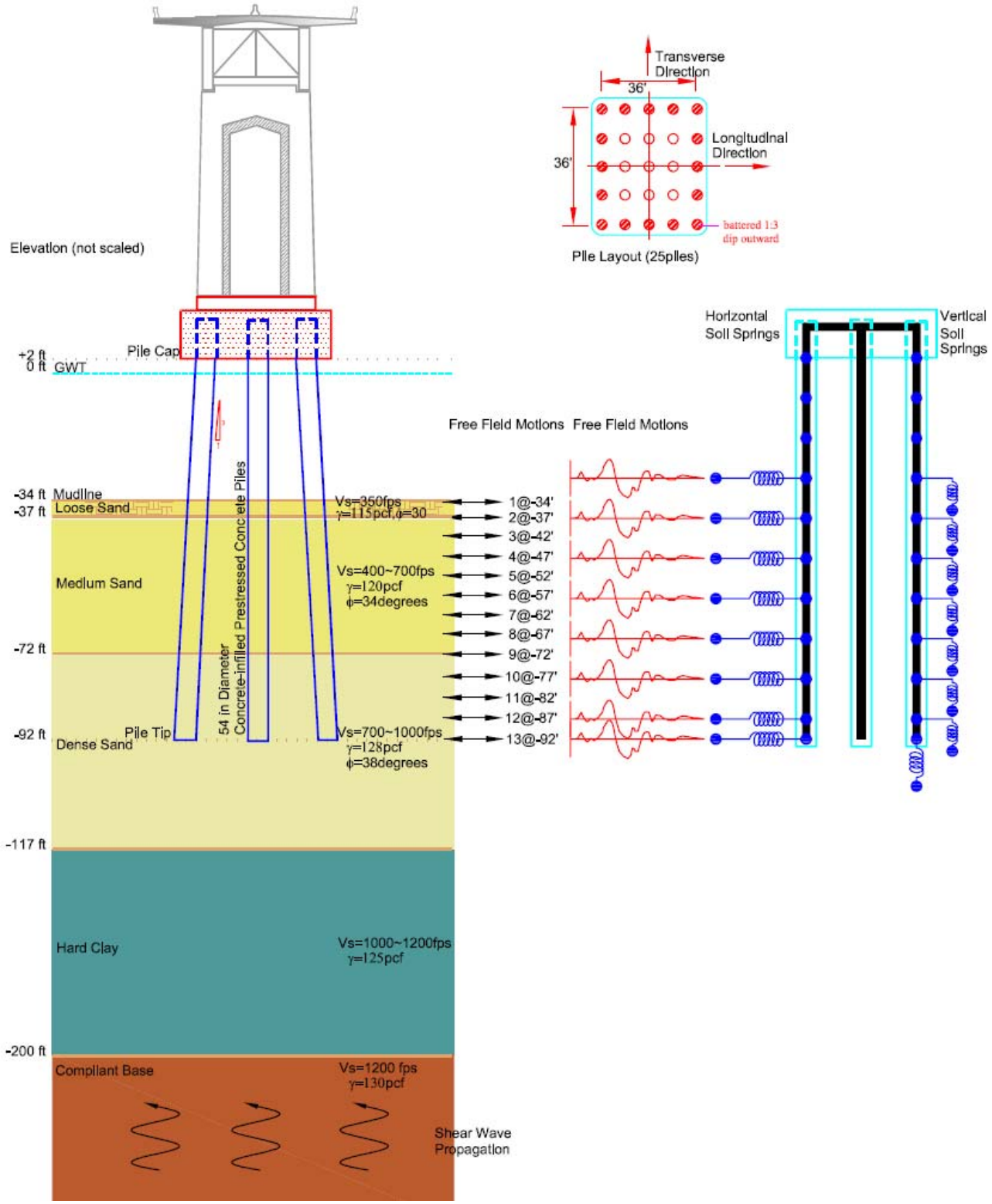


FIGURE A-18: IDEALIZED SOIL CONDITIONS AND FOUNDATION DATA AT PIER 18

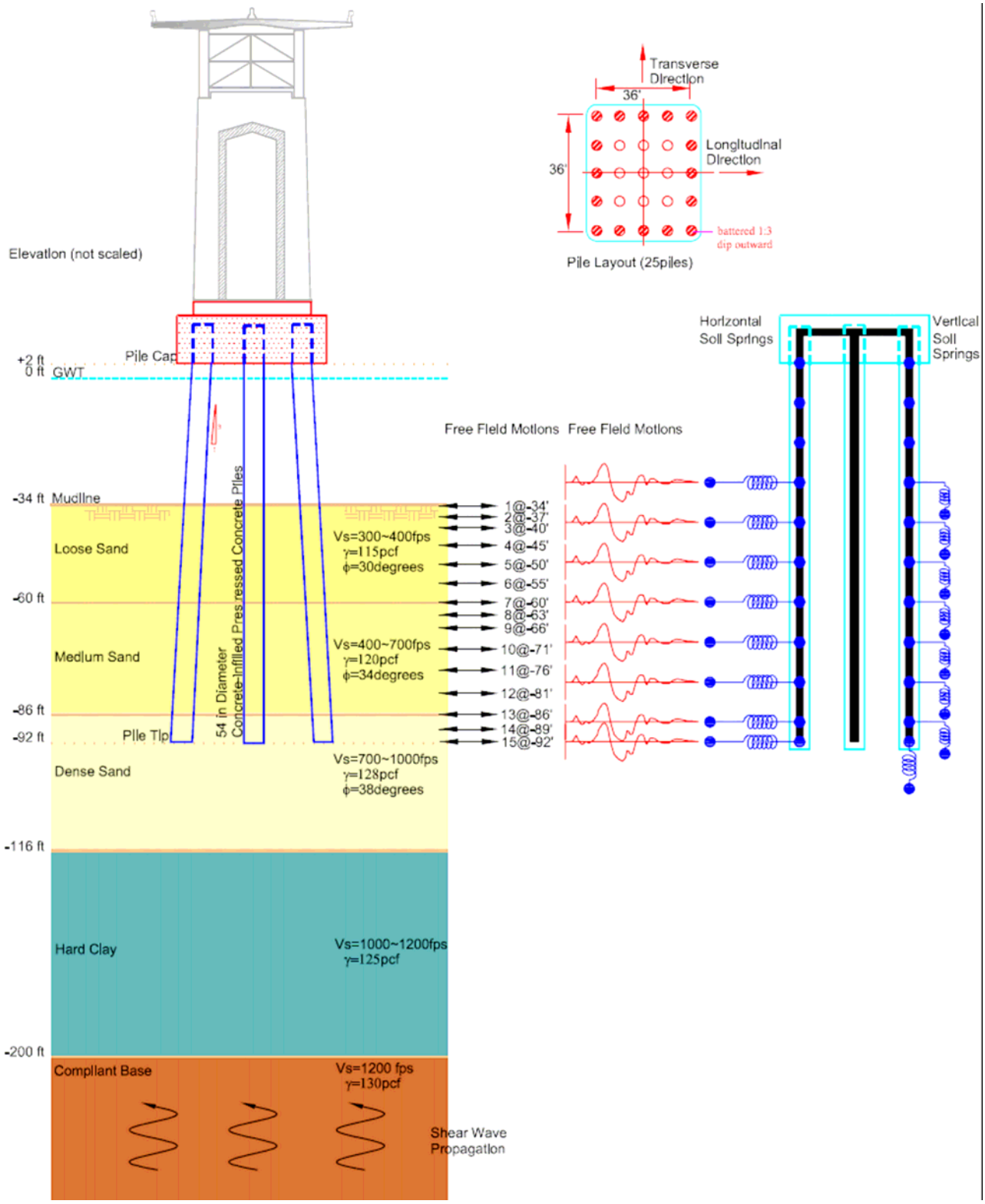


FIGURE A-19: IDEALIZED SOIL CONDITIONS AND FOUNDATION DATA AT PIER 19

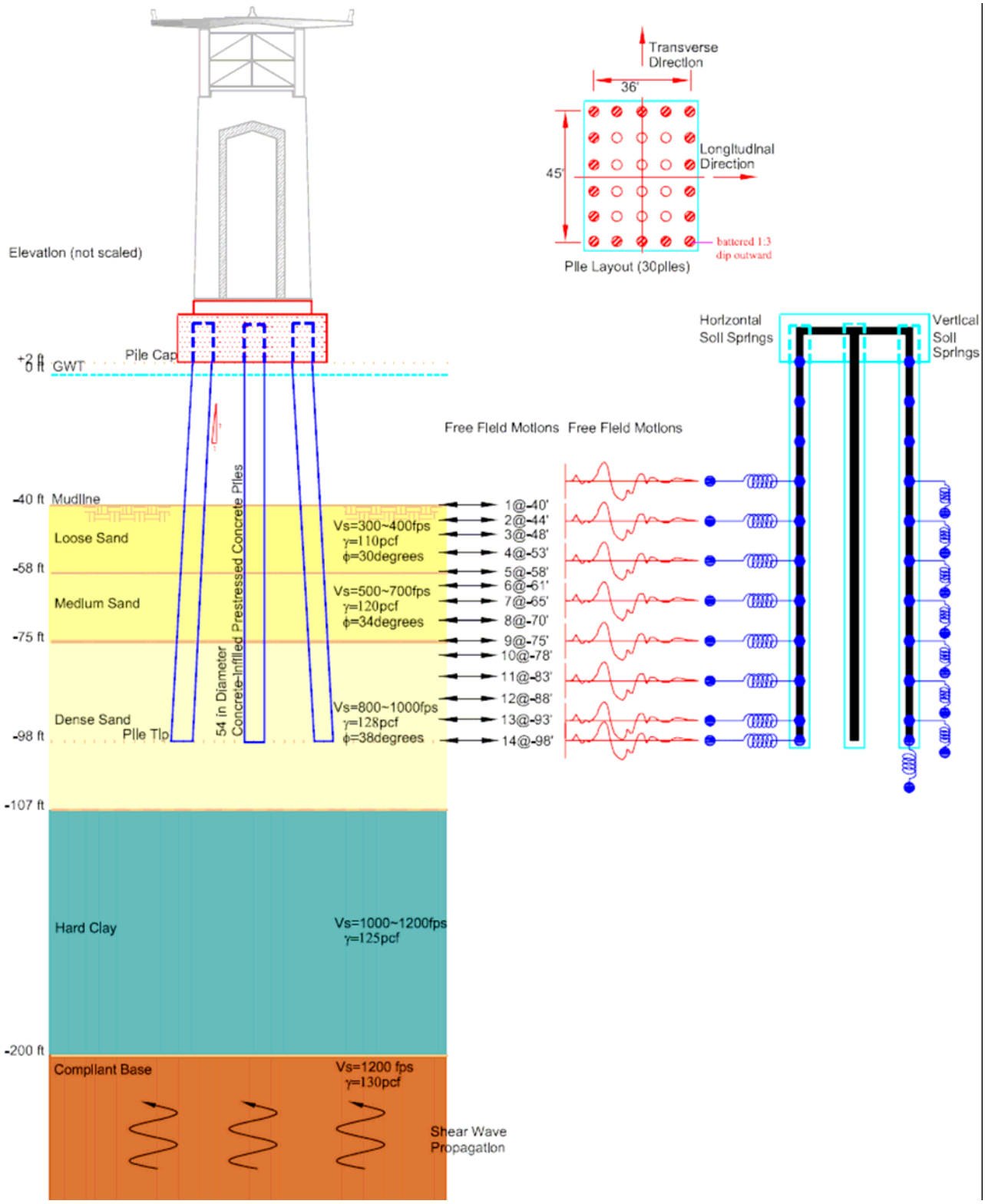


FIGURE A-20: IDEALIZED SOIL CONDITIONS AND FOUNDATION DATA AT PIER 20

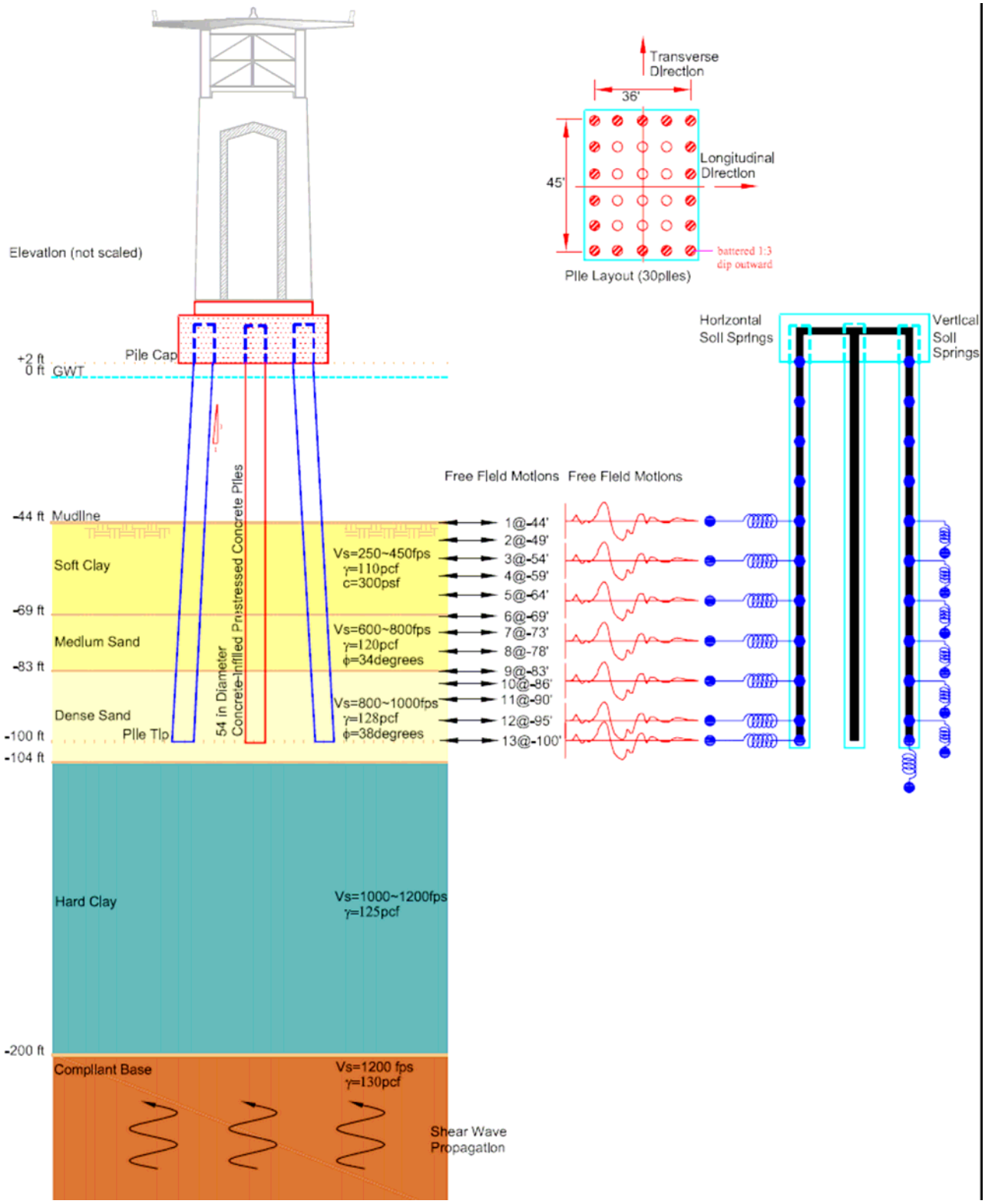


FIGURE A-21: IDEALIZED SOIL CONDITIONS AND FOUNDATION DATA AT PIER 21

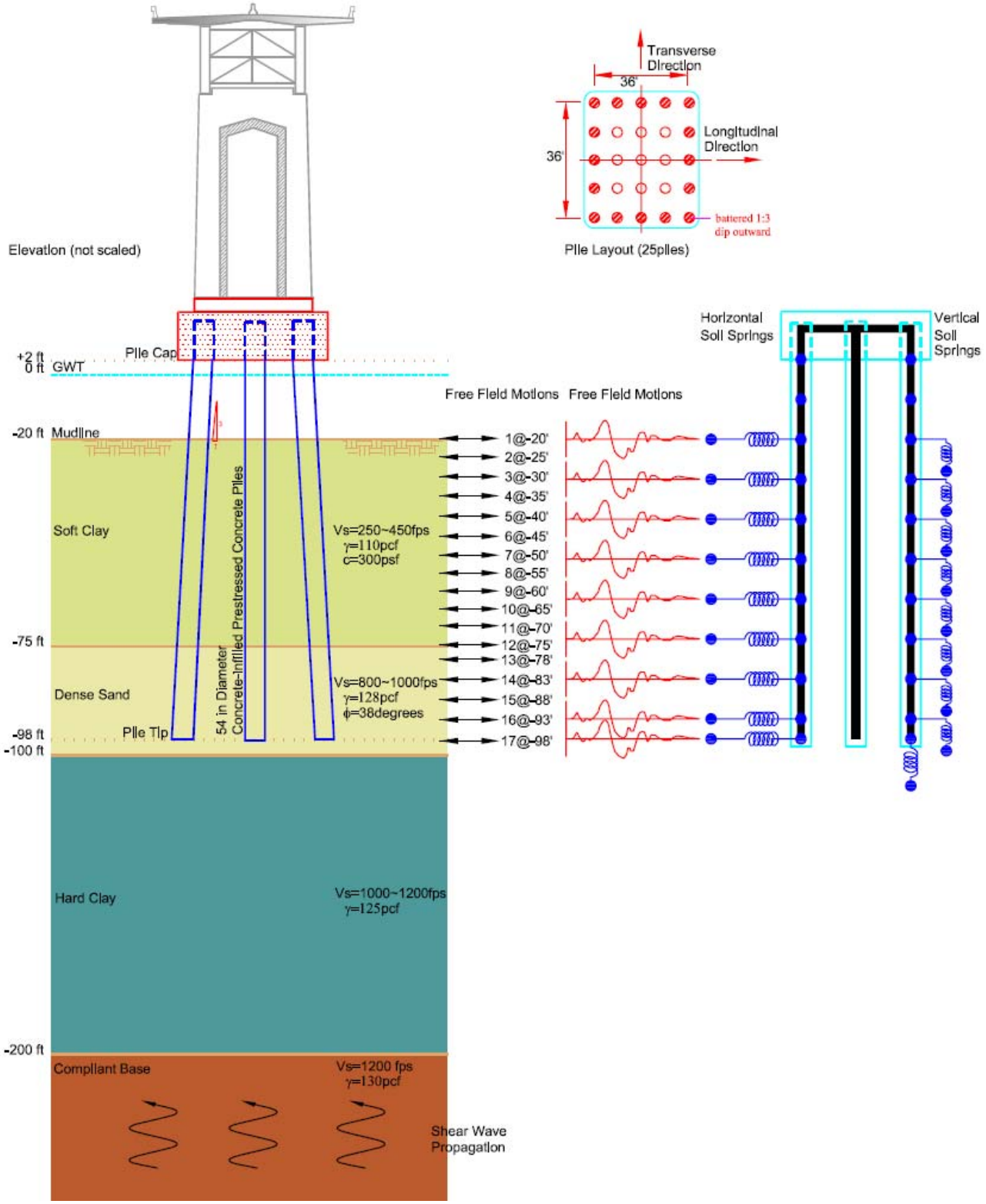


FIGURE A-22: IDEALIZED SOIL CONDITIONS AND FOUNDATION DATA AT PIER 22

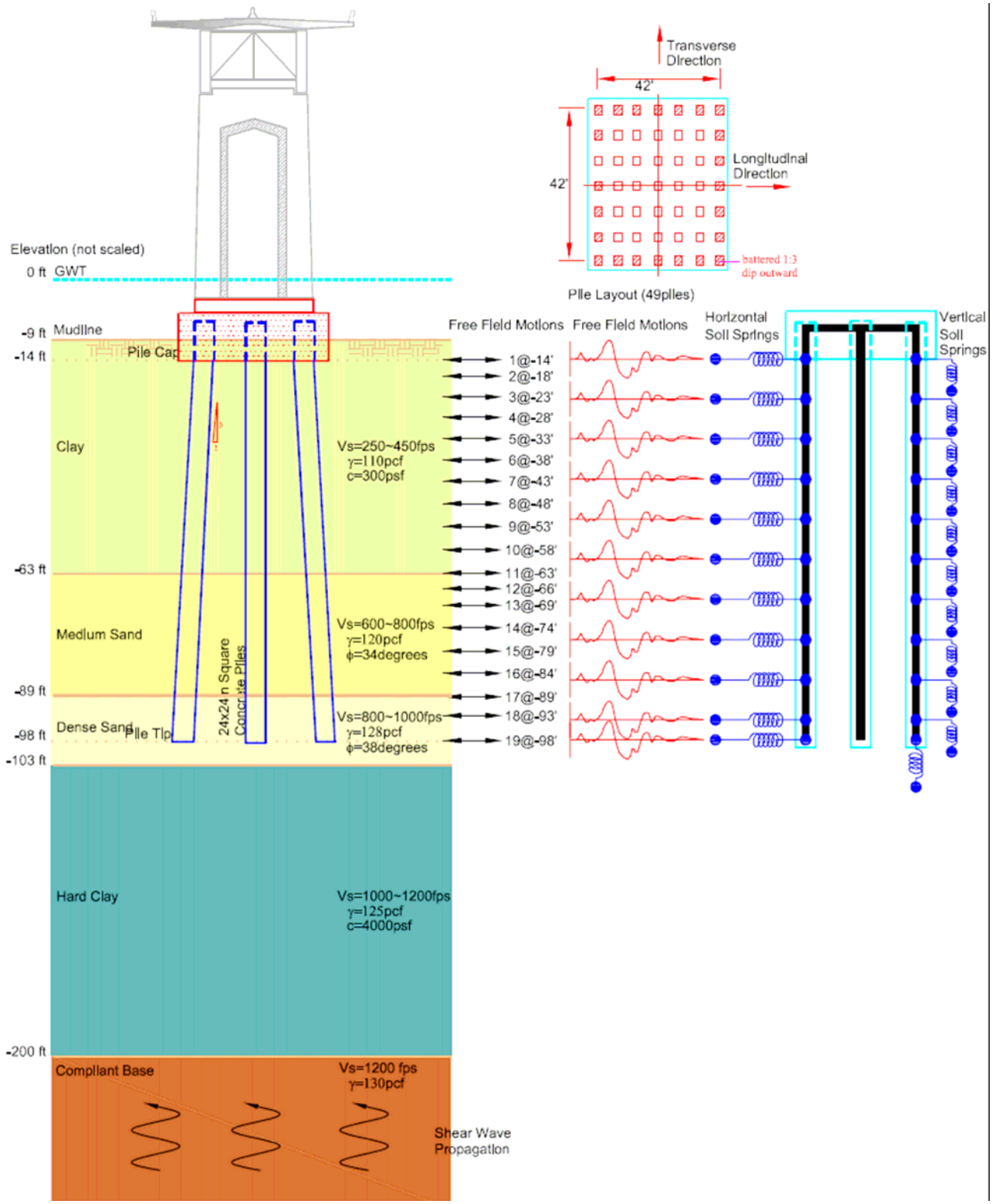


FIGURE A-23: IDEALIZED SOIL CONDITIONS AND FOUNDATION DATA AT PIER 23

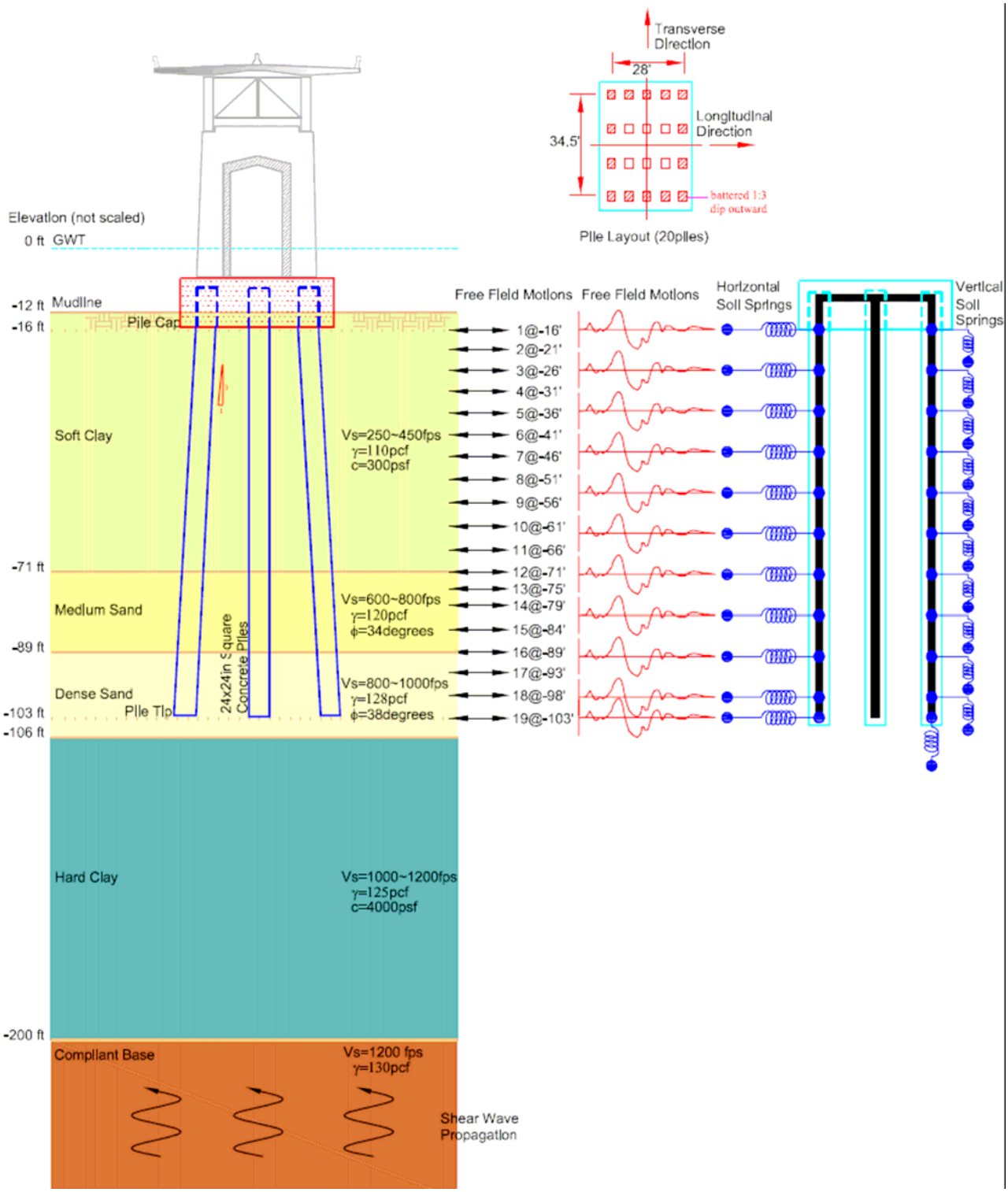


FIGURE A-24: IDEALIZED SOIL CONDITIONS AND FOUNDATION DATA AT PIER 24

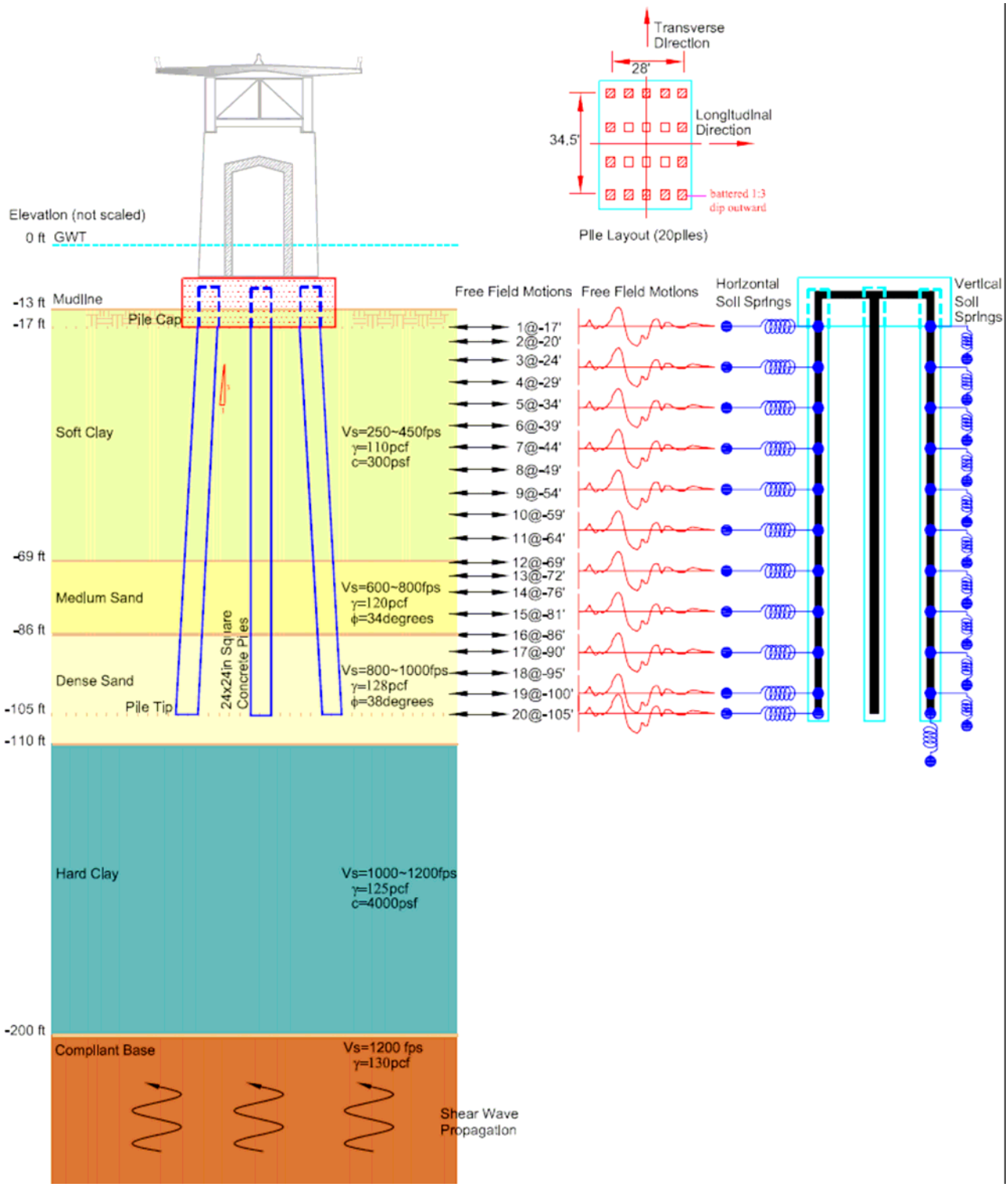


FIGURE A-25: IDEALIZED SOIL CONDITIONS AND FOUNDATION DATA AT PIER 25

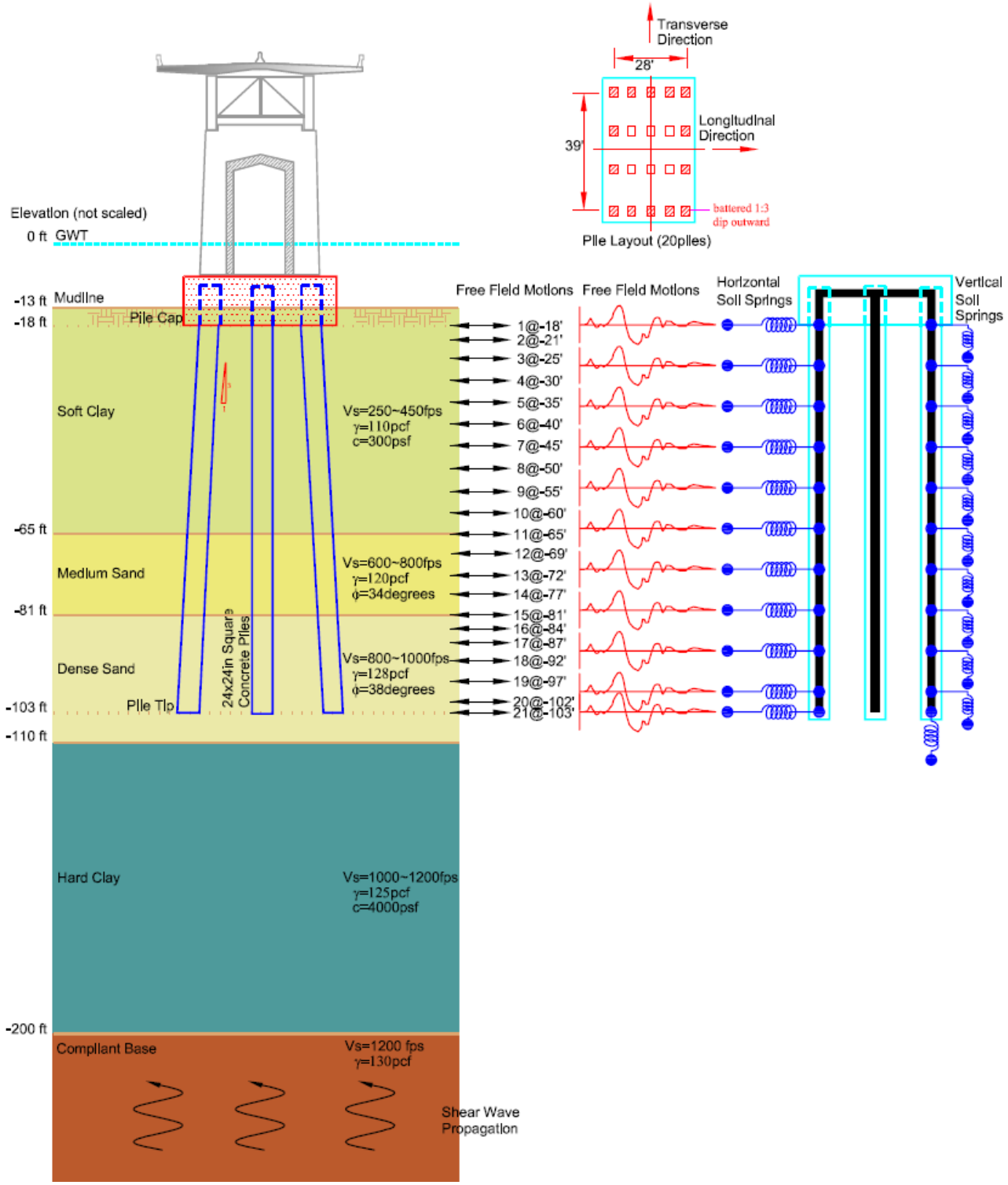


FIGURE A-26: IDEALIZED SOIL CONDITIONS AND FOUNDATION DATA AT PIER 26

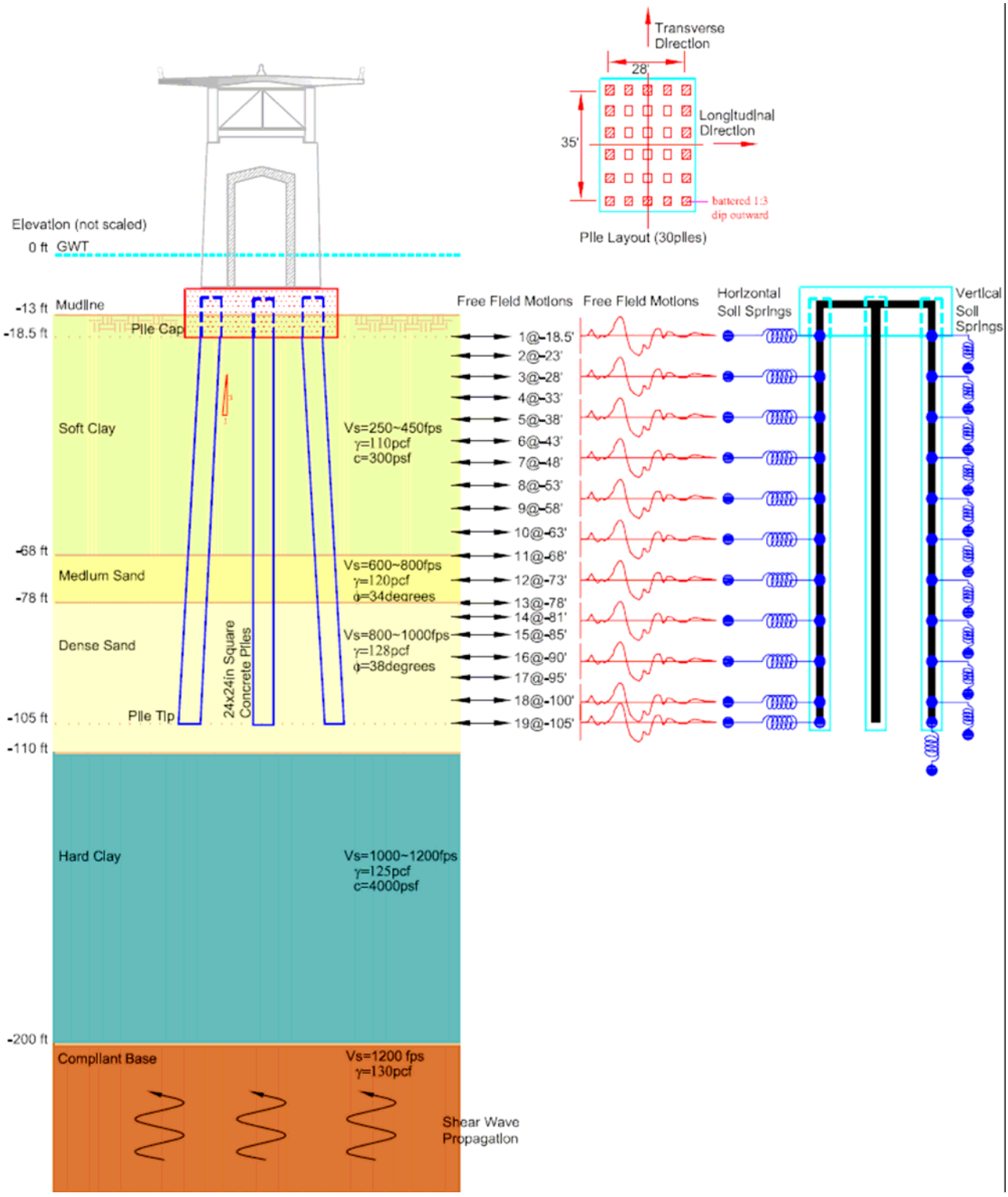


FIGURE A-27: IDEALIZED SOIL CONDITIONS AND FOUNDATION DATA AT PIER 27

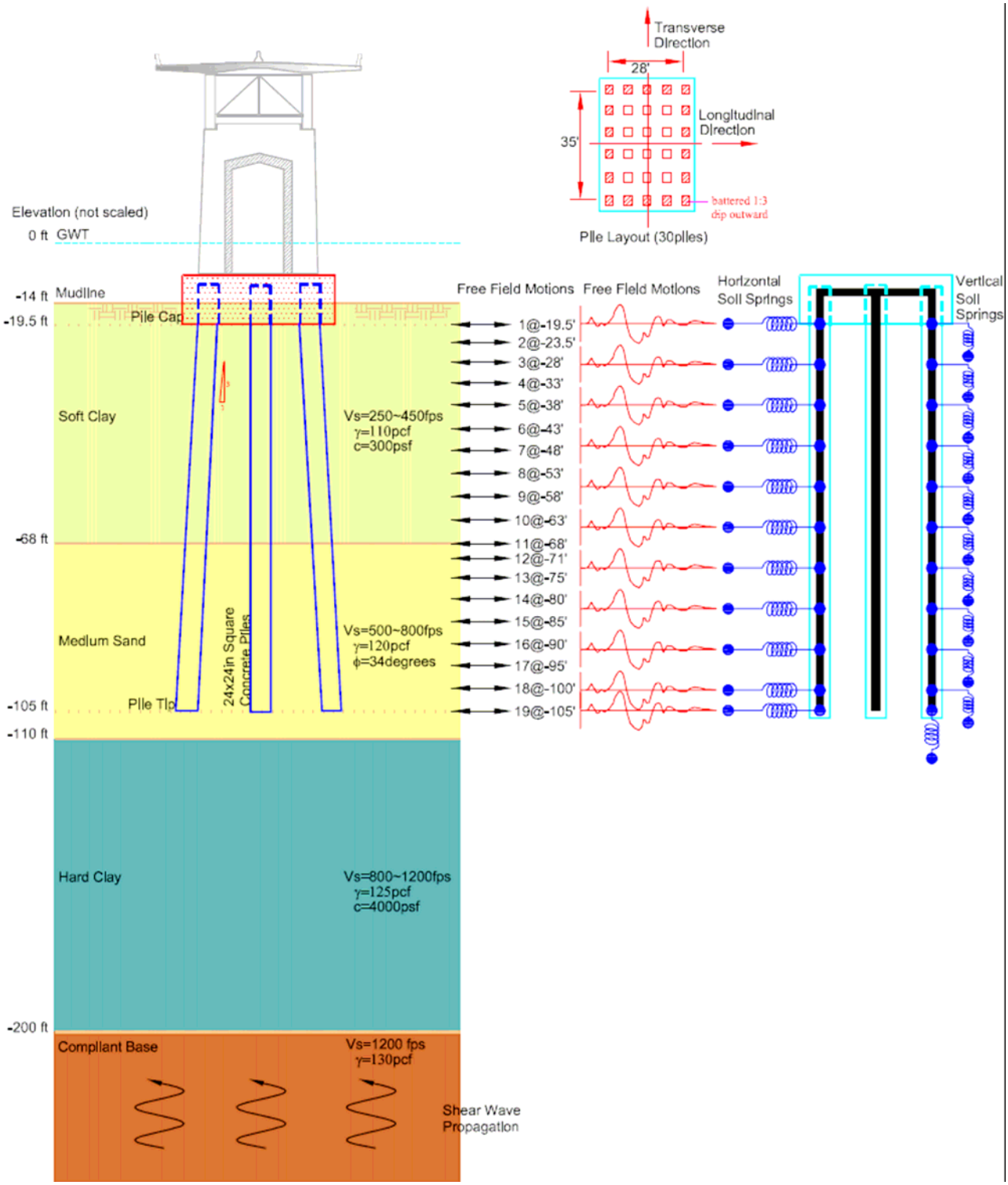


FIGURE A-28: IDEALIZED SOIL CONDITIONS AND FOUNDATION DATA AT PIER 28

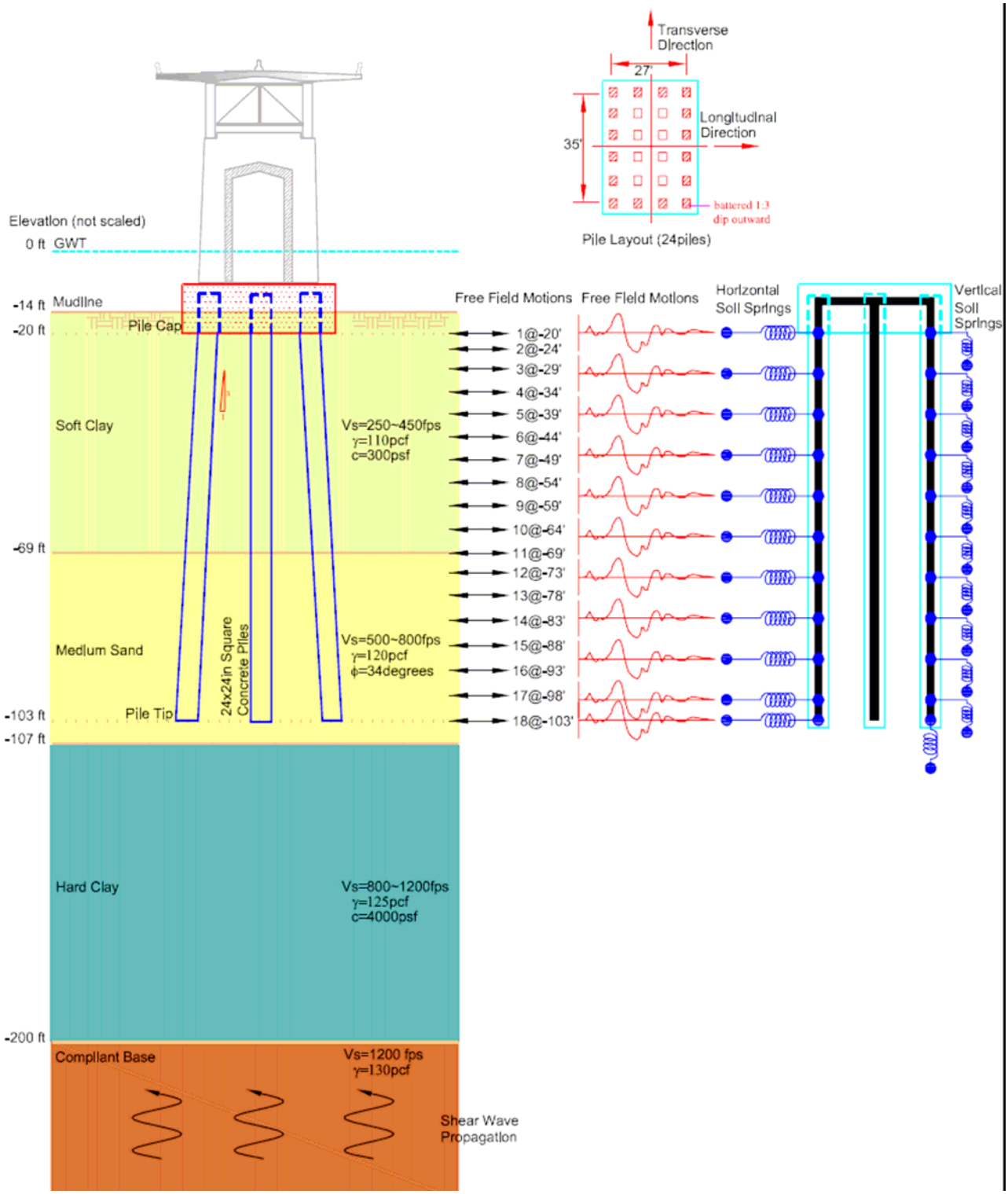


FIGURE A-29: IDEALIZED SOIL CONDITIONS AND FOUNDATION DATA AT PIER 29

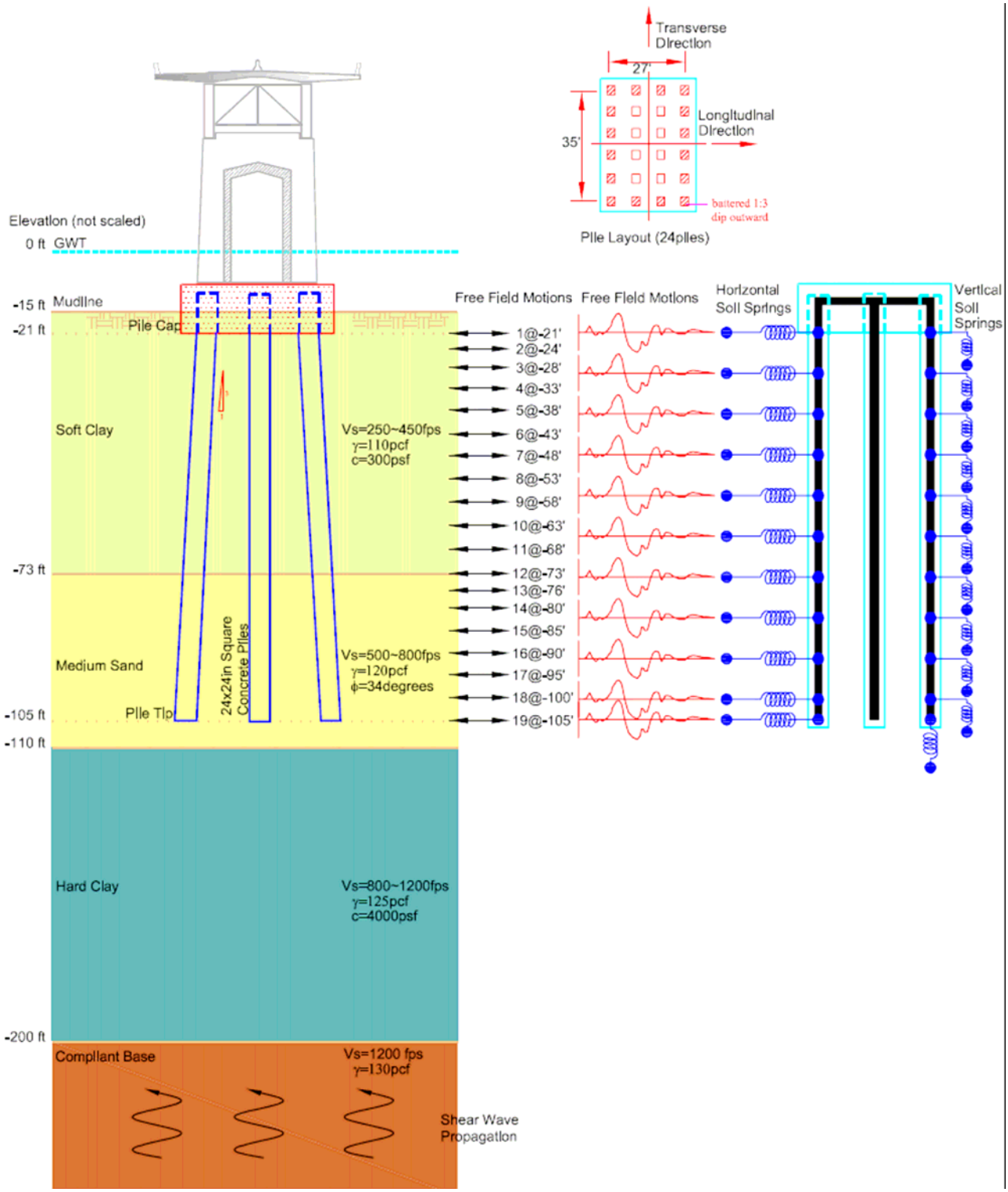


FIGURE A-30: IDEALIZED SOIL CONDITIONS AND FOUNDATION DATA AT PIER 30

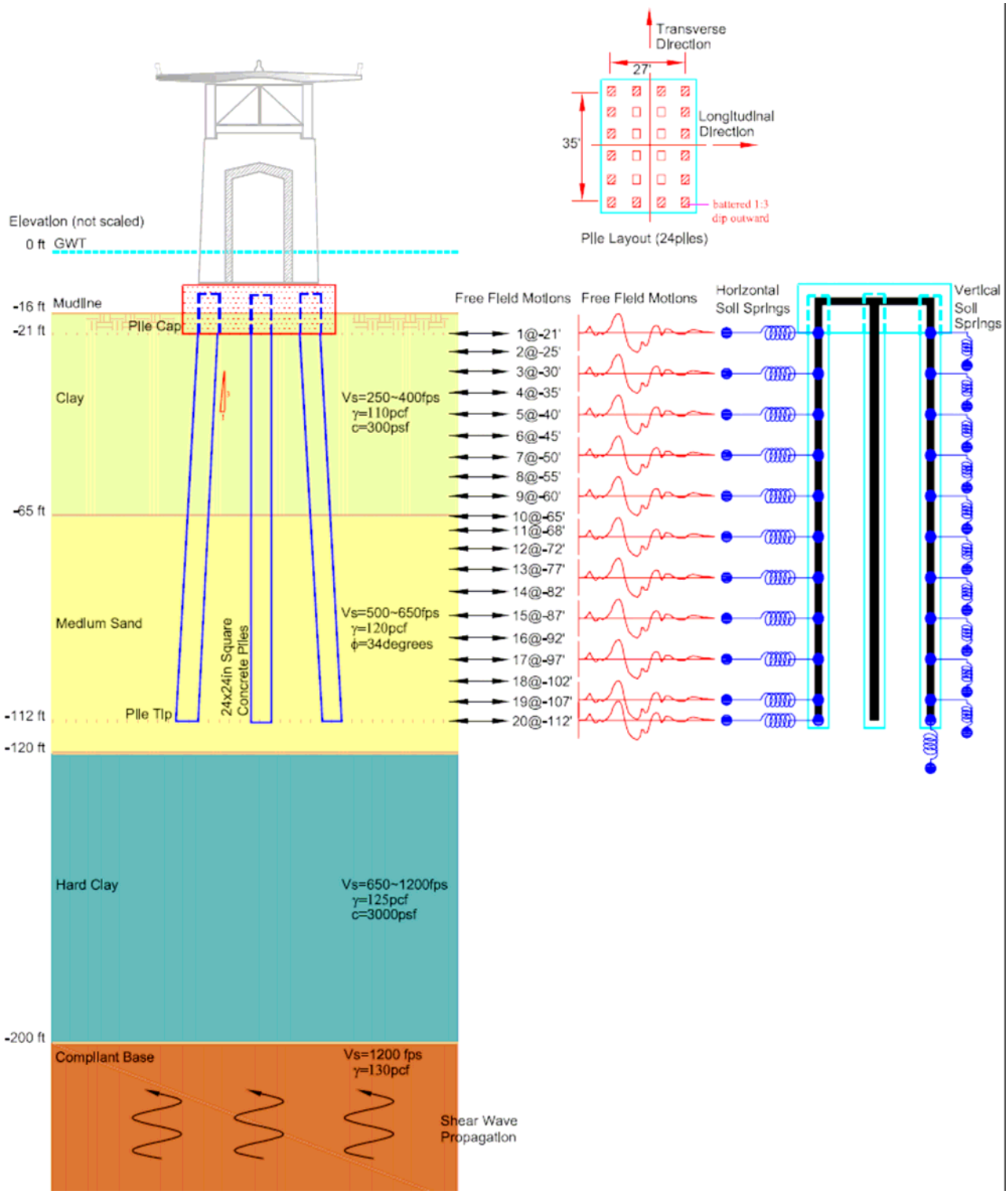


FIGURE A-31: IDEALIZED SOIL CONDITIONS AND FOUNDATION DATA AT PIER 31

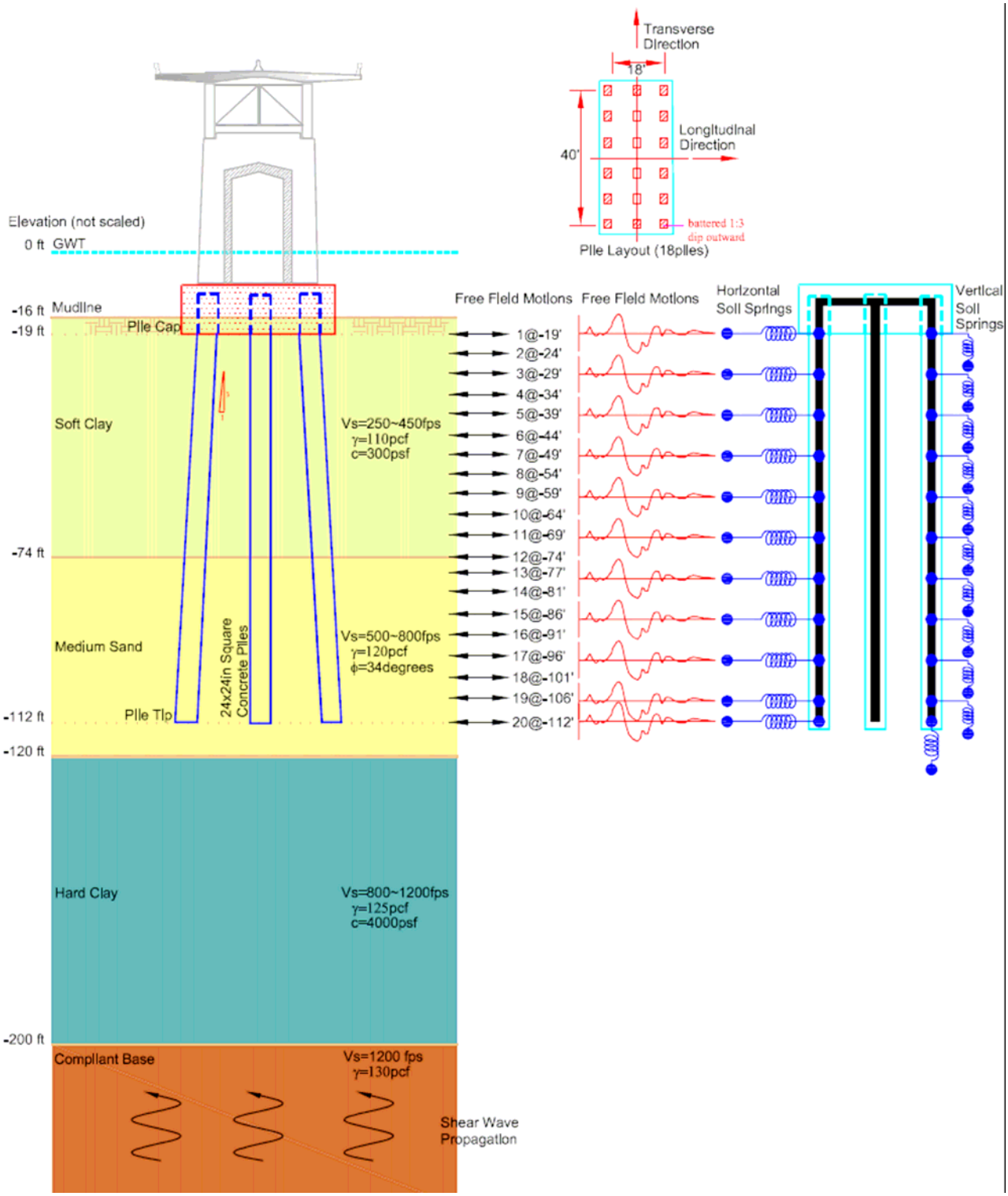


FIGURE A-32: IDEALIZED SOIL CONDITIONS AND FOUNDATION DATA AT PIER 32

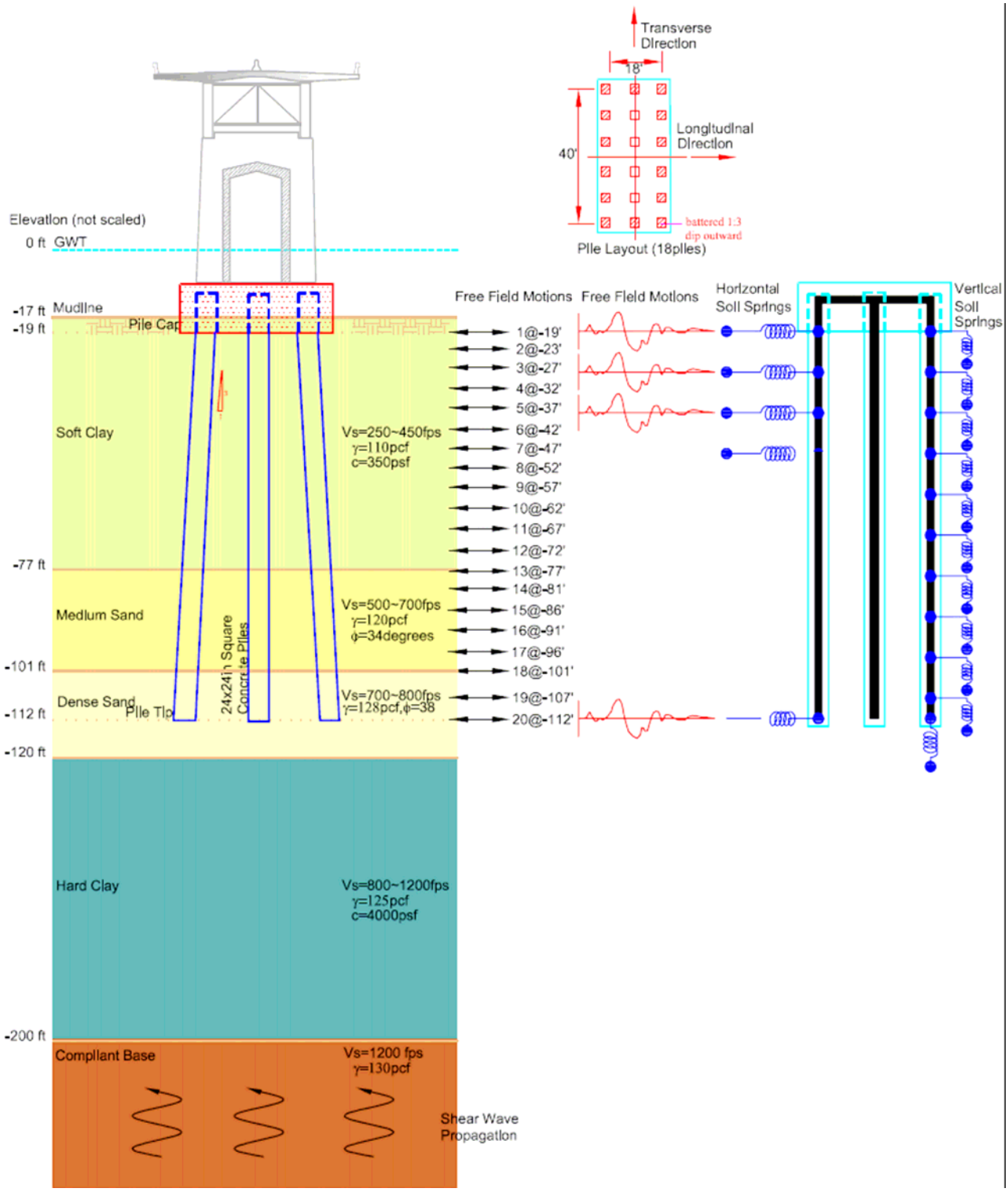


FIGURE A-33: IDEALIZED SOIL CONDITIONS AND FOUNDATION DATA AT PIER 33

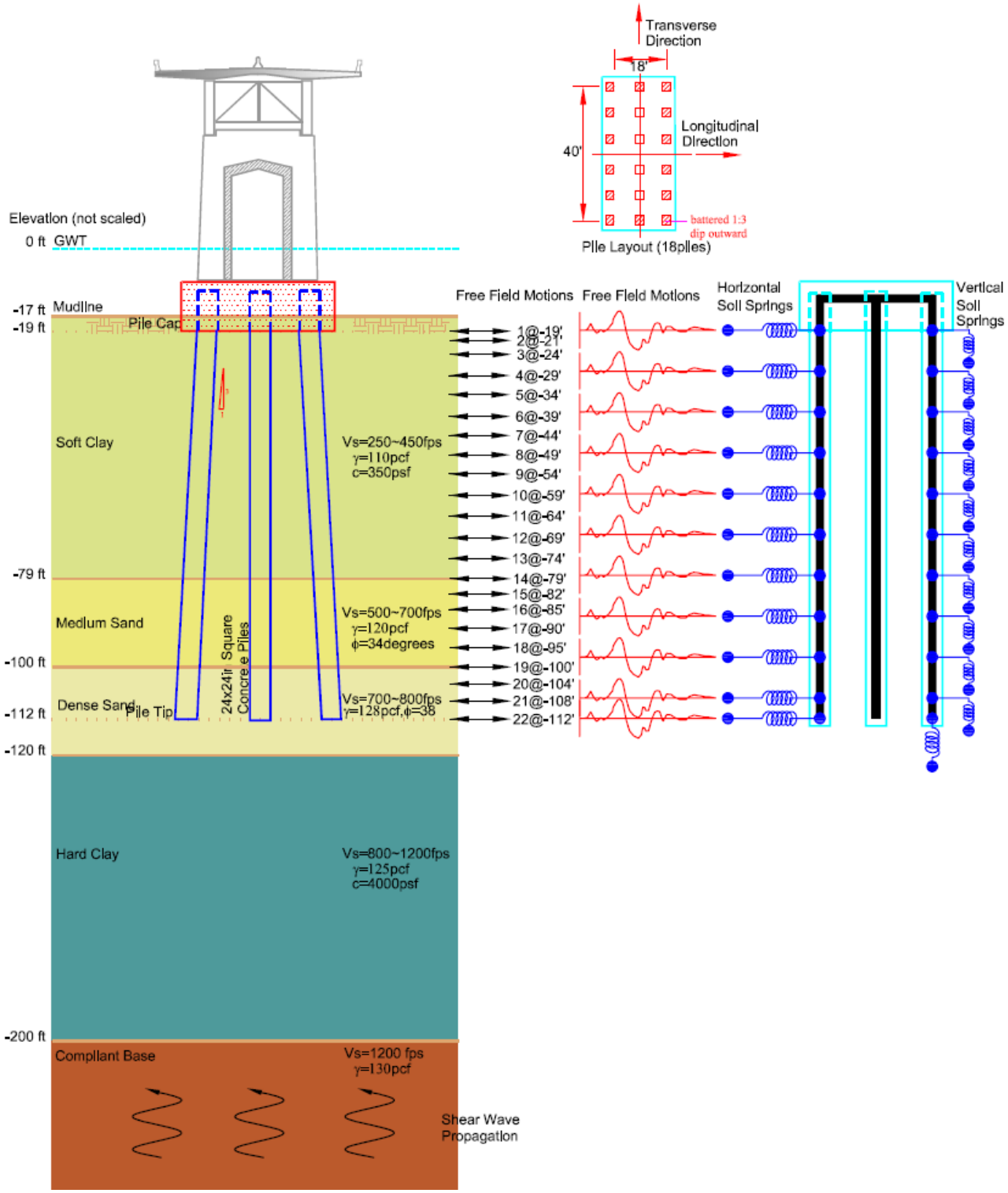


FIGURE A-34: IDEALIZED SOIL CONDITIONS AND FOUNDATION DATA AT PIER 34

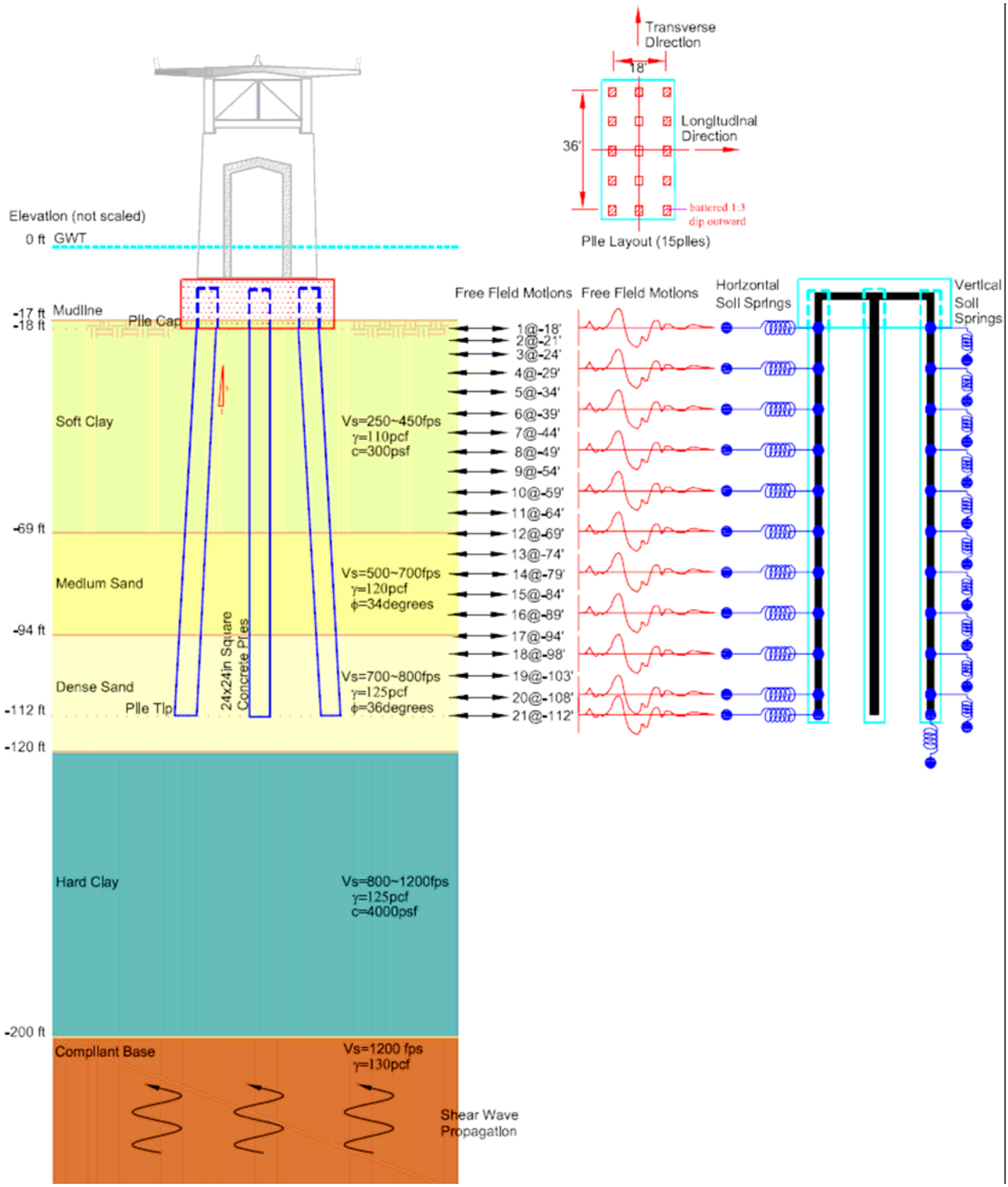


FIGURE A-35: IDEALIZED SOIL CONDITIONS AND FOUNDATION DATA AT PIER 35

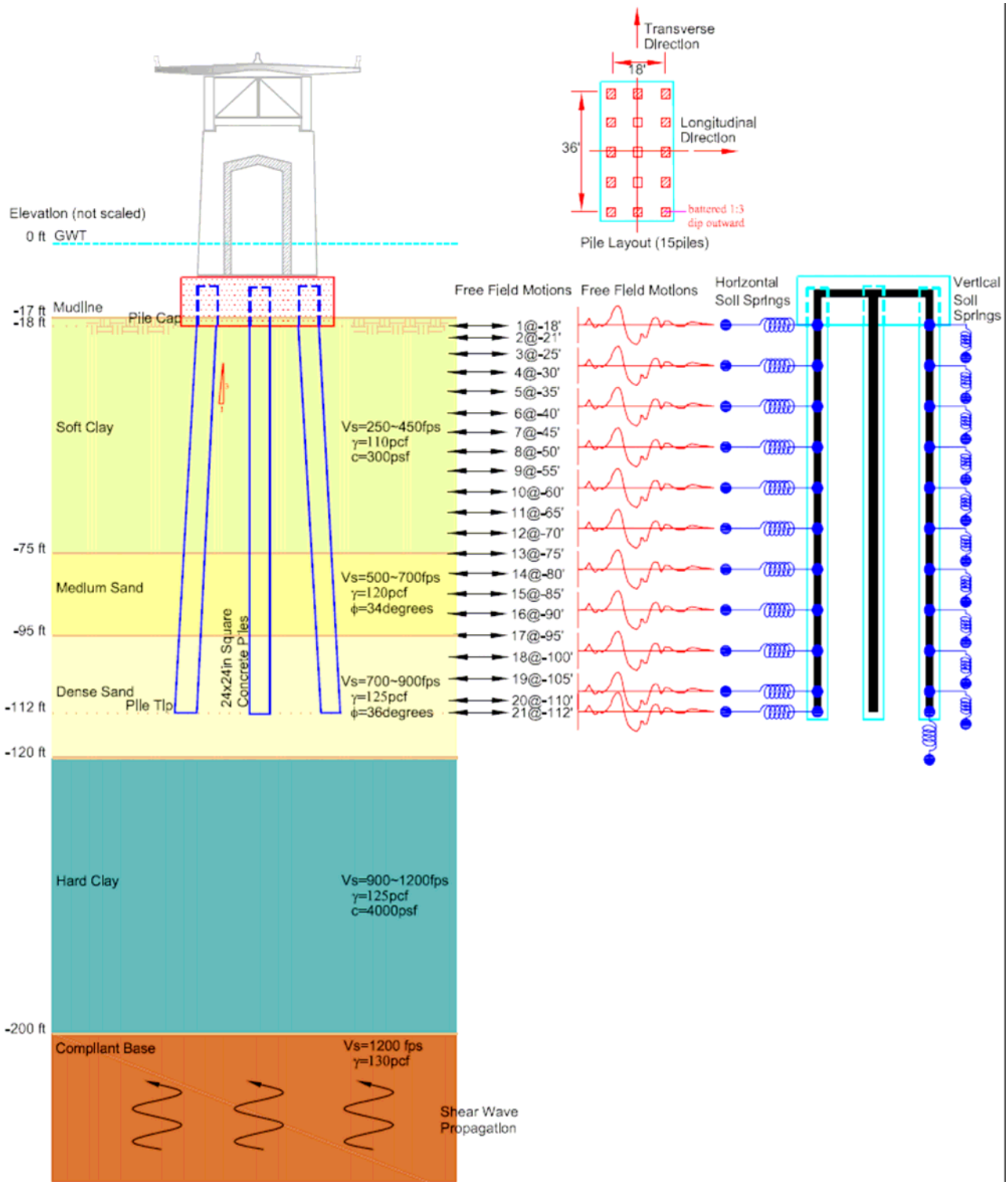


FIGURE A-36: IDEALIZED SOIL CONDITIONS AND FOUNDATION DATA AT PIER 36

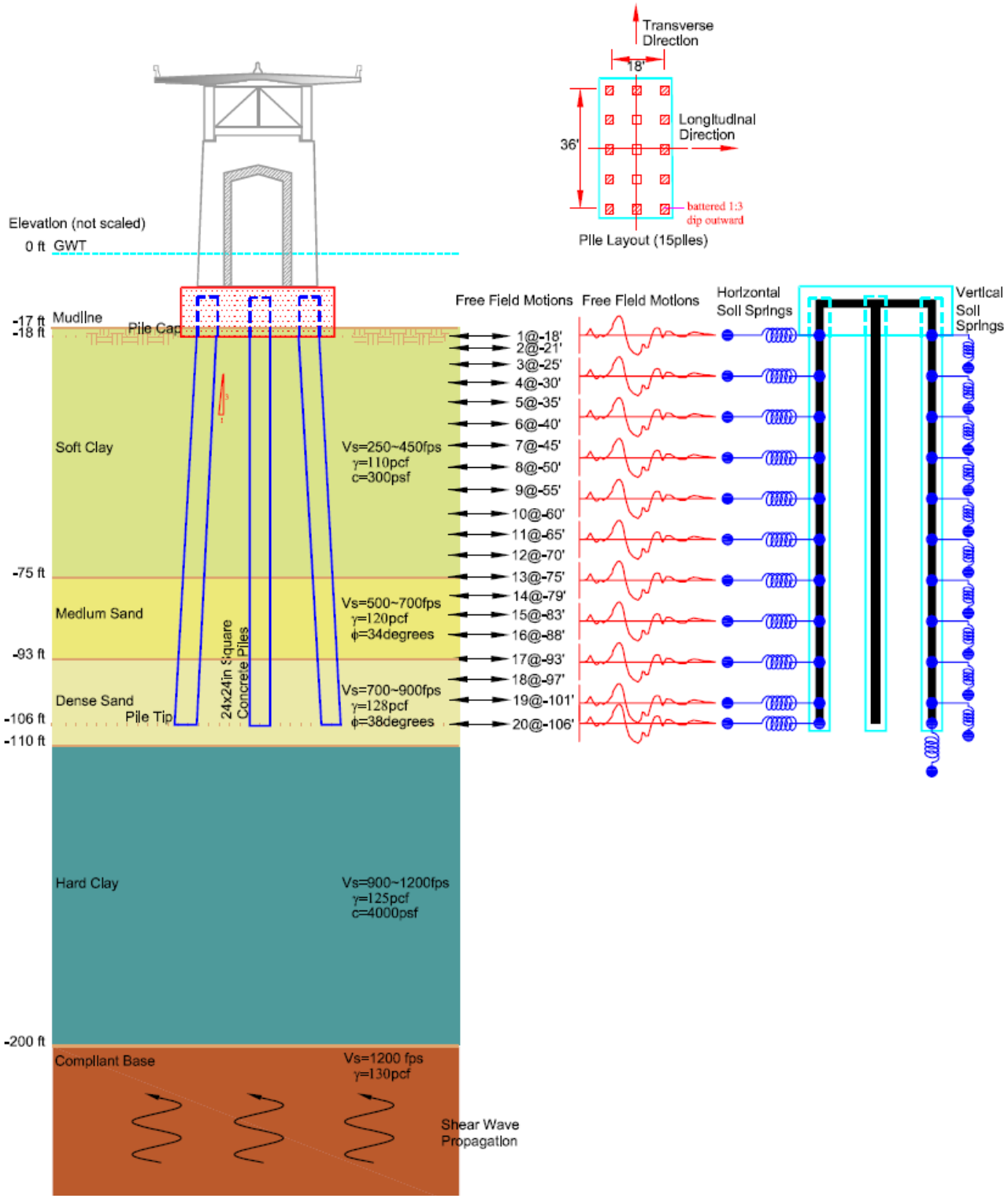


FIGURE A-37: IDEALIZED SOIL CONDITIONS AND FOUNDATION DATA AT PIER 37

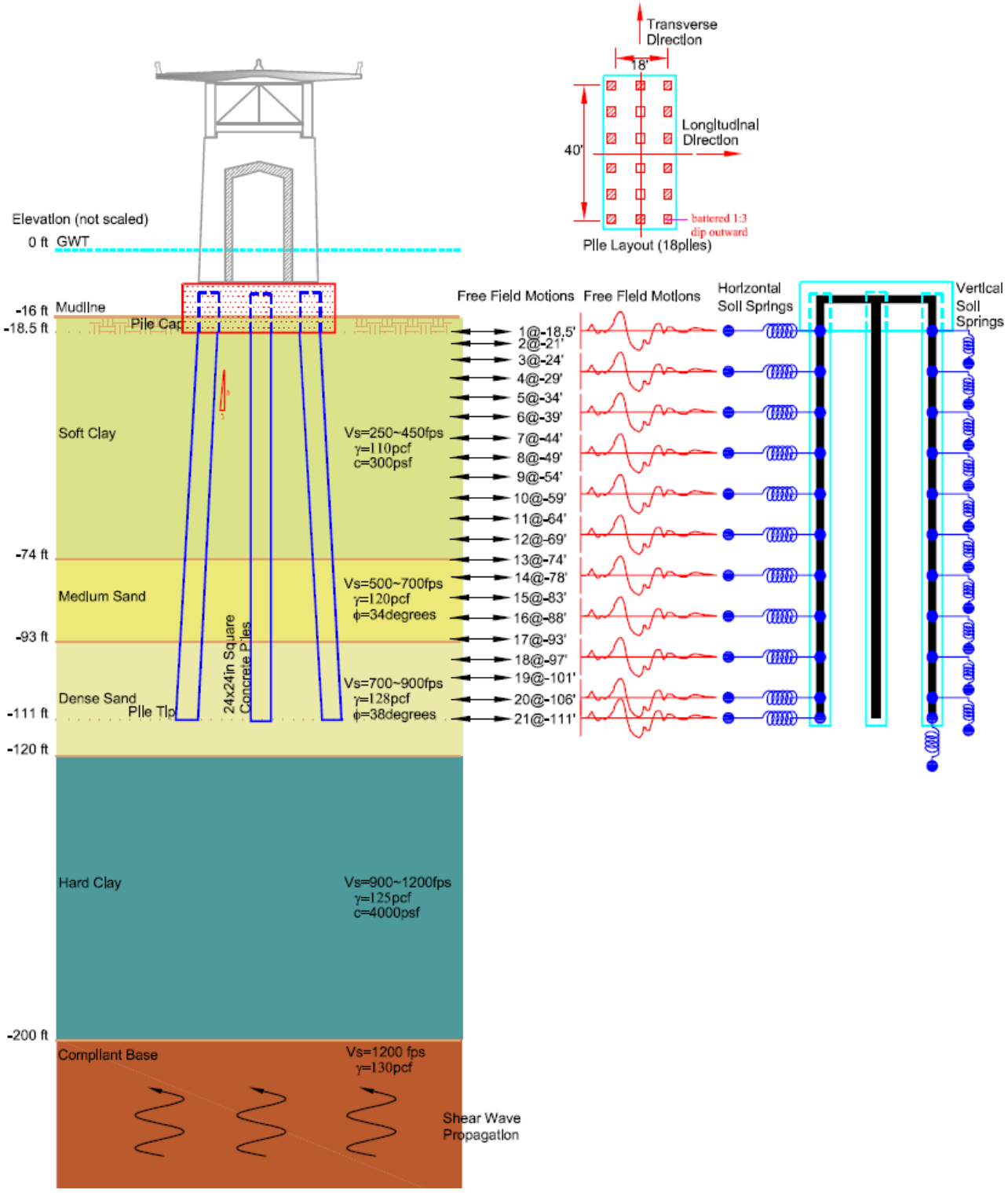


FIGURE A-38: IDEALIZED SOIL CONDITIONS AND FOUNDATION DATA AT PIER 38

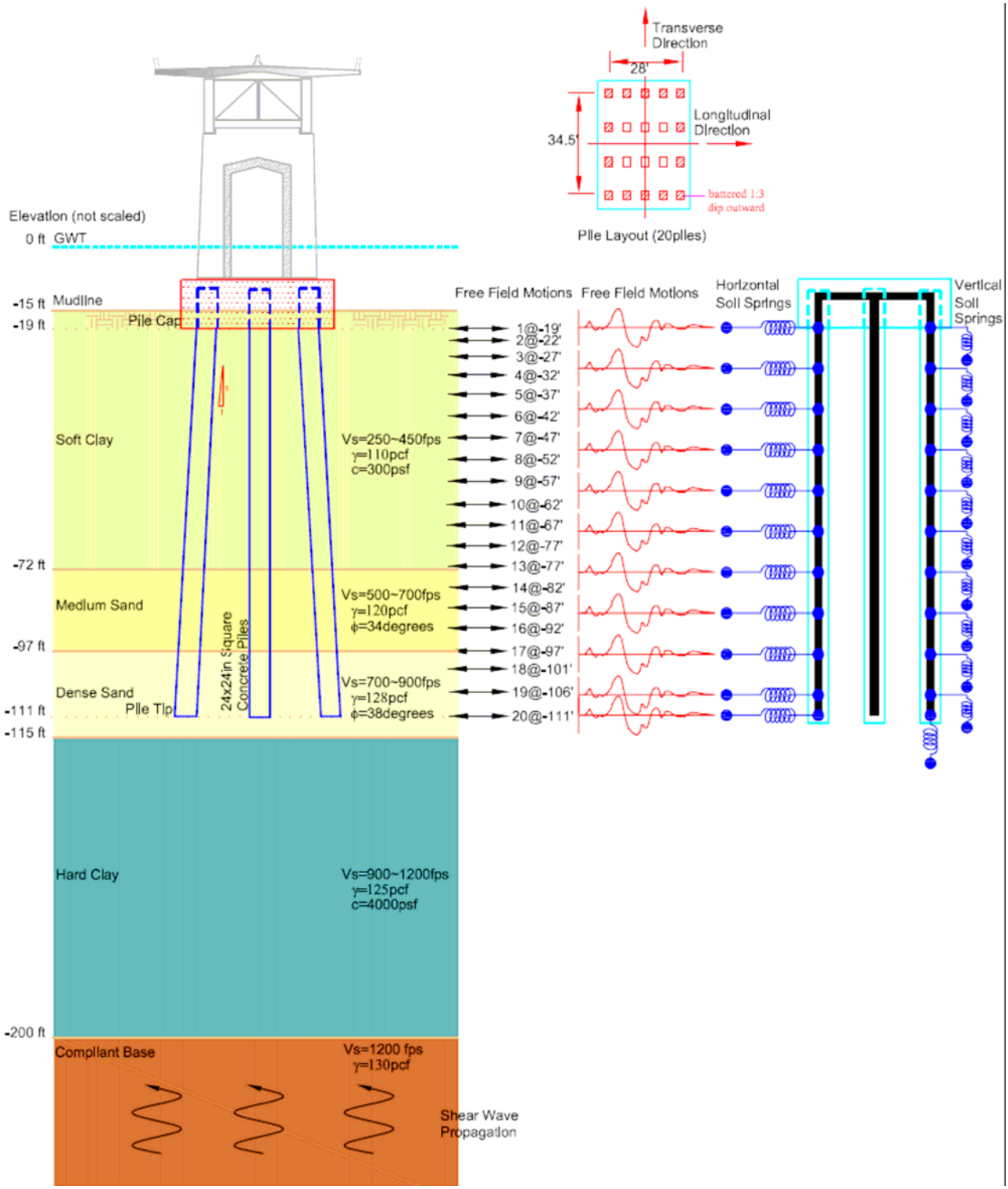


FIGURE A-39: IDEALIZED SOIL CONDITIONS AND FOUNDATION DATA AT PIER 39

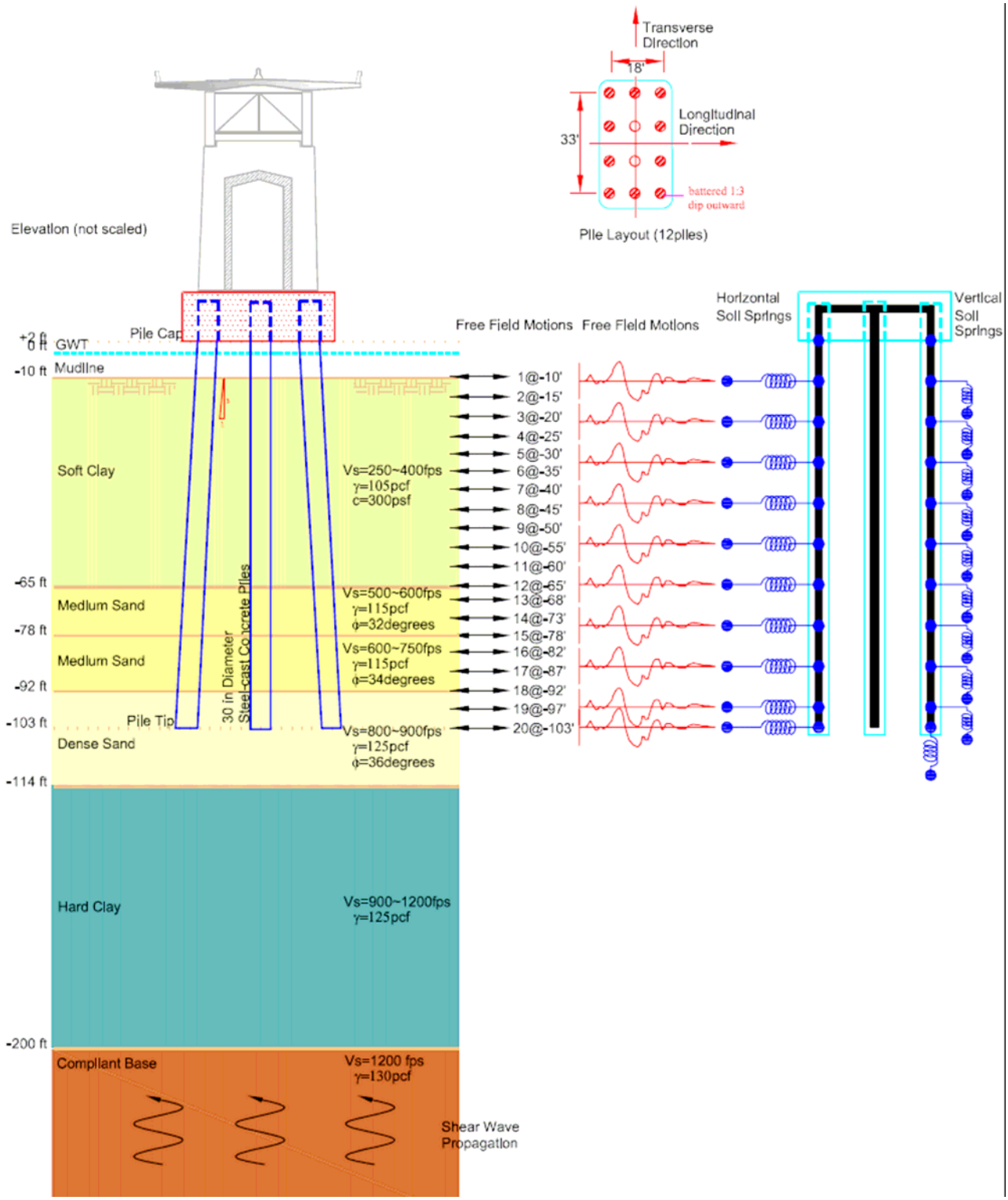


FIGURE A-40: IDEALIZED SOIL CONDITIONS AND FOUNDATION DATA AT PIER 40

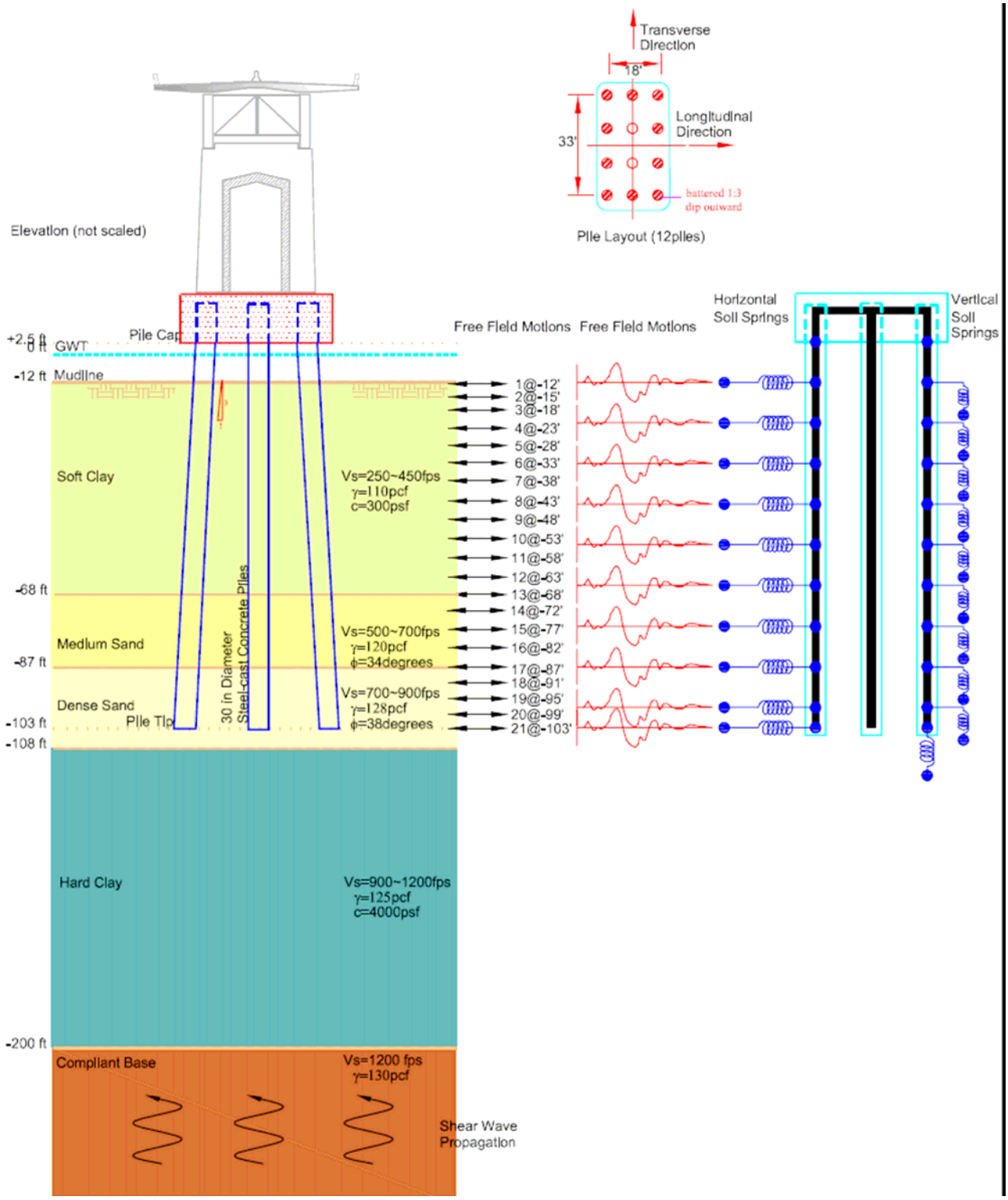


FIGURE A-41: IDEALIZED SOIL CONDITIONS AND FOUNDATION DATA AT ABUTMENT 41

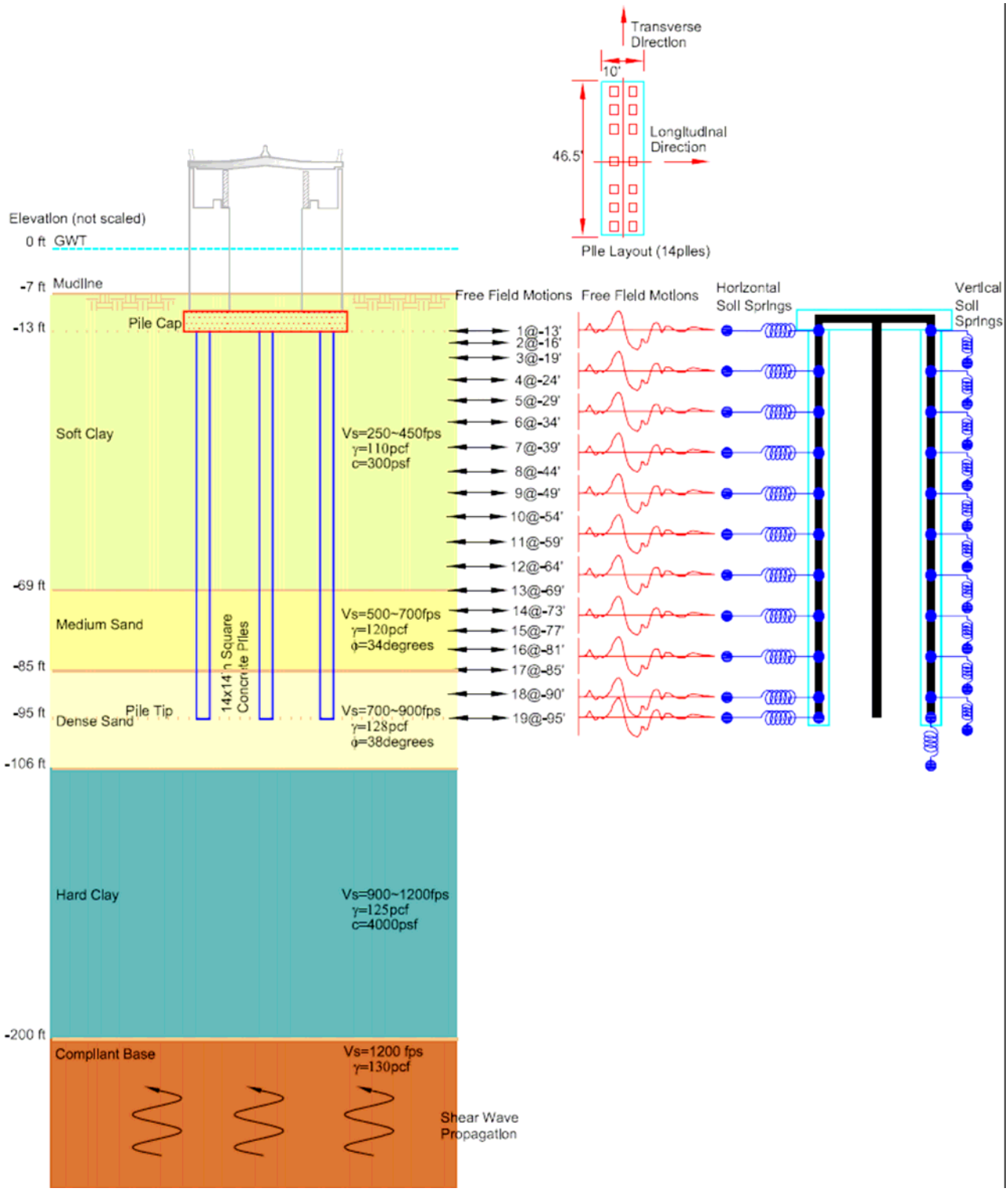


FIGURE A-42: IDEALIZED SOIL CONDITIONS AND FOUNDATION DATA AT PIERS 42~46

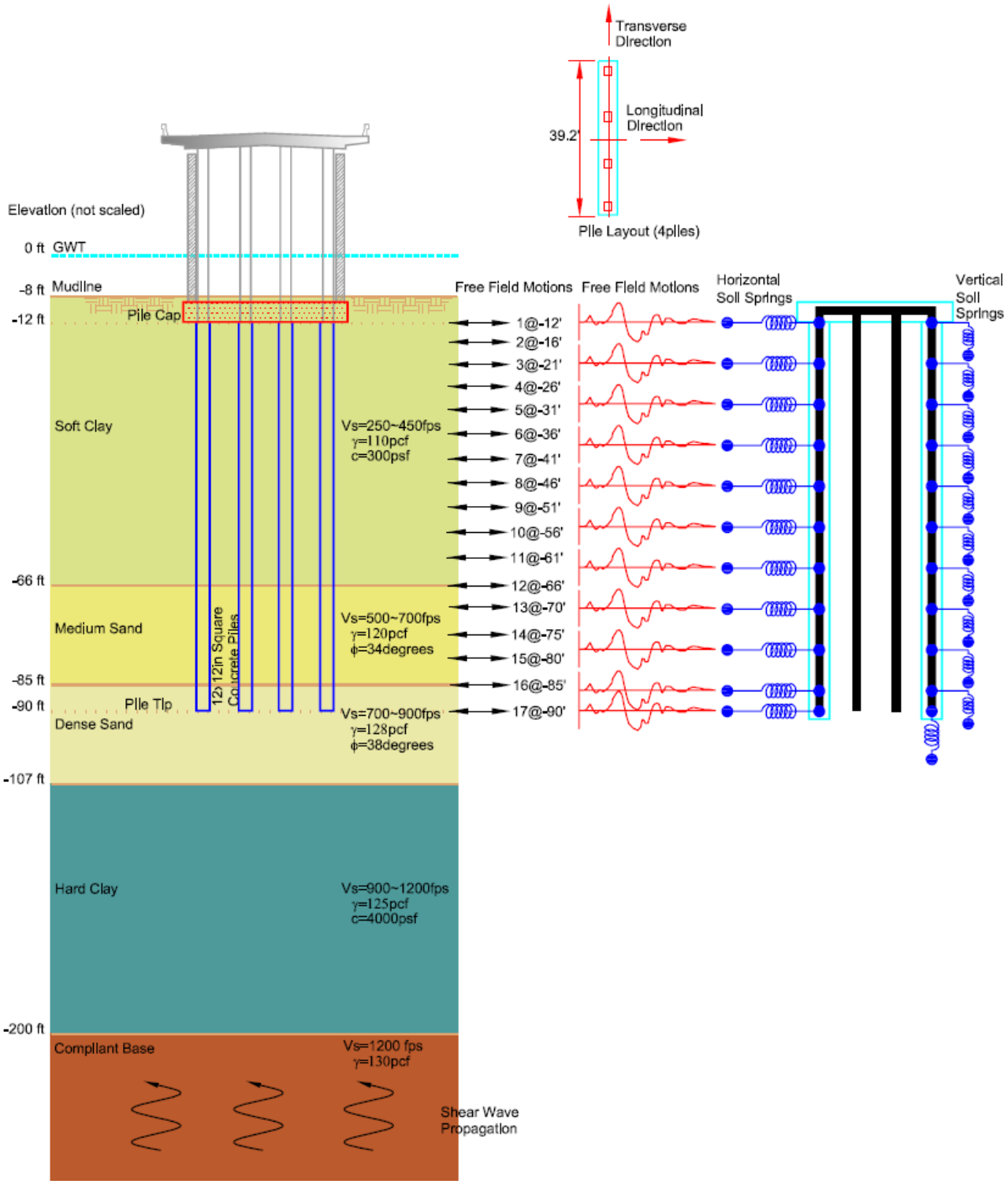


FIGURE A-43: IDEALIZED SOIL CONDITIONS AND FOUNDATION DATA AT PIERS 47~51

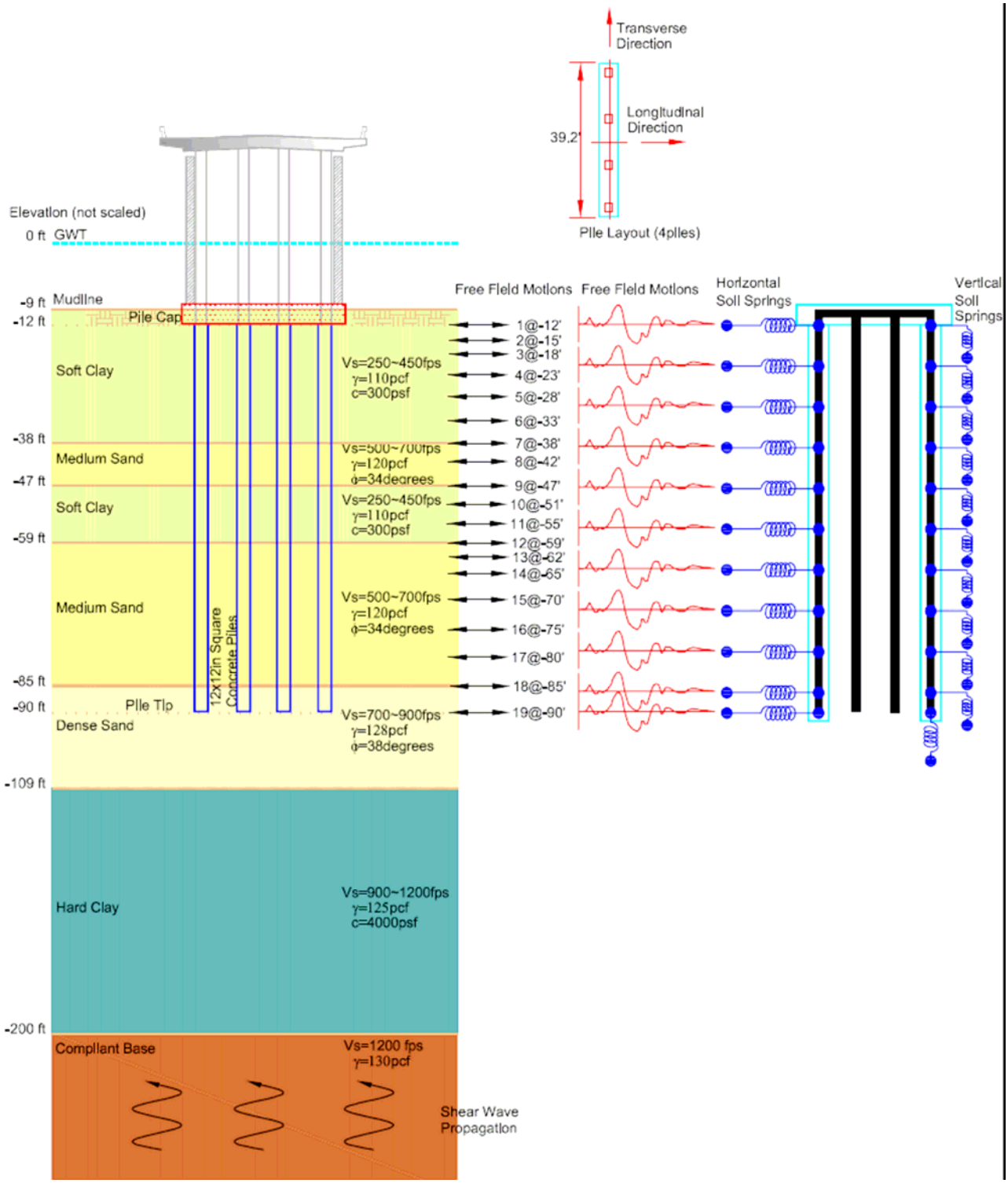


FIGURE A-44: IDEALIZED SOIL CONDITIONS AND FOUNDATION DATA AT PIERS 52 AND 53

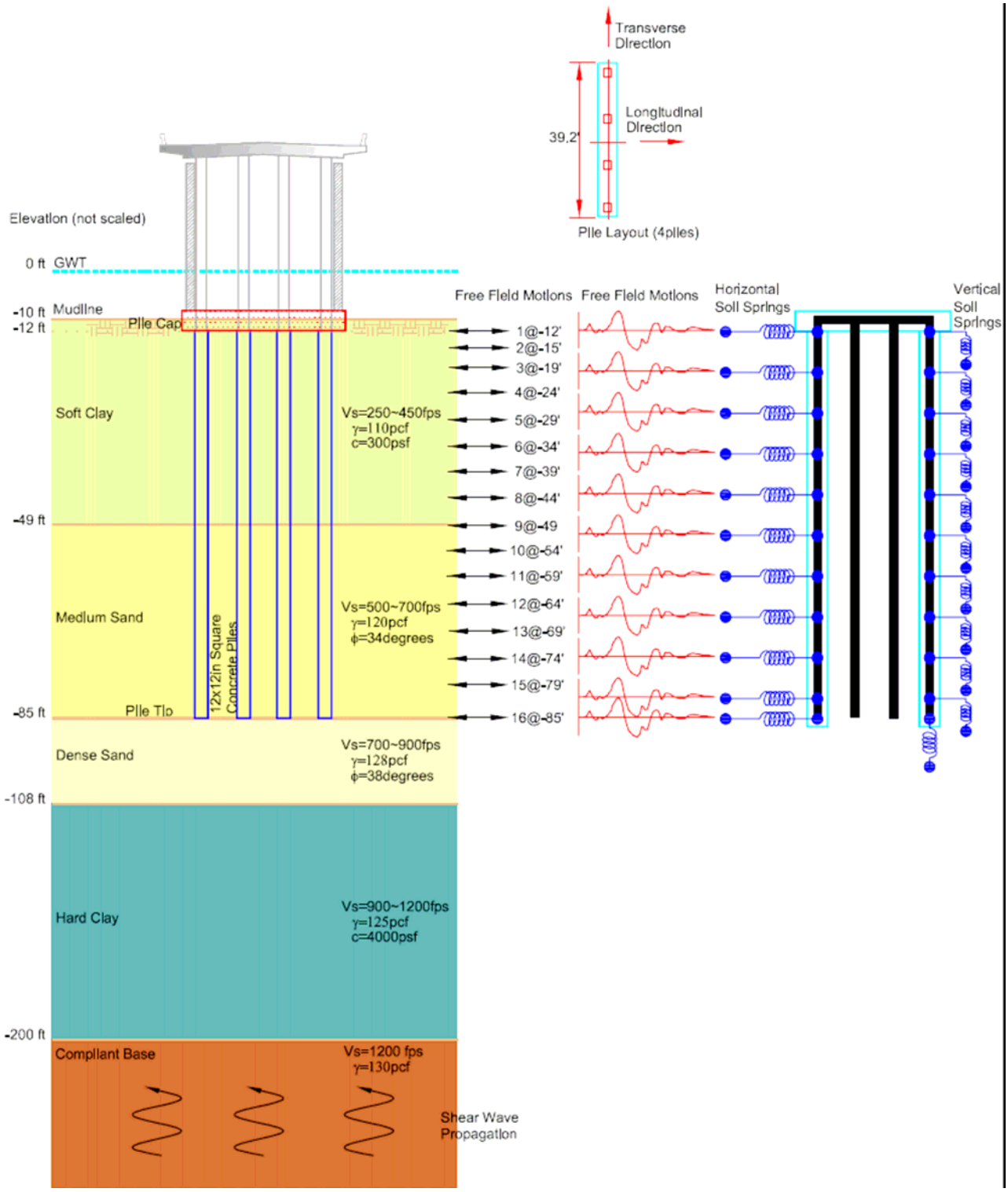


FIGURE A-45: IDEALIZED SOIL CONDITIONS AND FOUNDATION DATA AT PIERS 54~56

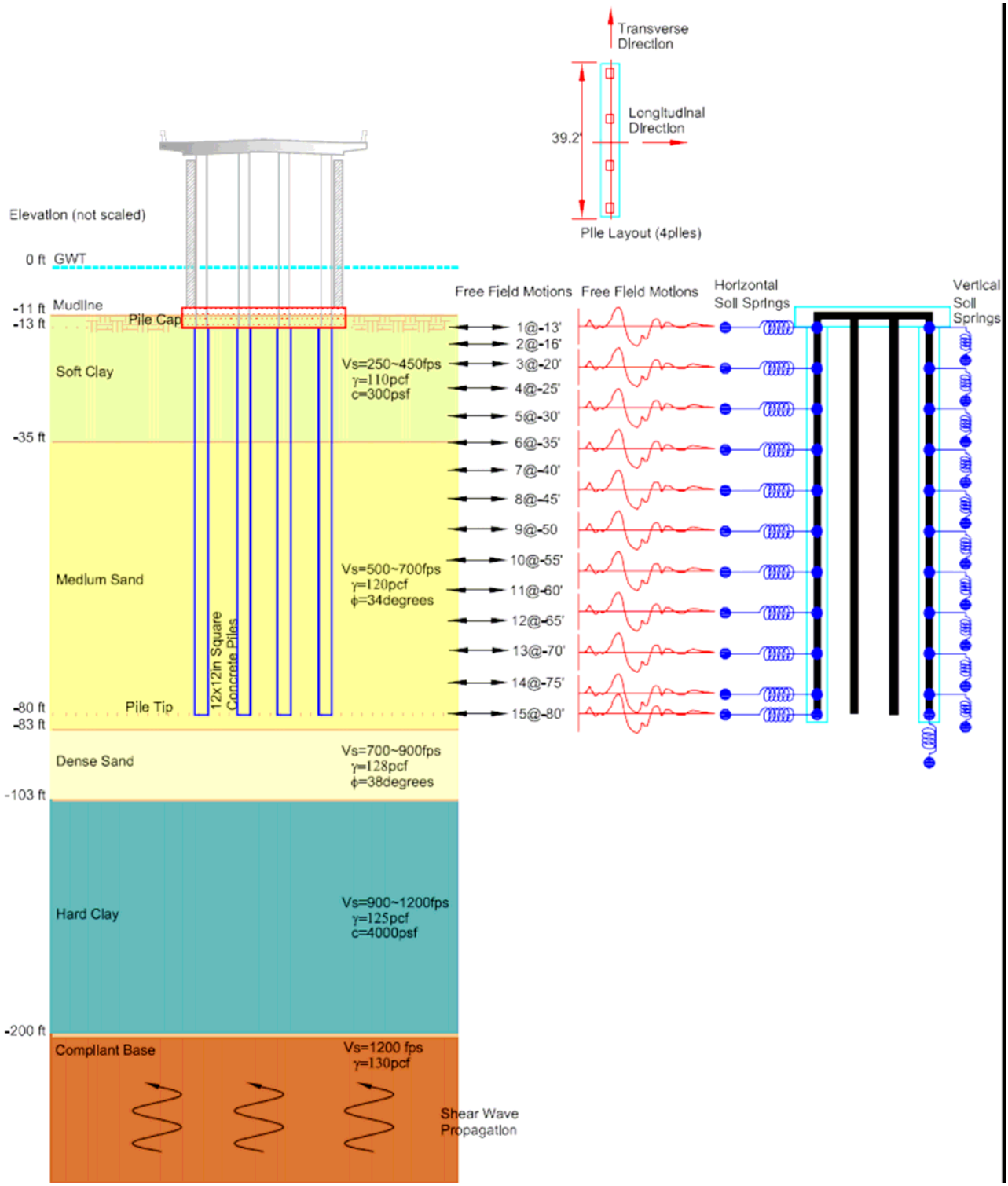


FIGURE A-46: IDEALIZED SOIL CONDITIONS AND FOUNDATION DATA AT PIERS 57 AND 58

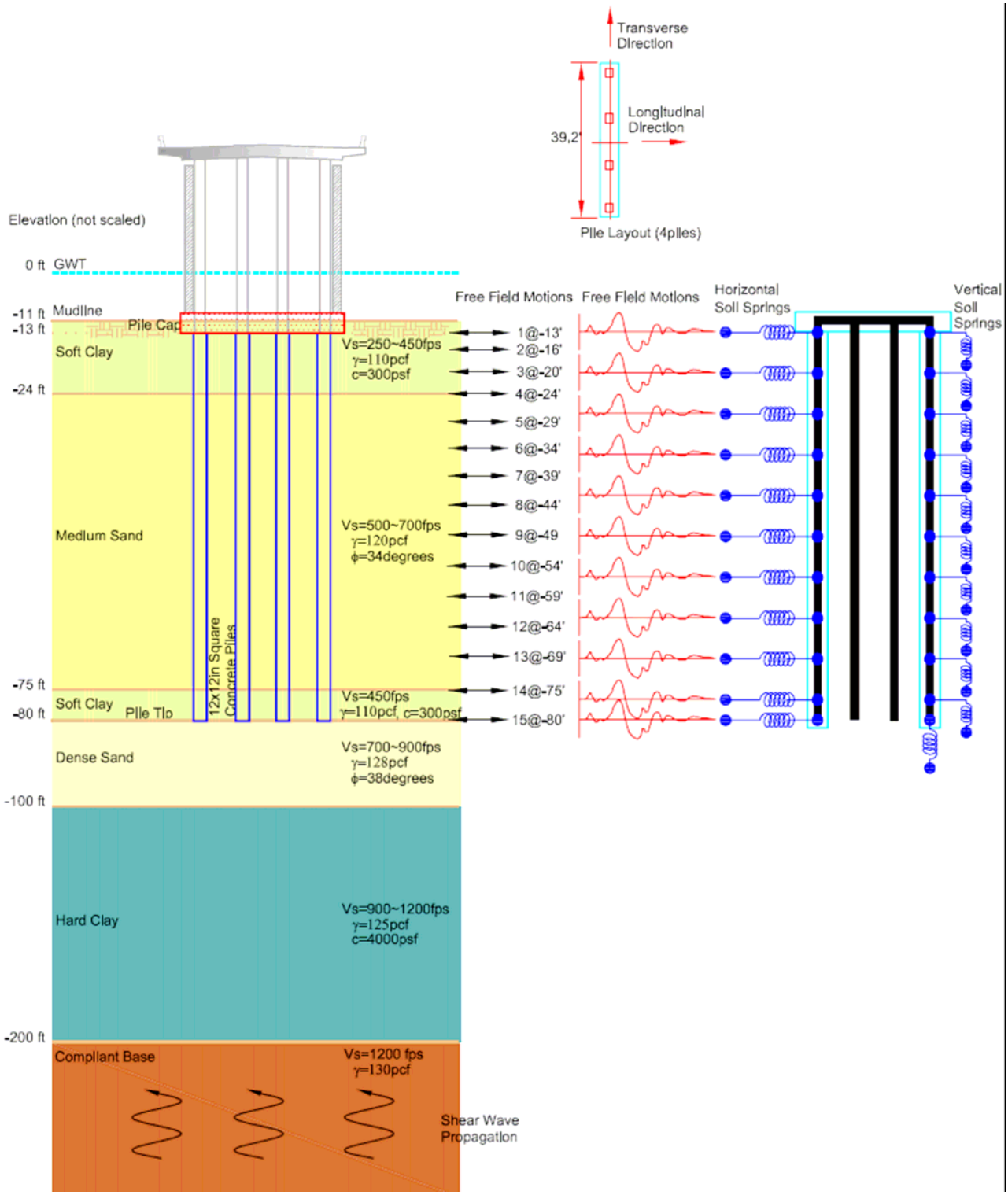


FIGURE A-47: IDEALIZED SOIL CONDITIONS AND FOUNDATION DATA AT PIERS 59~62

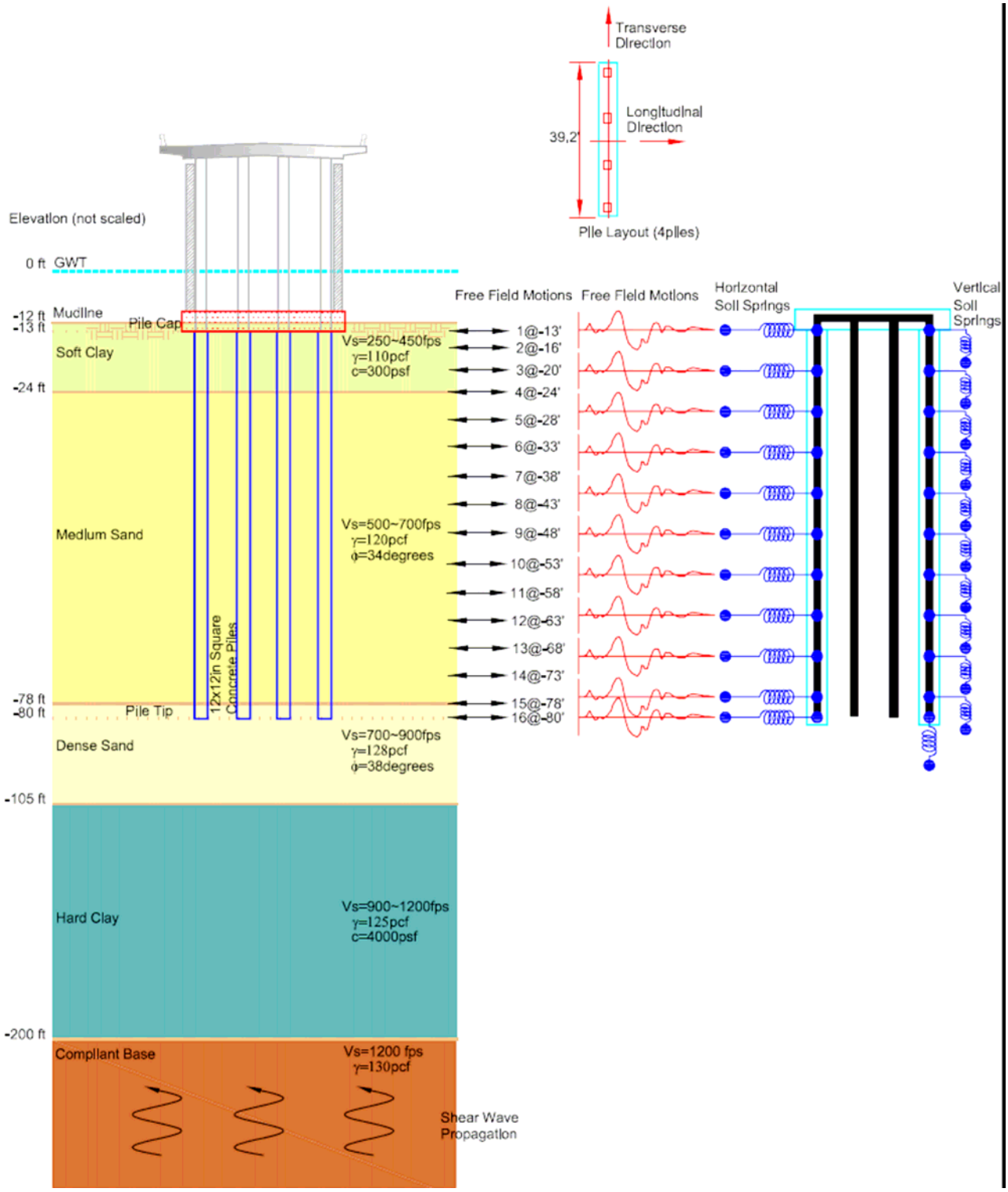


FIGURE A-48: IDEALIZED SOIL CONDITIONS AND FOUNDATION DATA AT PIERS 63~67

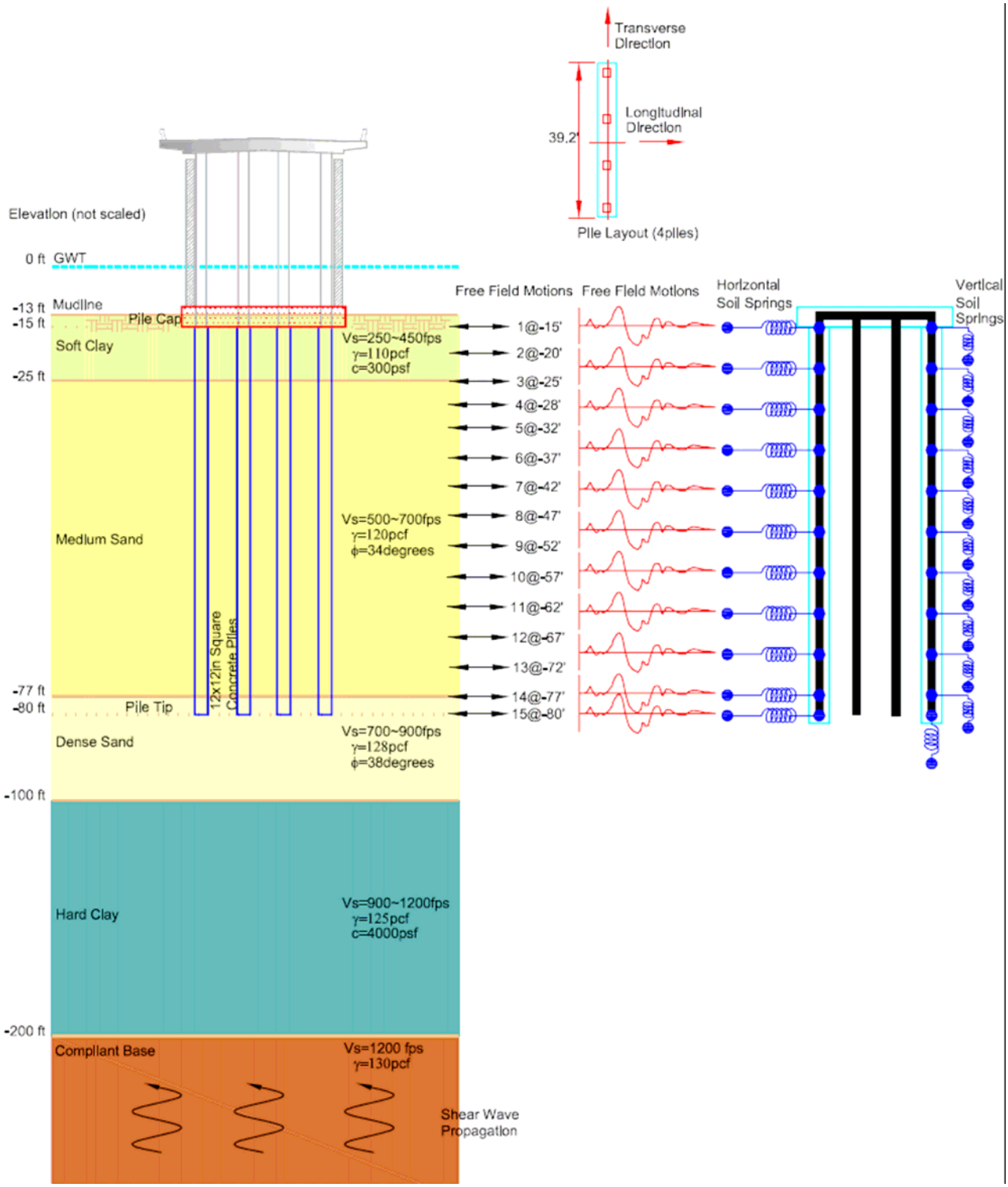


FIGURE A-49: IDEALIZED SOIL CONDITIONS AND FOUNDATION DATA AT PIERS 68~70

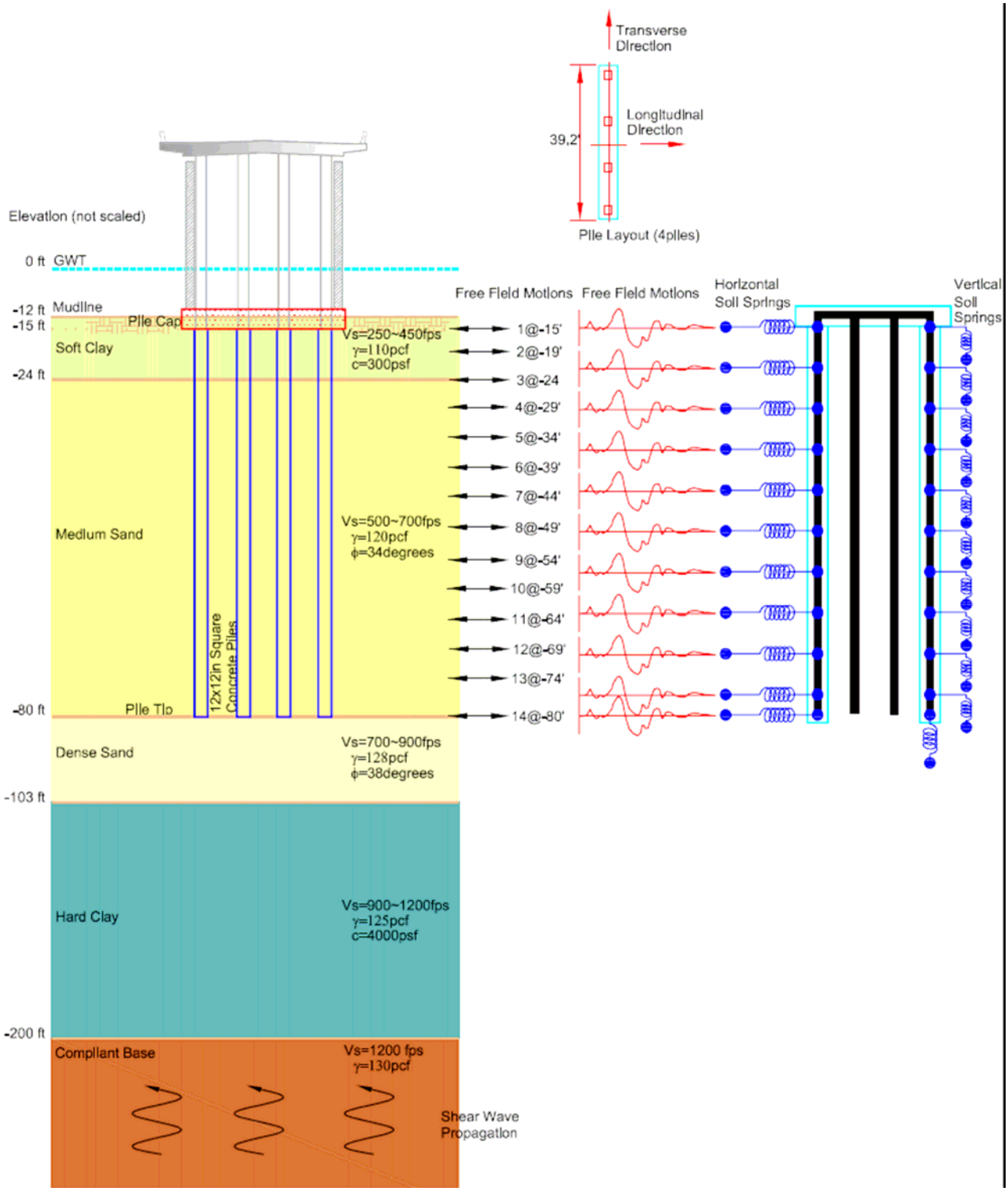
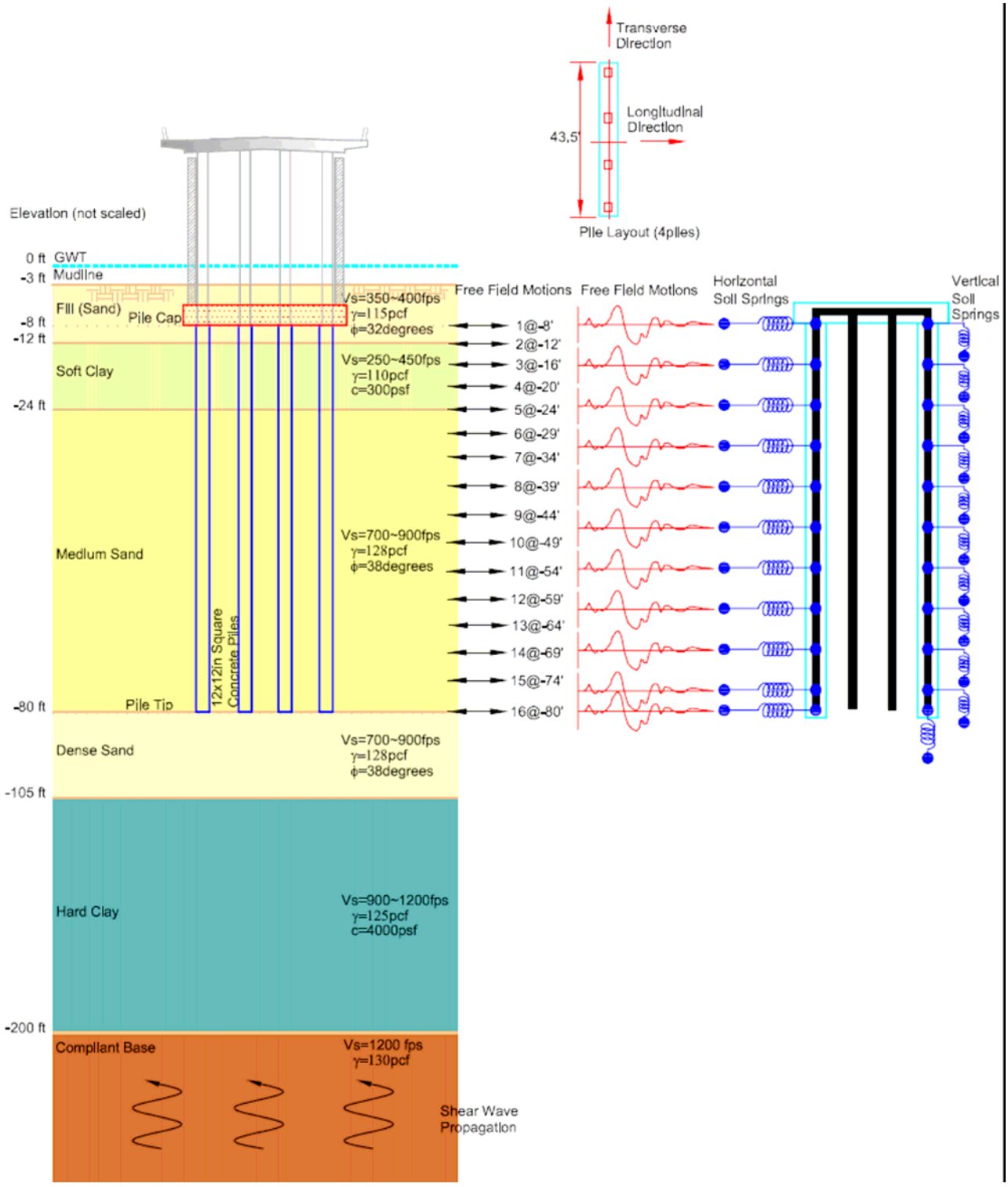


FIGURE A-50: IDEALIZED SOIL CONDITIONS AND FOUNDATION DATA AT ABUTMENT 71



9.0 APPENDIX B: *T-Z* AND *Q-U* CURVES

TABLE B-1: ABUTMENT 1 - *t-z* AND *q-u* CURVES

Node #	Elevation (ft)	Soil Type	t_{max} (lb/in)	z_c (in)	t_1 (lb/in)	z_1 (in)	t_2 (lb/in)	z_2 (in)	t_3 (lb/in)	z_3 (in)	t_4 (lb/in)	z_4 (in)	t_5 (lb/in)	z_5 (in)	t_6 (lb/in)	z_6 (in)	t_7 (lb/in)	z_7 (in)
1	15.0	Sand	99.6	0.20	39.5	0.01	53.0	0.02	69.1	0.04	79.1	0.06	86.1	0.08	94.5	0.12	99.6	0.20
2	10.0	Sand	199.1	0.20	79.0	0.01	105.9	0.02	138.2	0.04	158.3	0.06	172.2	0.08	189.0	0.12	199.1	0.20
3	5.0	Sand	300.4	0.20	119.2	0.01	159.8	0.02	208.5	0.04	238.8	0.06	259.8	0.08	285.1	0.12	300.4	0.20
4	0.0	Sand	386.1	0.20	153.3	0.01	205.4	0.02	267.9	0.04	306.9	0.06	333.9	0.08	366.4	0.12	386.1	0.20
5	-5.0	Sand	446.1	0.20	177.1	0.01	237.3	0.02	309.6	0.04	354.6	0.06	385.9	0.08	423.3	0.12	446.1	0.20
6	-10.0	Sand	497.7	0.20	197.6	0.01	264.8	0.02	345.4	0.04	395.7	0.06	430.5	0.08	472.3	0.12	497.7	0.20
7	-15.0	Sand	549.4	0.20	218.1	0.01	292.3	0.02	381.2	0.04	436.7	0.06	475.2	0.08	521.3	0.12	549.4	0.20
8	-20.0	Sand	601.0	0.20	238.6	0.01	319.7	0.02	417.1	0.04	477.8	0.06	519.9	0.08	570.3	0.12	601.0	0.20
9	-25.0	Sand	652.6	0.20	259.1	0.01	347.2	0.02	452.9	0.04	518.8	0.06	564.5	0.08	619.3	0.12	652.6	0.20
10	-30.0	Sand	704.2	0.20	279.6	0.01	374.7	0.02	488.7	0.04	559.9	0.06	609.2	0.08	668.3	0.12	704.2	0.20

q_{max} (kips)	u_c (in)	q_1 (kips)	u_1 (in)	q_2 (kips)	u_2 (in)	q_3 (kips)	u_3 (in)	q_4 (kips)	u_4 (in)
374.3	1.40	168.4	0.14	235.8	0.35	295.7	0.70	374.3	1.40

TABLE B-2: PIER 2 - *t-z* AND *q-u* CURVES

Node #	Elevation (ft)	Soil Type	t_{max} (lb/in)	z_c (in)	t_1 (lb/in)	z_1 (in)	t_2 (lb/in)	z_2 (in)	t_3 (lb/in)	z_3 (in)	t_4 (lb/in)	z_4 (in)	t_5 (lb/in)	z_5 (in)	t_6 (lb/in)	z_6 (in)	t_7 (lb/in)	z_7 (in)
1	0.5	Sand	292.4	0.20	116.1	0.01	155.5	0.02	202.9	0.04	232.4	0.06	252.9	0.08	277.5	0.12	292.4	0.20
2	-3.0	Sand	357.0	0.20	141.7	0.01	189.9	0.02	247.8	0.04	283.8	0.06	308.8	0.08	338.8	0.12	357.0	0.20
3	-6.0	Sand	417.0	0.20	165.6	0.01	221.9	0.02	289.4	0.04	331.5	0.06	360.7	0.08	395.8	0.12	417.0	0.20
4	-10.0	Sand	403.5	0.22	160.2	0.01	214.6	0.022	280.0	0.044	320.8	0.066	349.0	0.088	382.9	0.132	403.5	0.22
5	-14.0	Clay	360.0	0.24	142.9	0.01	191.5	0.024	249.8	0.048	286.2	0.072	311.4	0.096	341.6	0.144	360.0	0.24
6	-19.0	Clay	515.1	0.22	204.5	0.01	274.0	0.022	357.5	0.044	409.5	0.066	445.6	0.088	488.8	0.132	515.1	0.22
7	-22.0	Sand	701.2	0.20	278.4	0.01	373.0	0.02	486.6	0.04	557.5	0.06	606.6	0.08	665.5	0.12	701.2	0.20
8	-26.0	Sand	767.6	0.20	304.7	0.01	408.4	0.02	532.7	0.04	610.2	0.06	664.0	0.08	728.5	0.12	767.6	0.20
9	-30.0	Sand	581.5	0.22	230.9	0.01	309.4	0.022	403.6	0.044	462.3	0.066	503.0	0.088	551.8	0.132	581.5	0.22
10	-35.0	Clay	661.8	0.22	262.7	0.01	352.1	0.022	459.3	0.044	526.1	0.066	572.4	0.088	628.0	0.132	661.8	0.22
11	-40.0	Sand	1007.8	0.20	400.1	0.01	536.1	0.02	699.4	0.04	801.2	0.06	871.7	0.08	956.4	0.12	1007.8	0.20

q_{max} (kips)	u_c (in)	q_1 (kips)	u_1 (in)	q_2 (kips)	u_2 (in)	q_3 (kips)	u_3 (in)	q_4 (kips)	u_4 (in)
918.1	2.40	413.2	0.24	578.4	0.60	725.3	1.20	918.1	2.40

TABLE B-3: PIER 3 - *t-z* AND *q-u* CURVES

Node #	Elevation (ft)	Soil Type	t_{max} (lb/in)	z_c (in)	t_1 (lb/in)	z_1 (in)	t_2 (lb/in)	z_2 (in)	t_3 (lb/in)	z_3 (in)	t_4 (lb/in)	z_4 (in)	t_5 (lb/in)	z_5 (in)	t_6 (lb/in)	z_6 (in)	t_7 (lb/in)	z_7 (in)
1	-1.0	Clay	360.0	0.24	142.9	0.01	191.5	0.024	249.8	0.048	286.2	0.072	311.4	0.096	341.6	0.144	360.0	0.24
2	-5.0	Clay	360.0	0.24	142.9	0.01	191.5	0.024	249.8	0.048	286.2	0.072	311.4	0.096	341.6	0.144	360.0	0.24
3	-10.0	Clay	360.0	0.24	142.9	0.01	191.5	0.024	249.8	0.048	286.2	0.072	311.4	0.096	341.6	0.144	360.0	0.24
4	-15.0	Clay	360.0	0.24	142.9	0.01	191.5	0.024	249.8	0.048	286.2	0.072	311.4	0.096	341.6	0.144	360.0	0.24
5	-20.0	Clay	360.0	0.24	142.9	0.01	191.5	0.024	249.8	0.048	286.2	0.072	311.4	0.096	341.6	0.144	360.0	0.24
6	-25.0	Clay	514.3	0.22	204.2	0.01	273.6	0.022	356.9	0.044	408.8	0.066	444.8	0.088	488.0	0.132	514.3	0.22
7	-29.0	Sand	700.9	0.20	278.2	0.01	372.9	0.02	486.4	0.04	557.2	0.06	606.2	0.08	665.1	0.12	700.9	0.20
8	-33.0	Sand	769.6	0.20	305.5	0.01	409.4	0.02	534.1	0.04	611.8	0.06	665.7	0.08	730.3	0.12	769.6	0.20
9	-38.0	Sand	886.6	0.20	352.0	0.01	471.7	0.02	615.3	0.04	704.9	0.06	766.9	0.08	841.4	0.12	886.6	0.20
10	-41.0	Sand	1004.5	0.20	398.8	0.01	534.4	0.02	697.1	0.04	798.6	0.06	868.9	0.08	953.3	0.12	1004.5	0.20
11	-45.0	Sand	1084.3	0.20	430.5	0.01	576.8	0.02	752.5	0.04	862.0	0.06	937.9	0.08	1029.0	0.12	1084.3	0.20

q_{max} (kips)	u_c (in)	q_1 (kips)	u_1 (in)	q_2 (kips)	u_2 (in)	q_3 (kips)	u_3 (in)	q_4 (kips)	u_4 (in)
1021.4	2.40	459.6	0.24	643.5	0.60	806.9	1.20	1021.4	2.40

TABLE B-4: PIER 4 - *t-z* AND *q-u* CURVES

Node #	Elevation (ft)	Soil Type	t_{max} (lb/in)	z_c (in)	t_1 (lb/in)	z_1 (in)	t_2 (lb/in)	z_2 (in)	t_3 (lb/in)	z_3 (in)	t_4 (lb/in)	z_4 (in)	t_5 (lb/in)	z_5 (in)	t_6 (lb/in)	z_6 (in)	t_7 (lb/in)	z_7 (in)
1	-2.0	Clay	360.0	0.24	142.9	0.01	191.5	0.024	249.8	0.048	286.2	0.072	311.4	0.096	341.6	0.144	360.0	0.24
2	-7.0	Clay	360.0	0.24	142.9	0.01	191.5	0.024	249.8	0.048	286.2	0.072	311.4	0.096	341.6	0.144	360.0	0.24
3	-12.0	Clay	471.4	0.22	187.2	0.01	250.8	0.022	327.2	0.044	374.8	0.066	407.8	0.088	447.4	0.132	471.4	0.22
4	-16.0	Sand	618.2	0.20	245.4	0.01	328.9	0.02	429.1	0.04	491.5	0.06	534.8	0.08	586.7	0.12	618.2	0.20
5	-20.0	Sand	693.5	0.20	275.3	0.01	368.9	0.02	481.3	0.04	551.3	0.06	599.9	0.08	658.1	0.12	693.5	0.20
6	-25.0	Sand	777.6	0.20	308.7	0.01	413.7	0.02	539.6	0.04	618.2	0.06	672.6	0.08	737.9	0.12	777.6	0.20
7	-30.0	Sand	590.9	0.22	234.6	0.01	314.4	0.022	410.1	0.044	469.8	0.066	511.1	0.088	560.8	0.132	590.9	0.22
8	-33.0	Clay	655.0	0.22	260.0	0.01	348.5	0.022	454.6	0.044	520.7	0.066	566.6	0.088	621.6	0.132	655.0	0.22
9	-37.0	Sand	985.4	0.20	391.2	0.01	524.2	0.02	683.9	0.04	783.4	0.06	852.4	0.08	935.1	0.12	985.4	0.20
10	-41.0	Sand	1056.2	0.20	419.3	0.01	561.9	0.02	733.0	0.04	839.7	0.06	913.6	0.08	1002.3	0.12	1056.2	0.20
11	-45.0	Sand	1195.2	0.20	474.5	0.01	635.8	0.02	829.5	0.04	950.2	0.06	1033.8	0.08	1134.2	0.12	1195.2	0.20
12	-50.0	Sand	1351.9	0.20	536.7	0.01	719.2	0.02	938.2	0.04	1074.8	0.06	1169.4	0.08	1283.0	0.12	1351.9	0.20

q_{max} (kips)	u_c (in)	q_1 (kips)	u_1 (in)	q_2 (kips)	u_2 (in)	q_3 (kips)	u_3 (in)	q_4 (kips)	u_4 (in)
1273.6	2.40	573.1	0.24	802.4	0.60	1006.1	1.20	1273.6	2.40

TABLE B-5: PIER 5 - *t-z* AND *q-u* CURVES

Node #	Elevation (ft)	Soil Type	t_{max} (lb/in)	z_c (in)	t_1 (lb/in)	z_1 (in)	t_2 (lb/in)	z_2 (in)	t_3 (lb/in)	z_3 (in)	t_4 (lb/in)	z_4 (in)	t_5 (lb/in)	z_5 (in)	t_6 (lb/in)	z_6 (in)	t_7 (lb/in)	z_7 (in)
1	-2.0	Clay	360.0	0.24	142.9	0.01	191.5	0.024	249.8	0.048	286.2	0.072	311.4	0.096	341.6	0.144	360.0	0.24
2	-7.0	Clay	360.0	0.24	142.9	0.01	191.5	0.024	249.8	0.048	286.2	0.072	311.4	0.096	341.6	0.144	360.0	0.24
3	-12.0	Clay	360.0	0.24	142.9	0.01	191.5	0.024	249.8	0.048	286.2	0.072	311.4	0.096	341.6	0.144	360.0	0.24
4	-17.0	Clay	494.2	0.22	196.2	0.01	262.9	0.022	342.9	0.044	392.9	0.066	427.4	0.088	469.0	0.132	494.2	0.22
5	-21.0	Sand	663.7	0.20	263.5	0.01	353.1	0.02	460.6	0.04	527.7	0.06	574.1	0.08	629.9	0.12	663.7	0.20
6	-25.0	Sand	739.0	0.20	293.4	0.01	393.1	0.02	512.8	0.04	587.5	0.06	639.2	0.08	701.3	0.12	739.0	0.20
7	-30.0	Sand	569.4	0.22	226.1	0.01	302.9	0.022	395.2	0.044	452.7	0.066	492.5	0.088	540.4	0.132	569.4	0.22
8	-34.0	Clay	641.6	0.22	254.7	0.01	341.3	0.022	445.2	0.044	510.0	0.066	554.9	0.088	608.8	0.132	641.6	0.22
9	-38.0	Sand	962.9	0.20	382.3	0.01	512.3	0.02	668.3	0.04	765.5	0.06	833.0	0.08	913.8	0.12	962.9	0.20
10	-43.0	Sand	1090.6	0.20	433.0	0.01	580.2	0.02	756.9	0.04	867.1	0.06	943.4	0.08	1035.0	0.12	1090.6	0.20
11	-45.0	Sand	1199.8	0.20	476.3	0.01	638.3	0.02	832.6	0.04	953.8	0.06	1037.8	0.08	1138.6	0.12	1199.8	0.20

q_{max} (kips)	u_c (in)	q_1 (kips)	u_1 (in)	q_2 (kips)	u_2 (in)	q_3 (kips)	u_3 (in)	q_4 (kips)	u_4 (in)
1130.2	2.40	508.6	0.24	712.1	0.60	892.9	1.20	1130.2	2.40

TABLE B-6: PIER 6 - *t-z* AND *q-u* CURVES

Node #	Elevation (ft)	Soil Type	t_{max} (lb/in)	z_c (in)	t_1 (lb/in)	z_1 (in)	t_2 (lb/in)	z_2 (in)	t_3 (lb/in)	z_3 (in)	t_4 (lb/in)	z_4 (in)	t_5 (lb/in)	z_5 (in)	t_6 (lb/in)	z_6 (in)	t_7 (lb/in)	z_7 (in)
1	-1.0	Clay	360.0	0.24	142.9	0.01	191.5	0.024	249.8	0.048	286.2	0.072	311.4	0.096	341.6	0.144	360.0	0.24
2	-5.0	Clay	360.0	0.24	142.9	0.01	191.5	0.024	249.8	0.048	286.2	0.072	311.4	0.096	341.6	0.144	360.0	0.24
3	-9.0	Clay	360.0	0.24	142.9	0.01	191.5	0.024	249.8	0.048	286.2	0.072	311.4	0.096	341.6	0.144	360.0	0.24
4	-14.0	Clay	452.2	0.22	179.5	0.01	240.6	0.022	313.9	0.044	359.5	0.066	391.2	0.088	429.2	0.132	452.2	0.22
5	-18.0	Sand	584.3	0.20	232.0	0.01	310.9	0.02	405.5	0.04	464.5	0.06	505.4	0.08	554.5	0.12	584.3	0.20
6	-23.0	Sand	668.4	0.20	265.4	0.01	355.6	0.02	463.9	0.04	531.4	0.06	578.2	0.08	634.3	0.12	668.4	0.20
7	-28.0	Sand	756.9	0.20	300.5	0.01	402.7	0.02	525.3	0.04	601.7	0.06	654.7	0.08	718.3	0.12	756.9	0.20
8	-33.0	Sand	845.4	0.20	335.6	0.01	449.8	0.02	586.7	0.04	672.1	0.06	731.3	0.08	802.3	0.12	845.4	0.20
9	-38.0	Sand	987.5	0.20	392.1	0.01	525.4	0.02	685.3	0.04	785.1	0.06	854.2	0.08	937.2	0.12	987.5	0.20
10	-43.0	Sand	1138.6	0.20	452.0	0.01	605.7	0.02	790.2	0.04	905.1	0.06	984.8	0.08	1080.5	0.12	1138.6	0.20
11	-48.0	Sand	862.5	0.22	342.4	0.01	458.9	0.022	598.6	0.044	685.7	0.066	746.1	0.088	818.5	0.132	862.5	0.22
12	-51.0	Clay	533.3	0.24	211.7	0.01	283.7	0.024	370.1	0.048	424.0	0.072	461.3	0.096	506.1	0.144	533.3	0.24
13	-55.0	Clay	533.3	0.24	211.7	0.01	283.7	0.024	370.1	0.048	424.0	0.072	461.3	0.096	506.1	0.144	533.3	0.24

q_{max} (kips)	u_c (in)	q_1 (kips)	u_1 (in)	q_2 (kips)	u_2 (in)	q_3 (kips)	u_3 (in)	q_4 (kips)	u_4 (in)
976.3	2.40	439.3	0.24	615.1	0.60	771.3	1.20	976.3	2.40

TABLE B-7: PIER 7 - *t-z* AND *q-u* CURVES

Node #	Elevation (ft)	Soil Type	t_{max} (lb/in)	z_c (in)	t_1 (lb/in)	z_1 (in)	t_2 (lb/in)	z_2 (in)	t_3 (lb/in)	z_3 (in)	t_4 (lb/in)	z_4 (in)	t_5 (lb/in)	z_5 (in)	t_6 (lb/in)	z_6 (in)	t_7 (lb/in)	z_7 (in)
1	-6.0	Clay	360.0	0.24	142.9	0.01	191.5	0.024	249.8	0.048	286.2	0.072	311.4	0.096	341.6	0.144	360.0	0.24
2	-10.0	Clay	360.0	0.24	142.9	0.01	191.5	0.024	249.8	0.048	286.2	0.072	311.4	0.096	341.6	0.144	360.0	0.24
3	-14.0	Clay	266.8	0.22	105.9	0.01	141.9	0.022	185.2	0.044	212.1	0.066	230.8	0.088	253.2	0.132	266.8	0.22
4	-19.0	Sand	217.8	0.20	86.5	0.01	115.9	0.02	151.2	0.04	173.2	0.06	188.4	0.08	206.7	0.12	217.8	0.20
5	-24.0	Sand	306.4	0.20	121.6	0.01	163.0	0.02	212.6	0.04	243.6	0.06	265.0	0.08	290.7	0.12	306.4	0.20
6	-29.0	Sand	394.9	0.20	156.8	0.01	210.1	0.02	274.0	0.04	313.9	0.06	341.6	0.08	374.7	0.12	394.9	0.20
7	-34.0	Sand	486.2	0.22	193.0	0.01	258.7	0.022	337.4	0.044	386.6	0.066	420.6	0.088	461.4	0.132	486.2	0.22
8	-38.0	Clay	533.3	0.24	211.7	0.01	283.7	0.024	370.1	0.048	424.0	0.072	461.3	0.096	506.1	0.144	533.3	0.24
9	-43.0	Clay	533.3	0.24	211.7	0.01	283.7	0.024	370.1	0.048	424.0	0.072	461.3	0.096	506.1	0.144	533.3	0.24
10	-48.0	Clay	715.1	0.22	283.9	0.01	380.4	0.022	496.3	0.044	568.5	0.066	618.5	0.088	678.6	0.132	715.1	0.22
11	-51.0	Sand	938.4	0.20	372.5	0.01	499.2	0.02	651.2	0.04	746.0	0.06	811.7	0.08	890.5	0.12	938.4	0.20
12	-55.0	Sand	1027.4	0.20	407.9	0.01	546.6	0.02	713.0	0.04	816.8	0.06	888.7	0.08	975.0	0.12	1027.4	0.20

q_{max} (kips)	u_c (in)	q_1 (kips)	u_1 (in)	q_2 (kips)	u_2 (in)	q_3 (kips)	u_3 (in)	q_4 (kips)	u_4 (in)
1192.1	2.40	536.5	0.24	751.0	0.60	941.8	1.20	1192.1	2.40

TABLE B-8: PIER 8 - *t-z* AND *q-u* CURVES

Node #	Elevation (ft)	Soil Type	t_{max} (lb/in)	z_c (in)	t_1 (lb/in)	z_1 (in)	t_2 (lb/in)	z_2 (in)	t_3 (lb/in)	z_3 (in)	t_4 (lb/in)	z_4 (in)	t_5 (lb/in)	z_5 (in)	t_6 (lb/in)	z_6 (in)	t_7 (lb/in)	z_7 (in)
1	-16.0	Sand	0.0	0.20	0.0	0.01	0.0	0.02	0.0	0.04	0.0	0.06	0.0	0.08	0.0	0.12	0.0	0.20
2	-18.0	Sand	45.6	0.20	18.1	0.01	24.2	0.02	31.6	0.04	36.2	0.06	39.4	0.08	43.2	0.12	45.6	0.20
3	-23.0	Sand	120.8	0.20	48.0	0.01	64.3	0.02	83.9	0.04	96.1	0.06	104.5	0.08	114.7	0.12	120.8	0.20
4	-28.0	Sand	349.2	0.22	138.6	0.01	185.8	0.022	242.4	0.044	277.6	0.066	302.1	0.088	331.4	0.132	349.2	0.22
5	-31.0	Clay	533.3	0.24	211.7	0.01	283.7	0.024	370.1	0.048	424.0	0.072	461.3	0.096	506.1	0.144	533.3	0.24
6	-34.0	Clay	533.3	0.24	211.7	0.01	283.7	0.024	370.1	0.048	424.0	0.072	461.3	0.096	506.1	0.144	533.3	0.24
7	-39.0	Clay	533.3	0.24	211.7	0.01	283.7	0.024	370.1	0.048	424.0	0.072	461.3	0.096	506.1	0.144	533.3	0.24
8	-44.0	Clay	533.3	0.24	211.7	0.01	283.7	0.024	370.1	0.048	424.0	0.072	461.3	0.096	506.1	0.144	533.3	0.24
9	-49.0	Clay	626.7	0.22	248.8	0.01	333.4	0.022	434.9	0.044	498.2	0.066	542.1	0.088	594.7	0.132	626.7	0.22
10	-52.0	Sand	761.6	0.20	302.3	0.01	405.2	0.02	528.5	0.04	605.5	0.06	658.8	0.08	722.7	0.12	761.6	0.20
11	-56.0	Sand	850.6	0.20	337.7	0.01	452.5	0.02	590.3	0.04	676.3	0.06	735.8	0.08	807.2	0.12	850.6	0.20
12	-60.0	Sand	945.6	0.20	375.4	0.01	503.1	0.02	656.3	0.04	751.8	0.06	818.0	0.08	897.4	0.12	945.6	0.20

q_{max} (kips)	u_c (in)	q_1 (kips)	u_1 (in)	q_2 (kips)	u_2 (in)	q_3 (kips)	u_3 (in)	q_4 (kips)	u_4 (in)
940.5	2.40	423.2	0.24	592.5	0.60	743.0	1.20	940.5	2.40

TABLE B-9: PIER 9 - *t-z* AND *q-u* CURVES

Node #	Elevation (ft)	Soil Type	t_{max} (lb/in)	z_c (in)	t_1 (lb/in)	z_1 (in)	t_2 (lb/in)	z_2 (in)	t_3 (lb/in)	z_3 (in)	t_4 (lb/in)	z_4 (in)	t_5 (lb/in)	z_5 (in)	t_6 (lb/in)	z_6 (in)	t_7 (lb/in)	z_7 (in)
1	-18.0	Sand	0.0	0.20	0.0	0.01	0.0	0.02	0.0	0.04	0.0	0.06	0.0	0.08	0.0	0.12	0.0	0.20
2	-23.0	Sand	76.3	0.20	30.3	0.01	40.6	0.02	52.9	0.04	60.6	0.06	66.0	0.08	72.4	0.12	76.3	0.20
3	-27.0	Sand	151.6	0.20	60.2	0.01	80.7	0.02	105.2	0.04	120.6	0.06	131.2	0.08	143.9	0.12	151.6	0.20
4	-31.0	Sand	360.2	0.22	143.0	0.01	191.6	0.022	250.0	0.044	286.4	0.066	311.6	0.088	341.8	0.132	360.2	0.22
5	-36.0	Clay	533.3	0.24	211.7	0.01	283.7	0.024	370.1	0.048	424.0	0.072	461.3	0.096	506.1	0.144	533.3	0.24
6	-41.0	Clay	533.3	0.24	211.7	0.01	283.7	0.024	370.1	0.048	424.0	0.072	461.3	0.096	506.1	0.144	533.3	0.24
7	-46.0	Clay	533.3	0.24	211.7	0.01	283.7	0.024	370.1	0.048	424.0	0.072	461.3	0.096	506.1	0.144	533.3	0.24
8	-51.0	Clay	629.9	0.22	250.1	0.01	335.1	0.022	437.2	0.044	500.8	0.066	544.9	0.088	597.8	0.132	629.9	0.22
9	-55.0	Sand	779.9	0.20	309.6	0.01	414.9	0.02	541.3	0.04	620.0	0.06	674.6	0.08	740.1	0.12	779.9	0.20
10	-60.0	Sand	892.7	0.20	354.4	0.01	474.9	0.02	619.5	0.04	709.7	0.06	772.2	0.08	847.2	0.12	892.7	0.20

q_{max} (kips)	u_c (in)	q_1 (kips)	u_1 (in)	q_2 (kips)	u_2 (in)	q_3 (kips)	u_3 (in)	q_4 (kips)	u_4 (in)
887.8	2.40	399.5	0.24	559.3	0.60	701.4	1.20	887.8	2.40

TABLE B-10: PIER 10 - *t-z* AND *q-u* CURVES

Node #	Elevation (ft)	Soil Type	t_{max} (lb/in)	z_c (in)	t_1 (lb/in)	z_1 (in)	t_2 (lb/in)	z_2 (in)	t_3 (lb/in)	z_3 (in)	t_4 (lb/in)	z_4 (in)	t_5 (lb/in)	z_5 (in)	t_6 (lb/in)	z_6 (in)	t_7 (lb/in)	z_7 (in)
1	-16.0	Sand	0.0	0.20	0.0	0.01	0.0	0.02	0.0	0.04	0.0	0.06	0.0	0.08	0.0	0.12	0.0	0.20
2	-20.0	Sand	58.1	0.20	23.1	0.01	30.9	0.02	40.3	0.04	46.2	0.06	50.3	0.08	55.1	0.12	58.1	0.20
3	-24.0	Sand	116.2	0.20	46.1	0.01	61.8	0.02	80.6	0.04	92.4	0.06	100.5	0.08	110.3	0.12	116.2	0.20
4	-28.0	Sand	191.7	0.20	76.1	0.01	102.0	0.02	133.1	0.04	152.4	0.06	165.9	0.08	182.0	0.12	191.7	0.20
5	-33.0	Sand	282.5	0.20	112.2	0.01	150.3	0.02	196.1	0.04	224.6	0.06	244.4	0.08	268.1	0.12	282.5	0.20
6	-38.0	Sand	371.0	0.20	147.3	0.01	197.4	0.02	257.5	0.04	295.0	0.06	320.9	0.08	352.1	0.12	371.0	0.20
7	-43.0	Sand	474.3	0.22	188.3	0.01	252.3	0.022	329.2	0.044	377.1	0.066	410.3	0.088	450.1	0.132	474.3	0.22
8	-46.0	Clay	533.3	0.24	211.7	0.01	283.7	0.024	370.1	0.048	424.0	0.072	461.3	0.096	506.1	0.144	533.3	0.24
9	-50.0	Clay	634.0	0.22	251.7	0.01	337.3	0.022	440.0	0.044	504.0	0.066	548.4	0.088	601.7	0.132	634.0	0.22
10	-54.0	Sand	782.1	0.20	310.5	0.01	416.1	0.02	542.8	0.04	621.8	0.06	676.6	0.08	742.3	0.12	782.1	0.20
11	-58.0	Sand	883.1	0.20	350.6	0.01	469.8	0.02	612.8	0.04	702.0	0.06	763.8	0.08	838.0	0.12	883.1	0.20
12	-63.0	Sand	995.9	0.20	395.4	0.01	529.8	0.02	691.1	0.04	791.7	0.06	861.4	0.08	945.1	0.12	995.9	0.20

q_{max} (kips)	u_c (in)	q_1 (kips)	u_1 (in)	q_2 (kips)	u_2 (in)	q_3 (kips)	u_3 (in)	q_4 (kips)	u_4 (in)
990.4	2.40	445.7	0.24	624.0	0.60	782.4	1.20	990.4	2.40

TABLE B-11: PIER 11 - *t-z* AND *q-u* CURVES

Node #	Elevation (ft)	Soil Type	t_{max} (lb/in)	z_c (in)	t_1 (lb/in)	z_1 (in)	t_2 (lb/in)	z_2 (in)	t_3 (lb/in)	z_3 (in)	t_4 (lb/in)	z_4 (in)	t_5 (lb/in)	z_5 (in)	t_6 (lb/in)	z_6 (in)	t_7 (lb/in)	z_7 (in)
1	-19.0	Sand	0.0	0.20	0.0	0.01	0.0	0.02	0.0	0.04	0.0	0.06	0.0	0.08	0.0	0.12	0.0	0.20
2	-23.0	Sand	58.1	0.20	23.1	0.01	30.9	0.02	40.3	0.04	46.2	0.06	50.3	0.08	55.1	0.12	58.1	0.20
3	-27.0	Sand	116.2	0.20	46.1	0.01	61.8	0.02	80.6	0.04	92.4	0.06	100.5	0.08	110.3	0.12	116.2	0.20
4	-31.0	Sand	187.3	0.20	74.4	0.01	99.7	0.02	130.0	0.04	148.9	0.06	162.0	0.08	177.8	0.12	187.3	0.20
5	-35.0	Sand	269.2	0.20	106.9	0.01	143.2	0.02	186.8	0.04	214.0	0.06	232.9	0.08	255.5	0.12	269.2	0.20
6	-40.0	Sand	421.2	0.22	167.2	0.01	224.1	0.022	292.3	0.044	334.9	0.066	364.3	0.088	399.7	0.132	421.2	0.22
7	-43.0	Clay	533.3	0.24	211.7	0.01	283.7	0.024	370.1	0.048	424.0	0.072	461.3	0.096	506.1	0.144	533.3	0.24
8	-46.0	Clay	555.1	0.22	220.4	0.01	295.3	0.022	385.2	0.044	441.3	0.066	480.1	0.088	526.8	0.132	555.1	0.22
9	-49.0	Sand	618.4	0.20	245.5	0.01	329.0	0.02	429.2	0.04	491.6	0.06	534.9	0.08	586.9	0.12	618.4	0.20
10	-53.0	Sand	713.4	0.20	283.2	0.01	379.5	0.02	495.1	0.04	567.1	0.06	617.1	0.08	677.0	0.12	713.4	0.20
11	-58.0	Sand	826.2	0.20	328.0	0.01	439.5	0.02	573.4	0.04	656.8	0.06	714.6	0.08	784.0	0.12	826.2	0.20
12	-63.0	Sand	944.9	0.20	375.1	0.01	502.7	0.02	655.8	0.04	751.2	0.06	817.3	0.08	896.7	0.12	944.9	0.20

q_{max} (kips)	u_c (in)	q_1 (kips)	u_1 (in)	q_2 (kips)	u_2 (in)	q_3 (kips)	u_3 (in)	q_4 (kips)	u_4 (in)
939.7	2.40	422.9	0.24	592.0	0.60	742.4	1.20	939.7	2.40

TABLE B-12: PIER 12 - *t-z* AND *q-u* CURVES

Node #	Elevation (ft)	Soil Type	t_{max} (lb/in)	z_c (in)	t_1 (lb/in)	z_1 (in)	t_2 (lb/in)	z_2 (in)	t_3 (lb/in)	z_3 (in)	t_4 (lb/in)	z_4 (in)	t_5 (lb/in)	z_5 (in)	t_6 (lb/in)	z_6 (in)	t_7 (lb/in)	z_7 (in)
1	-19.0	Sand	0.0	0.20	0.0	0.01	0.0	0.02	0.0	0.04	0.0	0.06	0.0	0.08	0.0	0.12	0.0	0.20
2	-23.0	Sand	58.1	0.20	23.1	0.01	30.9	0.02	40.3	0.04	46.2	0.06	50.3	0.08	55.1	0.12	58.1	0.20
3	-27.0	Sand	119.8	0.20	47.6	0.01	63.8	0.02	83.2	0.04	95.3	0.06	103.7	0.08	113.7	0.12	119.8	0.20
4	-32.0	Sand	190.6	0.20	75.7	0.01	101.4	0.02	132.2	0.04	151.5	0.06	164.8	0.08	180.8	0.12	190.6	0.20
5	-35.0	Sand	258.5	0.20	102.6	0.01	137.5	0.02	179.4	0.04	205.5	0.06	223.6	0.08	245.3	0.12	258.5	0.20
6	-39.0	Sand	444.2	0.22	176.4	0.01	236.3	0.022	308.3	0.044	353.2	0.066	384.3	0.088	421.6	0.132	444.2	0.22
7	-44.0	Clay	568.1	0.22	225.5	0.01	302.2	0.022	394.2	0.044	451.6	0.066	491.4	0.088	539.1	0.132	568.1	0.22
8	-48.0	Sand	583.6	0.20	231.7	0.01	310.5	0.02	405.0	0.04	464.0	0.06	504.8	0.08	553.9	0.12	583.6	0.20
9	-52.0	Sand	678.6	0.20	269.4	0.01	361.0	0.02	471.0	0.04	539.5	0.06	587.0	0.08	644.0	0.12	678.6	0.20
10	-56.0	Sand	773.6	0.20	307.1	0.01	411.6	0.02	536.9	0.04	615.0	0.06	669.2	0.08	734.1	0.12	773.6	0.20
11	-60.0	Sand	868.6	0.20	344.8	0.01	462.1	0.02	602.8	0.04	690.5	0.06	751.3	0.08	824.3	0.12	868.6	0.20

q_{max} (kips)	u_c (in)	q_1 (kips)	u_1 (in)	q_2 (kips)	u_2 (in)	q_3 (kips)	u_3 (in)	q_4 (kips)	u_4 (in)
863.9	2.40	388.7	0.24	544.2	0.60	682.4	1.20	863.9	2.40

TABLE B-13: PIER 13 - *t-z* AND *q-u* CURVES

Node #	Elevation (ft)	Soil Type	t_{max} (lb/in)	z_c (in)	t_1 (lb/in)	z_1 (in)	t_2 (lb/in)	z_2 (in)	t_3 (lb/in)	z_3 (in)	t_4 (lb/in)	z_4 (in)	t_5 (lb/in)	z_5 (in)	t_6 (lb/in)	z_6 (in)	t_7 (lb/in)	z_7 (in)
1	-22.0	Sand	0.0	0.20	0.0	0.01	0.0	0.02	0.0	0.04	0.0	0.06	0.0	0.08	0.0	0.12	0.0	0.20
2	-27.0	Sand	72.6	0.20	28.8	0.01	38.6	0.02	50.4	0.04	57.7	0.06	62.8	0.08	68.9	0.12	72.6	0.20
3	-32.0	Sand	145.3	0.20	57.7	0.01	77.3	0.02	100.8	0.04	115.5	0.06	125.6	0.08	137.8	0.12	145.3	0.20
4	-37.0	Sand	225.3	0.20	89.4	0.01	119.9	0.02	156.4	0.04	179.1	0.06	194.9	0.08	213.8	0.12	225.3	0.20
5	-40.0	Sand	300.0	0.20	119.1	0.01	159.6	0.02	208.2	0.04	238.5	0.06	259.5	0.08	284.7	0.12	300.0	0.20
6	-44.0	Sand	366.4	0.20	145.5	0.01	194.9	0.02	254.3	0.04	291.3	0.06	316.9	0.08	347.7	0.12	366.4	0.20
7	-48.0	Sand	467.6	0.22	185.6	0.01	248.7	0.022	324.5	0.044	371.7	0.066	404.5	0.088	443.7	0.132	467.6	0.22
8	-51.0	Clay	533.3	0.24	211.7	0.01	283.7	0.024	370.1	0.048	424.0	0.072	461.3	0.096	506.1	0.144	533.3	0.24
9	-54.0	Clay	610.4	0.22	242.3	0.01	324.7	0.022	423.6	0.044	485.3	0.066	528.0	0.088	579.3	0.132	610.4	0.22
10	-58.0	Sand	735.0	0.20	291.8	0.01	391.0	0.02	510.1	0.04	584.3	0.06	635.8	0.08	697.5	0.12	735.0	0.20
11	-62.0	Sand	830.0	0.20	329.5	0.01	441.6	0.02	576.0	0.04	659.8	0.06	717.9	0.08	787.7	0.12	830.0	0.20
12	-66.0	Sand	925.0	0.20	367.2	0.01	492.1	0.02	641.9	0.04	735.4	0.06	800.1	0.08	877.8	0.12	925.0	0.20

q_{max} (kips)	u_c (in)	q_1 (kips)	u_1 (in)	q_2 (kips)	u_2 (in)	q_3 (kips)	u_3 (in)	q_4 (kips)	u_4 (in)
919.9	2.40	414.0	0.24	579.6	0.60	726.8	1.20	919.9	2.40

TABLE B-14: PIER 14 - *t-z* AND *q-u* CURVES

Node #	Elevation (ft)	Soil Type	t_{max} (lb/in)	z_c (in)	t_1 (lb/in)	z_1 (in)	t_2 (lb/in)	z_2 (in)	t_3 (lb/in)	z_3 (in)	t_4 (lb/in)	z_4 (in)	t_5 (lb/in)	z_5 (in)	t_6 (lb/in)	z_6 (in)	t_7 (lb/in)	z_7 (in)
1	-20.0	Sand	0.0	0.20	0.0	0.01	0.0	0.02	0.0	0.04	0.0	0.06	0.0	0.08	0.0	0.12	0.0	0.20
2	-24.0	Sand	58.1	0.20	23.1	0.01	30.9	0.02	40.3	0.04	46.2	0.06	50.3	0.08	55.1	0.12	58.1	0.20
3	-28.0	Sand	116.2	0.20	46.1	0.01	61.8	0.02	80.6	0.04	92.4	0.06	100.5	0.08	110.3	0.12	116.2	0.20
4	-32.0	Sand	187.3	0.20	74.4	0.01	99.7	0.02	130.0	0.04	148.9	0.06	162.0	0.08	177.8	0.12	187.3	0.20
5	-36.0	Sand	269.2	0.20	106.9	0.01	143.2	0.02	186.8	0.04	214.0	0.06	232.9	0.08	255.5	0.12	269.2	0.20
6	-41.0	Sand	421.2	0.22	167.2	0.01	224.1	0.022	292.3	0.044	334.9	0.066	364.3	0.088	399.7	0.132	421.2	0.22
7	-45.0	Clay	546.1	0.22	216.8	0.01	290.5	0.022	379.0	0.044	434.2	0.066	472.4	0.088	518.3	0.132	546.1	0.22
8	-50.0	Sand	618.2	0.20	245.4	0.01	328.9	0.02	429.1	0.04	491.5	0.06	534.8	0.08	586.7	0.12	618.2	0.20
9	-55.0	Sand	737.0	0.20	292.6	0.01	392.1	0.02	511.5	0.04	585.9	0.06	637.5	0.08	699.4	0.12	737.0	0.20
10	-60.0	Sand	855.7	0.20	339.7	0.01	455.2	0.02	593.9	0.04	680.3	0.06	740.2	0.08	812.1	0.12	855.7	0.20

q_{max} (kips)	u_c (in)	q_1 (kips)	u_1 (in)	q_2 (kips)	u_2 (in)	q_3 (kips)	u_3 (in)	q_4 (kips)	u_4 (in)
851.0	2.40	383.0	0.24	536.2	0.60	672.3	1.20	851.0	2.40

TABLE B-15: PIER 15 - *t-z* AND *q-u* CURVES

Node #	Elevation (ft)	Soil Type	t_{max} (lb/in)	z_c (in)	t_1 (lb/in)	z_1 (in)	t_2 (lb/in)	z_2 (in)	t_3 (lb/in)	z_3 (in)	t_4 (lb/in)	z_4 (in)	t_5 (lb/in)	z_5 (in)	t_6 (lb/in)	z_6 (in)	t_7 (lb/in)	z_7 (in)
1	-24.0	Sand	0.0	0.20	0.0	0.01	0.0	0.02	0.0	0.04	0.0	0.06	0.0	0.08	0.0	0.12	0.0	0.20
2	-27.0	Sand	47.2	0.20	18.7	0.01	25.1	0.02	32.8	0.04	37.5	0.06	40.8	0.08	44.8	0.12	47.2	0.20
3	-31.0	Sand	110.6	0.20	43.9	0.01	58.8	0.02	76.8	0.04	87.9	0.06	95.7	0.08	105.0	0.12	110.6	0.20
4	-35.0	Sand	188.4	0.20	74.8	0.01	100.2	0.02	130.7	0.04	149.8	0.06	163.0	0.08	178.8	0.12	188.4	0.20
5	-40.0	Sand	380.8	0.22	151.2	0.01	202.6	0.022	264.3	0.044	302.7	0.066	329.4	0.088	361.4	0.132	380.8	0.22
6	-45.0	Clay	508.9	0.22	202.0	0.01	270.8	0.022	353.2	0.044	404.6	0.066	440.2	0.088	483.0	0.132	508.9	0.22
7	-50.0	Sand	543.9	0.20	215.9	0.01	289.4	0.02	377.5	0.04	432.4	0.06	470.5	0.08	516.2	0.12	543.9	0.20
8	-55.0	Sand	662.6	0.20	263.1	0.01	352.5	0.02	459.9	0.04	526.8	0.06	573.2	0.08	628.8	0.12	662.6	0.20
9	-60.0	Sand	781.3	0.20	310.2	0.01	415.7	0.02	542.3	0.04	621.2	0.06	675.9	0.08	741.5	0.12	781.3	0.20
10	-65.0	Sand	900.1	0.20	357.3	0.01	478.8	0.02	624.7	0.04	715.6	0.06	778.6	0.08	854.2	0.12	900.1	0.20

q_{max} (kips)	u_c (in)	q_1 (kips)	u_1 (in)	q_2 (kips)	u_2 (in)	q_3 (kips)	u_3 (in)	q_4 (kips)	u_4 (in)
895.2	2.40	402.8	0.24	564.0	0.60	707.2	1.20	895.2	2.40

TABLE B-16: PIER 16 - *t-z* AND *q-u* CURVES

Node #	Elevation (ft)	Soil Type	t_{max} (lb/in)	z_c (in)	t_1 (lb/in)	z_1 (in)	t_2 (lb/in)	z_2 (in)	t_3 (lb/in)	z_3 (in)	t_4 (lb/in)	z_4 (in)	t_5 (lb/in)	z_5 (in)	t_6 (lb/in)	z_6 (in)	t_7 (lb/in)	z_7 (in)
1	-26.0	Sand	0.0	0.20	0.0	0.01	0.0	0.02	0.0	0.04	0.0	0.06	0.0	0.08	0.0	0.12	0.0	0.20
2	-30.0	Sand	58.1	0.20	23.1	0.01	30.9	0.02	40.3	0.04	46.2	0.06	50.3	0.08	55.1	0.12	58.1	0.20
3	-34.0	Sand	125.9	0.20	50.0	0.01	67.0	0.02	87.4	0.04	100.1	0.06	108.9	0.08	119.5	0.12	125.9	0.20
4	-38.0	Sand	200.1	0.20	79.5	0.01	106.5	0.02	138.9	0.04	159.1	0.06	173.1	0.08	189.9	0.12	200.1	0.20
5	-42.0	Sand	384.4	0.22	152.6	0.01	204.5	0.022	266.8	0.044	305.6	0.066	332.5	0.088	364.8	0.132	384.4	0.22
6	-46.0	Clay	491.7	0.22	195.2	0.01	261.6	0.022	341.2	0.044	390.9	0.066	425.3	0.088	466.6	0.132	491.7	0.22
7	-50.0	Sand	503.4	0.20	199.9	0.01	267.8	0.02	349.4	0.04	400.2	0.06	435.5	0.08	477.8	0.12	503.4	0.20
8	-55.0	Sand	616.2	0.20	244.6	0.01	327.8	0.02	427.7	0.04	489.9	0.06	533.0	0.08	584.8	0.12	616.2	0.20
9	-60.0	Sand	734.9	0.20	291.8	0.01	391.0	0.02	510.1	0.04	584.3	0.06	635.7	0.08	697.5	0.12	734.9	0.20
10	-65.0	Sand	853.7	0.20	338.9	0.01	454.2	0.02	592.4	0.04	678.7	0.06	738.4	0.08	810.1	0.12	853.7	0.20
11	-70.0	Sand	972.4	0.20	386.0	0.01	517.3	0.02	674.8	0.04	773.1	0.06	841.1	0.08	922.8	0.12	972.4	0.20

q_{max} (kips)	u_c (in)	q_1 (kips)	u_1 (in)	q_2 (kips)	u_2 (in)	q_3 (kips)	u_3 (in)	q_4 (kips)	u_4 (in)
1128.3	2.40	507.7	0.24	710.8	0.60	891.3	1.20	1128.3	2.40

TABLE B-17: PIER 17 - *t-z* AND *q-u* CURVES

Node #	Elevation (ft)	Soil Type	t_{max} (lb/in)	z_c (in)	t_1 (lb/in)	z_1 (in)	t_2 (lb/in)	z_2 (in)	t_3 (lb/in)	z_3 (in)	t_4 (lb/in)	z_4 (in)	t_5 (lb/in)	z_5 (in)	t_6 (lb/in)	z_6 (in)	t_7 (lb/in)	z_7 (in)
1	-34.0	Sand	0.0	0.20	0.0	0.01	0.0	0.02	0.0	0.04	0.0	0.06	0.0	0.08	0.0	0.12	0.0	0.20
2	-37.0	Sand	104.0	0.20	41.3	0.01	55.4	0.02	72.2	0.04	82.7	0.06	90.0	0.08	98.7	0.12	104.0	0.20
3	-42.0	Sand	250.5	0.20	99.5	0.01	133.3	0.02	173.9	0.04	199.2	0.06	216.7	0.08	237.7	0.12	250.5	0.20
4	-47.0	Sand	412.3	0.20	163.7	0.01	219.4	0.02	286.2	0.04	327.8	0.06	356.7	0.08	391.3	0.12	412.3	0.20
5	-52.0	Sand	574.2	0.20	227.9	0.01	305.5	0.02	398.5	0.04	456.5	0.06	496.7	0.08	544.9	0.12	574.2	0.20
6	-57.0	Sand	736.0	0.20	292.2	0.01	391.6	0.02	510.8	0.04	585.1	0.06	636.6	0.08	698.5	0.12	736.0	0.20
7	-62.0	Sand	897.8	0.20	356.4	0.01	477.7	0.02	623.1	0.04	713.8	0.06	776.6	0.08	852.1	0.12	897.8	0.20
8	-67.0	Sand	1059.7	0.20	420.7	0.01	563.7	0.02	735.4	0.04	842.4	0.06	916.6	0.08	1005.6	0.12	1059.7	0.20
9	-72.0	Sand	1318.0	0.20	523.2	0.01	701.2	0.02	914.7	0.04	1047.8	0.06	1140.1	0.08	1250.8	0.12	1318.0	0.20
10	-77.0	Sand	1600.3	0.20	635.3	0.01	851.4	0.02	1110.6	0.04	1272.2	0.06	1384.2	0.08	1518.7	0.12	1600.3	0.20
11	-82.0	Sand	1810.1	0.20	718.6	0.01	963.0	0.02	1256.2	0.04	1439.0	0.06	1565.7	0.08	1717.8	0.12	1810.1	0.20
12	-87.0	Sand	2019.9	0.20	801.9	0.01	1074.6	0.02	1401.8	0.04	1605.8	0.06	1747.2	0.08	1916.9	0.12	2019.9	0.20
13	-92.0	Sand	2229.7	0.20	885.2	0.01	1186.2	0.02	1547.4	0.04	1772.6	0.06	1928.7	0.08	2116.0	0.12	2229.7	0.20

q_{max} (kips)	u_c (in)	q_1 (kips)	u_1 (in)	q_2 (kips)	u_2 (in)	q_3 (kips)	u_3 (in)	q_4 (kips)	u_4 (in)
2251.8	5.40	1013.3	0.54	1418.6	1.35	1778.9	2.70	2251.8	5.40

TABLE B-18: PIER 18 - *t-z* AND *q-u* CURVES

Node #	Elevation (ft)	Soil Type	t_{max} (lb/in)	z_c (in)	t_1 (lb/in)	z_1 (in)	t_2 (lb/in)	z_2 (in)	t_3 (lb/in)	z_3 (in)	t_4 (lb/in)	z_4 (in)	t_5 (lb/in)	z_5 (in)	t_6 (lb/in)	z_6 (in)	t_7 (lb/in)	z_7 (in)
1	-34.0	Sand	0.0	0.20	0.0	0.01	0.0	0.02	0.0	0.04	0.0	0.06	0.0	0.08	0.0	0.12	0.0	0.20
2	-37.0	Sand	77.0	0.20	30.6	0.01	41.0	0.02	53.4	0.04	61.2	0.06	66.6	0.08	73.1	0.12	77.0	0.20
3	-40.0	Sand	166.8	0.20	66.2	0.01	88.8	0.02	115.8	0.04	132.6	0.06	144.3	0.08	158.3	0.12	166.8	0.20
4	-45.0	Sand	282.3	0.20	112.1	0.01	150.2	0.02	195.9	0.04	224.5	0.06	244.2	0.08	267.9	0.12	282.3	0.20
5	-50.0	Sand	410.7	0.20	163.0	0.01	218.5	0.02	285.0	0.04	326.5	0.06	355.2	0.08	389.7	0.12	410.7	0.20
6	-55.0	Sand	539.0	0.20	214.0	0.01	286.8	0.02	374.1	0.04	428.5	0.06	466.3	0.08	511.5	0.12	539.0	0.20
7	-60.0	Sand	710.1	0.20	281.9	0.01	377.8	0.02	492.8	0.04	564.5	0.06	614.3	0.08	673.9	0.12	710.1	0.20
8	-63.0	Sand	865.6	0.20	343.6	0.01	460.5	0.02	600.7	0.04	688.1	0.06	748.7	0.08	821.4	0.12	865.6	0.20
9	-66.0	Sand	978.9	0.20	388.6	0.01	520.8	0.02	679.3	0.04	778.2	0.06	846.7	0.08	928.9	0.12	978.9	0.20
10	-71.0	Sand	1124.5	0.20	446.4	0.01	598.2	0.02	780.4	0.04	894.0	0.06	972.7	0.08	1067.2	0.12	1124.5	0.20
11	-76.0	Sand	1286.4	0.20	510.7	0.01	684.3	0.02	892.7	0.04	1022.7	0.06	1112.7	0.08	1220.8	0.12	1286.4	0.20
12	-81.0	Sand	1448.2	0.20	574.9	0.01	770.4	0.02	1005.0	0.04	1151.3	0.06	1252.7	0.08	1374.3	0.12	1448.2	0.20
13	-86.0	Sand	1712.4	0.20	679.8	0.01	911.0	0.02	1188.4	0.04	1361.4	0.06	1481.2	0.08	1625.1	0.12	1712.4	0.20
14	-89.0	Sand	1958.6	0.20	777.6	0.01	1042.0	0.02	1359.3	0.04	1557.1	0.06	1694.2	0.08	1858.7	0.12	1958.6	0.20
15	-92.0	Sand	2084.5	0.20	827.5	0.01	1109.0	0.02	1446.6	0.04	1657.2	0.06	1803.1	0.08	1978.2	0.12	2084.5	0.20

q_{max} (kips)	u_c (in)	q_1 (kips)	u_1 (in)	q_2 (kips)	u_2 (in)	q_3 (kips)	u_3 (in)	q_4 (kips)	u_4 (in)
2105.2	5.40	947.3	0.54	1326.2	1.35	1663.1	2.70	2105.2	5.40

TABLE B-19: PIER 19 - *t-z* AND *q-u* CURVES

Node #	Elevation (ft)	Soil Type	t_{max} (lb/in)	z_c (in)	t_1 (lb/in)	z_1 (in)	t_2 (lb/in)	z_2 (in)	t_3 (lb/in)	z_3 (in)	t_4 (lb/in)	z_4 (in)	t_5 (lb/in)	z_5 (in)	t_6 (lb/in)	z_6 (in)	t_7 (lb/in)	z_7 (in)
1	-40.0	Sand	0.0	0.20	0.0	0.01	0.0	0.02	0.0	0.04	0.0	0.06	0.0	0.08	0.0	0.12	0.0	0.20
2	-44.0	Sand	92.9	0.20	36.9	0.01	49.4	0.02	64.5	0.04	73.9	0.06	80.4	0.08	88.2	0.12	92.9	0.20
3	-48.0	Sand	191.6	0.20	76.1	0.01	101.9	0.02	133.0	0.04	152.3	0.06	165.8	0.08	181.9	0.12	191.6	0.20
4	-53.0	Sand	302.0	0.20	119.9	0.01	160.6	0.02	209.6	0.04	240.1	0.06	261.2	0.08	286.6	0.12	302.0	0.20
5	-58.0	Sand	445.0	0.20	176.7	0.01	236.8	0.02	308.8	0.04	353.8	0.06	384.9	0.08	422.3	0.12	445.0	0.20
6	-61.0	Sand	586.6	0.20	232.9	0.01	312.1	0.02	407.1	0.04	466.4	0.06	507.5	0.08	556.7	0.12	586.6	0.20
7	-65.0	Sand	716.1	0.20	284.3	0.01	381.0	0.02	497.0	0.04	569.3	0.06	619.4	0.08	679.6	0.12	716.1	0.20
8	-70.0	Sand	869.9	0.20	345.3	0.01	462.8	0.02	603.7	0.04	691.5	0.06	752.4	0.08	825.5	0.12	869.9	0.20
9	-75.0	Sand	1094.1	0.20	434.3	0.01	582.0	0.02	759.3	0.04	869.8	0.06	946.4	0.08	1038.3	0.12	1094.1	0.20
10	-78.0	Sand	1321.3	0.20	524.5	0.01	702.9	0.02	917.0	0.04	1050.4	0.06	1142.9	0.08	1253.9	0.12	1321.3	0.20
11	-83.0	Sand	1510.1	0.20	599.5	0.01	803.4	0.02	1048.0	0.04	1200.5	0.06	1306.2	0.08	1433.1	0.12	1510.1	0.20
12	-88.0	Sand	1719.9	0.20	682.8	0.01	915.0	0.02	1193.6	0.04	1367.3	0.06	1487.7	0.08	1632.2	0.12	1719.9	0.20
13	-93.0	Sand	1929.7	0.20	766.1	0.01	1026.6	0.02	1339.2	0.04	1534.1	0.06	1669.2	0.08	1831.3	0.12	1929.7	0.20
14	-98.0	Sand	2139.5	0.20	849.4	0.01	1138.2	0.02	1484.8	0.04	1700.9	0.06	1850.7	0.08	2030.4	0.12	2139.5	0.20

q_{max} (kips)	u_c (in)	q_1 (kips)	u_1 (in)	q_2 (kips)	u_2 (in)	q_3 (kips)	u_3 (in)	q_4 (kips)	u_4 (in)
2160.7	5.40	972.3	0.54	1361.2	1.35	1707.0	2.70	2160.7	5.40

TABLE B-20: PIER 20 - *t-z* AND *q-u* CURVES

Node #	Elevation (ft)	Soil Type	t_{max} (lb/in)	z_c (in)	t_1 (lb/in)	z_1 (in)	t_2 (lb/in)	z_2 (in)	t_3 (lb/in)	z_3 (in)	t_4 (lb/in)	z_4 (in)	t_5 (lb/in)	z_5 (in)	t_6 (lb/in)	z_6 (in)	t_7 (lb/in)	z_7 (in)
1	-44.0	Clay	353.4	0.54	140.3	0.03	188.0	0.054	245.3	0.108	281.0	0.162	305.7	0.216	335.4	0.324	353.4	0.54
2	-49.0	Clay	353.4	0.54	140.3	0.03	188.0	0.054	245.3	0.108	281.0	0.162	305.7	0.216	335.4	0.324	353.4	0.54
3	-54.0	Clay	353.4	0.54	140.3	0.03	188.0	0.054	245.3	0.108	281.0	0.162	305.7	0.216	335.4	0.324	353.4	0.54
4	-59.0	Clay	353.4	0.54	140.3	0.03	188.0	0.054	245.3	0.108	281.0	0.162	305.7	0.216	335.4	0.324	353.4	0.54
5	-64.0	Clay	353.4	0.54	140.3	0.03	188.0	0.054	245.3	0.108	281.0	0.162	305.7	0.216	335.4	0.324	353.4	0.54
6	-69.0	Clay	543.4	0.37	215.7	0.02	289.1	0.037	377.1	0.074	432.0	0.111	470.1	0.148	515.7	0.222	543.4	0.37
7	-73.0	Sand	806.2	0.20	320.1	0.01	428.9	0.02	559.5	0.04	641.0	0.06	697.4	0.08	765.1	0.12	806.2	0.20
8	-78.0	Sand	960.0	0.20	381.1	0.01	510.7	0.02	666.2	0.04	763.2	0.06	830.4	0.08	911.0	0.12	960.0	0.20
9	-83.0	Sand	1190.4	0.20	472.6	0.01	633.3	0.02	826.2	0.04	946.4	0.06	1029.7	0.08	1129.7	0.12	1190.4	0.20
10	-86.0	Sand	1413.4	0.20	561.1	0.01	751.9	0.02	980.9	0.04	1123.6	0.06	1222.6	0.08	1341.3	0.12	1413.4	0.20
11	-90.0	Sand	1581.2	0.20	627.7	0.01	841.2	0.02	1097.4	0.04	1257.1	0.06	1367.8	0.08	1500.6	0.12	1581.2	0.20
12	-95.0	Sand	1780.5	0.20	706.9	0.01	947.2	0.02	1235.7	0.04	1415.5	0.06	1540.2	0.08	1689.7	0.12	1780.5	0.20
13	-100.0	Sand	1990.3	0.20	790.2	0.01	1058.9	0.02	1381.3	0.04	1582.3	0.06	1721.7	0.08	1888.8	0.12	1990.3	0.20

q_{max} (kips)	u_c (in)	q_1 (kips)	u_1 (in)	q_2 (kips)	u_2 (in)	q_3 (kips)	u_3 (in)	q_4 (kips)	u_4 (in)
2010.1	5.40	904.5	0.54	1266.3	1.35	1587.9	2.70	2010.1	5.40

TABLE B-21: PIER 21 - *t-z* AND *q-u* CURVES

Node #	Elevation (ft)	Soil Type	t_{max} (lb/in)	z_c (in)	t_1 (lb/in)	z_1 (in)	t_2 (lb/in)	z_2 (in)	t_3 (lb/in)	z_3 (in)	t_4 (lb/in)	z_4 (in)	t_5 (lb/in)	z_5 (in)	t_6 (lb/in)	z_6 (in)	t_7 (lb/in)	z_7 (in)
1	-20.0	Clay	353.4	0.54	140.3	0.03	188.0	0.054	245.3	0.108	281.0	0.162	305.7	0.216	335.4	0.324	353.4	0.54
2	-25.0	Clay	353.4	0.54	140.3	0.03	188.0	0.054	245.3	0.108	281.0	0.162	305.7	0.216	335.4	0.324	353.4	0.54
3	-30.0	Clay	353.4	0.54	140.3	0.03	188.0	0.054	245.3	0.108	281.0	0.162	305.7	0.216	335.4	0.324	353.4	0.54
4	-35.0	Clay	353.4	0.54	140.3	0.03	188.0	0.054	245.3	0.108	281.0	0.162	305.7	0.216	335.4	0.324	353.4	0.54
5	-40.0	Clay	353.4	0.54	140.3	0.03	188.0	0.054	245.3	0.108	281.0	0.162	305.7	0.216	335.4	0.324	353.4	0.54
6	-45.0	Clay	353.4	0.54	140.3	0.03	188.0	0.054	245.3	0.108	281.0	0.162	305.7	0.216	335.4	0.324	353.4	0.54
7	-50.0	Clay	353.4	0.54	140.3	0.03	188.0	0.054	245.3	0.108	281.0	0.162	305.7	0.216	335.4	0.324	353.4	0.54
8	-55.0	Clay	353.4	0.54	140.3	0.03	188.0	0.054	245.3	0.108	281.0	0.162	305.7	0.216	335.4	0.324	353.4	0.54
9	-60.0	Clay	353.4	0.54	140.3	0.03	188.0	0.054	245.3	0.108	281.0	0.162	305.7	0.216	335.4	0.324	353.4	0.54
10	-65.0	Clay	353.4	0.54	140.3	0.03	188.0	0.054	245.3	0.108	281.0	0.162	305.7	0.216	335.4	0.324	353.4	0.54
11	-70.0	Clay	353.4	0.54	140.3	0.03	188.0	0.054	245.3	0.108	281.0	0.162	305.7	0.216	335.4	0.324	353.4	0.54
12	-75.0	Clay	1045.5	0.37	415.1	0.02	556.2	0.037	725.6	0.074	831.2	0.111	904.4	0.148	992.2	0.222	1045.5	0.37
13	-78.0	Sand	1821.5	0.20	723.1	0.01	969.0	0.02	1264.1	0.04	1448.1	0.06	1575.6	0.08	1728.6	0.12	1821.5	0.20
14	-83.0	Sand	2010.3	0.20	798.1	0.01	1069.5	0.02	1395.2	0.04	1598.2	0.06	1738.9	0.08	1907.8	0.12	2010.3	0.20
15	-88.0	Sand	2220.1	0.20	881.4	0.01	1181.1	0.02	1540.8	0.04	1765.0	0.06	1920.4	0.08	2106.9	0.12	2220.1	0.20
16	-93.0	Sand	2429.9	0.20	964.7	0.01	1292.7	0.02	1686.4	0.04	1931.8	0.06	2101.9	0.08	2306.0	0.12	2429.9	0.20
17	-98.0	Sand	2639.7	0.20	1048.0	0.01	1404.3	0.02	1832.0	0.04	2098.6	0.06	2283.4	0.08	2505.1	0.12	2639.7	0.20

q_{max} (kips)	u_c (in)	q_1 (kips)	u_1 (in)	q_2 (kips)	u_2 (in)	q_3 (kips)	u_3 (in)	q_4 (kips)	u_4 (in)
1777.2	5.40	799.8	0.54	1119.7	1.35	1404.0	2.70	1777.2	5.40

TABLE B-22: PIER 22 - *t-z* AND *q-u* CURVES

Node #	Elevation (ft)	Soil Type	t_{max} (lb/in)	z_c (in)	t_1 (lb/in)	z_1 (in)	t_2 (lb/in)	z_2 (in)	t_3 (lb/in)	z_3 (in)	t_4 (lb/in)	z_4 (in)	t_5 (lb/in)	z_5 (in)	t_6 (lb/in)	z_6 (in)	t_7 (lb/in)	z_7 (in)
1	-14.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
2	-18.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
3	-23.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
4	-28.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
5	-33.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
6	-38.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
7	-43.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
8	-48.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
9	-53.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
10	-58.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
11	-63.0	Clay	522.4	0.22	207.4	0.01	277.9	0.022	362.6	0.044	415.3	0.066	451.9	0.088	495.8	0.132	522.4	0.22
12	-66.0	Sand	872.3	0.20	346.3	0.01	464.1	0.02	605.4	0.04	693.5	0.06	754.5	0.08	827.8	0.12	872.3	0.20
13	-69.0	Sand	936.4	0.20	371.8	0.01	498.2	0.02	649.9	0.04	744.4	0.06	810.0	0.08	888.6	0.12	936.4	0.20
14	-74.0	Sand	1018.8	0.20	404.5	0.01	542.0	0.02	707.1	0.04	810.0	0.06	881.3	0.08	966.9	0.12	1018.8	0.20
15	-79.0	Sand	1110.4	0.20	440.8	0.01	590.7	0.02	770.6	0.04	882.8	0.06	960.5	0.08	1053.8	0.12	1110.4	0.20
16	-84.0	Sand	1202.0	0.20	477.2	0.01	639.5	0.02	834.2	0.04	955.6	0.06	1039.7	0.08	1140.7	0.12	1202.0	0.20
17	-89.0	Sand	1383.9	0.20	549.4	0.01	736.2	0.02	960.4	0.04	1100.2	0.06	1197.1	0.08	1313.3	0.12	1383.9	0.20
18	-93.0	Sand	1573.4	0.20	624.6	0.01	837.1	0.02	1091.9	0.04	1250.9	0.06	1361.0	0.08	1493.2	0.12	1573.4	0.20
19	-98.0	Sand	1686.2	0.20	669.4	0.01	897.1	0.02	1170.2	0.04	1340.5	0.06	1458.6	0.08	1600.2	0.12	1686.2	0.20

q_{max} (kips)	u_c (in)	q_1 (kips)	u_1 (in)	q_2 (kips)	u_2 (in)	q_3 (kips)	u_3 (in)	q_4 (kips)	u_4 (in)
1677.0	2.40	754.7	0.24	1056.5	0.60	1324.8	1.20	1677.0	2.40

TABLE B-23: PIER 23 - *t-z* AND *q-u* CURVES

Node #	Elevation (ft)	Soil Type	t_{max} (lb/in)	z_c (in)	t_1 (lb/in)	z_1 (in)	t_2 (lb/in)	z_2 (in)	t_3 (lb/in)	z_3 (in)	t_4 (lb/in)	z_4 (in)	t_5 (lb/in)	z_5 (in)	t_6 (lb/in)	z_6 (in)	t_7 (lb/in)	z_7 (in)
1	-16.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
2	-21.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
3	-26.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
4	-31.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
5	-36.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
6	-41.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
7	-46.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
8	-51.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
9	-56.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
10	-61.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
11	-66.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
12	-71.0	Clay	584.7	0.22	232.1	0.01	311.0	0.022	405.8	0.044	464.8	0.066	505.7	0.088	554.9	0.132	584.7	0.22
13	-75.0	Sand	1006.0	0.20	399.4	0.01	535.2	0.02	698.1	0.04	799.7	0.06	870.2	0.08	954.7	0.12	1006.0	0.20
14	-79.0	Sand	1083.8	0.20	430.3	0.01	576.6	0.02	752.2	0.04	861.6	0.06	937.5	0.08	1028.5	0.12	1083.8	0.20
15	-84.0	Sand	1170.8	0.20	464.8	0.01	622.9	0.02	812.5	0.04	930.8	0.06	1012.8	0.08	1111.1	0.12	1170.8	0.20
16	-89.0	Sand	1350.6	0.20	536.2	0.01	718.5	0.02	937.3	0.04	1073.7	0.06	1168.2	0.08	1281.7	0.12	1350.6	0.20
17	-93.0	Sand	1537.9	0.20	610.6	0.01	818.2	0.02	1067.3	0.04	1222.7	0.06	1330.3	0.08	1459.5	0.12	1537.9	0.20
18	-98.0	Sand	1650.7	0.20	655.3	0.01	878.2	0.02	1145.6	0.04	1312.3	0.06	1427.9	0.08	1566.5	0.12	1650.7	0.20
19	-103.0	Sand	1769.5	0.20	702.5	0.01	941.4	0.02	1228.0	0.04	1406.7	0.06	1530.6	0.08	1679.2	0.12	1769.5	0.20

q_{max} (kips)	u_c (in)	q_1 (kips)	u_1 (in)	q_2 (kips)	u_2 (in)	q_3 (kips)	u_3 (in)	q_4 (kips)	u_4 (in)
1075.4	2.40	484.0	0.24	677.5	0.60	849.6	1.20	1075.4	2.40

TABLE B-24: PIER 24 - *t-z* AND *q-u* CURVES

Node #	Elevation (ft)	Soil Type	t_{max} (lb/in)	z_c (in)	t_1 (lb/in)	z_1 (in)	t_2 (lb/in)	z_2 (in)	t_3 (lb/in)	z_3 (in)	t_4 (lb/in)	z_4 (in)	t_5 (lb/in)	z_5 (in)	t_6 (lb/in)	z_6 (in)	t_7 (lb/in)	z_7 (in)
1	-17.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
2	-20.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
3	-24.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
4	-29.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
5	-34.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
6	-39.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
7	-44.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
8	-49.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
9	-54.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
10	-59.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
11	-64.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
12	-69.0	Clay	537.5	0.22	213.4	0.01	286.0	0.022	373.1	0.044	427.3	0.066	465.0	0.088	510.1	0.132	537.5	0.22
13	-72.0	Sand	907.1	0.20	360.1	0.01	482.6	0.02	629.6	0.04	721.2	0.06	784.7	0.08	860.9	0.12	907.1	0.20
14	-76.0	Sand	980.4	0.20	389.2	0.01	521.6	0.02	680.4	0.04	779.4	0.06	848.1	0.08	930.4	0.12	980.4	0.20
15	-81.0	Sand	1067.4	0.20	423.8	0.01	567.9	0.02	740.8	0.04	848.6	0.06	923.3	0.08	1013.0	0.12	1067.4	0.20
16	-86.0	Sand	1240.0	0.20	492.3	0.01	659.7	0.02	860.6	0.04	985.8	0.06	1072.6	0.08	1176.8	0.12	1240.0	0.20
17	-90.0	Sand	1420.2	0.20	563.8	0.01	755.6	0.02	985.6	0.04	1129.1	0.06	1228.5	0.08	1347.8	0.12	1420.2	0.20
18	-95.0	Sand	1533.0	0.20	608.6	0.01	815.6	0.02	1063.9	0.04	1218.7	0.06	1326.1	0.08	1454.8	0.12	1533.0	0.20
19	-100.0	Sand	1651.7	0.20	655.7	0.01	878.7	0.02	1146.3	0.04	1313.1	0.06	1428.8	0.08	1567.5	0.12	1651.7	0.20
20	-105.0	Sand	1770.5	0.20	702.9	0.01	941.9	0.02	1228.7	0.04	1407.5	0.06	1531.5	0.08	1680.2	0.12	1770.5	0.20

q_{max} (kips)	u_c (in)	q_1 (kips)	u_1 (in)	q_2 (kips)	u_2 (in)	q_3 (kips)	u_3 (in)	q_4 (kips)	u_4 (in)
782.6	2.40	352.2	0.24	493.0	0.60	618.2	1.20	782.6	2.40

TABLE B-25: PIER 25 - *t-z* AND *q-u* CURVES

Node #	Elevation (ft)	Soil Type	t_{max} (lb/in)	z_c (in)	t_1 (lb/in)	z_1 (in)	t_2 (lb/in)	z_2 (in)	t_3 (lb/in)	z_3 (in)	t_4 (lb/in)	z_4 (in)	t_5 (lb/in)	z_5 (in)	t_6 (lb/in)	z_6 (in)	t_7 (lb/in)	z_7 (in)
1	-18.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
2	-21.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
3	-25.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
4	-30.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
5	-35.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
6	-40.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
7	-45.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
8	-50.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
9	-55.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
10	-60.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
11	-65.0	Clay	511.9	0.22	203.2	0.01	272.3	0.022	355.2	0.044	406.9	0.066	442.8	0.088	485.7	0.132	511.9	0.22
12	-69.0	Sand	860.3	0.20	341.6	0.01	457.7	0.02	597.1	0.04	684.0	0.06	744.2	0.08	816.5	0.12	860.3	0.20
13	-73.0	Sand	933.6	0.20	370.6	0.01	496.7	0.02	647.9	0.04	742.2	0.06	807.6	0.08	886.0	0.12	933.6	0.20
14	-77.0	Sand	1006.9	0.20	399.7	0.01	535.7	0.02	698.8	0.04	800.5	0.06	870.9	0.08	955.5	0.12	1006.9	0.20
15	-81.0	Sand	1154.3	0.20	458.3	0.01	614.1	0.02	801.1	0.04	917.7	0.06	998.5	0.08	1095.5	0.12	1154.3	0.20
16	-84.0	Sand	1300.8	0.20	516.4	0.01	692.0	0.02	902.7	0.04	1034.1	0.06	1125.2	0.08	1234.4	0.12	1300.8	0.20
17	-87.0	Sand	1383.9	0.20	549.4	0.01	736.2	0.02	960.4	0.04	1100.2	0.06	1197.1	0.08	1313.3	0.12	1383.9	0.20
18	-92.0	Sand	1490.7	0.20	591.8	0.01	793.1	0.02	1034.6	0.04	1185.1	0.06	1289.5	0.08	1414.7	0.12	1490.7	0.20
19	-97.0	Sand	1609.5	0.20	639.0	0.01	856.2	0.02	1117.0	0.04	1279.5	0.06	1392.2	0.08	1527.4	0.12	1609.5	0.20
20	-102.0	Sand	1378.2	0.20	547.1	0.01	733.2	0.02	956.5	0.04	1095.7	0.06	1192.1	0.08	1307.9	0.12	1378.2	0.20
21	-103.0	Sand	1094.6	0.20	434.6	0.01	582.3	0.02	759.7	0.04	870.2	0.06	946.9	0.08	1038.8	0.12	1094.6	0.20

q_{max} (kips)	u_c (in)	q_1 (kips)	u_1 (in)	q_2 (kips)	u_2 (in)	q_3 (kips)	u_3 (in)	q_4 (kips)	u_4 (in)
773.9	2.40	348.3	0.24	487.6	0.60	611.4	1.20	773.9	2.40

TABLE B-26: PIER 26 - *t-z* AND *q-u* CURVES

Node #	Elevation (ft)	Soil Type	t_{max} (lb/in)	z_c (in)	t_1 (lb/in)	z_1 (in)	t_2 (lb/in)	z_2 (in)	t_3 (lb/in)	z_3 (in)	t_4 (lb/in)	z_4 (in)	t_5 (lb/in)	z_5 (in)	t_6 (lb/in)	z_6 (in)	t_7 (lb/in)	z_7 (in)
1	-18.5	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
2	-23.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
3	-28.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
4	-33.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
5	-38.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
6	-43.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
7	-48.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
8	-53.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
9	-58.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
10	-63.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
11	-68.0	Clay	539.1	0.22	214.0	0.01	286.8	0.022	374.2	0.044	428.6	0.066	466.4	0.088	511.6	0.132	539.1	0.22
12	-73.0	Sand	924.1	0.20	366.9	0.01	491.6	0.02	641.3	0.04	734.6	0.06	799.3	0.08	876.9	0.12	924.1	0.20
13	-78.0	Sand	1080.8	0.20	429.1	0.01	575.0	0.02	750.1	0.04	859.2	0.06	934.9	0.08	1025.7	0.12	1080.8	0.20
14	-81.0	Sand	1233.3	0.20	489.6	0.01	656.1	0.02	855.9	0.04	980.5	0.06	1066.8	0.08	1170.4	0.12	1233.3	0.20
15	-85.0	Sand	1328.3	0.20	527.3	0.01	706.6	0.02	921.8	0.04	1056.0	0.06	1149.0	0.08	1260.5	0.12	1328.3	0.20
16	-90.0	Sand	1441.1	0.20	572.1	0.01	766.7	0.02	1000.1	0.04	1145.7	0.06	1246.5	0.08	1367.6	0.12	1441.1	0.20
17	-95.0	Sand	1559.8	0.20	619.2	0.01	829.8	0.02	1082.5	0.04	1240.0	0.06	1349.2	0.08	1480.3	0.12	1559.8	0.20
18	-100.0	Sand	1352.0	0.20	536.7	0.01	719.3	0.02	938.3	0.04	1074.8	0.06	1169.5	0.08	1283.0	0.12	1352.0	0.20
19	-105.0	Sand	1120.2	0.20	444.7	0.01	596.0	0.02	777.4	0.04	890.6	0.06	969.0	0.08	1063.1	0.12	1120.2	0.20

q_{max} (kips)	u_c (in)	q_1 (kips)	u_1 (in)	q_2 (kips)	u_2 (in)	q_3 (kips)	u_3 (in)	q_4 (kips)	u_4 (in)
792.0	2.40	356.4	0.24	499.0	0.60	625.7	1.20	792.0	2.40

TABLE B-27: PIER 27 - *t-z* AND *q-u* CURVES

Node #	Elevation (ft)	Soil Type	t_{max} (lb/in)	z_c (in)	t_1 (lb/in)	z_1 (in)	t_2 (lb/in)	z_2 (in)	t_3 (lb/in)	z_3 (in)	t_4 (lb/in)	z_4 (in)	t_5 (lb/in)	z_5 (in)	t_6 (lb/in)	z_6 (in)	t_7 (lb/in)	z_7 (in)
1	-19.5	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
2	-23.5	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
3	-28.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
4	-33.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
5	-38.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
6	-43.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
7	-48.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
8	-53.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
9	-58.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
10	-63.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
11	-68.0	Clay	522.4	0.22	207.4	0.01	277.9	0.022	362.6	0.044	415.3	0.066	451.9	0.088	495.8	0.132	522.4	0.22
12	-71.0	Sand	876.9	0.20	348.1	0.01	466.5	0.02	608.5	0.04	697.1	0.06	758.5	0.08	832.2	0.12	876.9	0.20
13	-75.0	Sand	950.1	0.20	377.2	0.01	505.5	0.02	659.4	0.04	755.4	0.06	821.9	0.08	901.7	0.12	950.1	0.20
14	-80.0	Sand	1037.1	0.20	411.7	0.01	551.8	0.02	719.8	0.04	824.5	0.06	897.1	0.08	984.2	0.12	1037.1	0.20
15	-85.0	Sand	1128.7	0.20	448.1	0.01	600.5	0.02	783.3	0.04	897.3	0.06	976.3	0.08	1071.2	0.12	1128.7	0.20
16	-90.0	Sand	1220.3	0.20	484.5	0.01	649.2	0.02	846.9	0.04	970.1	0.06	1055.6	0.08	1158.1	0.12	1220.3	0.20
17	-95.0	Sand	1311.9	0.20	520.8	0.01	697.9	0.02	910.4	0.04	1042.9	0.06	1134.8	0.08	1245.0	0.12	1311.9	0.20
18	-100.0	Sand	1405.4	0.20	558.0	0.01	747.7	0.02	975.4	0.04	1117.3	0.06	1215.7	0.08	1333.8	0.12	1405.4	0.20
19	-105.0	Sand	1503.0	0.20	596.7	0.01	799.6	0.02	1043.1	0.04	1194.9	0.06	1300.1	0.08	1426.3	0.12	1503.0	0.20

q_{max} (kips)	u_c (in)	q_1 (kips)	u_1 (in)	q_2 (kips)	u_2 (in)	q_3 (kips)	u_3 (in)	q_4 (kips)	u_4 (in)
756.3	2.40	340.3	0.24	476.4	0.60	597.4	1.20	756.3	2.40

TABLE B-28: PIER 28 - *t-z* AND *q-u* CURVES

Node #	Elevation (ft)	Soil Type	t_{max} (lb/in)	z_c (in)	t_1 (lb/in)	z_1 (in)	t_2 (lb/in)	z_2 (in)	t_3 (lb/in)	z_3 (in)	t_4 (lb/in)	z_4 (in)	t_5 (lb/in)	z_5 (in)	t_6 (lb/in)	z_6 (in)	t_7 (lb/in)	z_7 (in)
1	-20.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
2	-24.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
3	-29.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
4	-34.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
5	-39.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
6	-44.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
7	-49.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
8	-54.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
9	-59.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
10	-64.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
11	-69.0	Clay	534.6	0.22	212.2	0.01	284.4	0.022	371.0	0.044	425.0	0.066	462.4	0.088	507.3	0.132	534.6	0.22
12	-73.0	Sand	910.3	0.20	361.4	0.01	484.3	0.02	631.8	0.04	723.7	0.06	787.4	0.08	863.9	0.12	910.3	0.20
13	-78.0	Sand	997.3	0.20	395.9	0.01	530.6	0.02	692.1	0.04	792.9	0.06	862.7	0.08	946.5	0.12	997.3	0.20
14	-83.0	Sand	1088.9	0.20	432.3	0.01	579.3	0.02	755.7	0.04	865.7	0.06	941.9	0.08	1033.4	0.12	1088.9	0.20
15	-88.0	Sand	1180.5	0.20	468.7	0.01	628.0	0.02	819.3	0.04	938.5	0.06	1021.1	0.08	1120.3	0.12	1180.5	0.20
16	-93.0	Sand	1272.1	0.20	505.0	0.01	676.7	0.02	882.8	0.04	1011.3	0.06	1100.3	0.08	1207.2	0.12	1272.1	0.20
17	-98.0	Sand	1363.6	0.20	541.4	0.01	725.5	0.02	946.4	0.04	1084.1	0.06	1179.5	0.08	1294.1	0.12	1363.6	0.20
18	-103.0	Sand	1455.2	0.20	577.7	0.01	774.2	0.02	1009.9	0.04	1156.9	0.06	1258.8	0.08	1381.0	0.12	1455.2	0.20

q_{max} (kips)	u_c (in)	q_1 (kips)	u_1 (in)	q_2 (kips)	u_2 (in)	q_3 (kips)	u_3 (in)	q_4 (kips)	u_4 (in)
549.2	2.40	247.1	0.24	346.0	0.60	433.8	1.20	549.2	2.40

TABLE B-29: PIER 29 - *t-z* AND *q-u* CURVES

Node #	Elevation (ft)	Soil Type	t_{max} (lb/in)	z_c (in)	t_1 (lb/in)	z_1 (in)	t_2 (lb/in)	z_2 (in)	t_3 (lb/in)	z_3 (in)	t_4 (lb/in)	z_4 (in)	t_5 (lb/in)	z_5 (in)	t_6 (lb/in)	z_6 (in)	t_7 (lb/in)	z_7 (in)
1	-21.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
2	-24.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
3	-28.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
4	-33.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
5	-38.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
6	-43.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
7	-48.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
8	-53.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
9	-58.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
10	-63.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
11	-68.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
12	-73.0	Clay	552.7	0.22	219.4	0.01	294.0	0.022	383.6	0.044	439.4	0.066	478.1	0.088	524.5	0.132	552.7	0.22
13	-76.0	Sand	937.4	0.20	372.2	0.01	498.7	0.02	650.6	0.04	745.2	0.06	810.9	0.08	889.6	0.12	937.4	0.20
14	-80.0	Sand	1010.7	0.20	401.2	0.01	537.7	0.02	701.4	0.04	803.5	0.06	874.2	0.08	959.1	0.12	1010.7	0.20
15	-85.0	Sand	1097.7	0.20	435.8	0.01	584.0	0.02	761.8	0.04	872.7	0.06	949.5	0.08	1041.7	0.12	1097.7	0.20
16	-90.0	Sand	1189.3	0.20	472.1	0.01	632.7	0.02	825.3	0.04	945.5	0.06	1028.7	0.08	1128.6	0.12	1189.3	0.20
17	-95.0	Sand	1280.8	0.20	508.5	0.01	681.4	0.02	888.9	0.04	1018.3	0.06	1107.9	0.08	1215.5	0.12	1280.8	0.20
18	-100.0	Sand	1372.4	0.20	544.8	0.01	730.1	0.02	952.5	0.04	1091.1	0.06	1187.1	0.08	1302.4	0.12	1372.4	0.20
19	-105.0	Sand	1464.0	0.20	581.2	0.01	778.8	0.02	1016.0	0.04	1163.9	0.06	1266.4	0.08	1389.3	0.12	1464.0	0.20

q_{max} (kips)	u_c (in)	q_1 (kips)	u_1 (in)	q_2 (kips)	u_2 (in)	q_3 (kips)	u_3 (in)	q_4 (kips)	u_4 (in)
736.6	2.40	331.5	0.24	464.1	0.60	581.9	1.20	736.6	2.40

TABLE B-30: PIER 30 - *t-z* AND *q-u* CURVES

Node #	Elevation (ft)	Soil Type	t_{max} (lb/in)	z_c (in)	t_1 (lb/in)	z_1 (in)	t_2 (lb/in)	z_2 (in)	t_3 (lb/in)	z_3 (in)	t_4 (lb/in)	z_4 (in)	t_5 (lb/in)	z_5 (in)	t_6 (lb/in)	z_6 (in)	t_7 (lb/in)	z_7 (in)
1	-21.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
2	-25.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
3	-30.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
4	-35.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
5	-40.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
6	-45.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
7	-50.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
8	-55.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
9	-60.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
10	-65.0	Clay	485.8	0.22	192.8	0.01	258.4	0.022	337.1	0.044	386.2	0.066	420.2	0.088	461.0	0.132	485.8	0.22
11	-68.0	Sand	806.4	0.20	320.1	0.01	429.0	0.02	559.6	0.04	641.1	0.06	697.5	0.08	765.2	0.12	806.4	0.20
12	-72.0	Sand	841.2	0.20	334.0	0.01	447.5	0.02	583.8	0.04	668.7	0.06	727.6	0.08	798.3	0.12	841.2	0.20
13	-77.0	Sand	930.8	0.20	369.5	0.01	495.2	0.02	646.0	0.04	740.0	0.06	805.1	0.08	883.3	0.12	930.8	0.20
14	-82.0	Sand	1030.3	0.20	409.0	0.01	548.1	0.02	715.0	0.04	819.1	0.06	891.2	0.08	977.8	0.12	1030.3	0.20
15	-87.0	Sand	1129.8	0.20	448.5	0.01	601.1	0.02	784.1	0.04	898.2	0.06	977.3	0.08	1072.2	0.12	1129.8	0.20
16	-92.0	Sand	1229.4	0.20	488.1	0.01	654.0	0.02	853.2	0.04	977.3	0.06	1063.4	0.08	1166.7	0.12	1229.4	0.20
17	-97.0	Sand	1328.9	0.20	527.6	0.01	707.0	0.02	922.2	0.04	1056.5	0.06	1149.5	0.08	1261.1	0.12	1328.9	0.20
18	-102.0	Sand	1428.4	0.20	567.1	0.01	759.9	0.02	991.3	0.04	1135.6	0.06	1235.6	0.08	1355.6	0.12	1428.4	0.20
19	-107.0	Sand	1084.6	0.20	430.6	0.01	577.0	0.02	752.7	0.04	862.2	0.06	938.2	0.08	1029.3	0.12	1084.6	0.20
20	-112.0	Sand	1182.3	0.20	469.4	0.01	629.0	0.02	820.5	0.04	940.0	0.06	1022.7	0.08	1122.0	0.12	1182.3	0.20

q_{max} (kips)	u_c (in)	q_1 (kips)	u_1 (in)	q_2 (kips)	u_2 (in)	q_3 (kips)	u_3 (in)	q_4 (kips)	u_4 (in)
522.5	2.40	235.1	0.24	329.1	0.60	412.7	1.20	522.5	2.40

TABLE B-31: PIER 31 - *t-z* AND *q-u* CURVES

Node #	Elevation (ft)	Soil Type	t_{max} (lb/in)	z_c (in)	t_1 (lb/in)	z_1 (in)	t_2 (lb/in)	z_2 (in)	t_3 (lb/in)	z_3 (in)	t_4 (lb/in)	z_4 (in)	t_5 (lb/in)	z_5 (in)	t_6 (lb/in)	z_6 (in)	t_7 (lb/in)	z_7 (in)
1	-19.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
2	-24.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
3	-29.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
4	-34.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
5	-39.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
6	-44.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
7	-49.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
8	-54.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
9	-59.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
10	-64.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
11	-69.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
12	-74.0	Clay	552.7	0.22	219.4	0.01	294.0	0.022	383.6	0.044	439.4	0.066	478.1	0.088	524.5	0.132	552.7	0.22
13	-77.0	Sand	937.4	0.20	372.2	0.01	498.7	0.02	650.6	0.04	745.2	0.06	810.9	0.08	889.6	0.12	937.4	0.20
14	-81.0	Sand	1010.7	0.20	401.2	0.01	537.7	0.02	701.4	0.04	803.5	0.06	874.2	0.08	959.1	0.12	1010.7	0.20
15	-86.0	Sand	1097.7	0.20	435.8	0.01	584.0	0.02	761.8	0.04	872.7	0.06	949.5	0.08	1041.7	0.12	1097.7	0.20
16	-91.0	Sand	1189.3	0.20	472.1	0.01	632.7	0.02	825.3	0.04	945.5	0.06	1028.7	0.08	1128.6	0.12	1189.3	0.20
17	-96.0	Sand	1280.8	0.20	508.5	0.01	681.4	0.02	888.9	0.04	1018.3	0.06	1107.9	0.08	1215.5	0.12	1280.8	0.20
18	-101.0	Sand	1372.4	0.20	544.8	0.01	730.1	0.02	952.5	0.04	1091.1	0.06	1187.1	0.08	1302.4	0.12	1372.4	0.20
19	-106.0	Sand	1249.6	0.20	496.1	0.01	664.8	0.02	867.2	0.04	993.4	0.06	1080.9	0.08	1185.9	0.12	1249.6	0.20
20	-112.0	Sand	1120.1	0.20	444.7	0.01	595.9	0.02	777.4	0.04	890.5	0.06	968.9	0.08	1063.0	0.12	1120.1	0.20

q_{max} (kips)	u_c (in)	q_1 (kips)	u_1 (in)	q_2 (kips)	u_2 (in)	q_3 (kips)	u_3 (in)	q_4 (kips)	u_4 (in)
594.0	2.40	267.3	0.24	374.2	0.60	469.2	1.20	594.0	2.40

TABLE B-32: PIER 32 - *t-z* AND *q-u* CURVES

Node #	Elevation (ft)	Soil Type	t_{max} (lb/in)	z_c (in)	t_1 (lb/in)	z_1 (in)	t_2 (lb/in)	z_2 (in)	t_3 (lb/in)	z_3 (in)	t_4 (lb/in)	z_4 (in)	t_5 (lb/in)	z_5 (in)	t_6 (lb/in)	z_6 (in)	t_7 (lb/in)	z_7 (in)
1	-19.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
2	-23.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
3	-27.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
4	-32.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
5	-37.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
6	-42.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
7	-47.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
8	-52.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
9	-57.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
10	-62.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
11	-67.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
12	-72.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
13	-77.0	Clay	572.4	0.22	227.2	0.01	304.5	0.022	397.2	0.044	455.1	0.066	495.1	0.088	543.2	0.132	572.4	0.22
14	-81.0	Sand	986.0	0.20	391.4	0.01	524.6	0.02	684.3	0.04	783.9	0.06	852.9	0.08	935.7	0.12	986.0	0.20
15	-86.0	Sand	1073.0	0.20	426.0	0.01	570.8	0.02	744.7	0.04	853.0	0.06	928.1	0.08	1018.3	0.12	1073.0	0.20
16	-91.0	Sand	1164.6	0.20	462.3	0.01	619.6	0.02	808.2	0.04	925.8	0.06	1007.4	0.08	1105.2	0.12	1164.6	0.20
17	-96.0	Sand	1256.2	0.20	498.7	0.01	668.3	0.02	871.8	0.04	998.6	0.06	1086.6	0.08	1192.1	0.12	1256.2	0.20
18	-101.0	Sand	1453.7	0.20	577.1	0.01	773.4	0.02	1008.9	0.04	1155.7	0.06	1257.4	0.08	1379.5	0.12	1453.7	0.20
19	-107.0	Sand	1344.5	0.20	533.8	0.01	715.3	0.02	933.1	0.04	1068.9	0.06	1163.0	0.08	1276.0	0.12	1344.5	0.20
20	-112.0	Sand	1119.1	0.20	444.3	0.01	595.3	0.02	776.6	0.04	889.7	0.06	968.0	0.08	1062.0	0.12	1119.1	0.20

q_{max} (kips)	u_c (in)	q_1 (kips)	u_1 (in)	q_2 (kips)	u_2 (in)	q_3 (kips)	u_3 (in)	q_4 (kips)	u_4 (in)
791.2	2.40	356.0	0.24	498.5	0.60	625.0	1.20	791.2	2.40

TABLE B-33: PIER 33 - *t-z* AND *q-u* CURVES

Node #	Elevation (ft)	Soil Type	t_{max} (lb/in)	z_c (in)	t_1 (lb/in)	z_1 (in)	t_2 (lb/in)	z_2 (in)	t_3 (lb/in)	z_3 (in)	t_4 (lb/in)	z_4 (in)	t_5 (lb/in)	z_5 (in)	t_6 (lb/in)	z_6 (in)	t_7 (lb/in)	z_7 (in)
1	-19.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
2	-21.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
3	-24.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
4	-29.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
5	-34.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
6	-39.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
7	-44.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
8	-49.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
9	-54.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
10	-59.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
11	-64.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
12	-69.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
13	-74.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
14	-79.0	Clay	583.0	0.22	231.4	0.01	310.1	0.022	404.6	0.044	463.4	0.066	504.3	0.088	553.2	0.132	583.0	0.22
15	-82.0	Sand	993.4	0.20	394.4	0.01	528.5	0.02	689.4	0.04	789.7	0.06	859.3	0.08	942.7	0.12	993.4	0.20
16	-85.0	Sand	1057.5	0.20	419.8	0.01	562.6	0.02	733.9	0.04	840.7	0.06	914.7	0.08	1003.6	0.12	1057.5	0.20
17	-90.0	Sand	1139.9	0.20	452.5	0.01	606.4	0.02	791.1	0.04	906.2	0.06	986.0	0.08	1081.8	0.12	1139.9	0.20
18	-95.0	Sand	1231.5	0.20	488.9	0.01	655.2	0.02	854.7	0.04	979.0	0.06	1065.2	0.08	1168.7	0.12	1231.5	0.20
19	-100.0	Sand	1415.4	0.20	561.9	0.01	753.0	0.02	982.3	0.04	1125.3	0.06	1224.3	0.08	1343.2	0.12	1415.4	0.20
20	-104.0	Sand	1601.1	0.20	635.6	0.01	851.8	0.02	1111.1	0.04	1272.8	0.06	1384.9	0.08	1519.4	0.12	1601.1	0.20
21	-108.0	Sand	1368.6	0.20	543.3	0.01	728.1	0.02	949.8	0.04	1088.1	0.06	1183.9	0.08	1298.8	0.12	1368.6	0.20
22	-112.0	Sand	1117.0	0.20	443.5	0.01	594.3	0.02	775.2	0.04	888.0	0.06	966.2	0.08	1060.1	0.12	1117.0	0.20

q_{max} (kips)	u_c (in)	q_1 (kips)	u_1 (in)	q_2 (kips)	u_2 (in)	q_3 (kips)	u_3 (in)	q_4 (kips)	u_4 (in)
789.8	2.40	355.4	0.24	497.5	0.60	623.9	1.20	789.8	2.40

TABLE B-34: PIER 34 - *t-z* AND *q-u* CURVES

Node #	Elevation (ft)	Soil Type	t_{max} (lb/in)	z_c (in)	t_1 (lb/in)	z_1 (in)	t_2 (lb/in)	z_2 (in)	t_3 (lb/in)	z_3 (in)	t_4 (lb/in)	z_4 (in)	t_5 (lb/in)	z_5 (in)	t_6 (lb/in)	z_6 (in)	t_7 (lb/in)	z_7 (in)
1	-18.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
2	-21.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
3	-24.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
4	-29.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
5	-34.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
6	-39.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
7	-44.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
8	-49.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
9	-54.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
10	-59.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
11	-64.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
12	-69.0	Clay	516.4	0.22	205.0	0.01	274.7	0.022	358.4	0.044	410.6	0.066	446.7	0.088	490.1	0.132	516.4	0.22
13	-74.0	Sand	878.7	0.20	348.8	0.01	467.4	0.02	609.8	0.04	698.5	0.06	760.0	0.08	833.8	0.12	878.7	0.20
14	-79.0	Sand	970.2	0.20	385.2	0.01	516.2	0.02	673.3	0.04	771.3	0.06	839.3	0.08	920.8	0.12	970.2	0.20
15	-84.0	Sand	1061.8	0.20	421.5	0.01	564.9	0.02	736.9	0.04	844.1	0.06	918.5	0.08	1007.7	0.12	1061.8	0.20
16	-89.0	Sand	1153.4	0.20	457.9	0.01	613.6	0.02	800.5	0.04	916.9	0.06	997.7	0.08	1094.6	0.12	1153.4	0.20
17	-94.0	Sand	1285.8	0.20	510.5	0.01	684.1	0.02	892.4	0.04	1022.2	0.06	1112.2	0.08	1220.2	0.12	1285.8	0.20
18	-98.0	Sand	1420.3	0.20	563.9	0.01	755.6	0.02	985.7	0.04	1129.1	0.06	1228.6	0.08	1347.9	0.12	1420.3	0.20
19	-103.0	Sand	1521.3	0.20	604.0	0.01	809.3	0.02	1055.8	0.04	1209.4	0.06	1315.9	0.08	1443.7	0.12	1521.3	0.20
20	-108.0	Sand	1343.6	0.20	533.4	0.01	714.8	0.02	932.4	0.04	1068.1	0.06	1162.2	0.08	1275.1	0.12	1343.6	0.20
21	-112.0	Sand	1141.0	0.20	453.0	0.01	607.0	0.02	791.9	0.04	907.1	0.06	987.0	0.08	1082.8	0.12	1141.0	0.20

q_{max} (kips)	u_c (in)	q_1 (kips)	u_1 (in)	q_2 (kips)	u_2 (in)	q_3 (kips)	u_3 (in)	q_4 (kips)	u_4 (in)
806.7	2.40	363.0	0.24	508.2	0.60	637.3	1.20	806.7	2.40

TABLE B-35: PIER 35 - *t-z* AND *q-u* CURVES

Node #	Elevation (ft)	Soil Type	t_{max} (lb/in)	z_c (in)	t_1 (lb/in)	z_1 (in)	t_2 (lb/in)	z_2 (in)	t_3 (lb/in)	z_3 (in)	t_4 (lb/in)	z_4 (in)	t_5 (lb/in)	z_5 (in)	t_6 (lb/in)	z_6 (in)	t_7 (lb/in)	z_7 (in)
1	-18.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
2	-21.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
3	-25.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
4	-30.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
5	-35.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
6	-40.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
7	-45.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
8	-50.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
9	-55.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
10	-60.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
11	-65.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
12	-70.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
13	-75.0	Clay	561.8	0.22	223.1	0.01	298.9	0.022	389.9	0.044	446.7	0.066	486.0	0.088	533.2	0.132	561.8	0.22
14	-80.0	Sand	969.5	0.20	384.9	0.01	515.8	0.02	672.8	0.04	770.7	0.06	838.6	0.08	920.0	0.12	969.5	0.20
15	-85.0	Sand	1061.0	0.20	421.2	0.01	564.5	0.02	736.4	0.04	843.5	0.06	917.8	0.08	1006.9	0.12	1061.0	0.20
16	-90.0	Sand	1152.6	0.20	457.6	0.01	613.2	0.02	799.9	0.04	916.3	0.06	997.0	0.08	1093.8	0.12	1152.6	0.20
17	-95.0	Sand	1290.3	0.20	512.3	0.01	686.5	0.02	895.5	0.04	1025.8	0.06	1116.1	0.08	1224.5	0.12	1290.3	0.20
18	-100.0	Sand	1435.4	0.20	569.9	0.01	763.7	0.02	996.2	0.04	1141.2	0.06	1241.7	0.08	1362.2	0.12	1435.4	0.20
19	-105.0	Sand	1541.8	0.20	612.1	0.01	820.2	0.02	1070.0	0.04	1225.7	0.06	1333.6	0.08	1463.1	0.12	1541.8	0.20
20	-110.0	Sand	1353.5	0.20	537.4	0.01	720.1	0.02	939.3	0.04	1076.1	0.06	1170.8	0.08	1284.5	0.12	1353.5	0.20
21	-112.0	Sand	1126.3	0.20	447.1	0.01	599.2	0.02	781.7	0.04	895.4	0.06	974.3	0.08	1068.9	0.12	1126.3	0.20

q_{max} (kips)	u_c (in)	q_1 (kips)	u_1 (in)	q_2 (kips)	u_2 (in)	q_3 (kips)	u_3 (in)	q_4 (kips)	u_4 (in)
796.3	2.40	358.3	0.24	501.7	0.60	629.1	1.20	796.3	2.40

TABLE B-36: PIER 36 - *t-z* AND *q-u* CURVES

Node #	Elevation (ft)	Soil Type	t_{max} (lb/in)	z_c (in)	t_1 (lb/in)	z_1 (in)	t_2 (lb/in)	z_2 (in)	t_3 (lb/in)	z_3 (in)	t_4 (lb/in)	z_4 (in)	t_5 (lb/in)	z_5 (in)	t_6 (lb/in)	z_6 (in)	t_7 (lb/in)	z_7 (in)
1	-18.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
2	-21.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
3	-25.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
4	-30.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
5	-35.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
6	-40.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
7	-45.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
8	-50.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
9	-55.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
10	-60.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
11	-65.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
12	-70.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
13	-75.0	Clay	557.3	0.22	221.2	0.01	296.5	0.022	386.7	0.044	443.0	0.066	482.0	0.088	528.8	0.132	557.3	0.22
14	-79.0	Sand	951.2	0.20	377.6	0.01	506.0	0.02	660.1	0.04	756.2	0.06	822.7	0.08	902.6	0.12	951.2	0.20
15	-83.0	Sand	1029.0	0.20	408.5	0.01	547.4	0.02	714.1	0.04	818.1	0.06	890.1	0.08	976.5	0.12	1029.0	0.20
16	-88.0	Sand	1116.0	0.20	443.1	0.01	593.7	0.02	774.5	0.04	887.2	0.06	965.3	0.08	1059.1	0.12	1116.0	0.20
17	-93.0	Sand	1291.9	0.20	512.9	0.01	687.3	0.02	896.6	0.04	1027.1	0.06	1117.5	0.08	1226.1	0.12	1291.9	0.20
18	-97.0	Sand	1469.6	0.20	583.4	0.01	781.8	0.02	1019.9	0.04	1168.3	0.06	1271.2	0.08	1394.7	0.12	1469.6	0.20
19	-101.0	Sand	1570.5	0.20	623.5	0.01	835.5	0.02	1089.9	0.04	1248.6	0.06	1358.5	0.08	1490.4	0.12	1570.5	0.20
20	-106.0	Sand	1683.3	0.20	668.3	0.01	895.5	0.02	1168.2	0.04	1338.2	0.06	1456.1	0.08	1597.5	0.12	1683.3	0.20

q_{max} (kips)	u_c (in)	q_1 (kips)	u_1 (in)	q_2 (kips)	u_2 (in)	q_3 (kips)	u_3 (in)	q_4 (kips)	u_4 (in)
930.1	2.40	418.5	0.24	586.0	0.60	734.8	1.20	930.1	2.40

TABLE B-37: PIER 37 - *t-z* AND *q-u* CURVES

Node #	Elevation (ft)	Soil Type	t_{max} (lb/in)	z_c (in)	t_1 (lb/in)	z_1 (in)	t_2 (lb/in)	z_2 (in)	t_3 (lb/in)	z_3 (in)	t_4 (lb/in)	z_4 (in)	t_5 (lb/in)	z_5 (in)	t_6 (lb/in)	z_6 (in)	t_7 (lb/in)	z_7 (in)
1	-18.5	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
2	-21.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
3	-24.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
4	-29.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
5	-34.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
6	-39.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
7	-44.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
8	-49.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
9	-54.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
10	-59.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
11	-64.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
12	-69.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
13	-74.0	Clay	557.3	0.22	221.2	0.01	296.5	0.022	386.7	0.044	443.0	0.066	482.0	0.088	528.8	0.132	557.3	0.22
14	-78.0	Sand	955.7	0.20	379.4	0.01	508.4	0.02	663.3	0.04	759.8	0.06	826.7	0.08	907.0	0.12	955.7	0.20
15	-83.0	Sand	1042.7	0.20	414.0	0.01	554.7	0.02	723.7	0.04	829.0	0.06	902.0	0.08	989.6	0.12	1042.7	0.20
16	-88.0	Sand	1134.3	0.20	450.3	0.01	603.5	0.02	787.2	0.04	901.8	0.06	981.2	0.08	1076.5	0.12	1134.3	0.20
17	-93.0	Sand	1311.5	0.20	520.7	0.01	697.7	0.02	910.2	0.04	1042.7	0.06	1134.5	0.08	1244.6	0.12	1311.5	0.20
18	-97.0	Sand	1490.4	0.20	591.7	0.01	792.9	0.02	1034.4	0.04	1184.9	0.06	1289.2	0.08	1414.4	0.12	1490.4	0.20
19	-101.0	Sand	1591.4	0.20	631.8	0.01	846.6	0.02	1104.4	0.04	1265.1	0.06	1376.5	0.08	1510.2	0.12	1591.4	0.20
20	-106.0	Sand	1704.2	0.20	676.6	0.01	906.6	0.02	1182.7	0.04	1354.8	0.06	1474.1	0.08	1617.2	0.12	1704.2	0.20
21	-111.0	Sand	1822.9	0.20	723.7	0.01	969.8	0.02	1265.1	0.04	1449.2	0.06	1576.8	0.08	1729.9	0.12	1822.9	0.20

q_{max} (kips)	u_c (in)	q_1 (kips)	u_1 (in)	q_2 (kips)	u_2 (in)	q_3 (kips)	u_3 (in)	q_4 (kips)	u_4 (in)
805.8	2.40	362.6	0.24	507.6	0.60	636.6	1.20	805.8	2.40

TABLE B-38: PIER 38 - *t-z* AND *q-u* CURVES

Node #	Elevation (ft)	Soil Type	t_{max} (lb/in)	z_c (in)	t_1 (lb/in)	z_1 (in)	t_2 (lb/in)	z_2 (in)	t_3 (lb/in)	z_3 (in)	t_4 (lb/in)	z_4 (in)	t_5 (lb/in)	z_5 (in)	t_6 (lb/in)	z_6 (in)	t_7 (lb/in)	z_7 (in)
1	-19.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
2	-22.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
3	-27.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
4	-32.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
5	-37.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
6	-42.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
7	-47.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
8	-52.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
9	-57.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
10	-62.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
11	-67.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
12	-72.0	Clay	554.3	0.22	220.0	0.01	294.9	0.022	384.7	0.044	440.6	0.066	479.4	0.088	526.0	0.132	554.3	0.22
13	-77.0	Sand	954.3	0.20	378.9	0.01	507.7	0.02	662.3	0.04	758.7	0.06	825.5	0.08	905.7	0.12	954.3	0.20
14	-82.0	Sand	1045.9	0.20	415.2	0.01	556.4	0.02	725.9	0.04	831.5	0.06	904.7	0.08	992.6	0.12	1045.9	0.20
15	-87.0	Sand	1137.5	0.20	451.6	0.01	605.1	0.02	789.4	0.04	904.3	0.06	983.9	0.08	1079.5	0.12	1137.5	0.20
16	-92.0	Sand	1229.1	0.20	487.9	0.01	653.9	0.02	853.0	0.04	977.1	0.06	1063.1	0.08	1166.4	0.12	1229.1	0.20
17	-97.0	Sand	1411.8	0.20	560.5	0.01	751.1	0.02	979.8	0.04	1122.3	0.06	1221.2	0.08	1339.8	0.12	1411.8	0.20
18	-101.0	Sand	1599.6	0.20	635.1	0.01	851.0	0.02	1110.1	0.04	1271.7	0.06	1383.7	0.08	1518.1	0.12	1599.6	0.20
19	-106.0	Sand	1707.3	0.20	677.8	0.01	908.3	0.02	1184.8	0.04	1357.3	0.06	1476.8	0.08	1620.2	0.12	1707.3	0.20
20	-111.0	Sand	1820.6	0.20	722.8	0.01	968.5	0.02	1263.5	0.04	1447.4	0.06	1574.8	0.08	1727.7	0.12	1820.6	0.20

TABLE B-39: PIER 39 - *t-z* AND *q-u* CURVES

Node #	Elevation (ft)	Soil Type	t_{max} (lb/in)	z_c (in)	t_1 (lb/in)	z_1 (in)	t_2 (lb/in)	z_2 (in)	t_3 (lb/in)	z_3 (in)	t_4 (lb/in)	z_4 (in)	t_5 (lb/in)	z_5 (in)	t_6 (lb/in)	z_6 (in)	t_7 (lb/in)	z_7 (in)
1	-10.0	Clay	196.3	0.30	78.0	0.02	104.5	0.03	136.3	0.06	156.1	0.09	169.8	0.12	186.3	0.18	196.3	0.30
2	-15.0	Clay	196.3	0.30	78.0	0.02	104.5	0.03	136.3	0.06	156.1	0.09	169.8	0.12	186.3	0.18	196.3	0.30
3	-20.0	Clay	196.3	0.30	78.0	0.02	104.5	0.03	136.3	0.06	156.1	0.09	169.8	0.12	186.3	0.18	196.3	0.30
4	-25.0	Clay	196.3	0.30	78.0	0.02	104.5	0.03	136.3	0.06	156.1	0.09	169.8	0.12	186.3	0.18	196.3	0.30
5	-30.0	Clay	196.3	0.30	78.0	0.02	104.5	0.03	136.3	0.06	156.1	0.09	169.8	0.12	186.3	0.18	196.3	0.30
6	-35.0	Clay	196.3	0.30	78.0	0.02	104.5	0.03	136.3	0.06	156.1	0.09	169.8	0.12	186.3	0.18	196.3	0.30
7	-40.0	Clay	196.3	0.30	78.0	0.02	104.5	0.03	136.3	0.06	156.1	0.09	169.8	0.12	186.3	0.18	196.3	0.30
8	-45.0	Clay	196.3	0.30	78.0	0.02	104.5	0.03	136.3	0.06	156.1	0.09	169.8	0.12	186.3	0.18	196.3	0.30
9	-50.0	Clay	196.3	0.30	78.0	0.02	104.5	0.03	136.3	0.06	156.1	0.09	169.8	0.12	186.3	0.18	196.3	0.30
10	-55.0	Clay	196.3	0.30	78.0	0.02	104.5	0.03	136.3	0.06	156.1	0.09	169.8	0.12	186.3	0.18	196.3	0.30
11	-60.0	Clay	196.3	0.30	78.0	0.02	104.5	0.03	136.3	0.06	156.1	0.09	169.8	0.12	186.3	0.18	196.3	0.30
12	-65.0	Clay	451.0	0.25	179.1	0.01	240.0	0.025	313.0	0.05	358.6	0.075	390.2	0.1	428.0	0.15	451.0	0.25
13	-68.0	Sand	736.4	0.20	292.4	0.01	391.8	0.02	511.1	0.04	585.4	0.06	637.0	0.08	698.8	0.12	736.4	0.20
14	-73.0	Sand	805.4	0.20	319.7	0.01	428.5	0.02	558.9	0.04	640.3	0.06	696.6	0.08	764.3	0.12	805.4	0.20
15	-78.0	Sand	912.3	0.20	362.2	0.01	485.3	0.02	633.1	0.04	725.3	0.06	789.1	0.08	865.8	0.12	912.3	0.20
16	-82.0	Sand	1021.3	0.20	405.5	0.01	543.3	0.02	708.8	0.04	812.0	0.06	883.4	0.08	969.2	0.12	1021.3	0.20
17	-87.0	Sand	1106.7	0.20	439.4	0.01	588.8	0.02	768.1	0.04	879.9	0.06	957.3	0.08	1050.3	0.12	1106.7	0.20
18	-92.0	Sand	1241.1	0.20	492.7	0.01	660.3	0.02	861.3	0.04	986.7	0.06	1073.5	0.08	1177.8	0.12	1241.1	0.20
19	-97.0	Sand	1387.9	0.20	551.0	0.01	738.4	0.02	963.2	0.04	1103.4	0.06	1200.5	0.08	1317.1	0.12	1387.9	0.20
20	-103.0	Sand	1507.9	0.20	598.7	0.01	802.2	0.02	1046.5	0.04	1198.8	0.06	1304.4	0.08	1431.0	0.12	1507.9	0.20

q_{max} (kips)	u_c (in)	q_1 (kips)	u_1 (in)	q_2 (kips)	u_2 (in)	q_3 (kips)	u_3 (in)	q_4 (kips)	u_4 (in)
887.9	3.00	399.5	0.30	559.3	0.75	701.4	1.50	887.9	3.00

TABLE B-40: PIER 40 - *t-z* AND *q-u* CURVES

Node #	Elevation (ft)	Soil Type	t_{max} (lb/in)	z_c (in)	t_1 (lb/in)	z_1 (in)	t_2 (lb/in)	z_2 (in)	t_3 (lb/in)	z_3 (in)	t_4 (lb/in)	z_4 (in)	t_5 (lb/in)	z_5 (in)	t_6 (lb/in)	z_6 (in)	t_7 (lb/in)	z_7 (in)
1	-12.0	Clay	196.3	0.30	78.0	0.02	104.5	0.03	136.3	0.06	156.1	0.09	169.8	0.12	186.3	0.18	196.3	0.30
2	-15.0	Clay	196.3	0.30	78.0	0.02	104.5	0.03	136.3	0.06	156.1	0.09	169.8	0.12	186.3	0.18	196.3	0.30
3	-18.0	Clay	196.3	0.30	78.0	0.02	104.5	0.03	136.3	0.06	156.1	0.09	169.8	0.12	186.3	0.18	196.3	0.30
4	-23.0	Clay	196.3	0.30	78.0	0.02	104.5	0.03	136.3	0.06	156.1	0.09	169.8	0.12	186.3	0.18	196.3	0.30
5	-28.0	Clay	196.3	0.30	78.0	0.02	104.5	0.03	136.3	0.06	156.1	0.09	169.8	0.12	186.3	0.18	196.3	0.30
6	-33.0	Clay	196.3	0.30	78.0	0.02	104.5	0.03	136.3	0.06	156.1	0.09	169.8	0.12	186.3	0.18	196.3	0.30
7	-38.0	Clay	196.3	0.30	78.0	0.02	104.5	0.03	136.3	0.06	156.1	0.09	169.8	0.12	186.3	0.18	196.3	0.30
8	-43.0	Clay	196.3	0.30	78.0	0.02	104.5	0.03	136.3	0.06	156.1	0.09	169.8	0.12	186.3	0.18	196.3	0.30
9	-48.0	Clay	196.3	0.30	78.0	0.02	104.5	0.03	136.3	0.06	156.1	0.09	169.8	0.12	186.3	0.18	196.3	0.30
10	-53.0	Clay	196.3	0.30	78.0	0.02	104.5	0.03	136.3	0.06	156.1	0.09	169.8	0.12	186.3	0.18	196.3	0.30
11	-58.0	Clay	196.3	0.30	78.0	0.02	104.5	0.03	136.3	0.06	156.1	0.09	169.8	0.12	186.3	0.18	196.3	0.30
12	-63.0	Clay	196.3	0.30	78.0	0.02	104.5	0.03	136.3	0.06	156.1	0.09	169.8	0.12	186.3	0.18	196.3	0.30
13	-68.0	Clay	532.2	0.25	211.3	0.01	283.1	0.025	369.4	0.05	423.1	0.075	460.4	0.1	505.1	0.15	532.2	0.25
14	-72.0	Sand	908.6	0.20	360.7	0.01	483.4	0.02	630.5	0.04	722.3	0.06	785.9	0.08	862.2	0.12	908.6	0.20
15	-77.0	Sand	994.0	0.20	394.6	0.01	528.8	0.02	689.8	0.04	790.2	0.06	859.8	0.08	943.3	0.12	994.0	0.20
16	-82.0	Sand	1083.9	0.20	430.3	0.01	576.6	0.02	752.2	0.04	861.7	0.06	937.6	0.08	1028.6	0.12	1083.9	0.20
17	-87.0	Sand	1255.8	0.20	498.6	0.01	668.1	0.02	871.5	0.04	998.4	0.06	1086.3	0.08	1191.8	0.12	1255.8	0.20
18	-91.0	Sand	1429.4	0.20	567.5	0.01	760.4	0.02	992.0	0.04	1136.4	0.06	1236.4	0.08	1356.5	0.12	1429.4	0.20
19	-95.0	Sand	1522.7	0.20	604.5	0.01	810.1	0.02	1056.7	0.04	1210.5	0.06	1317.1	0.08	1445.0	0.12	1522.7	0.20
20	-99.0	Sand	1615.9	0.20	641.5	0.01	859.7	0.02	1121.4	0.04	1284.6	0.06	1397.8	0.08	1533.5	0.12	1615.9	0.20
21	-103.0	Sand	1709.2	0.20	678.5	0.01	909.3	0.02	1186.2	0.04	1358.8	0.06	1478.4	0.08	1622.0	0.12	1709.2	0.20

q_{max} (kips)	u_c (in)	q_1 (kips)	u_1 (in)	q_2 (kips)	u_2 (in)	q_3 (kips)	u_3 (in)	q_4 (kips)	u_4 (in)
944.4	3.00	425.0	0.30	594.9	0.75	746.0	1.50	944.4	3.00

TABLE B-41: PIER 41 - *t-z* AND *q-u* CURVES

Node #	Elevation (ft)	Soil Type	t_{max} (lb/in)	z_c (in)	t_1 (lb/in)	z_1 (in)	t_2 (lb/in)	z_2 (in)	t_3 (lb/in)	z_3 (in)	t_4 (lb/in)	z_4 (in)	t_5 (lb/in)	z_5 (in)	t_6 (lb/in)	z_6 (in)	t_7 (lb/in)	z_7 (in)
1	-13.0	Clay	116.7	0.14	46.3	0.01	62.1	0.014	81.0	0.028	92.8	0.042	100.9	0.056	110.7	0.084	116.7	0.14
2	-16.0	Clay	116.7	0.14	46.3	0.01	62.1	0.014	81.0	0.028	92.8	0.042	100.9	0.056	110.7	0.084	116.7	0.14
3	-19.0	Clay	116.7	0.14	46.3	0.01	62.1	0.014	81.0	0.028	92.8	0.042	100.9	0.056	110.7	0.084	116.7	0.14
4	-24.0	Clay	116.7	0.14	46.3	0.01	62.1	0.014	81.0	0.028	92.8	0.042	100.9	0.056	110.7	0.084	116.7	0.14
5	-29.0	Clay	116.7	0.14	46.3	0.01	62.1	0.014	81.0	0.028	92.8	0.042	100.9	0.056	110.7	0.084	116.7	0.14
6	-34.0	Clay	116.7	0.14	46.3	0.01	62.1	0.014	81.0	0.028	92.8	0.042	100.9	0.056	110.7	0.084	116.7	0.14
7	-39.0	Clay	116.7	0.14	46.3	0.01	62.1	0.014	81.0	0.028	92.8	0.042	100.9	0.056	110.7	0.084	116.7	0.14
8	-44.0	Clay	116.7	0.14	46.3	0.01	62.1	0.014	81.0	0.028	92.8	0.042	100.9	0.056	110.7	0.084	116.7	0.14
9	-49.0	Clay	116.7	0.14	46.3	0.01	62.1	0.014	81.0	0.028	92.8	0.042	100.9	0.056	110.7	0.084	116.7	0.14
10	-54.0	Clay	116.7	0.14	46.3	0.01	62.1	0.014	81.0	0.028	92.8	0.042	100.9	0.056	110.7	0.084	116.7	0.14
11	-59.0	Clay	116.7	0.14	46.3	0.01	62.1	0.014	81.0	0.028	92.8	0.042	100.9	0.056	110.7	0.084	116.7	0.14
12	-64.0	Clay	116.7	0.14	46.3	0.01	62.1	0.014	81.0	0.028	92.8	0.042	100.9	0.056	110.7	0.084	116.7	0.14
13	-69.0	Clay	342.7	0.17	136.1	0.01	182.3	0.017	237.9	0.034	272.5	0.051	296.5	0.068	325.2	0.102	342.7	0.17
14	-73.0	Sand	590.2	0.20	234.3	0.01	314.0	0.02	409.6	0.04	469.2	0.06	510.5	0.08	560.1	0.12	590.2	0.20
15	-77.0	Sand	632.9	0.20	251.3	0.01	336.7	0.02	439.2	0.04	503.2	0.06	547.5	0.08	600.6	0.12	632.9	0.20
16	-81.0	Sand	675.6	0.20	268.2	0.01	359.4	0.02	468.9	0.04	537.1	0.06	584.4	0.08	641.2	0.12	675.6	0.20
17	-85.0	Sand	774.7	0.20	307.5	0.01	412.1	0.02	537.6	0.04	615.9	0.06	670.1	0.08	735.2	0.12	774.7	0.20
18	-90.0	Sand	887.0	0.20	352.1	0.01	471.9	0.02	615.6	0.04	705.2	0.06	767.3	0.08	841.8	0.12	887.0	0.20
19	-95.0	Sand	956.3	0.20	379.6	0.01	508.7	0.02	663.6	0.04	760.2	0.06	827.2	0.08	907.5	0.12	956.3	0.20

q_{max} (kips)	u_c (in)	q_1 (kips)	u_1 (in)	q_2 (kips)	u_2 (in)	q_3 (kips)	u_3 (in)	q_4 (kips)	u_4 (in)
369.9	1.40	166.4	0.14	233.0	0.35	292.2	0.70	369.9	1.40

TABLE B-42: PIERS 42~46 - *t-z* AND *q-u* CURVES

Node #	Elevation (ft)	Soil Type	t_{max} (lb/in)	z_c (in)	t_1 (lb/in)	z_1 (in)	t_2 (lb/in)	z_2 (in)	t_3 (lb/in)	z_3 (in)	t_4 (lb/in)	z_4 (in)	t_5 (lb/in)	z_5 (in)	t_6 (lb/in)	z_6 (in)	t_7 (lb/in)	z_7 (in)
1	-12.0	Clay	100.0	0.12	39.7	0.01	53.2	0.012	69.4	0.024	79.5	0.036	86.5	0.048	94.9	0.072	100.0	0.12
2	-16.0	Clay	100.0	0.12	39.7	0.01	53.2	0.012	69.4	0.024	79.5	0.036	86.5	0.048	94.9	0.072	100.0	0.12
3	-21.0	Clay	100.0	0.12	39.7	0.01	53.2	0.012	69.4	0.024	79.5	0.036	86.5	0.048	94.9	0.072	100.0	0.12
4	-26.0	Clay	100.0	0.12	39.7	0.01	53.2	0.012	69.4	0.024	79.5	0.036	86.5	0.048	94.9	0.072	100.0	0.12
5	-31.0	Clay	100.0	0.12	39.7	0.01	53.2	0.012	69.4	0.024	79.5	0.036	86.5	0.048	94.9	0.072	100.0	0.12
6	-36.0	Clay	100.0	0.12	39.7	0.01	53.2	0.012	69.4	0.024	79.5	0.036	86.5	0.048	94.9	0.072	100.0	0.12
7	-41.0	Clay	100.0	0.12	39.7	0.01	53.2	0.012	69.4	0.024	79.5	0.036	86.5	0.048	94.9	0.072	100.0	0.12
8	-46.0	Clay	100.0	0.12	39.7	0.01	53.2	0.012	69.4	0.024	79.5	0.036	86.5	0.048	94.9	0.072	100.0	0.12
9	-51.0	Clay	100.0	0.12	39.7	0.01	53.2	0.012	69.4	0.024	79.5	0.036	86.5	0.048	94.9	0.072	100.0	0.12
10	-56.0	Clay	100.0	0.12	39.7	0.01	53.2	0.012	69.4	0.024	79.5	0.036	86.5	0.048	94.9	0.072	100.0	0.12
11	-61.0	Clay	100.0	0.12	39.7	0.01	53.2	0.012	69.4	0.024	79.5	0.036	86.5	0.048	94.9	0.072	100.0	0.12
12	-66.0	Clay	278.6	0.16	110.6	0.01	148.2	0.016	193.4	0.032	221.5	0.048	241.0	0.064	264.4	0.096	278.6	0.16
13	-70.0	Sand	477.9	0.20	189.7	0.01	254.2	0.02	331.6	0.04	379.9	0.06	413.4	0.08	453.5	0.12	477.9	0.20
14	-75.0	Sand	521.4	0.20	207.0	0.01	277.4	0.02	361.8	0.04	414.5	0.06	451.0	0.08	494.8	0.12	521.4	0.20
15	-80.0	Sand	567.2	0.20	225.2	0.01	301.7	0.02	393.6	0.04	450.9	0.06	490.6	0.08	538.2	0.12	567.2	0.20
16	-85.0	Sand	658.7	0.20	261.5	0.01	350.4	0.02	457.2	0.04	523.7	0.06	569.8	0.08	625.1	0.12	658.7	0.20
17	-90.0	Sand	757.1	0.20	300.6	0.01	402.8	0.02	525.4	0.04	601.9	0.06	654.9	0.08	718.5	0.12	757.1	0.20

q_{max} (kips)	u_c (in)	q_1 (kips)	u_1 (in)	q_2 (kips)	u_2 (in)	q_3 (kips)	u_3 (in)	q_4 (kips)	u_4 (in)
251.0	1.20	112.9	0.12	158.1	0.30	198.3	0.60	251.0	1.20

TABLE B-43: PIERS 47~51 - *t-z* AND *q-u* CURVES

Node #	Elevation (ft)	Soil Type	t_{max} (lb/in)	z_c (in)	t_1 (lb/in)	z_1 (in)	t_2 (lb/in)	z_2 (in)	t_3 (lb/in)	z_3 (in)	t_4 (lb/in)	z_4 (in)	t_5 (lb/in)	z_5 (in)	t_6 (lb/in)	z_6 (in)	t_7 (lb/in)	z_7 (in)
1	-12.0	Clay	100.0	0.12	39.7	0.01	53.2	0.012	69.4	0.024	79.5	0.036	86.5	0.048	94.9	0.072	100.0	0.12
2	-15.0	Clay	100.0	0.12	39.7	0.01	53.2	0.012	69.4	0.024	79.5	0.036	86.5	0.048	94.9	0.072	100.0	0.12
3	-18.0	Clay	100.0	0.12	39.7	0.01	53.2	0.012	69.4	0.024	79.5	0.036	86.5	0.048	94.9	0.072	100.0	0.12
4	-23.0	Clay	100.0	0.12	39.7	0.01	53.2	0.012	69.4	0.024	79.5	0.036	86.5	0.048	94.9	0.072	100.0	0.12
5	-28.0	Clay	100.0	0.12	39.7	0.01	53.2	0.012	69.4	0.024	79.5	0.036	86.5	0.048	94.9	0.072	100.0	0.12
6	-33.0	Clay	100.0	0.12	39.7	0.01	53.2	0.012	69.4	0.024	79.5	0.036	86.5	0.048	94.9	0.072	100.0	0.12
7	-38.0	Clay	168.9	0.16	67.1	0.01	89.9	0.016	117.2	0.032	134.3	0.048	146.1	0.064	160.3	0.096	168.9	0.16
8	-42.0	Sand	258.4	0.20	102.6	0.01	137.5	0.02	179.3	0.04	205.4	0.06	223.5	0.08	245.2	0.12	258.4	0.20
9	-47.0	Sand	189.5	0.16	75.2	0.01	100.8	0.016	131.5	0.032	150.7	0.048	163.9	0.064	179.8	0.096	189.5	0.16
10	-51.0	Clay	100.0	0.12	39.7	0.01	53.2	0.012	69.4	0.024	79.5	0.036	86.5	0.048	94.9	0.072	100.0	0.12
11	-55.0	Clay	100.0	0.12	39.7	0.01	53.2	0.012	69.4	0.024	79.5	0.036	86.5	0.048	94.9	0.072	100.0	0.12
12	-59.0	Clay	253.2	0.16	100.5	0.01	134.7	0.016	175.7	0.032	201.3	0.048	219.0	0.064	240.3	0.096	253.2	0.16
13	-62.0	Sand	420.2	0.20	166.8	0.01	223.5	0.02	291.6	0.04	334.0	0.06	363.5	0.08	398.8	0.12	420.2	0.20
14	-65.0	Sand	452.2	0.20	179.5	0.01	240.6	0.02	313.9	0.04	359.5	0.06	391.2	0.08	429.2	0.12	452.2	0.20
15	-70.0	Sand	493.4	0.20	195.9	0.01	262.5	0.02	342.5	0.04	392.3	0.06	426.8	0.08	468.3	0.12	493.4	0.20
16	-75.0	Sand	539.2	0.20	214.1	0.01	286.9	0.02	374.2	0.04	428.7	0.06	466.4	0.08	511.7	0.12	539.2	0.20
17	-80.0	Sand	585.0	0.20	232.3	0.01	311.2	0.02	406.0	0.04	465.1	0.06	506.0	0.08	555.2	0.12	585.0	0.20
18	-85.0	Sand	677.8	0.20	269.1	0.01	360.6	0.02	470.4	0.04	538.9	0.06	586.3	0.08	643.3	0.12	677.8	0.20
19	-90.0	Sand	777.4	0.20	308.6	0.01	413.6	0.02	539.5	0.04	618.1	0.06	672.5	0.08	737.8	0.12	777.4	0.20

q_{max} (kips)	u_c (in)	q_1 (kips)	u_1 (in)	q_2 (kips)	u_2 (in)	q_3 (kips)	u_3 (in)	q_4 (kips)	u_4 (in)
386.6	1.20	174.0	0.12	243.6	0.30	305.4	0.60	386.6	1.20

TABLE B-44: PIERS 52 AND 53 - *t-z* AND *q-u* CURVES

Node #	Elevation (ft)	Soil Type	t_{max} (lb/in)	z_c (in)	t_1 (lb/in)	z_1 (in)	t_2 (lb/in)	z_2 (in)	t_3 (lb/in)	z_3 (in)	t_4 (lb/in)	z_4 (in)	t_5 (lb/in)	z_5 (in)	t_6 (lb/in)	z_6 (in)	t_7 (lb/in)	z_7 (in)
1	-12.0	Clay	100.0	0.12	39.7	0.01	53.2	0.012	69.4	0.024	79.5	0.036	86.5	0.048	94.9	0.072	100.0	0.12
2	-15.0	Clay	100.0	0.12	39.7	0.01	53.2	0.012	69.4	0.024	79.5	0.036	86.5	0.048	94.9	0.072	100.0	0.12
3	-19.0	Clay	100.0	0.12	39.7	0.01	53.2	0.012	69.4	0.024	79.5	0.036	86.5	0.048	94.9	0.072	100.0	0.12
4	-24.0	Clay	100.0	0.12	39.7	0.01	53.2	0.012	69.4	0.024	79.5	0.036	86.5	0.048	94.9	0.072	100.0	0.12
5	-29.0	Clay	100.0	0.12	39.7	0.01	53.2	0.012	69.4	0.024	79.5	0.036	86.5	0.048	94.9	0.072	100.0	0.12
6	-34.0	Clay	100.0	0.12	39.7	0.01	53.2	0.012	69.4	0.024	79.5	0.036	86.5	0.048	94.9	0.072	100.0	0.12
7	-39.0	Clay	100.0	0.12	39.7	0.01	53.2	0.012	69.4	0.024	79.5	0.036	86.5	0.048	94.9	0.072	100.0	0.12
8	-44.0	Clay	100.0	0.12	39.7	0.01	53.2	0.012	69.4	0.024	79.5	0.036	86.5	0.048	94.9	0.072	100.0	0.12
9	-49.0	Clay	209.0	0.16	83.0	0.01	111.2	0.016	145.1	0.032	166.2	0.048	180.8	0.064	198.4	0.096	209.0	0.16
10	-54.0	Sand	340.9	0.20	135.4	0.01	181.4	0.02	236.6	0.04	271.0	0.06	294.9	0.08	323.6	0.12	340.9	0.20
11	-59.0	Sand	386.7	0.20	153.5	0.01	205.7	0.02	268.4	0.04	307.5	0.06	334.5	0.08	367.0	0.12	386.7	0.20
12	-64.0	Sand	432.5	0.20	171.7	0.01	230.1	0.02	300.2	0.04	343.9	0.06	374.1	0.08	410.5	0.12	432.5	0.20
13	-69.0	Sand	478.3	0.20	189.9	0.01	254.5	0.02	331.9	0.04	380.3	0.06	413.7	0.08	453.9	0.12	478.3	0.20
14	-74.0	Sand	524.1	0.20	208.1	0.01	278.8	0.02	363.7	0.04	416.7	0.06	453.3	0.08	497.4	0.12	524.1	0.20
15	-79.0	Sand	572.2	0.20	227.2	0.01	304.4	0.02	397.1	0.04	454.9	0.06	494.9	0.08	543.0	0.12	572.2	0.20
16	-85.0	Sand	624.8	0.20	248.1	0.01	332.4	0.02	433.6	0.04	496.7	0.06	540.5	0.08	593.0	0.12	624.8	0.20

q_{max} (kips)	u_c (in)	q_1 (kips)	u_1 (in)	q_2 (kips)	u_2 (in)	q_3 (kips)	u_3 (in)	q_4 (kips)	u_4 (in)
353.7	1.20	159.2	0.12	222.8	0.30	279.4	0.60	353.7	1.20

TABLE B-45: PIERS 54~56 - *t-z* AND *q-u* CURVES

Node #	Elevation (ft)	Soil Type	t_{max} (lb/in)	z_c (in)	t_1 (lb/in)	z_1 (in)	t_2 (lb/in)	z_2 (in)	t_3 (lb/in)	z_3 (in)	t_4 (lb/in)	z_4 (in)	t_5 (lb/in)	z_5 (in)	t_6 (lb/in)	z_6 (in)	t_7 (lb/in)	z_7 (in)
1	-13.0	Clay	100.0	0.12	39.7	0.01	53.2	0.012	69.4	0.024	79.5	0.036	86.5	0.048	94.9	0.072	100.0	0.12
2	-16.0	Clay	100.0	0.12	39.7	0.01	53.2	0.012	69.4	0.024	79.5	0.036	86.5	0.048	94.9	0.072	100.0	0.12
3	-20.0	Clay	100.0	0.12	39.7	0.01	53.2	0.012	69.4	0.024	79.5	0.036	86.5	0.048	94.9	0.072	100.0	0.12
4	-25.0	Clay	100.0	0.12	39.7	0.01	53.2	0.012	69.4	0.024	79.5	0.036	86.5	0.048	94.9	0.072	100.0	0.12
5	-30.0	Clay	100.0	0.12	39.7	0.01	53.2	0.012	69.4	0.024	79.5	0.036	86.5	0.048	94.9	0.072	100.0	0.12
6	-35.0	Clay	152.3	0.16	60.4	0.01	81.0	0.016	105.7	0.032	121.0	0.048	131.7	0.064	144.5	0.096	152.3	0.16
7	-40.0	Sand	227.4	0.20	90.3	0.01	121.0	0.02	157.8	0.04	180.8	0.06	196.7	0.08	215.8	0.12	227.4	0.20
8	-45.0	Sand	273.2	0.20	108.5	0.01	145.3	0.02	189.6	0.04	217.2	0.06	236.3	0.08	259.3	0.12	273.2	0.20
9	-50.0	Sand	319.0	0.20	126.6	0.01	169.7	0.02	221.4	0.04	253.6	0.06	275.9	0.08	302.7	0.12	319.0	0.20
10	-55.0	Sand	364.8	0.20	144.8	0.01	194.1	0.02	253.2	0.04	290.0	0.06	315.5	0.08	346.2	0.12	364.8	0.20
11	-60.0	Sand	410.6	0.20	163.0	0.01	218.4	0.02	284.9	0.04	326.4	0.06	355.2	0.08	389.6	0.12	410.6	0.20
12	-65.0	Sand	456.4	0.20	181.2	0.01	242.8	0.02	316.7	0.04	362.8	0.06	394.8	0.08	433.1	0.12	456.4	0.20
13	-70.0	Sand	502.2	0.20	199.4	0.01	267.1	0.02	348.5	0.04	399.2	0.06	434.4	0.08	476.5	0.12	502.2	0.20
14	-75.0	Sand	547.9	0.20	217.5	0.01	291.5	0.02	380.3	0.04	435.6	0.06	474.0	0.08	520.0	0.12	547.9	0.20
15	-80.0	Sand	593.7	0.20	235.7	0.01	315.9	0.02	412.1	0.04	472.0	0.06	513.6	0.08	563.5	0.12	593.7	0.20

q_{max} (kips)	u_c (in)	q_1 (kips)	u_1 (in)	q_2 (kips)	u_2 (in)	q_3 (kips)	u_3 (in)	q_4 (kips)	u_4 (in)
261.4	1.20	117.6	0.12	164.7	0.30	206.5	0.60	261.4	1.20

TABLE B-46: PIERS 57 AND 58 - *t-z* AND *q-u* CURVES

Node #	Elevation (ft)	Soil Type	t_{max} (lb/in)	z_c (in)	t_1 (lb/in)	z_1 (in)	t_2 (lb/in)	z_2 (in)	t_3 (lb/in)	z_3 (in)	t_4 (lb/in)	z_4 (in)	t_5 (lb/in)	z_5 (in)	t_6 (lb/in)	z_6 (in)	t_7 (lb/in)	z_7 (in)
1	-13.0	Clay	100.0	0.12	39.7	0.01	53.2	0.012	69.4	0.024	79.5	0.036	86.5	0.048	94.9	0.072	100.0	0.12
2	-16.0	Clay	100.0	0.12	39.7	0.01	53.2	0.012	69.4	0.024	79.5	0.036	86.5	0.048	94.9	0.072	100.0	0.12
3	-20.0	Clay	100.0	0.12	39.7	0.01	53.2	0.012	69.4	0.024	79.5	0.036	86.5	0.048	94.9	0.072	100.0	0.12
4	-24.0	Clay	110.6	0.16	43.9	0.01	58.9	0.016	76.8	0.032	88.0	0.048	95.7	0.064	105.0	0.096	110.6	0.16
5	-29.0	Sand	144.2	0.20	57.2	0.01	76.7	0.02	100.1	0.04	114.6	0.06	124.7	0.08	136.8	0.12	144.2	0.20
6	-34.0	Sand	190.0	0.20	75.4	0.01	101.1	0.02	131.8	0.04	151.0	0.06	164.3	0.08	180.3	0.12	190.0	0.20
7	-39.0	Sand	235.8	0.20	93.6	0.01	125.4	0.02	163.6	0.04	187.4	0.06	203.9	0.08	223.7	0.12	235.8	0.20
8	-44.0	Sand	281.5	0.20	111.8	0.01	149.8	0.02	195.4	0.04	223.8	0.06	243.5	0.08	267.2	0.12	281.5	0.20
9	-49.0	Sand	327.3	0.20	130.0	0.01	174.1	0.02	227.2	0.04	260.2	0.06	283.1	0.08	310.6	0.12	327.3	0.20
10	-54.0	Sand	373.1	0.20	148.1	0.01	198.5	0.02	258.9	0.04	296.6	0.06	322.8	0.08	354.1	0.12	373.1	0.20
11	-59.0	Sand	418.9	0.20	166.3	0.01	222.9	0.02	290.7	0.04	333.0	0.06	362.4	0.08	397.5	0.12	418.9	0.20
12	-64.0	Sand	464.7	0.20	184.5	0.01	247.2	0.02	322.5	0.04	369.4	0.06	402.0	0.08	441.0	0.12	464.7	0.20
13	-69.0	Sand	512.8	0.20	203.6	0.01	272.8	0.02	355.9	0.04	407.7	0.06	443.6	0.08	486.6	0.12	512.8	0.20
14	-75.0	Sand	319.0	0.16	126.6	0.01	169.7	0.016	221.4	0.032	253.6	0.048	275.9	0.064	302.7	0.096	319.0	0.16
15	-80.0	Clay	100.0	0.12	39.7	0.01	53.2	0.012	69.4	0.024	79.5	0.036	86.5	0.048	94.9	0.072	100.0	0.12

q_{max} (kips)	u_c (in)	q_1 (kips)	u_1 (in)	q_2 (kips)	u_2 (in)	q_3 (kips)	u_3 (in)	q_4 (kips)	u_4 (in)
341.5	1.20	153.7	0.12	215.1	0.30	269.8	0.60	341.5	1.20

TABLE B-48: PIERS 59~62 - *t-z* AND *q-u* CURVES

Node #	Elevation (ft)	Soil Type	t_{max} (lb/in)	z_c (in)	t_1 (lb/in)	z_1 (in)	t_2 (lb/in)	z_2 (in)	t_3 (lb/in)	z_3 (in)	t_4 (lb/in)	z_4 (in)	t_5 (lb/in)	z_5 (in)	t_6 (lb/in)	z_6 (in)	t_7 (lb/in)	z_7 (in)
1	-13.0	Clay	100.0	0.12	39.7	0.01	53.2	0.012	69.4	0.024	79.5	0.036	86.5	0.048	94.9	0.072	100.0	0.12
2	-16.0	Clay	100.0	0.12	39.7	0.01	53.2	0.012	69.4	0.024	79.5	0.036	86.5	0.048	94.9	0.072	100.0	0.12
3	-20.0	Clay	100.0	0.12	39.7	0.01	53.2	0.012	69.4	0.024	79.5	0.036	86.5	0.048	94.9	0.072	100.0	0.12
4	-24.0	Clay	104.6	0.16	41.5	0.01	55.6	0.016	72.6	0.032	83.1	0.048	90.4	0.064	99.2	0.096	104.6	0.16
5	-28.0	Sand	129.7	0.20	51.5	0.01	69.0	0.02	90.0	0.04	103.1	0.06	112.2	0.08	123.1	0.12	129.7	0.20
6	-33.0	Sand	173.2	0.20	68.8	0.01	92.2	0.02	120.2	0.04	137.7	0.06	149.9	0.08	164.4	0.12	173.2	0.20
7	-38.0	Sand	219.0	0.20	87.0	0.01	116.5	0.02	152.0	0.04	174.1	0.06	189.5	0.08	207.9	0.12	219.0	0.20
8	-43.0	Sand	264.8	0.20	105.1	0.01	140.9	0.02	183.8	0.04	210.5	0.06	229.1	0.08	251.3	0.12	264.8	0.20
9	-48.0	Sand	310.6	0.20	123.3	0.01	165.2	0.02	215.6	0.04	246.9	0.06	268.7	0.08	294.8	0.12	310.6	0.20
10	-53.0	Sand	356.4	0.20	141.5	0.01	189.6	0.02	247.3	0.04	283.3	0.06	308.3	0.08	338.2	0.12	356.4	0.20
11	-58.0	Sand	402.2	0.20	159.7	0.01	214.0	0.02	279.1	0.04	319.7	0.06	347.9	0.08	381.7	0.12	402.2	0.20
12	-63.0	Sand	448.0	0.20	177.8	0.01	238.3	0.02	310.9	0.04	356.1	0.06	387.5	0.08	425.1	0.12	448.0	0.20
13	-68.0	Sand	493.8	0.20	196.0	0.01	262.7	0.02	342.7	0.04	392.5	0.06	427.1	0.08	468.6	0.12	493.8	0.20
14	-73.0	Sand	539.6	0.20	214.2	0.01	287.0	0.02	374.5	0.04	428.9	0.06	466.7	0.08	512.0	0.12	539.6	0.20
15	-78.0	Sand	620.3	0.20	246.3	0.01	330.0	0.02	430.5	0.04	493.2	0.06	536.6	0.08	588.7	0.12	620.3	0.20
16	-80.0	Sand	690.1	0.20	274.0	0.01	367.1	0.02	478.9	0.04	548.6	0.06	596.9	0.08	654.9	0.12	690.1	0.20

q_{max} (kips)	u_c (in)	q_1 (kips)	u_1 (in)	q_2 (kips)	u_2 (in)	q_3 (kips)	u_3 (in)	q_4 (kips)	u_4 (in)
343.2	1.20	154.4	0.12	216.2	0.30	271.1	0.60	343.2	1.20

TABLE B-48: PIERS 63~67 - *t-z* AND *q-u* CURVES

Node #	Elevation (ft)	Soil Type	t_{max} (lb/in)	z_c (in)	t_1 (lb/in)	z_1 (in)	t_2 (lb/in)	z_2 (in)	t_3 (lb/in)	z_3 (in)	t_4 (lb/in)	z_4 (in)	t_5 (lb/in)	z_5 (in)	t_6 (lb/in)	z_6 (in)	t_7 (lb/in)	z_7 (in)
1	-15.0	Clay	100.0	0.12	39.7	0.01	53.2	0.012	69.4	0.024	79.5	0.036	86.5	0.048	94.9	0.072	100.0	0.12
2	-20.0	Clay	100.0	0.12	39.7	0.01	53.2	0.012	69.4	0.024	79.5	0.036	86.5	0.048	94.9	0.072	100.0	0.12
3	-25.0	Clay	102.3	0.16	40.6	0.01	54.4	0.016	71.0	0.032	81.3	0.048	88.5	0.064	97.1	0.096	102.3	0.16
4	-28.0	Sand	120.6	0.20	47.9	0.01	64.1	0.02	83.7	0.04	95.9	0.06	104.3	0.08	114.4	0.12	120.6	0.20
5	-32.0	Sand	157.2	0.20	62.4	0.01	83.6	0.02	109.1	0.04	125.0	0.06	136.0	0.08	149.2	0.12	157.2	0.20
6	-37.0	Sand	200.7	0.20	79.7	0.01	106.8	0.02	139.3	0.04	159.6	0.06	173.6	0.08	190.5	0.12	200.7	0.20
7	-42.0	Sand	246.5	0.20	97.9	0.01	131.1	0.02	171.1	0.04	196.0	0.06	213.2	0.08	233.9	0.12	246.5	0.20
8	-47.0	Sand	292.3	0.20	116.0	0.01	155.5	0.02	202.8	0.04	232.4	0.06	252.8	0.08	277.4	0.12	292.3	0.20
9	-52.0	Sand	338.1	0.20	134.2	0.01	179.9	0.02	234.6	0.04	268.8	0.06	292.4	0.08	320.8	0.12	338.1	0.20
10	-57.0	Sand	383.9	0.20	152.4	0.01	204.2	0.02	266.4	0.04	305.2	0.06	332.0	0.08	364.3	0.12	383.9	0.20
11	-62.0	Sand	429.7	0.20	170.6	0.01	228.6	0.02	298.2	0.04	341.6	0.06	371.7	0.08	407.7	0.12	429.7	0.20
12	-67.0	Sand	475.4	0.20	188.8	0.01	252.9	0.02	330.0	0.04	378.0	0.06	411.3	0.08	451.2	0.12	475.4	0.20
13	-72.0	Sand	521.2	0.20	206.9	0.01	277.3	0.02	361.7	0.04	414.4	0.06	450.9	0.08	494.7	0.12	521.2	0.20
14	-77.0	Sand	603.7	0.20	239.7	0.01	321.2	0.02	419.0	0.04	479.9	0.06	522.2	0.08	572.9	0.12	603.7	0.20
15	-80.0	Sand	681.1	0.20	270.4	0.01	362.3	0.02	472.7	0.04	541.5	0.06	589.1	0.08	646.3	0.12	681.1	0.20

q_{max} (kips)	u_c (in)	q_1 (kips)	u_1 (in)	q_2 (kips)	u_2 (in)	q_3 (kips)	u_3 (in)	q_4 (kips)	u_4 (in)
338.7	1.20	152.4	0.12	213.4	0.30	267.6	0.60	338.7	1.20

TABLE B-49: PIERS 68~70 - *t-z* AND *q-u* CURVES

Node #	Elevation (ft)	Soil Type	t_{max} (lb/in)	z_c (in)	t_1 (lb/in)	z_1 (in)	t_2 (lb/in)	z_2 (in)	t_3 (lb/in)	z_3 (in)	t_4 (lb/in)	z_4 (in)	t_5 (lb/in)	z_5 (in)	t_6 (lb/in)	z_6 (in)	t_7 (lb/in)	z_7 (in)
1	-15.0	Clay	100.0	0.12	39.7	0.01	53.2	0.012	69.4	0.024	79.5	0.036	86.5	0.048	94.9	0.072	100.0	0.12
2	-19.0	Clay	100.0	0.12	39.7	0.01	53.2	0.012	69.4	0.024	79.5	0.036	86.5	0.048	94.9	0.072	100.0	0.12
3	-24.0	Clay	106.9	0.16	42.4	0.01	56.8	0.016	74.2	0.032	85.0	0.048	92.4	0.064	101.4	0.096	106.9	0.16
4	-29.0	Sand	136.6	0.20	54.2	0.01	72.7	0.02	94.8	0.04	108.6	0.06	118.2	0.08	129.6	0.12	136.6	0.20
5	-34.0	Sand	182.4	0.20	72.4	0.01	97.0	0.02	126.6	0.04	145.0	0.06	157.8	0.08	173.1	0.12	182.4	0.20
6	-39.0	Sand	228.2	0.20	90.6	0.01	121.4	0.02	158.4	0.04	181.4	0.06	197.4	0.08	216.5	0.12	228.2	0.20
7	-44.0	Sand	274.0	0.20	108.8	0.01	145.8	0.02	190.1	0.04	217.8	0.06	237.0	0.08	260.0	0.12	274.0	0.20
8	-49.0	Sand	319.8	0.20	126.9	0.01	170.1	0.02	221.9	0.04	254.2	0.06	276.6	0.08	303.5	0.12	319.8	0.20
9	-54.0	Sand	365.6	0.20	145.1	0.01	194.5	0.02	253.7	0.04	290.6	0.06	316.2	0.08	346.9	0.12	365.6	0.20
10	-59.0	Sand	411.3	0.20	163.3	0.01	218.8	0.02	285.5	0.04	327.0	0.06	355.8	0.08	390.4	0.12	411.3	0.20
11	-64.0	Sand	457.1	0.20	181.5	0.01	243.2	0.02	317.3	0.04	363.4	0.06	395.4	0.08	433.8	0.12	457.1	0.20
12	-69.0	Sand	502.9	0.20	199.7	0.01	267.6	0.02	349.0	0.04	399.8	0.06	435.0	0.08	477.3	0.12	502.9	0.20
13	-74.0	Sand	551.0	0.20	218.7	0.01	293.1	0.02	382.4	0.04	438.0	0.06	476.6	0.08	522.9	0.12	551.0	0.20
14	-80.0	Sand	603.7	0.20	239.7	0.01	321.1	0.02	418.9	0.04	479.9	0.06	522.2	0.08	572.9	0.12	603.7	0.20

q_{max} (kips)	u_c (in)	q_1 (kips)	u_1 (in)	q_2 (kips)	u_2 (in)	q_3 (kips)	u_3 (in)	q_4 (kips)	u_4 (in)
341.7	1.20	153.8	0.12	215.3	0.30	270.0	0.60	341.7	1.20

TABLE B-50: ABUTMENT 71 - *t-z* AND *q-u* CURVES

Node #	Elevation (ft)	Soil Type	t_{max} (lb/in)	z_c (in)	t_1 (lb/in)	z_1 (in)	t_2 (lb/in)	z_2 (in)	t_3 (lb/in)	z_3 (in)	t_4 (lb/in)	z_4 (in)	t_5 (lb/in)	z_5 (in)	t_6 (lb/in)	z_6 (in)	t_7 (lb/in)	z_7 (in)
1	-8.0	Sand	35.3	0.20	14.0	0.01	18.8	0.02	24.5	0.04	28.1	0.06	30.6	0.08	33.5	0.12	35.3	0.20
2	-12.0	Sand	74.7	0.16	29.7	0.01	39.8	0.016	51.9	0.032	59.4	0.048	64.6	0.064	70.9	0.096	74.7	0.16
3	-16.0	Clay	100.0	0.12	39.7	0.01	53.2	0.012	69.4	0.024	79.5	0.036	86.5	0.048	94.9	0.072	100.0	0.12
4	-20.0	Clay	100.0	0.12	39.7	0.01	53.2	0.012	69.4	0.024	79.5	0.036	86.5	0.048	94.9	0.072	100.0	0.12
5	-24.0	Clay	140.9	0.16	55.9	0.01	75.0	0.016	97.8	0.032	112.0	0.048	121.9	0.064	133.7	0.096	140.9	0.16
6	-29.0	Sand	204.7	0.20	81.3	0.01	108.9	0.02	142.1	0.04	162.8	0.06	177.1	0.08	194.3	0.12	204.7	0.20
7	-34.0	Sand	250.5	0.20	99.5	0.01	133.3	0.02	173.9	0.04	199.2	0.06	216.7	0.08	237.7	0.12	250.5	0.20
8	-39.0	Sand	296.3	0.20	117.6	0.01	157.6	0.02	205.6	0.04	235.6	0.06	256.3	0.08	281.2	0.12	296.3	0.20
9	-44.0	Sand	342.1	0.20	135.8	0.01	182.0	0.02	237.4	0.04	272.0	0.06	295.9	0.08	324.6	0.12	342.1	0.20
10	-49.0	Sand	387.9	0.20	154.0	0.01	206.4	0.02	269.2	0.04	308.4	0.06	335.5	0.08	368.1	0.12	387.9	0.20
11	-54.0	Sand	433.7	0.20	172.2	0.01	230.7	0.02	301.0	0.04	344.8	0.06	375.1	0.08	411.5	0.12	433.7	0.20
12	-59.0	Sand	479.5	0.20	190.3	0.01	255.1	0.02	332.7	0.04	381.2	0.06	414.7	0.08	455.0	0.12	479.5	0.20
13	-64.0	Sand	525.2	0.20	208.5	0.01	279.4	0.02	364.5	0.04	417.6	0.06	454.3	0.08	498.5	0.12	525.2	0.20
14	-69.0	Sand	571.0	0.20	226.7	0.01	303.8	0.02	396.3	0.04	454.0	0.06	493.9	0.08	541.9	0.12	571.0	0.20
15	-74.0	Sand	619.1	0.20	245.8	0.01	329.4	0.02	429.7	0.04	492.2	0.06	535.5	0.08	587.5	0.12	619.1	0.20
16	-80.0	Sand	671.8	0.20	266.7	0.01	357.4	0.02	466.2	0.04	534.1	0.06	581.1	0.08	637.5	0.12	671.8	0.20

q_{max} (kips)	u_c (in)	q_1 (kips)	u_1 (in)	q_2 (kips)	u_2 (in)	q_3 (kips)	u_3 (in)	q_4 (kips)	u_4 (in)
380.3	1.20	171.1	0.12	239.6	0.30	300.4	0.60	380.3	1.20

10.0 APPENDIX C: Q-δ CURVES

FIGURE C-1: ABUTMENT 1 - Q-δ CURVES

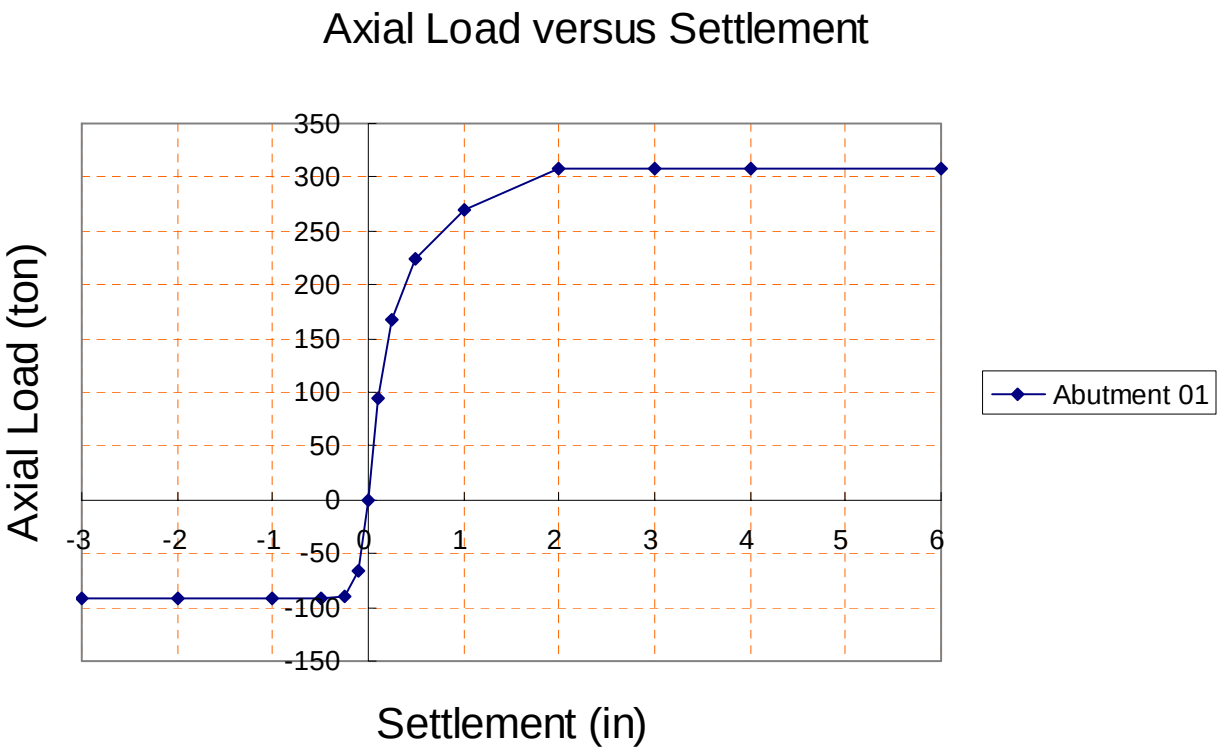


FIGURE C-2: PIER 2 - Q-δ CURVES

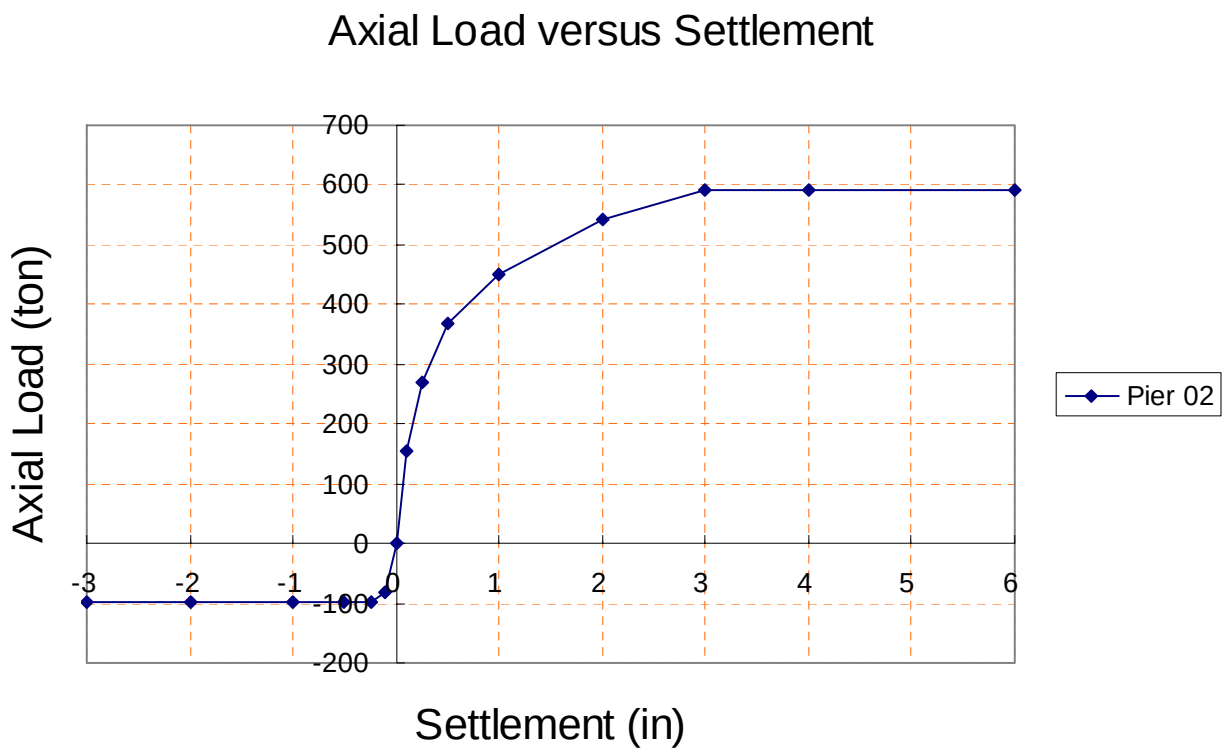


FIGURE C-3: PIER 3 - Q-δ CURVES

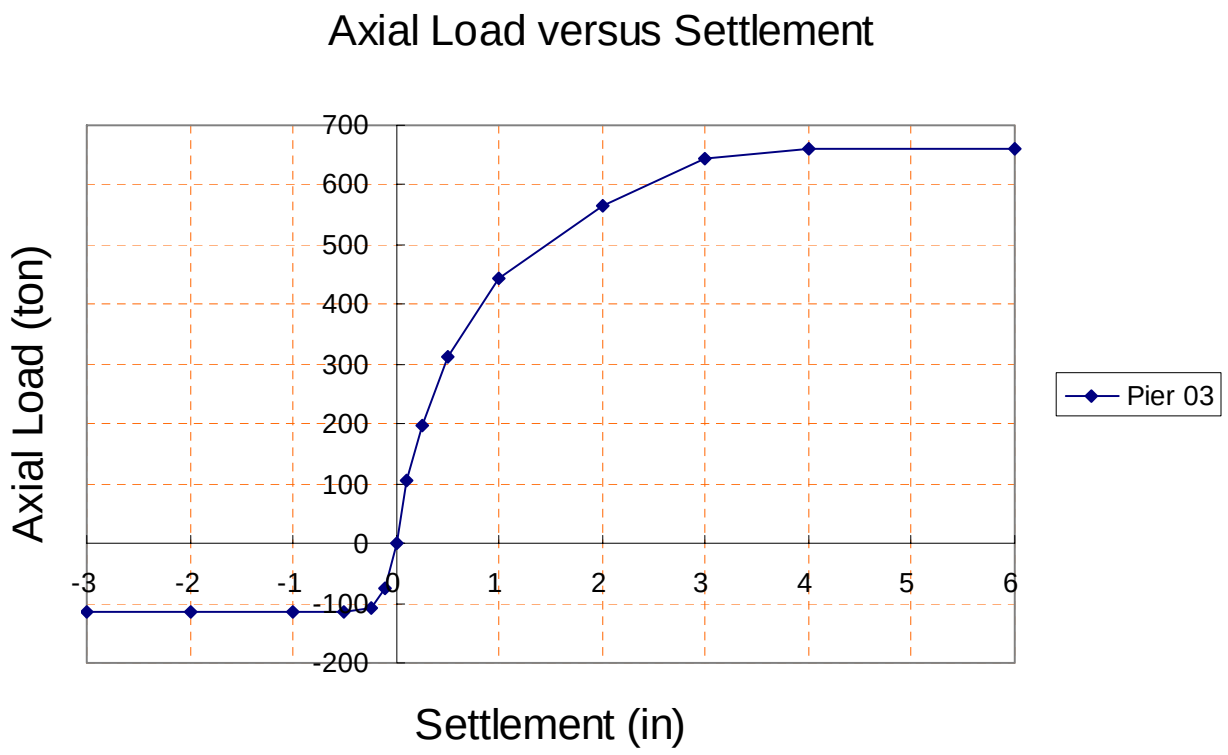


FIGURE C-4: PIER 4 - Q-δ CURVES

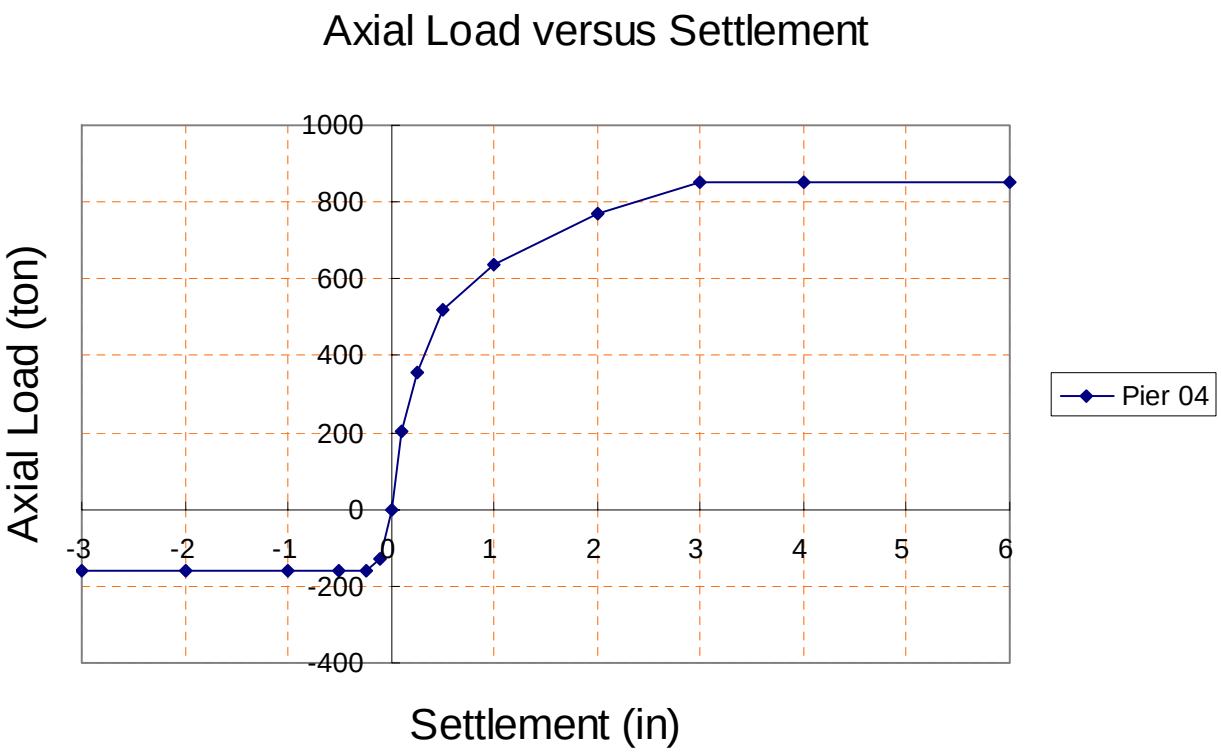


FIGURE C-5: PIER 5 - Q-δ CURVES

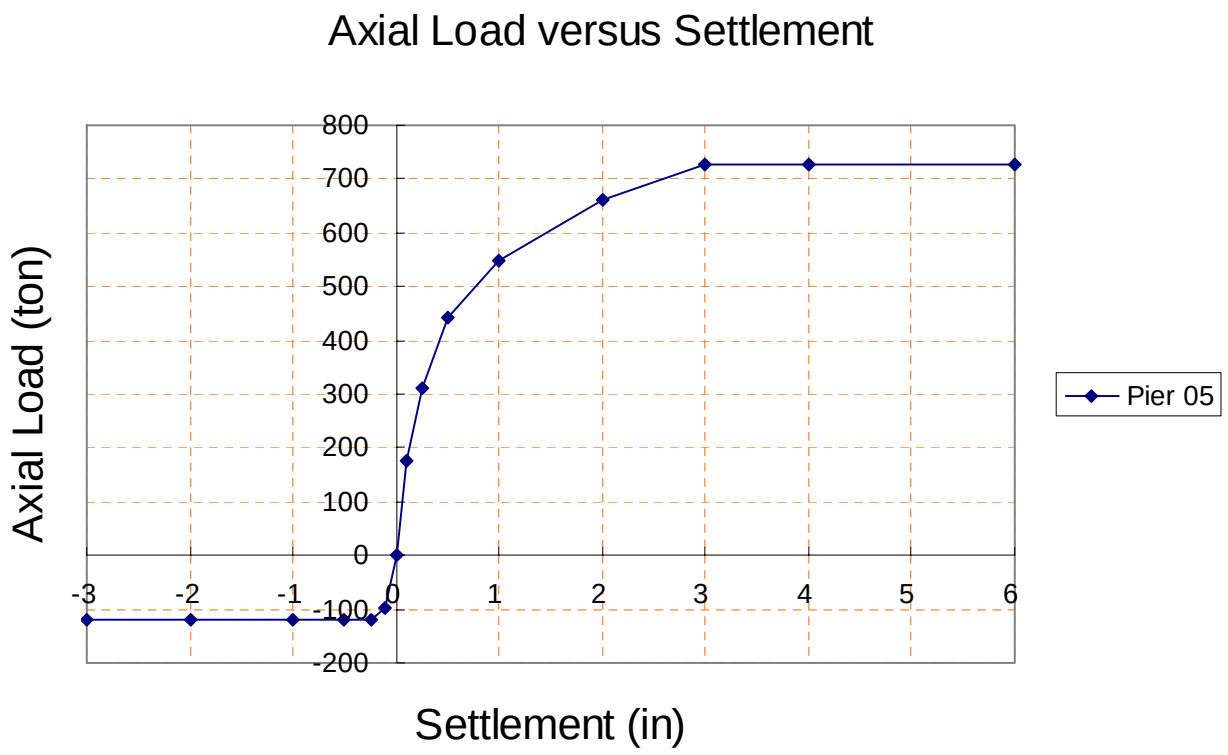


FIGURE C-6: PIER 6 - Q-δ CURVES

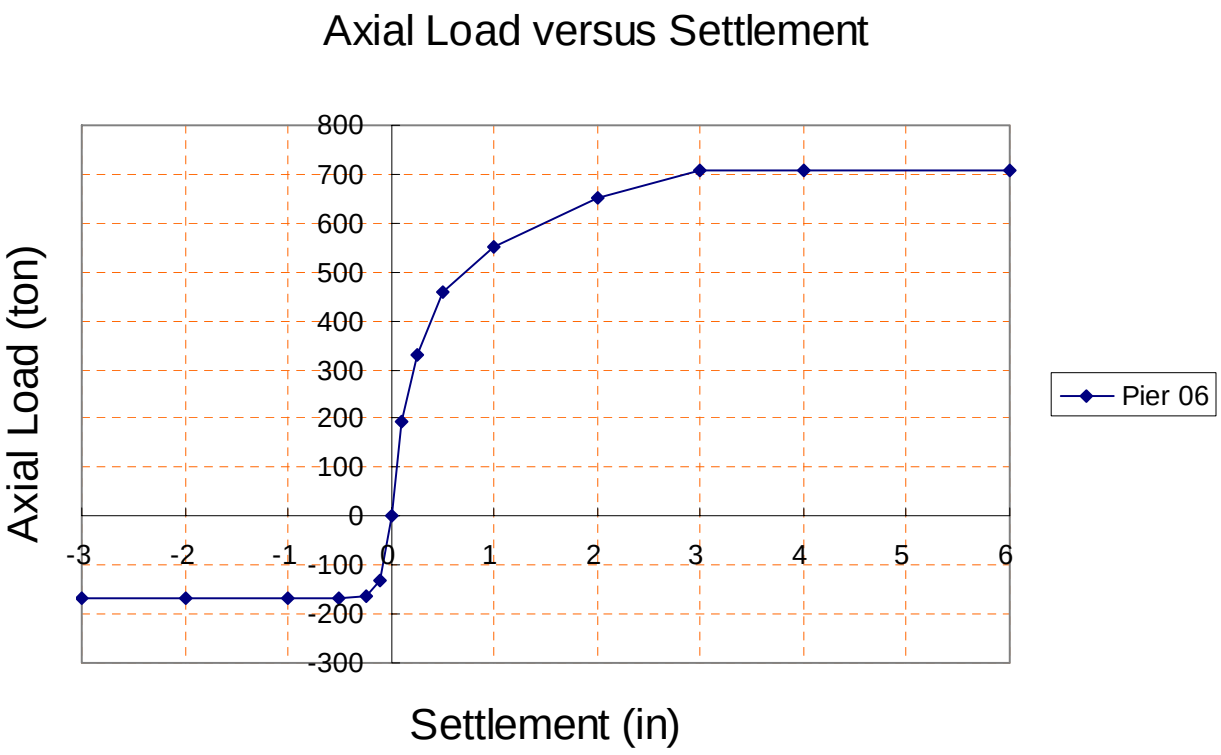


FIGURE C-7: PIER 7 - Q-δ CURVES

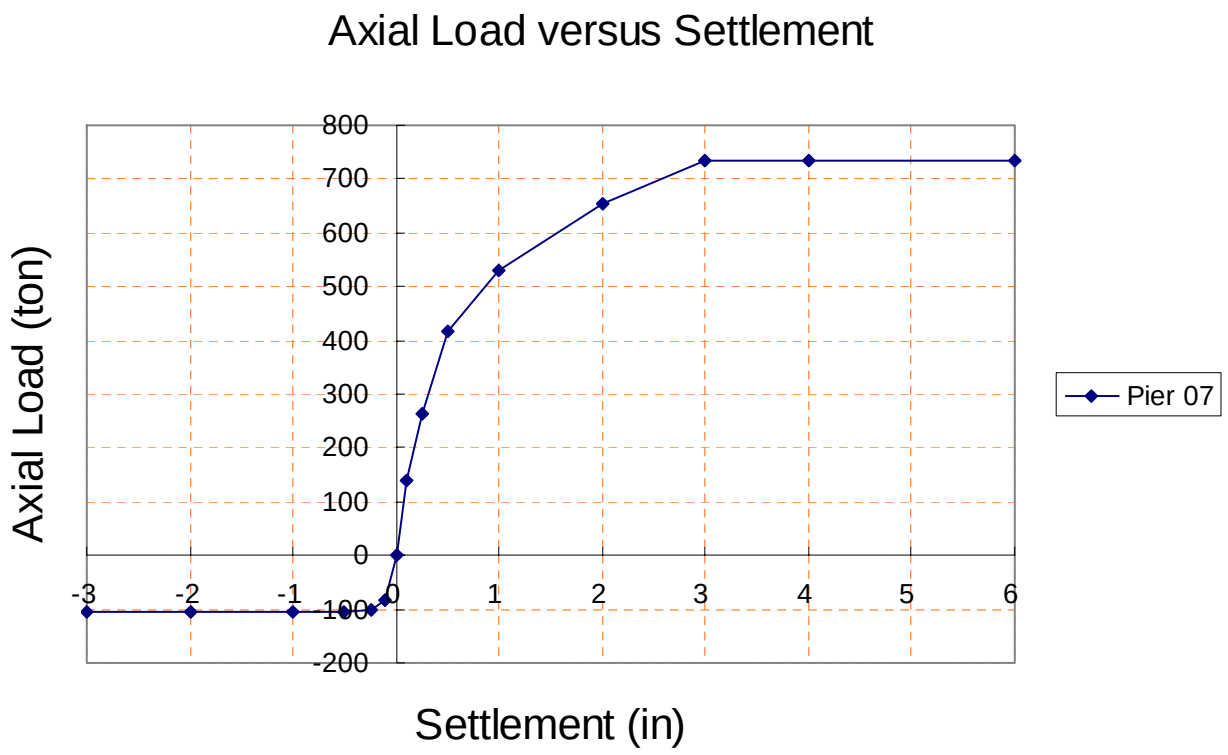


FIGURE C-8: PIER 8 - Q-δ CURVES

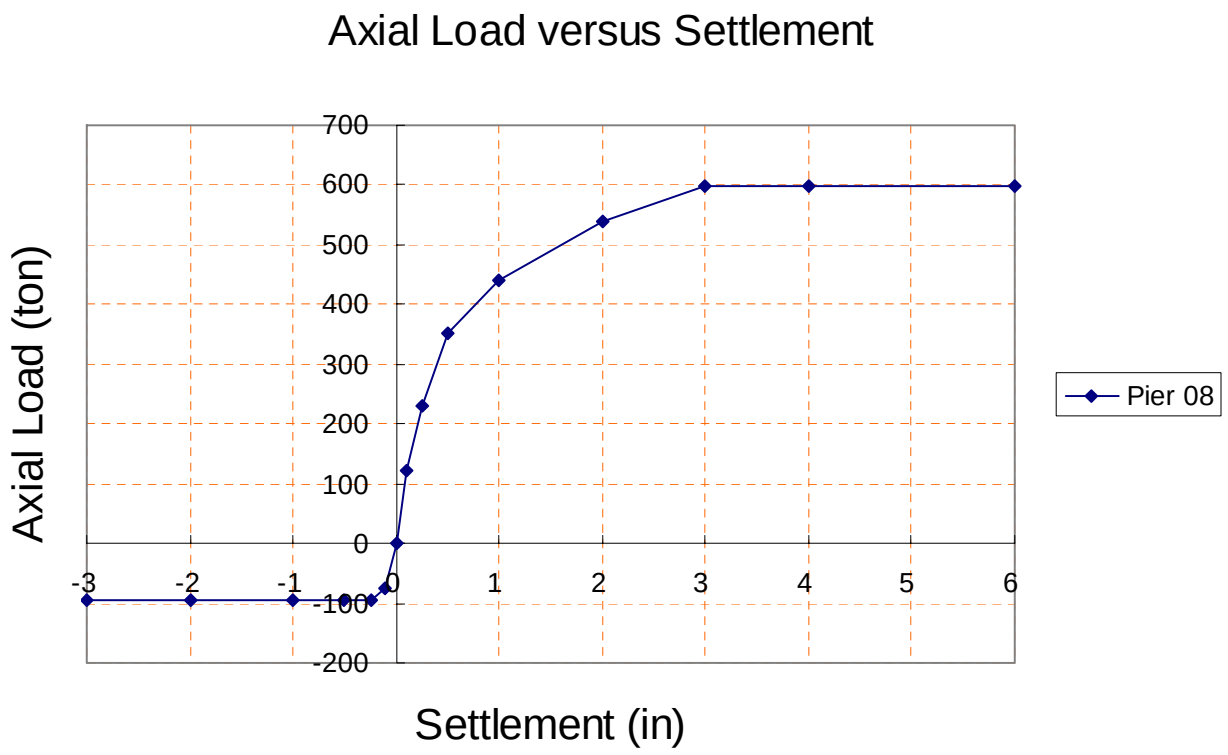


FIGURE C-9: PIER 9 - Q-δ CURVES

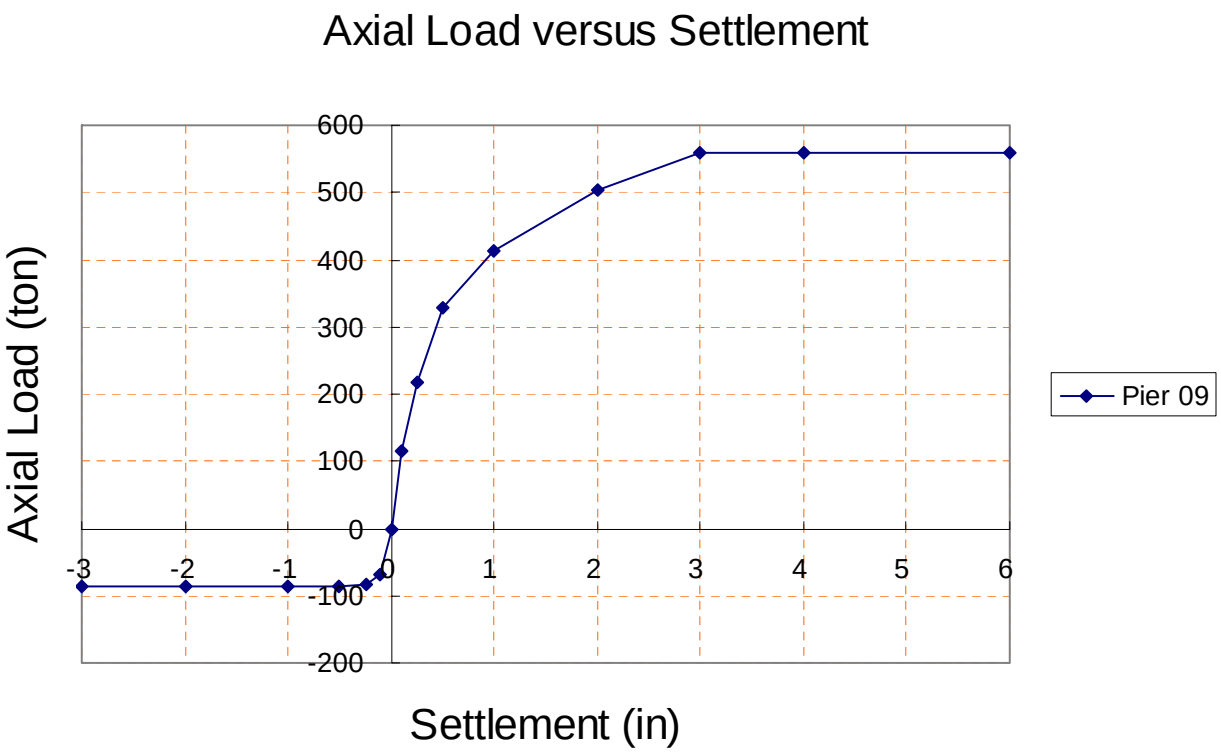


FIGURE C-10: PIER 10 - Q-δ CURVES

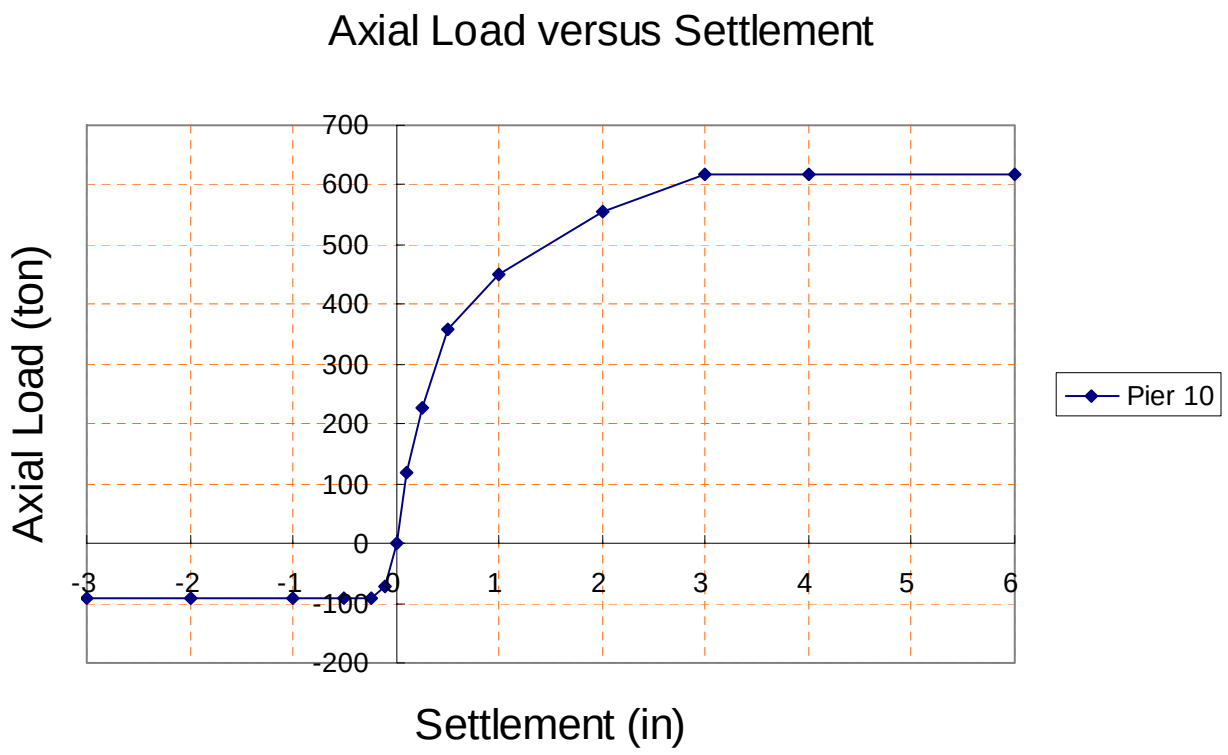


FIGURE C-11: PIER 11 - Q-δ CURVES

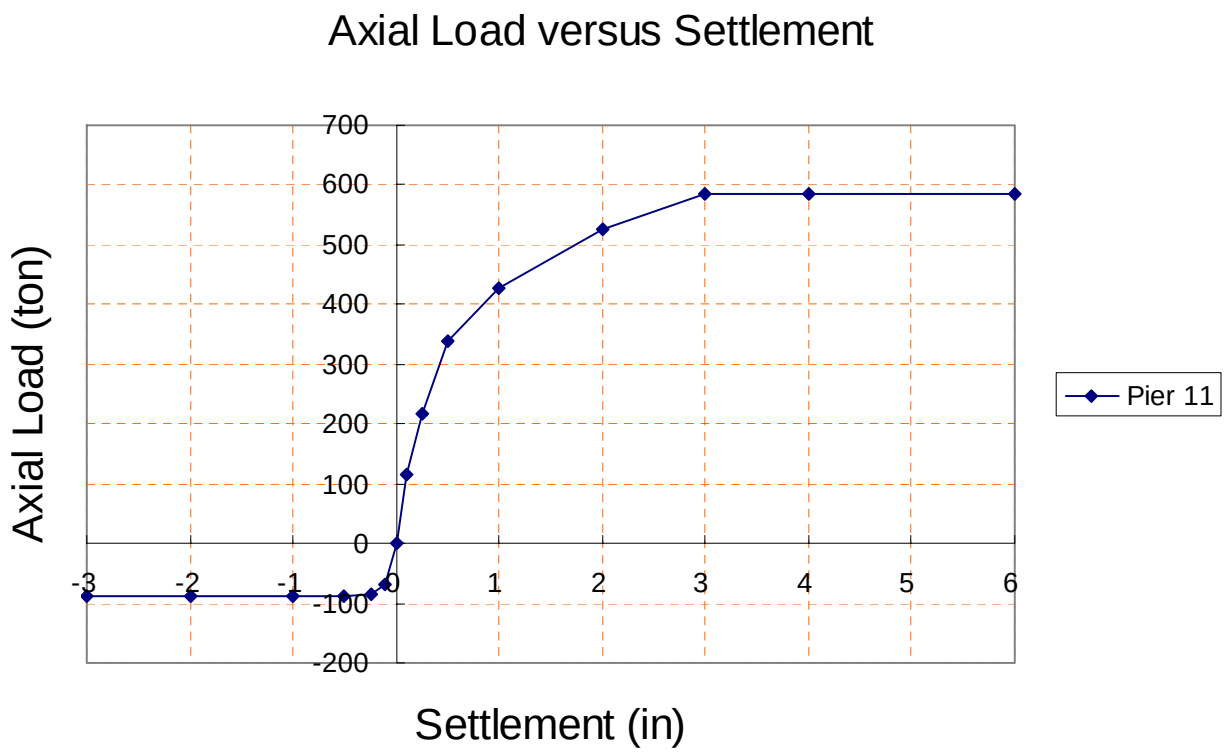


FIGURE C-12: PIER 12 - Q-δ CURVES

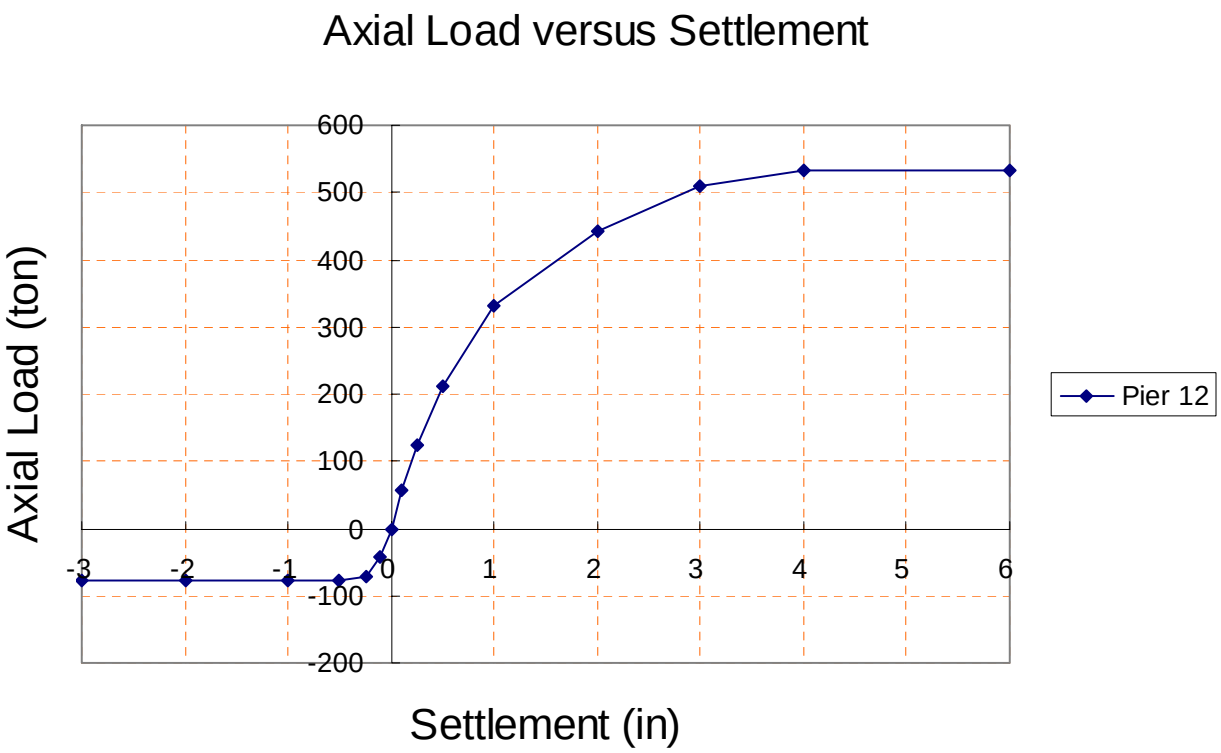


FIGURE C-13: PIER 13 - Q-δ CURVES

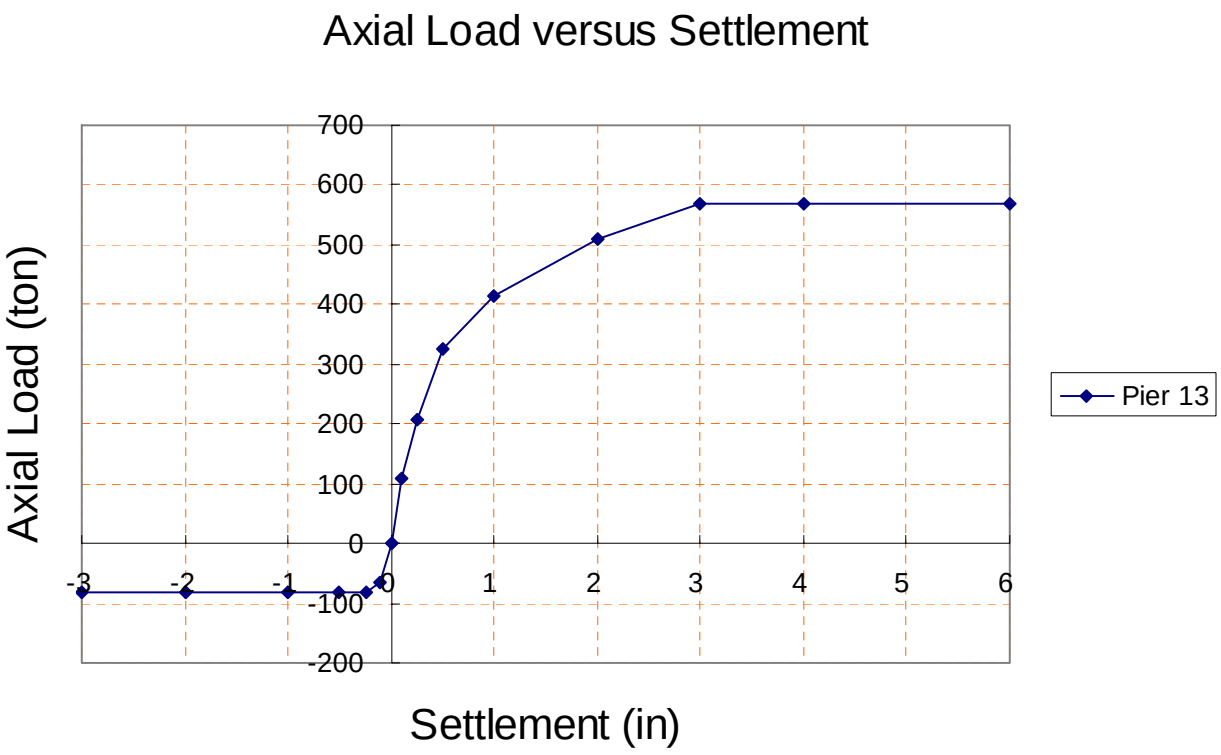


FIGURE C-14: PIER 14 - Q-δ CURVES

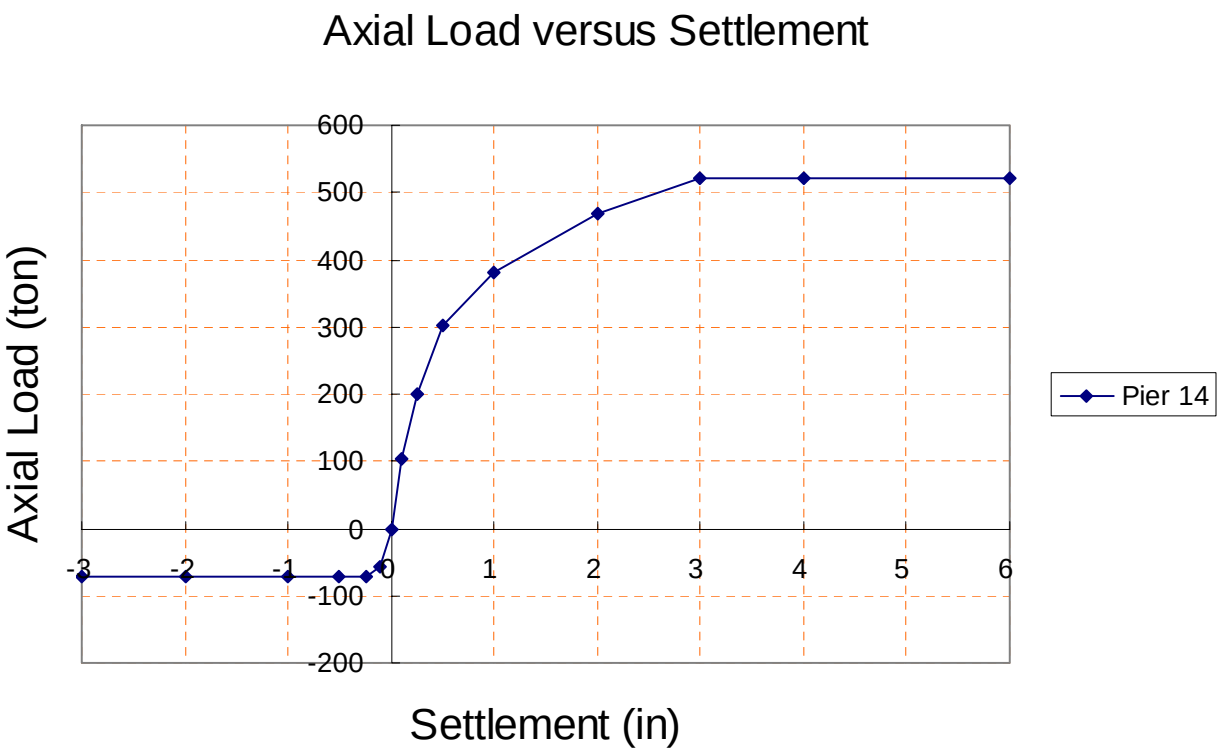


FIGURE C-15: PIER 15 - Q-δ CURVES

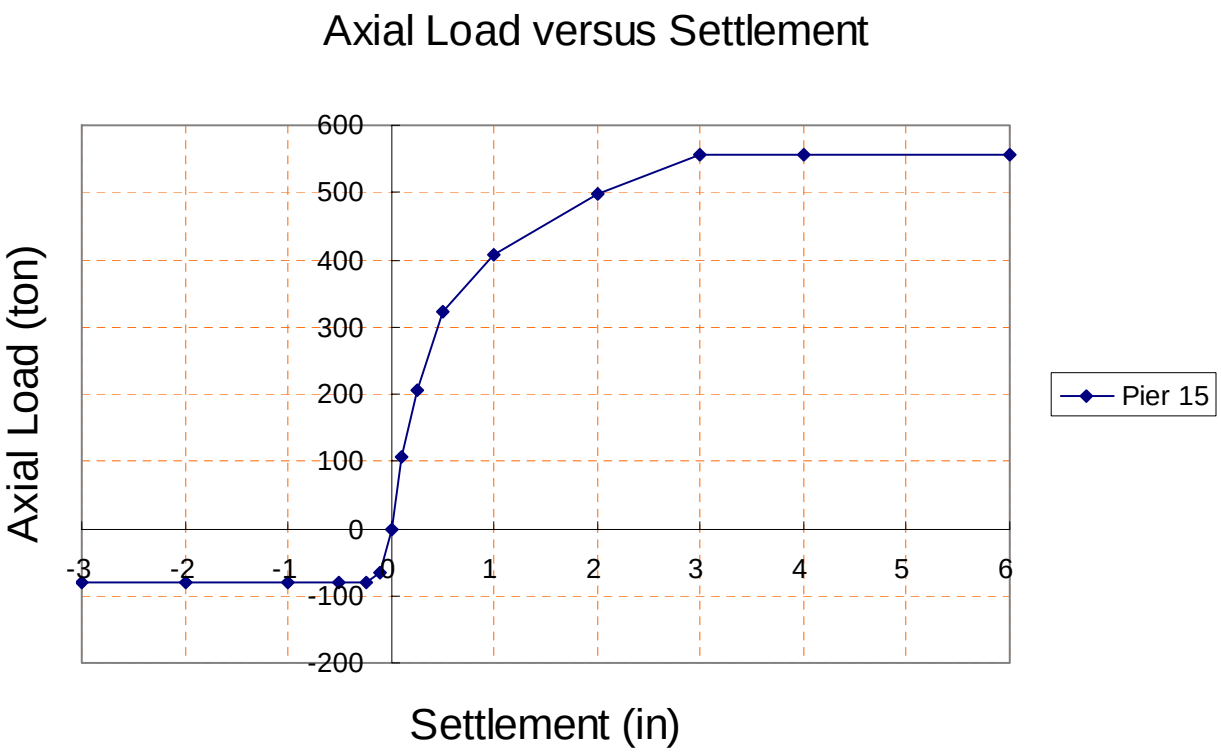


FIGURE C-16: PIER 16 - Q-δ CURVES

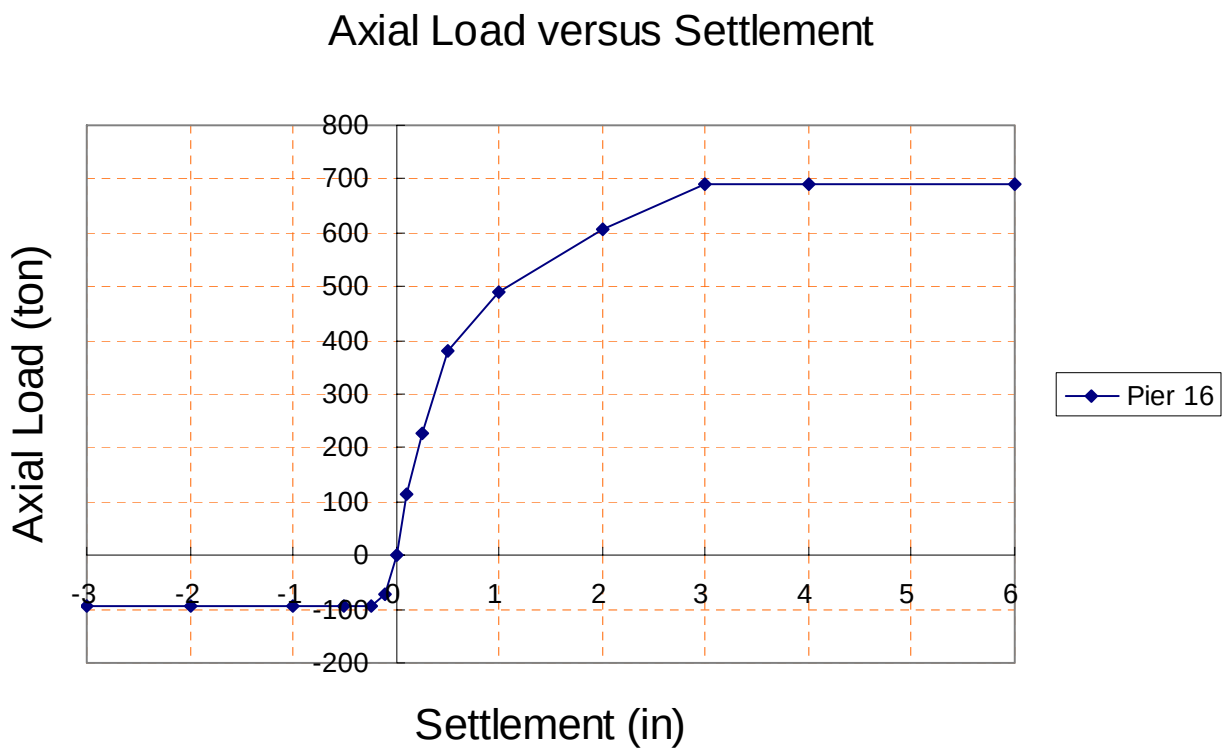


FIGURE C-17: PIER 17 - Q-δ CURVES

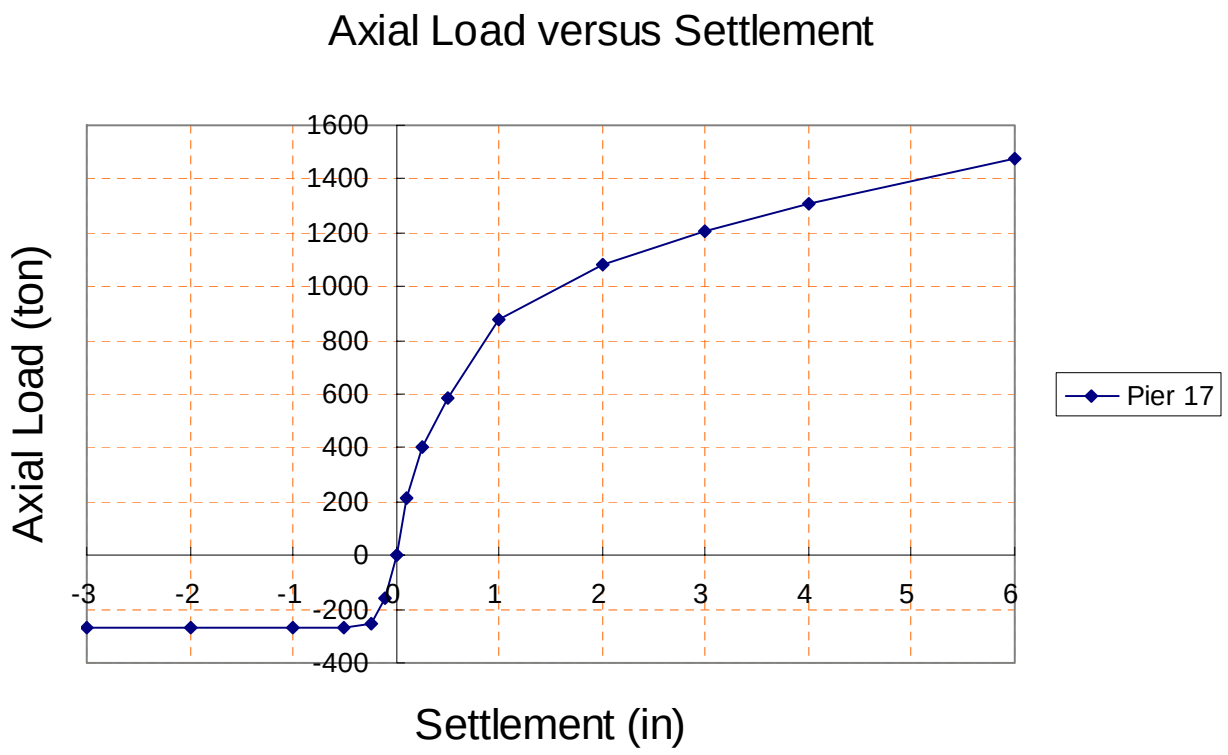


FIGURE C-18: PIER 18 - Q-δ CURVES

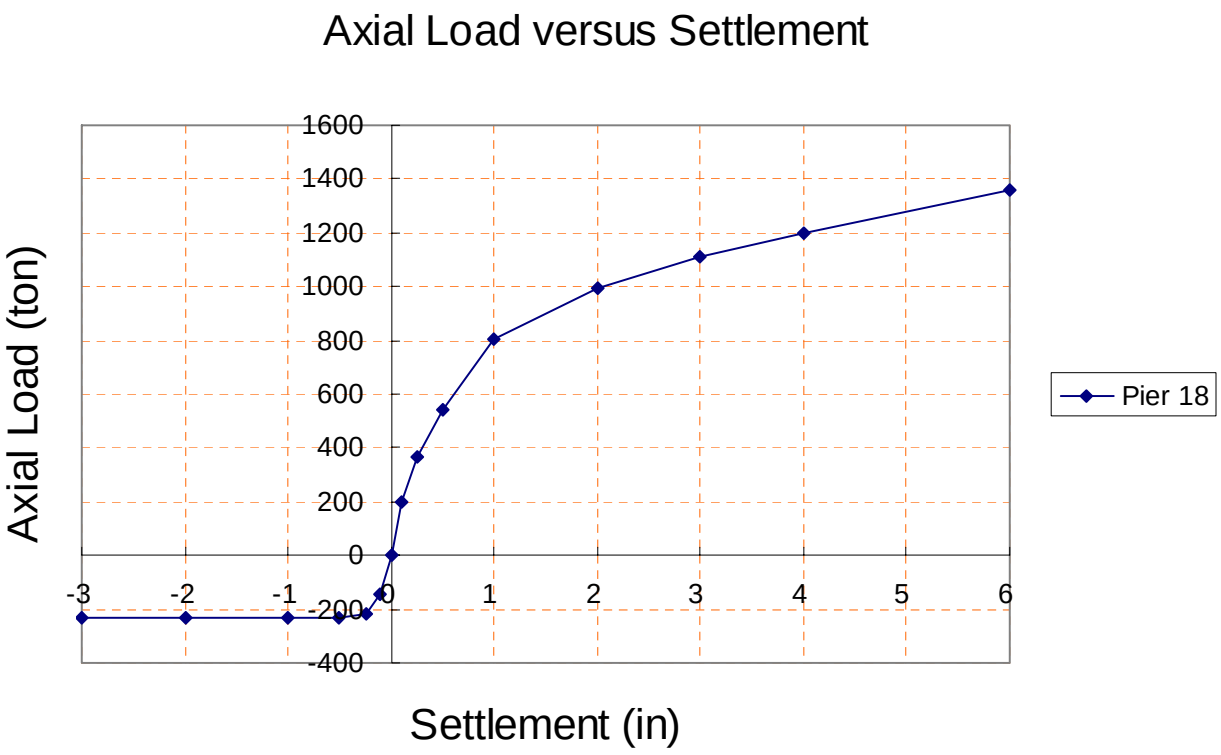


FIGURE C-19: PIER 19 - Q-δ CURVES

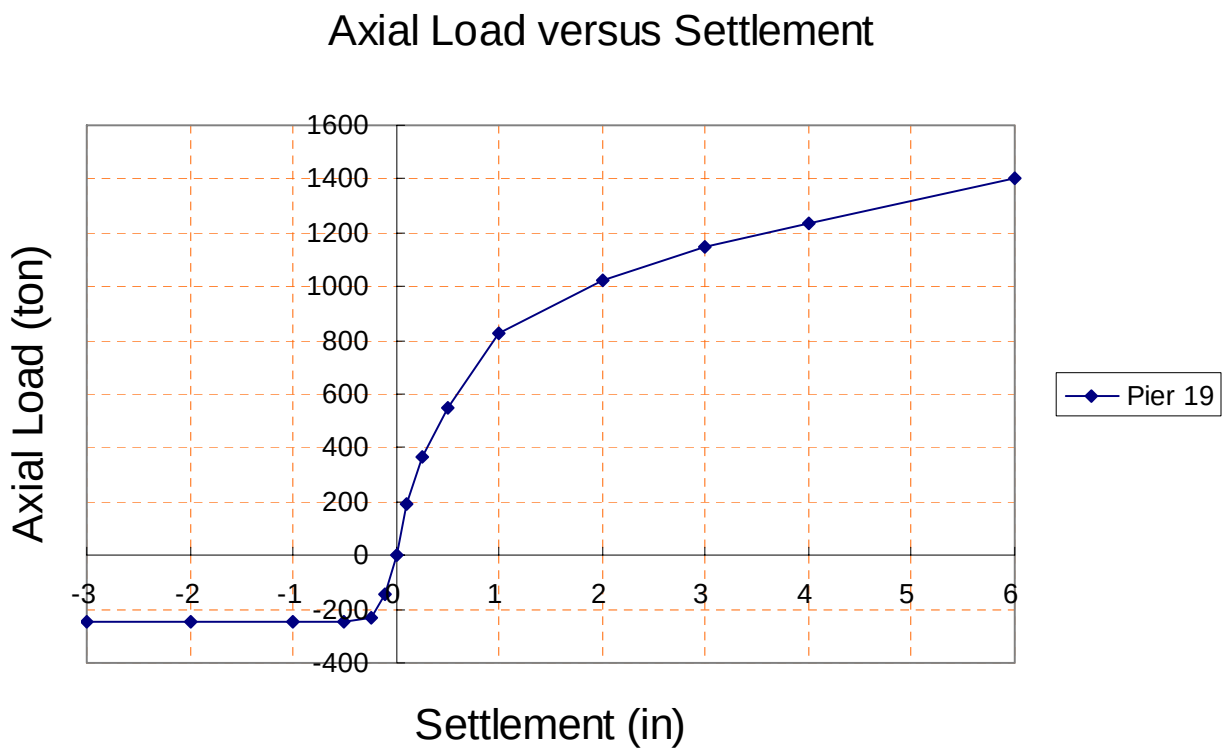


FIGURE C-20: PIER 20 - Q-δ CURVES

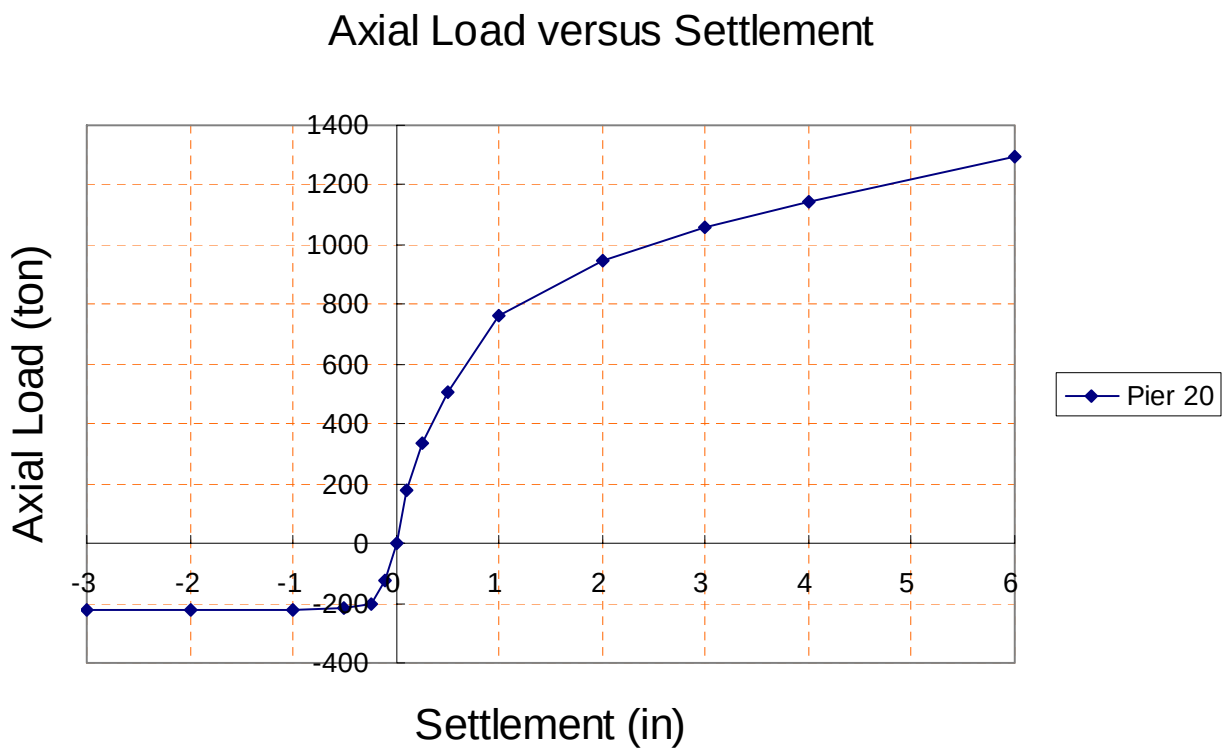


FIGURE C-21: PIER 21 - Q-δ CURVES

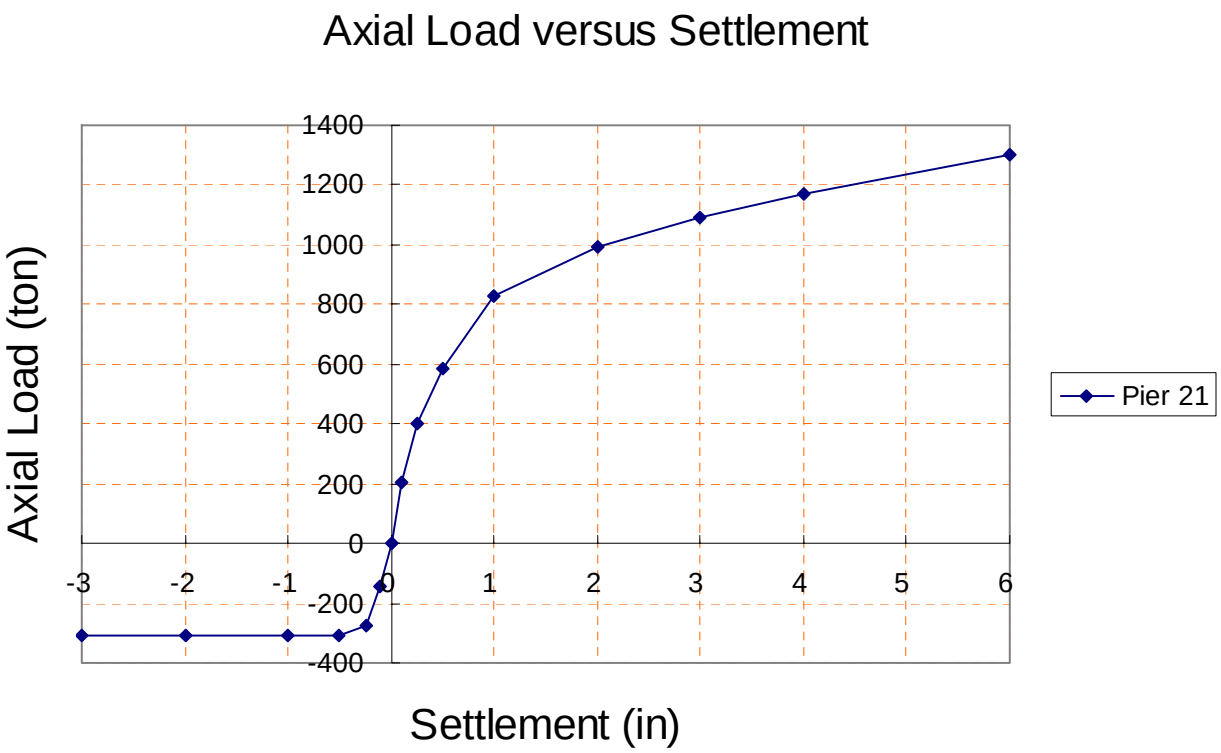


FIGURE C-22: PIER 22 - Q-δ CURVES

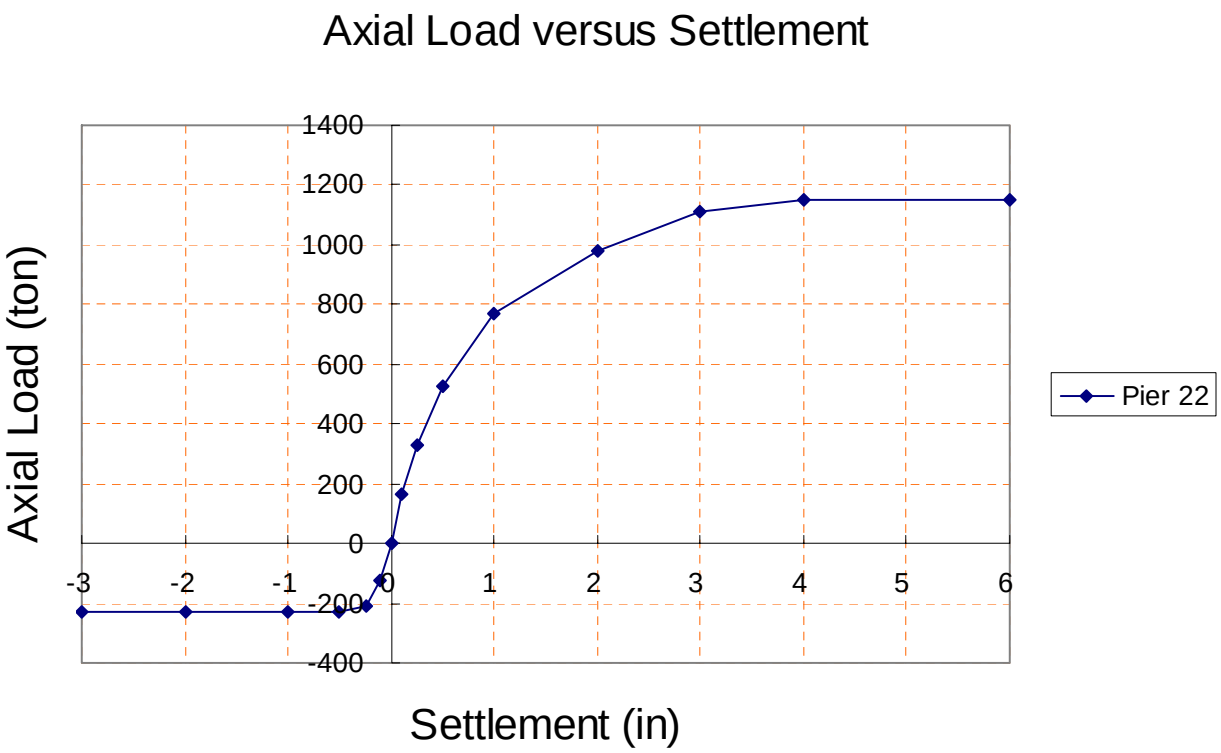


FIGURE C-23: PIER 23 - Q-δ CURVES

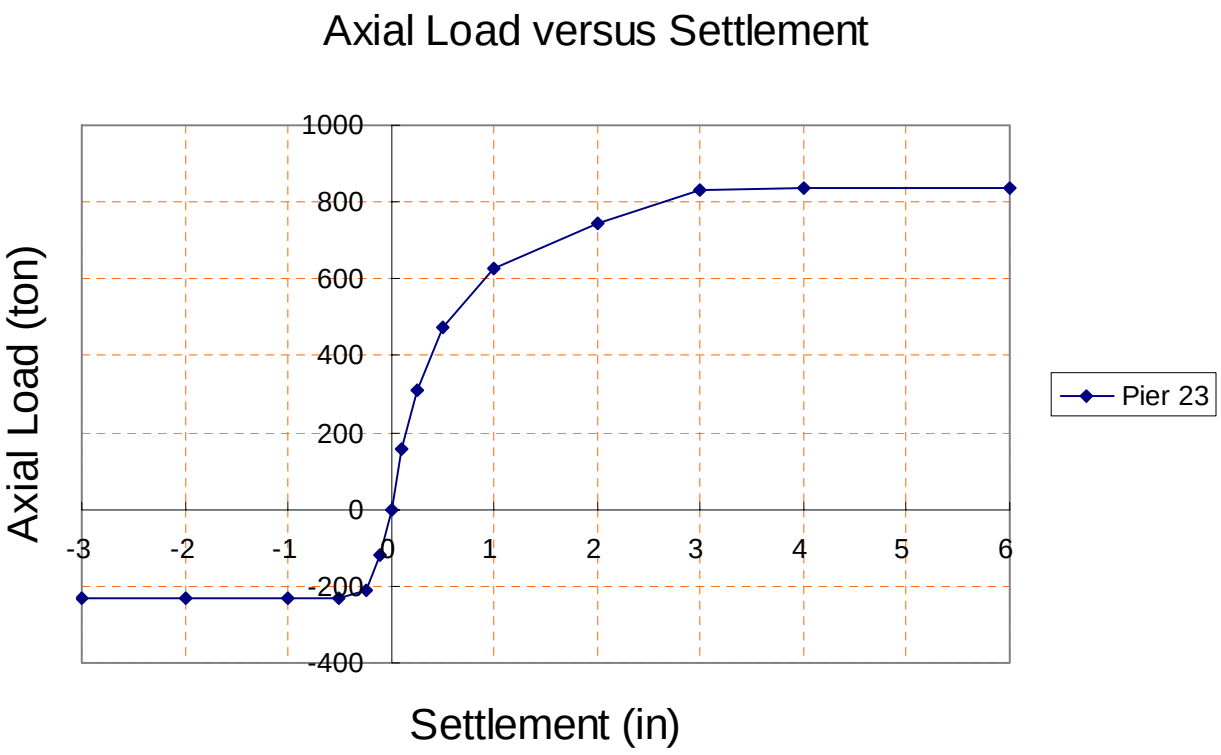


FIGURE C-24: PIER 24 - Q-δ CURVES

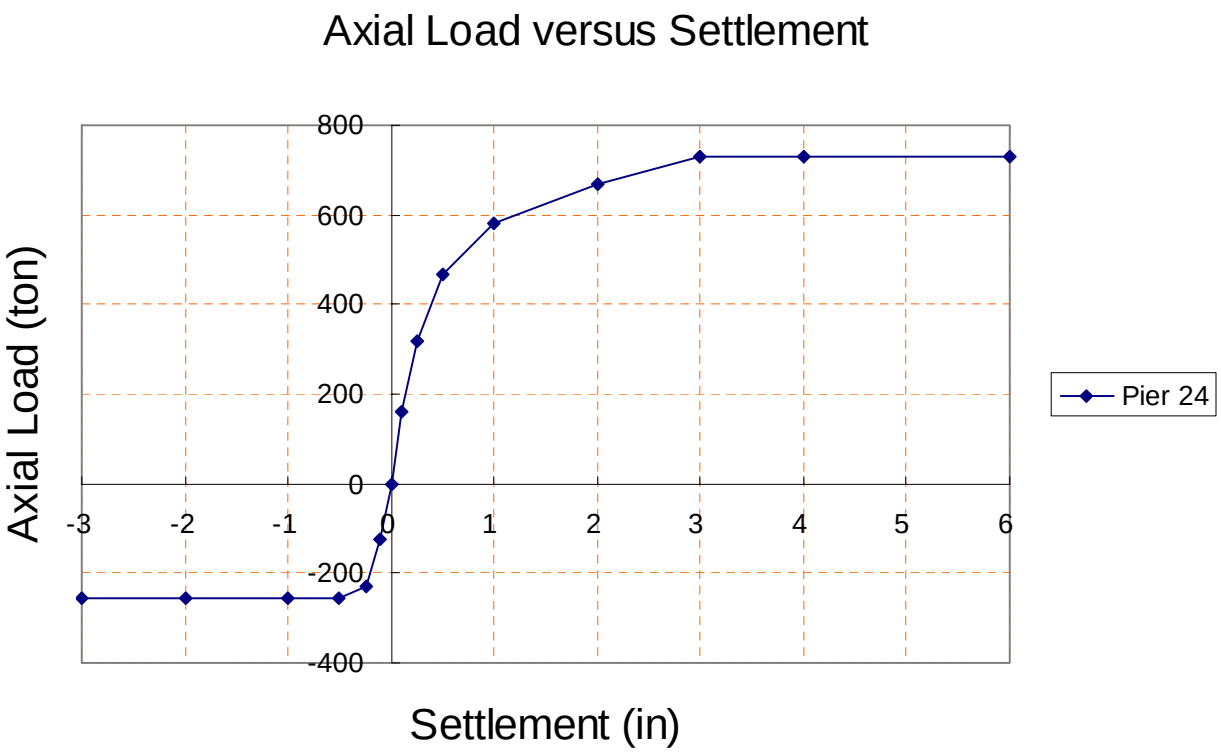


FIGURE C-25: PIER 25 - Q-δ CURVES

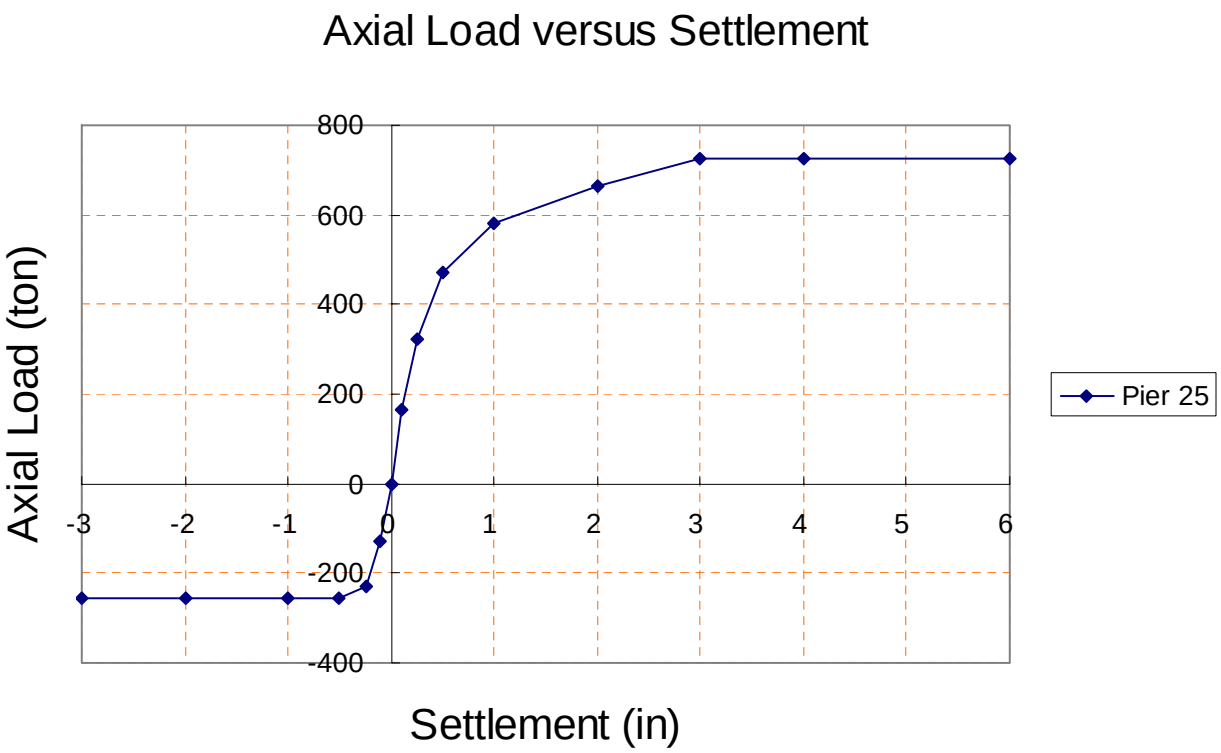


FIGURE C-26: PIER 26 - Q-δ CURVES

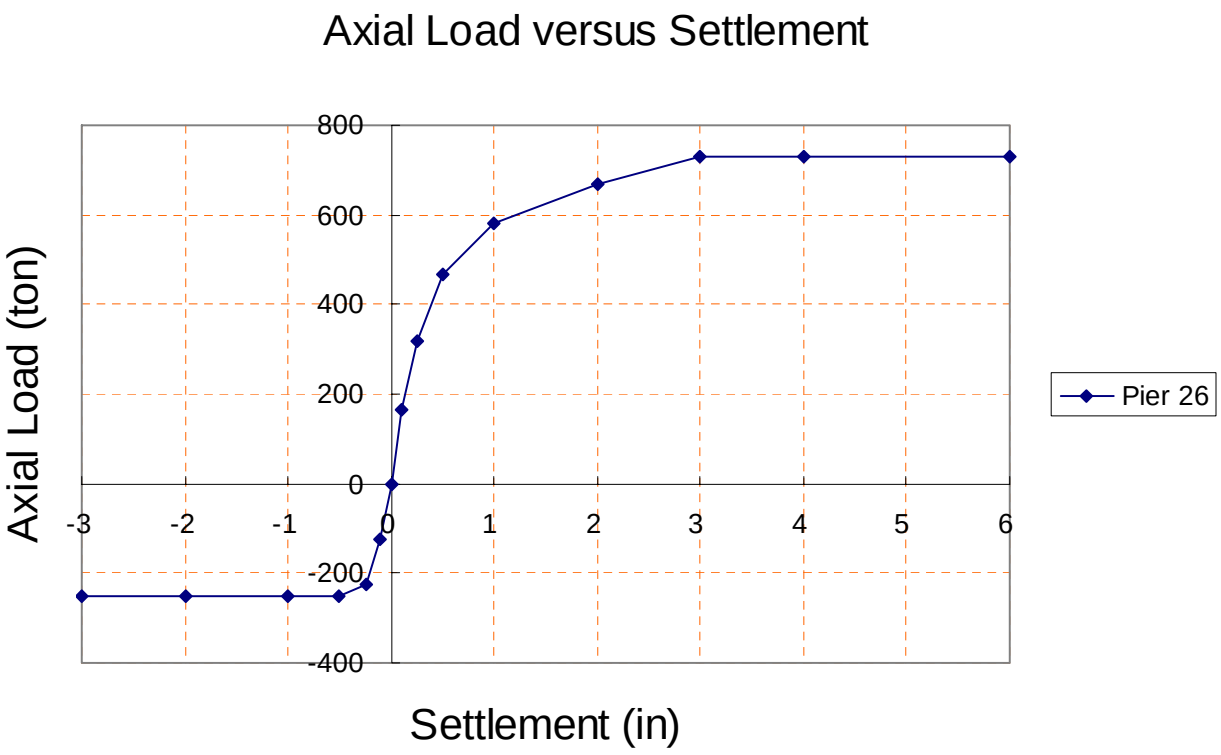


FIGURE C-27: PIER 27 - Q-δ CURVES

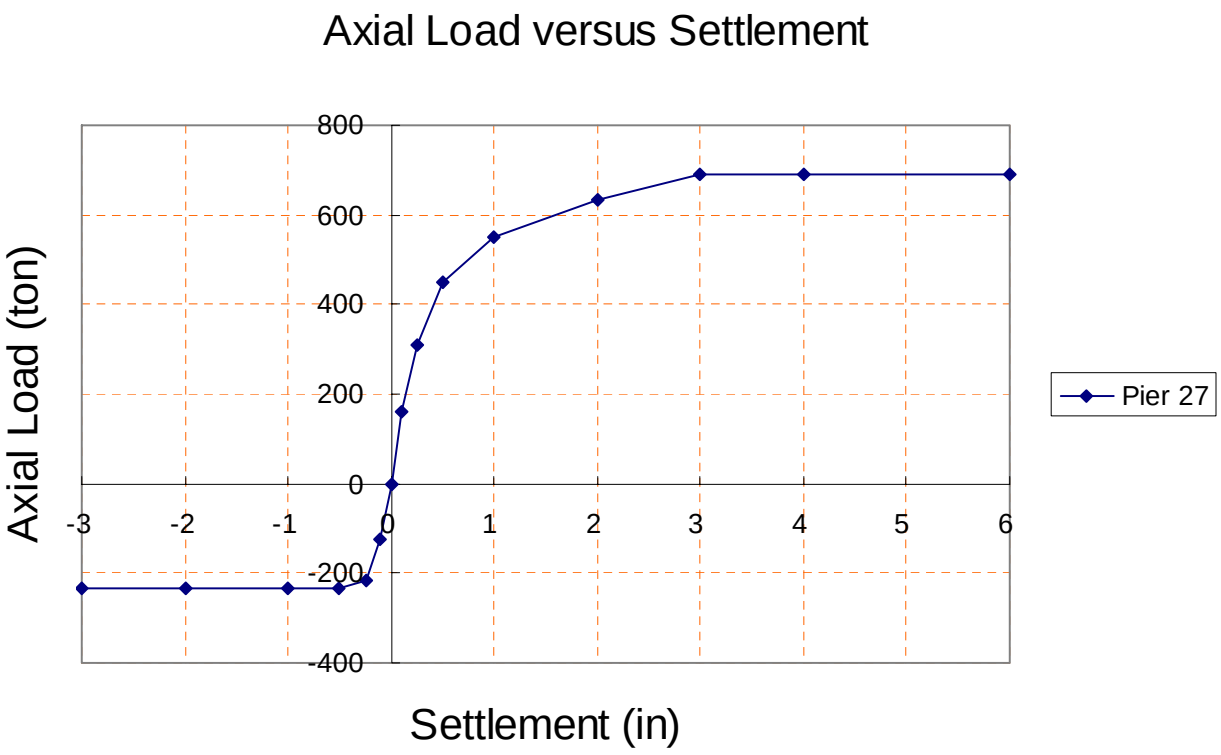


FIGURE C-28: PIER 28 - Q-δ CURVES

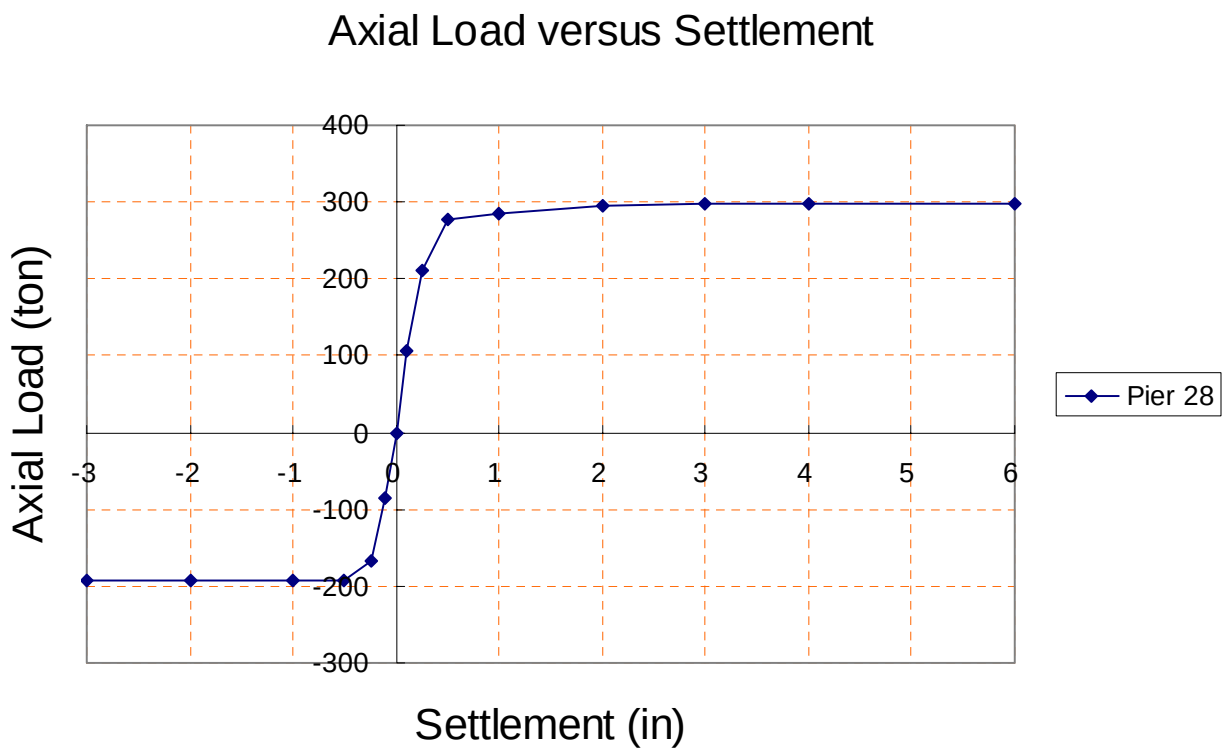


FIGURE C-29: PIER 29 - Q-δ CURVES

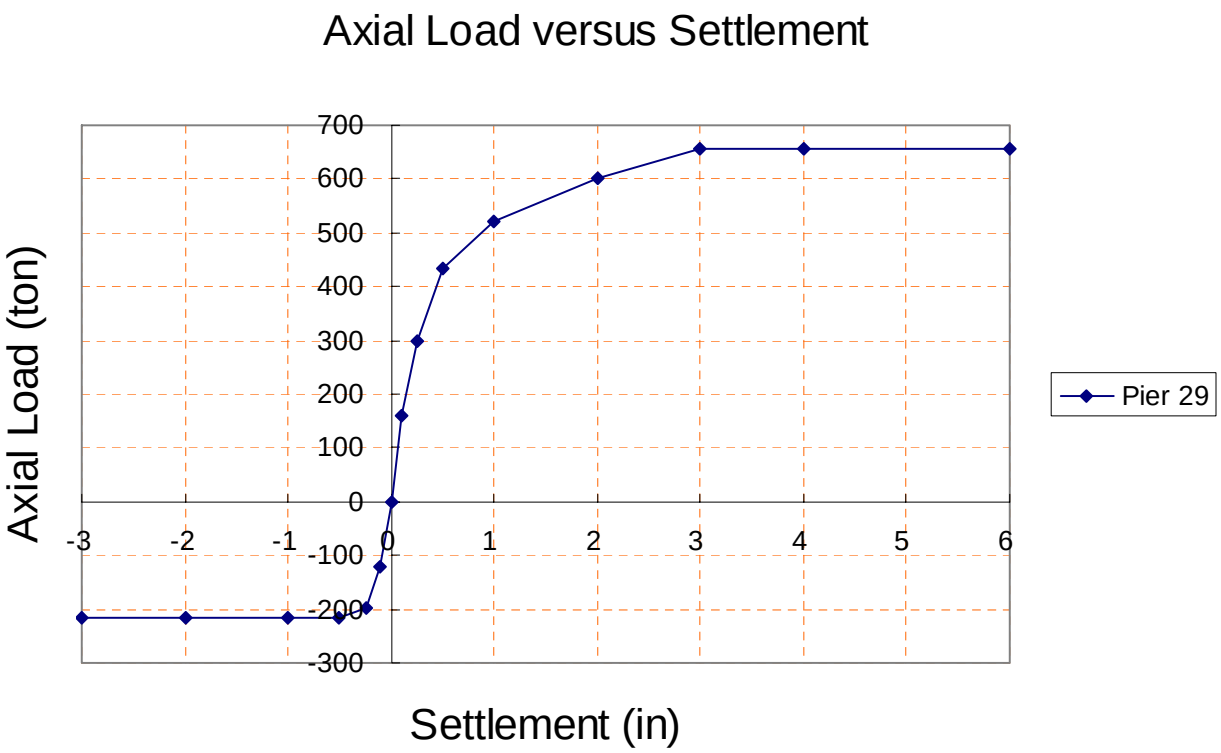


FIGURE C-30: PIER 30 - Q-δ CURVES

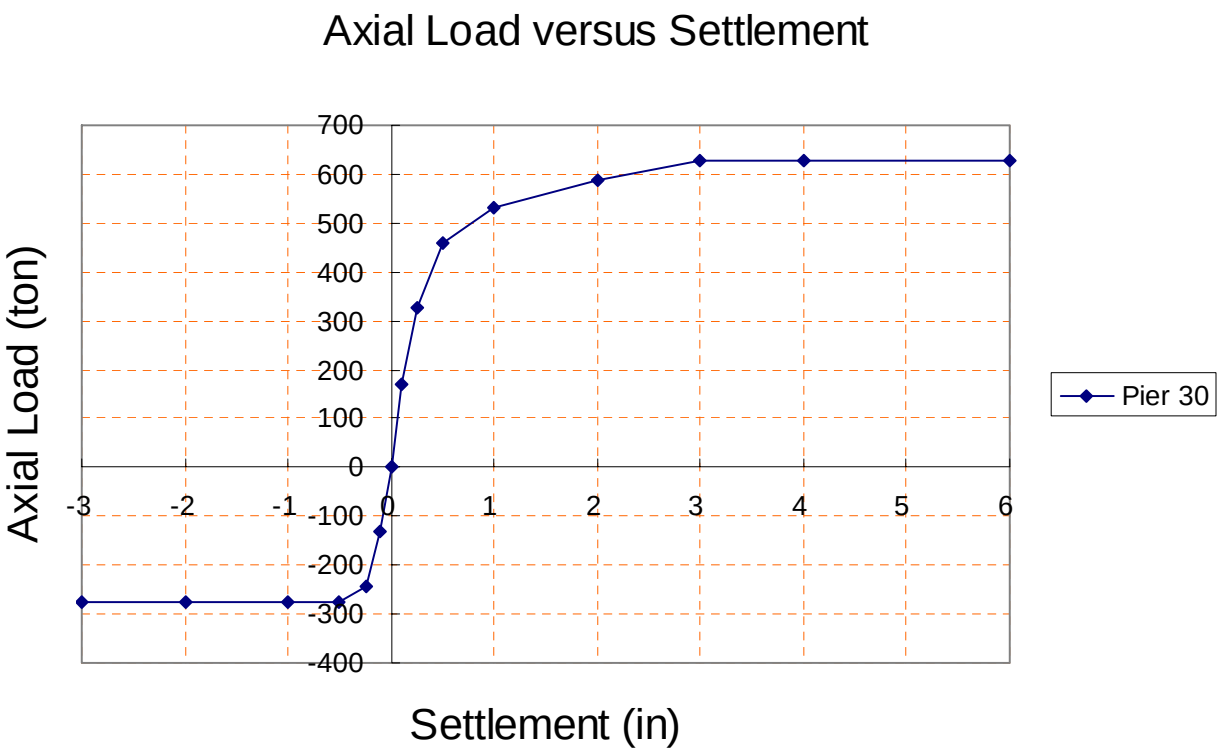


FIGURE C-31: PIER 31 - Q-δ CURVES

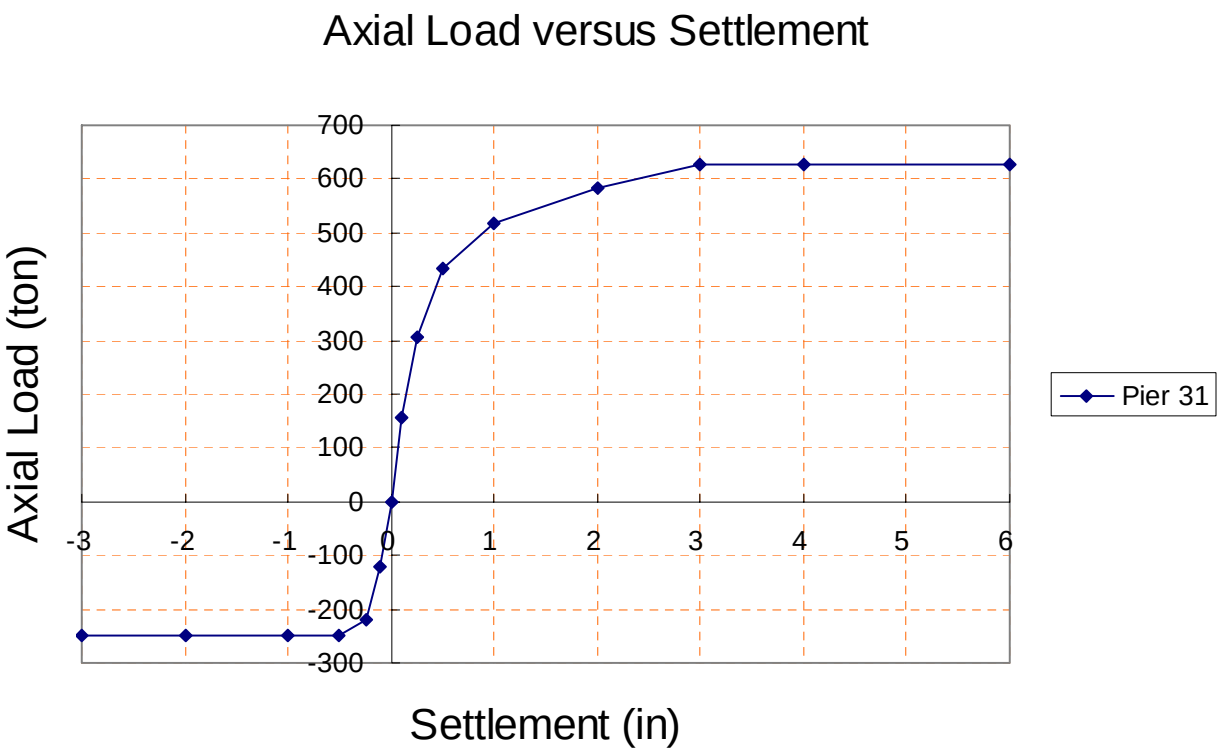


FIGURE C-32: PIER 32 - Q-δ CURVES

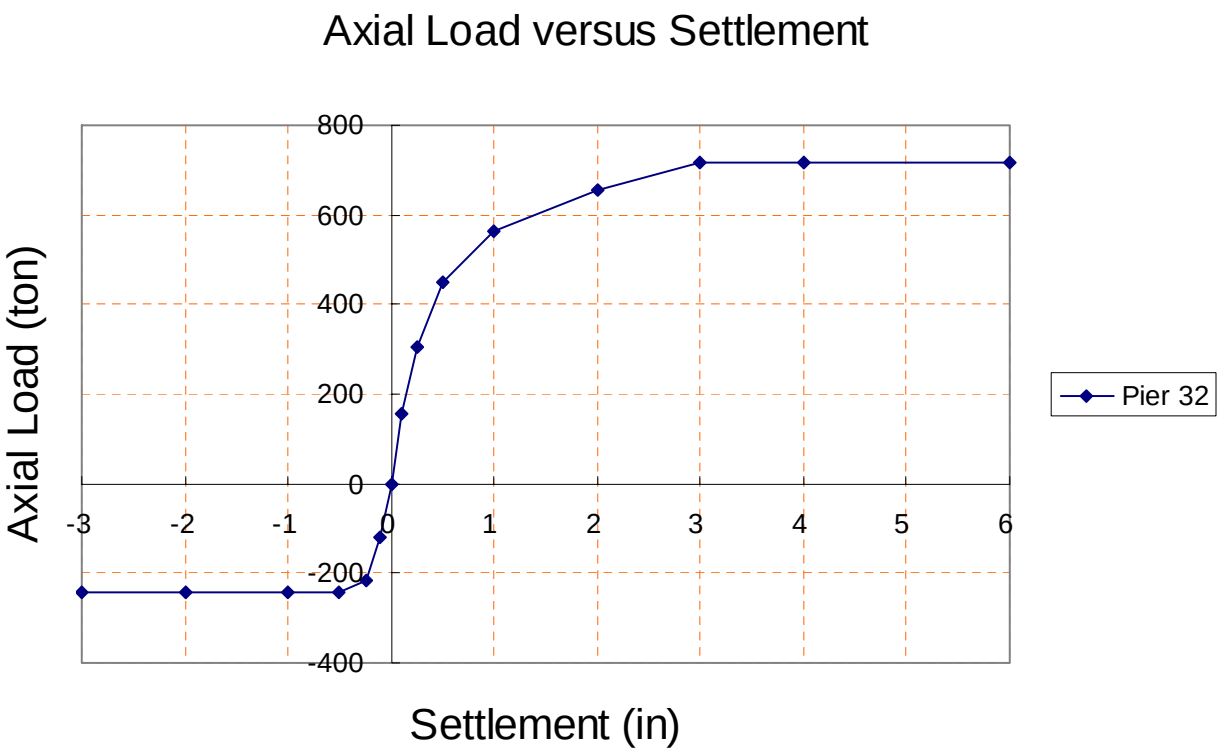


FIGURE C-33: PIER 33 - Q-δ CURVES

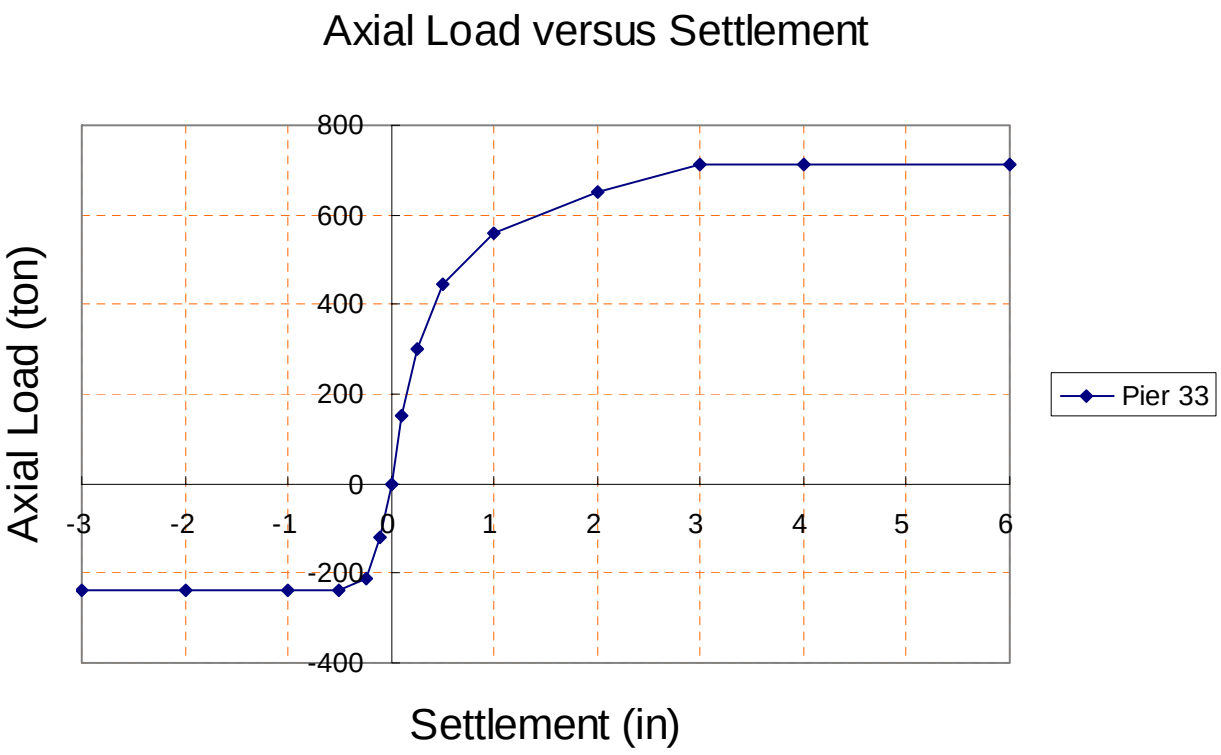


FIGURE C-34: PIER 34 - Q-δ CURVES

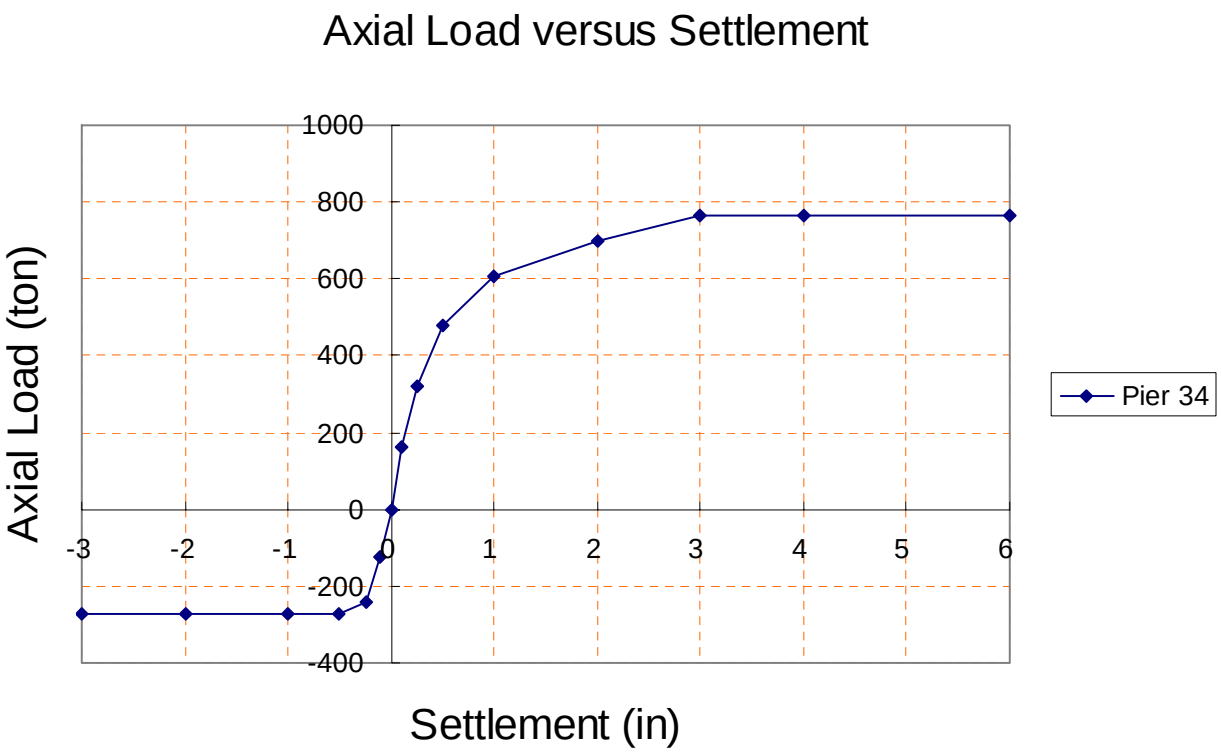


FIGURE C-35: PIER 35 - Q-δ CURVES

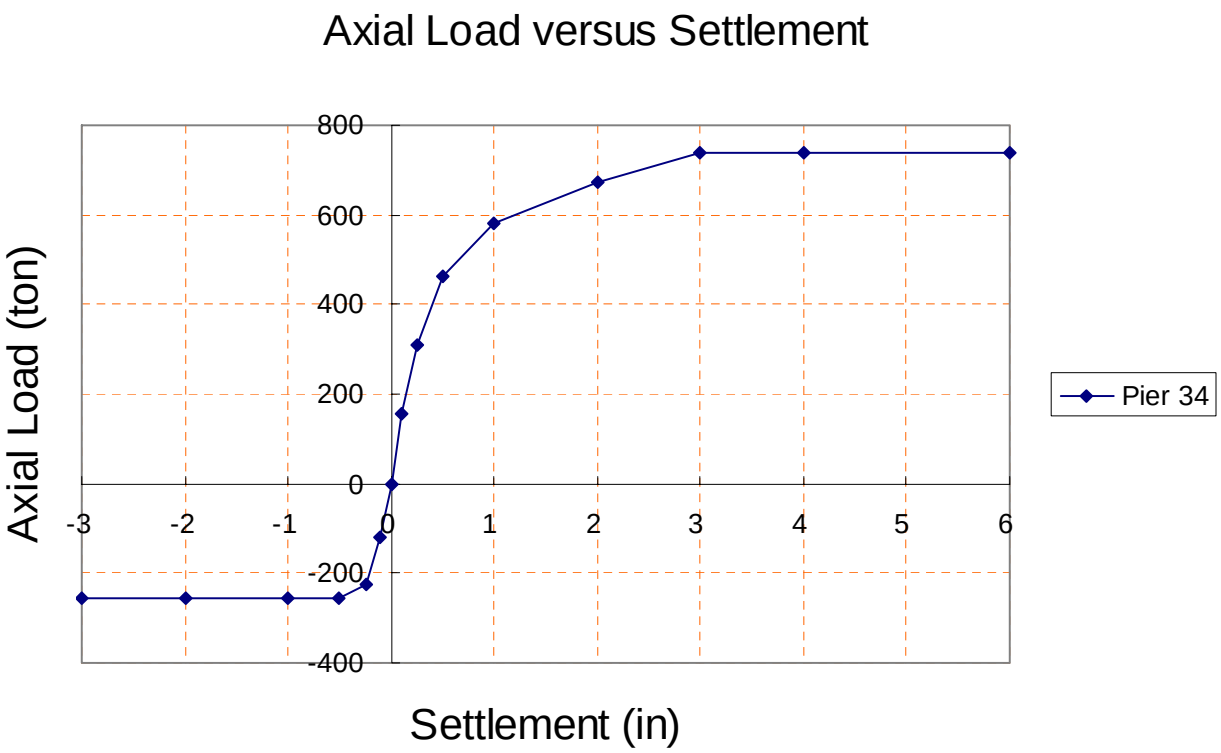


FIGURE C-36: PIER 36 - Q-δ CURVES

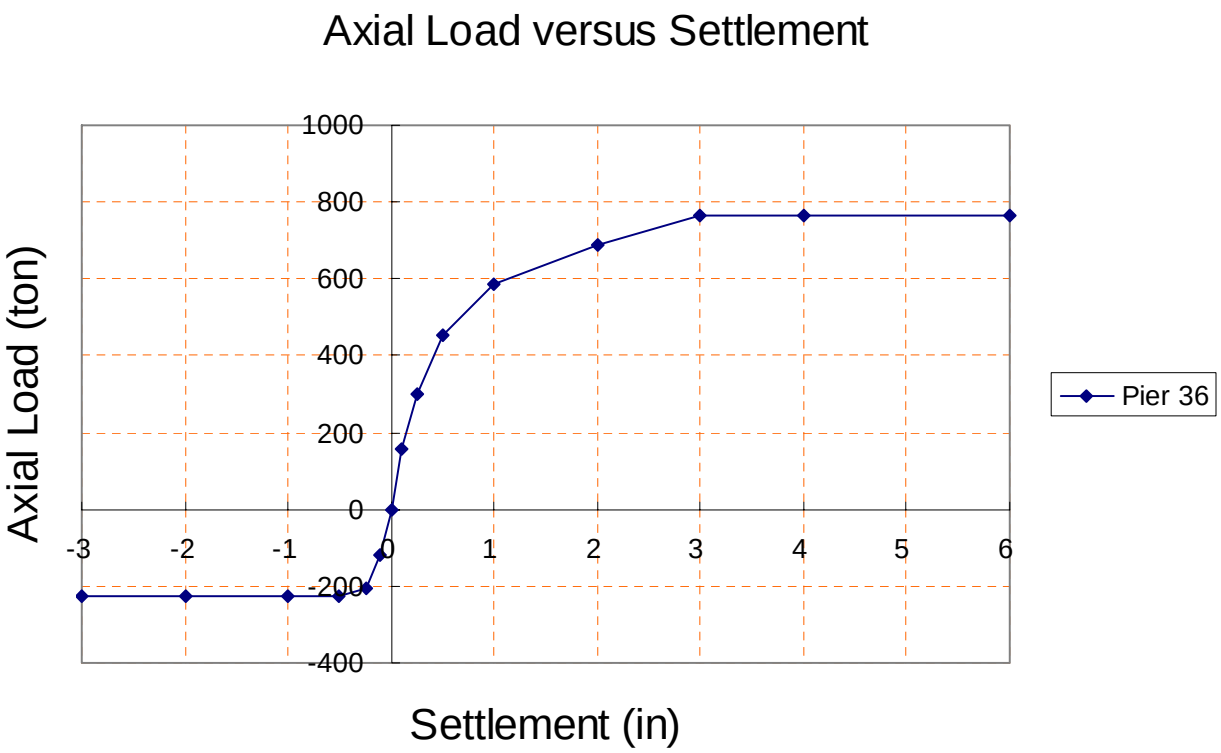


FIGURE C-37: PIER 37 - Q-δ CURVES

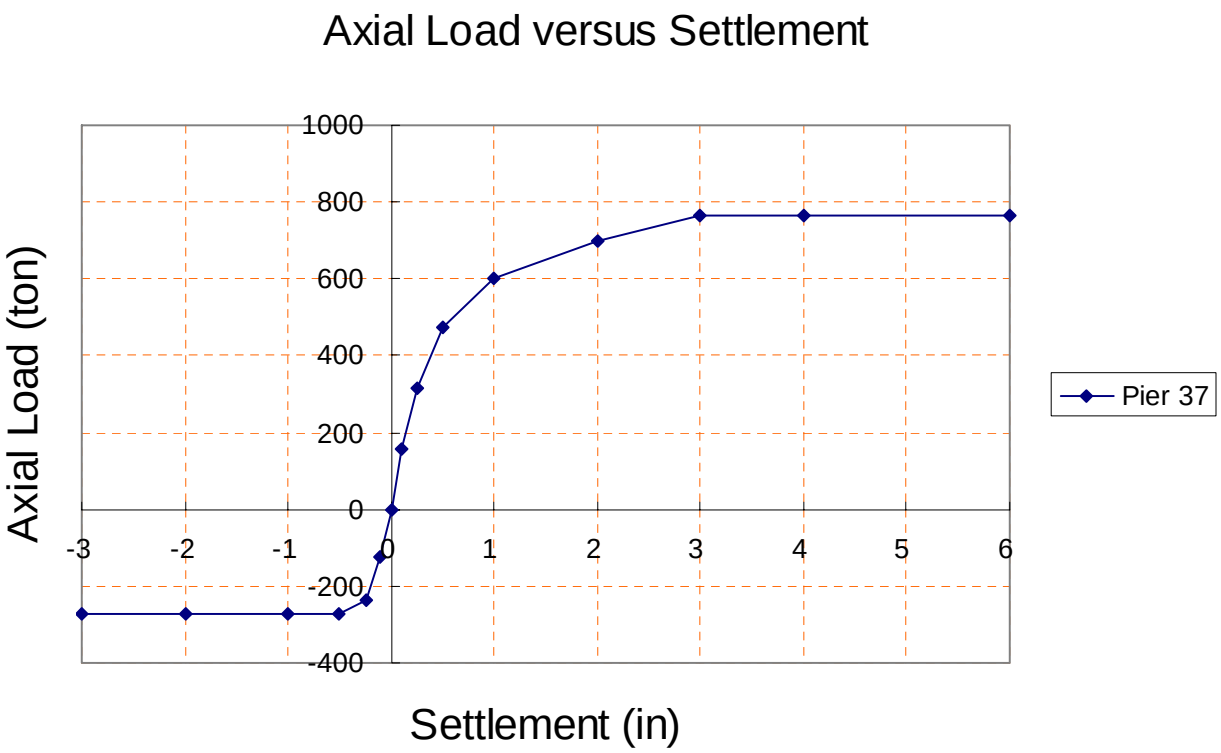


FIGURE C-38: PIER 38 - Q-δ CURVES

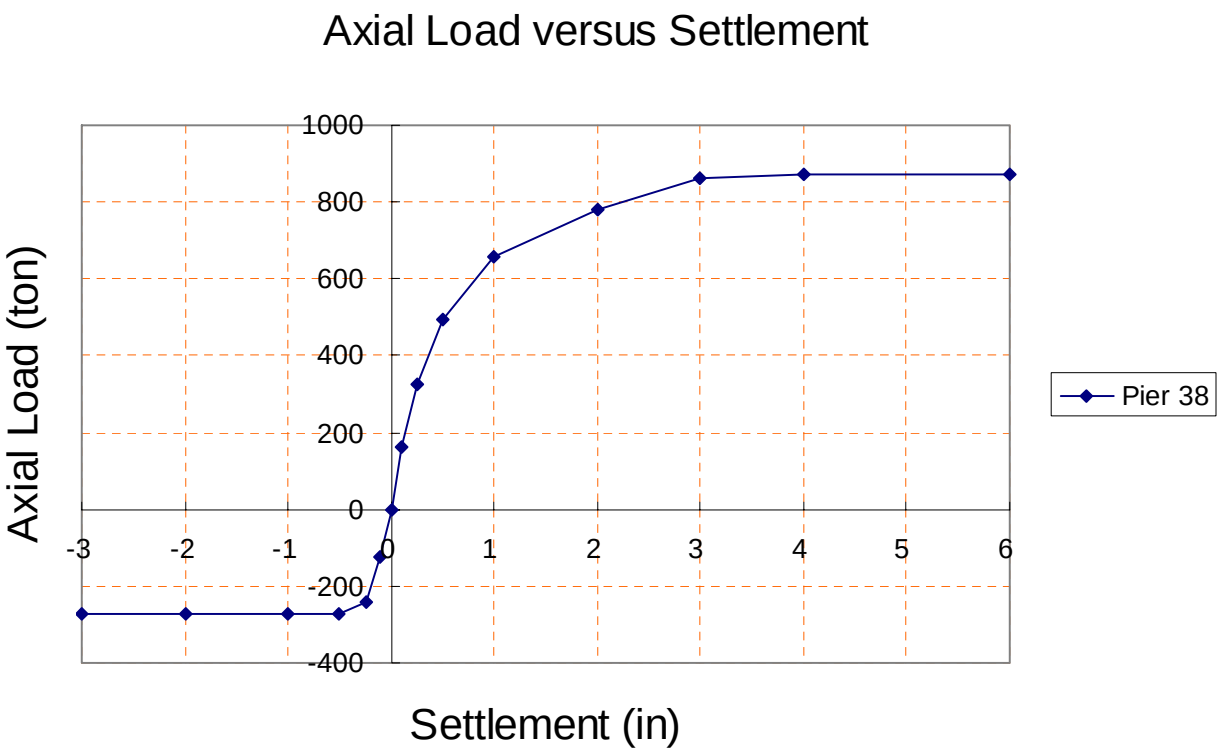


FIGURE C-39: PIER 39 - Q-δ CURVES

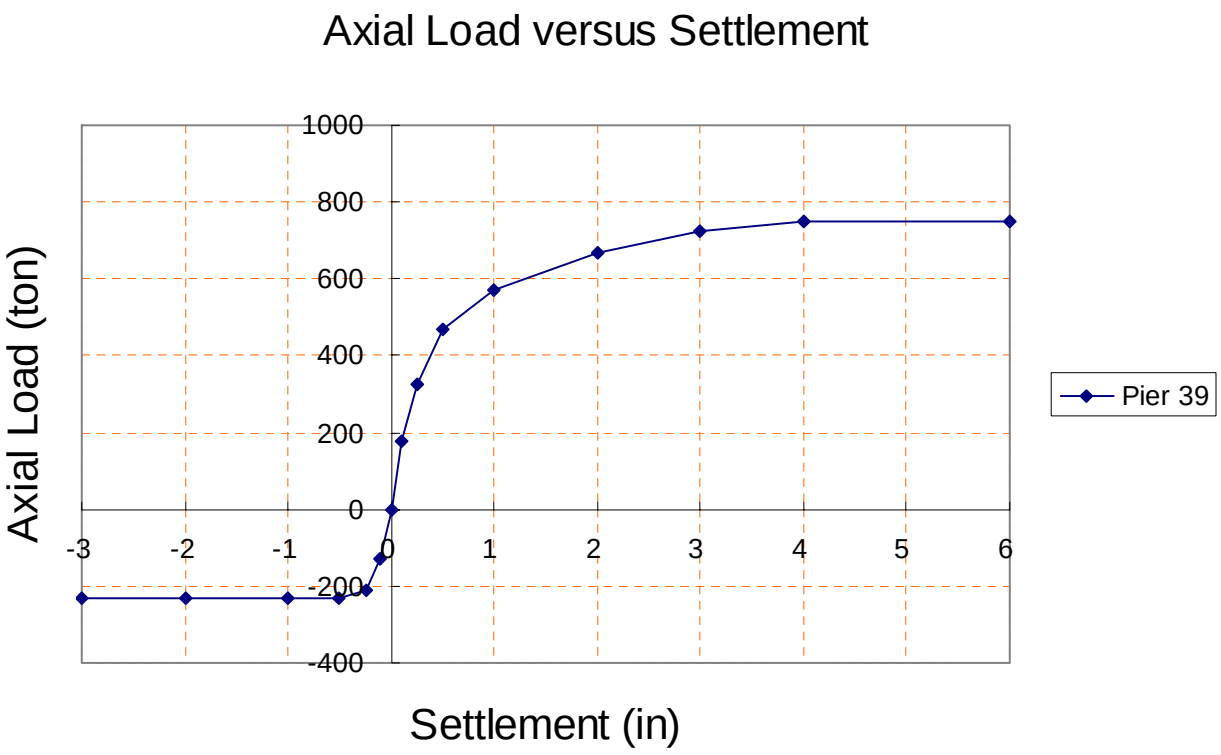


FIGURE C-40: PIER 40 - Q-δ CURVES

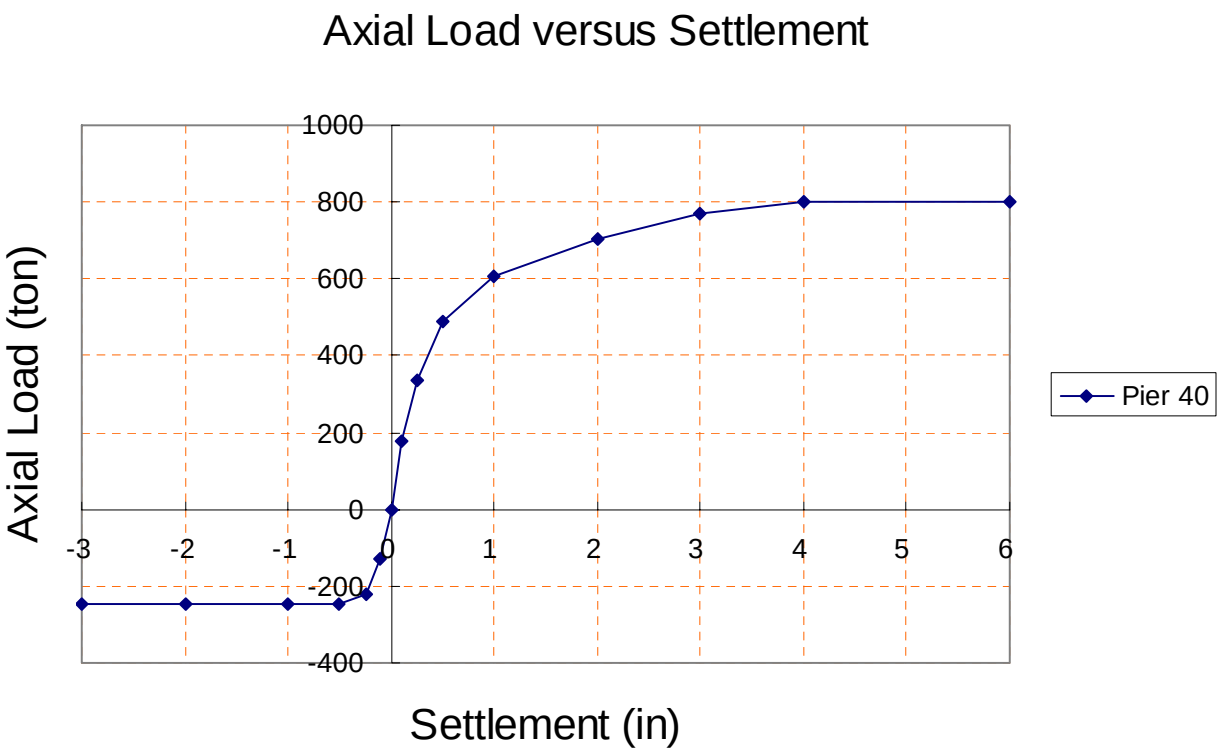


FIGURE C-41: PIER 41 - Q-δ CURVES

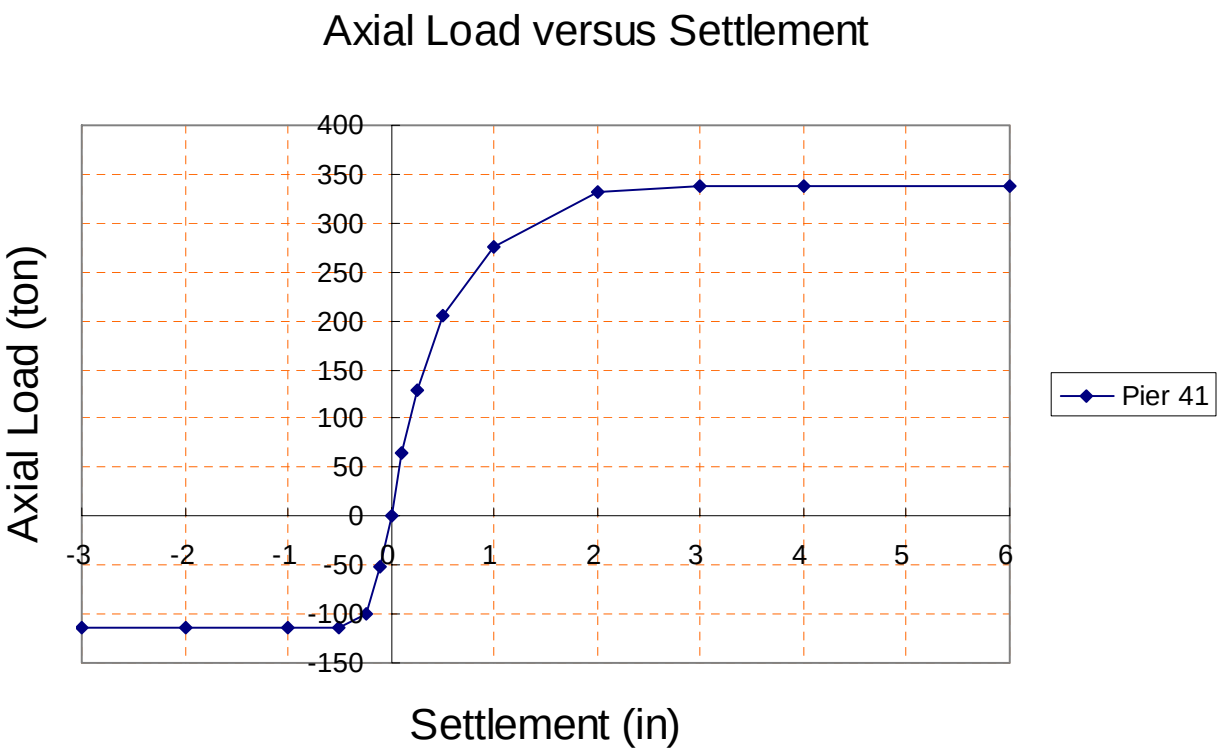


FIGURE C-42: PIERS 42~46 - Q-δ CURVES

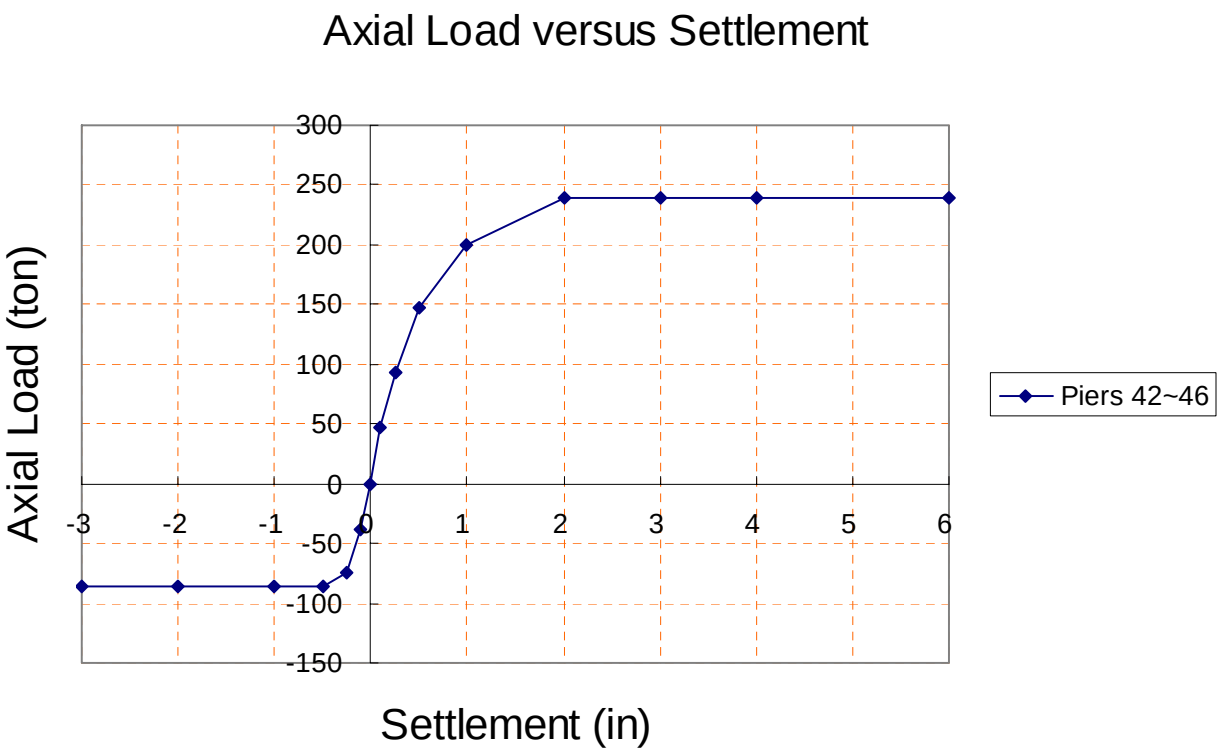


FIGURE C-43: PIERS 47~51 - Q-δ CURVES

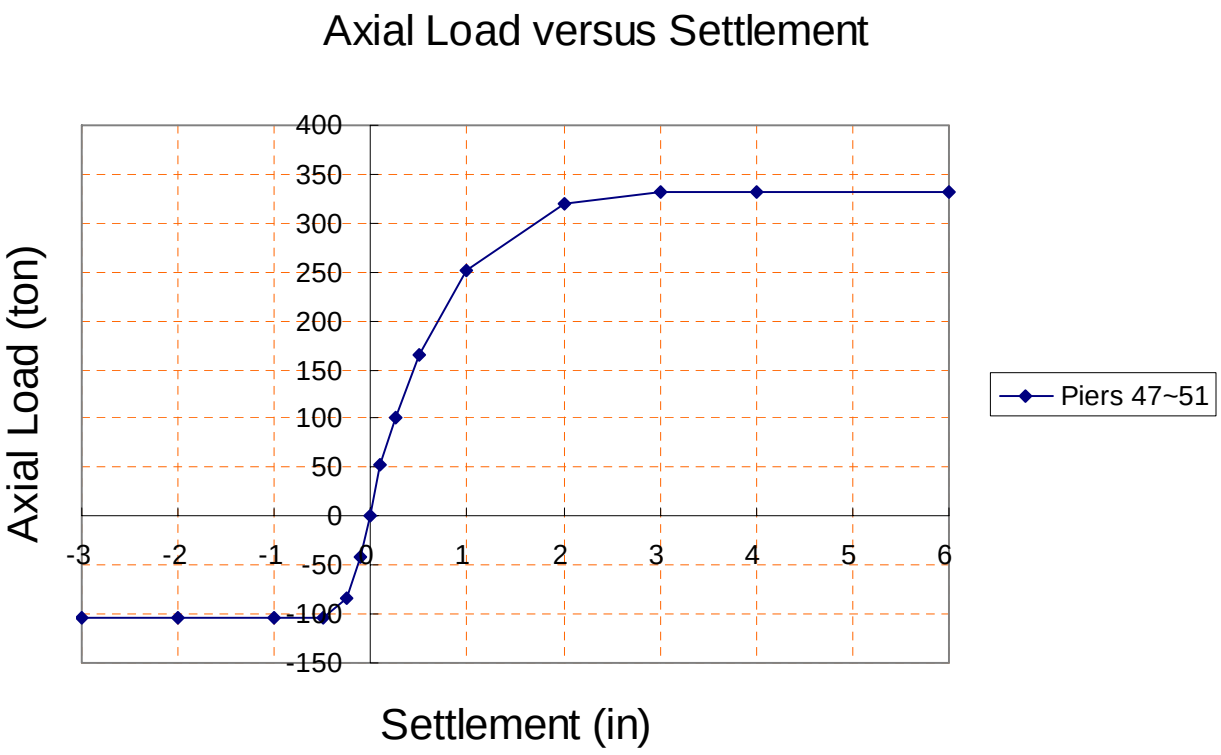


FIGURE C-44: PIERS 52 AND 53 - Q-δ CURVES

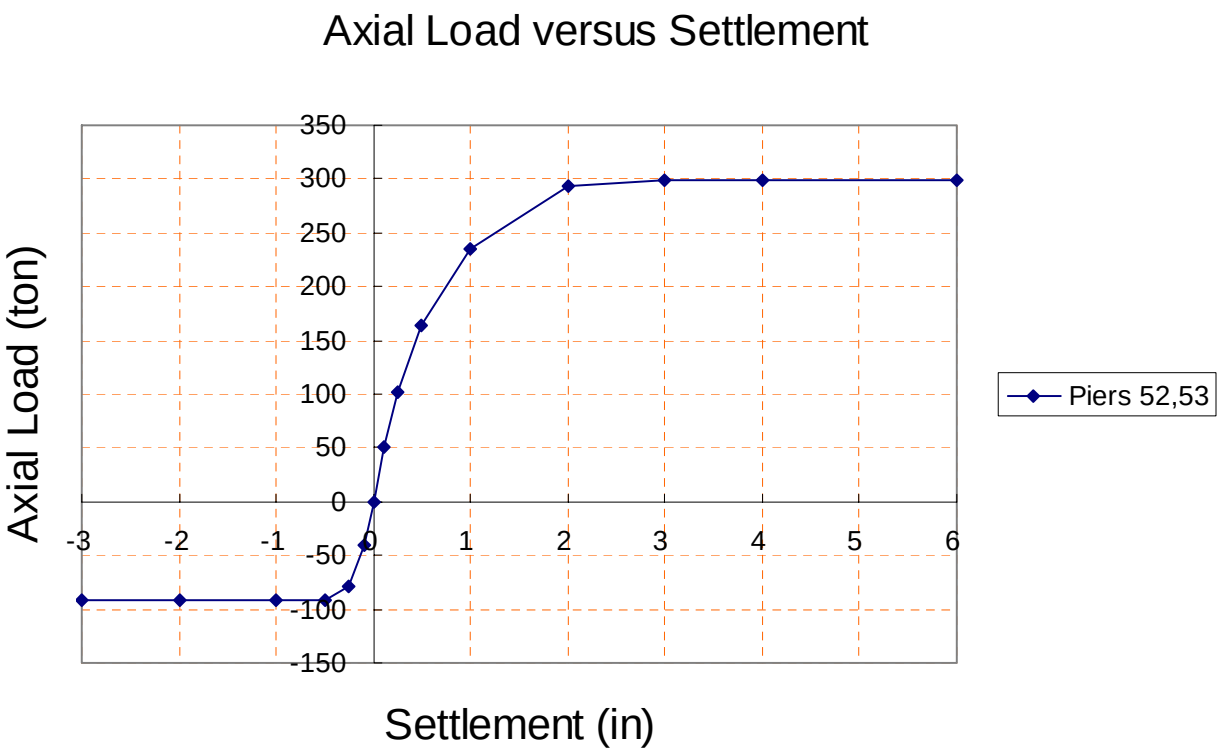


FIGURE C-45: PIERS 54~56 - Q-δ CURVES

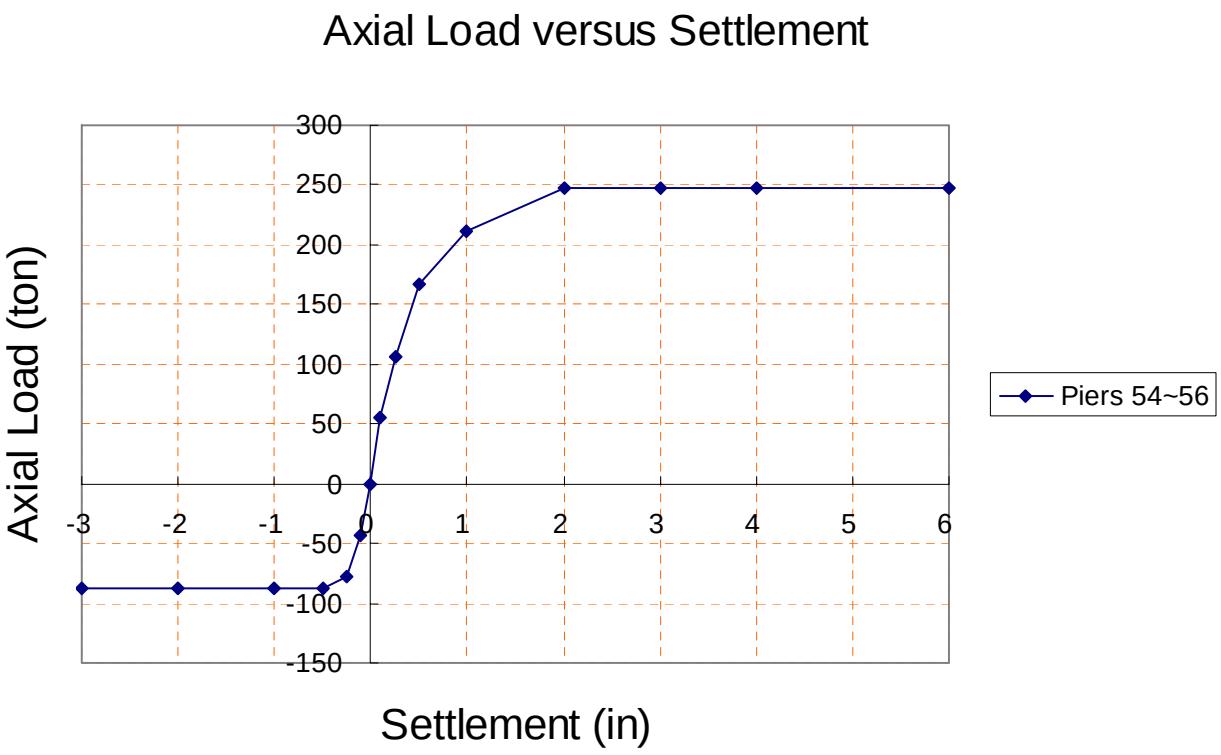


FIGURE C-46: PIERS 57 AND 58 - Q-δ CURVES

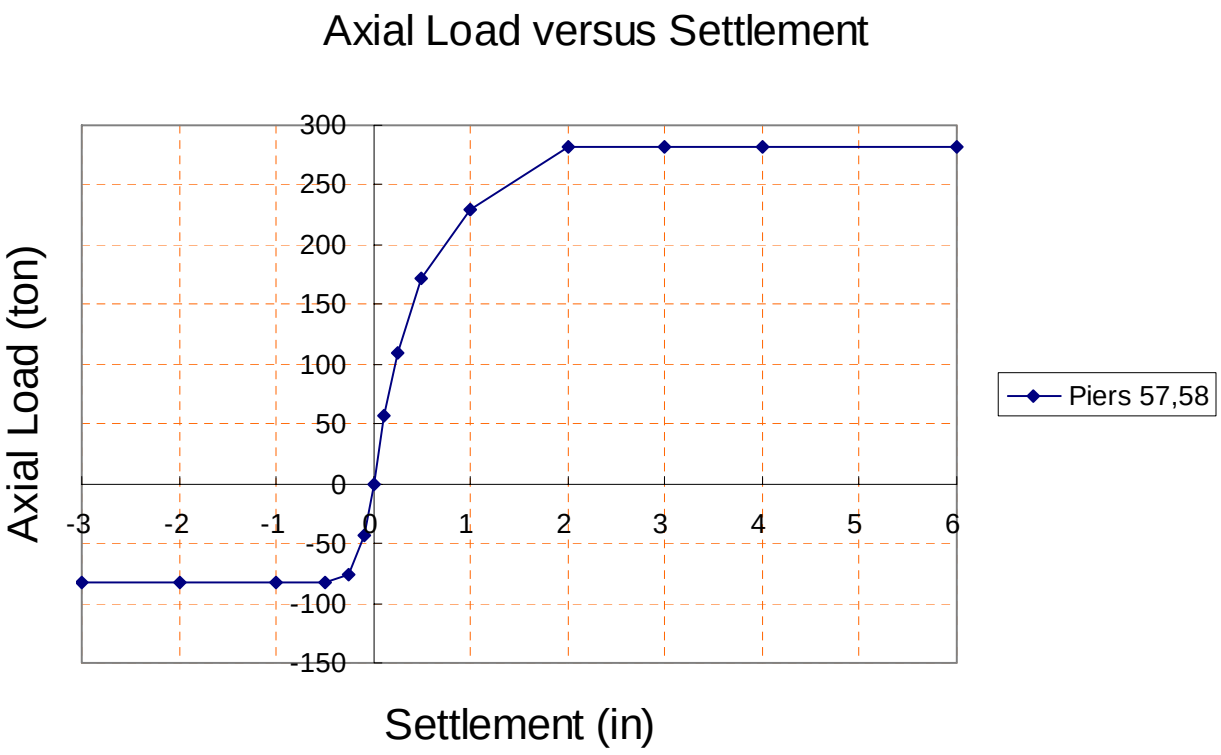


FIGURE C-47: PIERS 59~62 - Q-δ CURVES

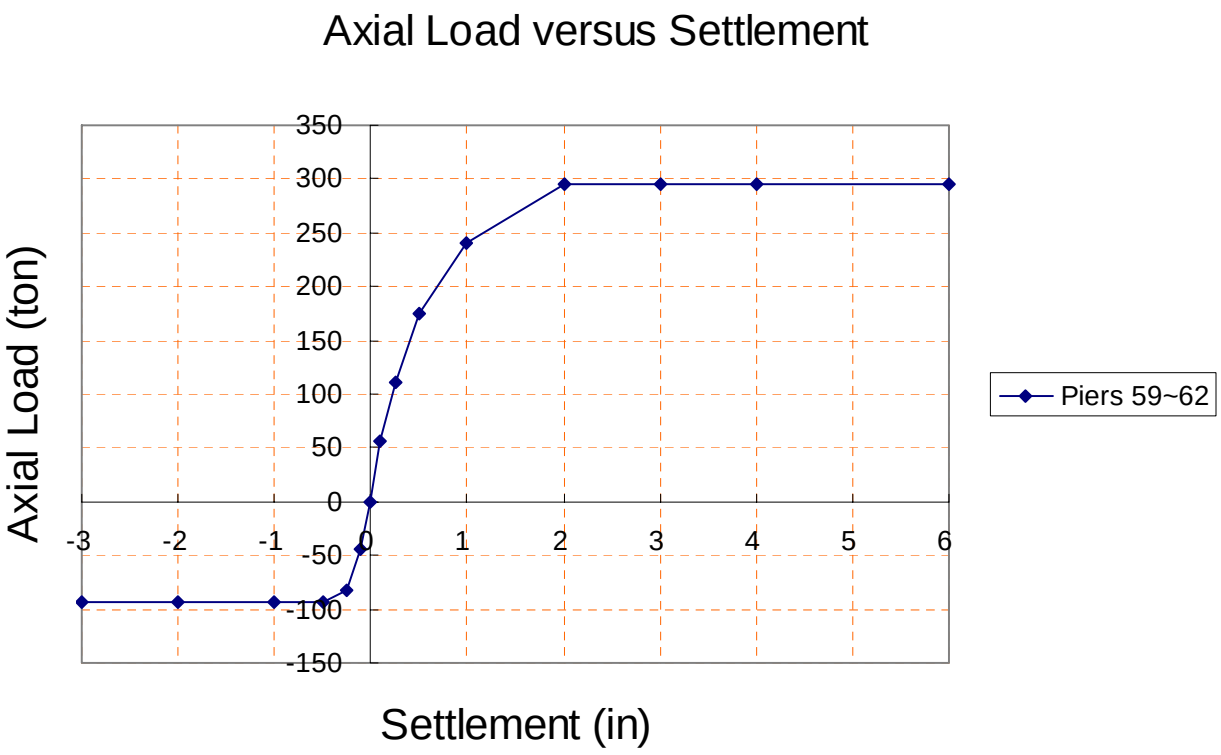


FIGURE C-48: PIERS 63~67 - Q-δ CURVES

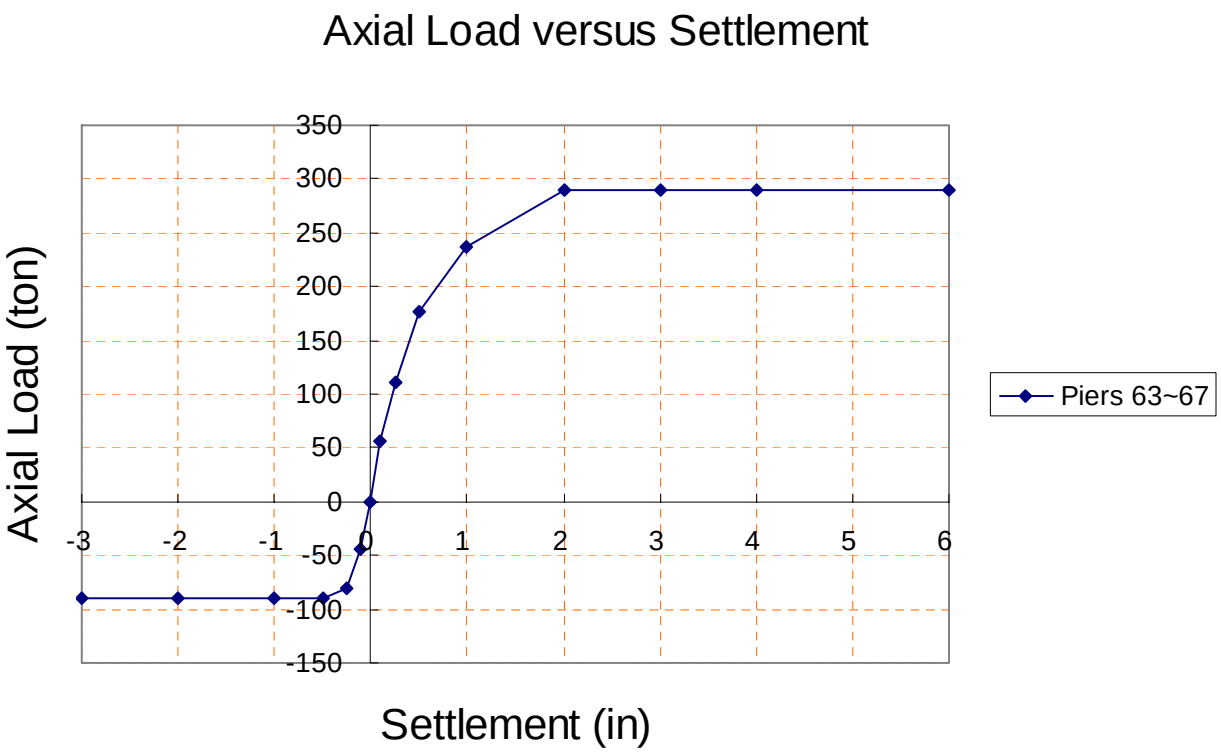


FIGURE C-49: PIERS 68~70 - Q-δ CURVES

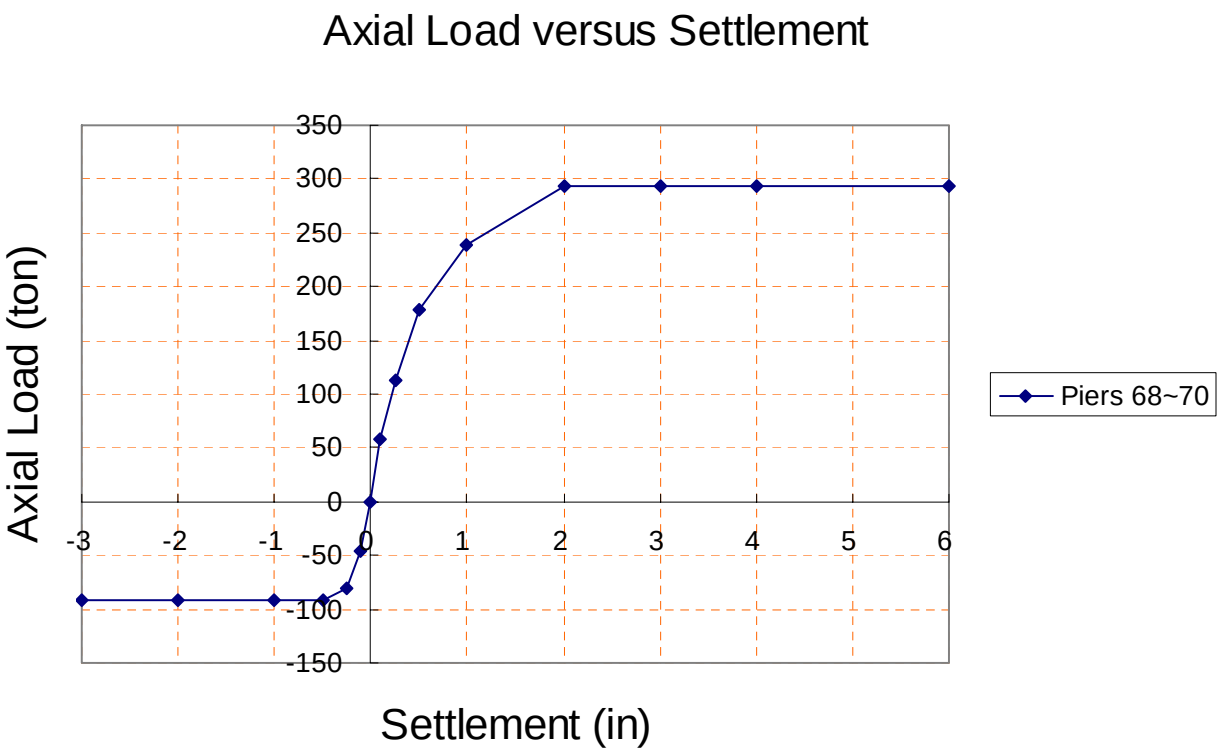
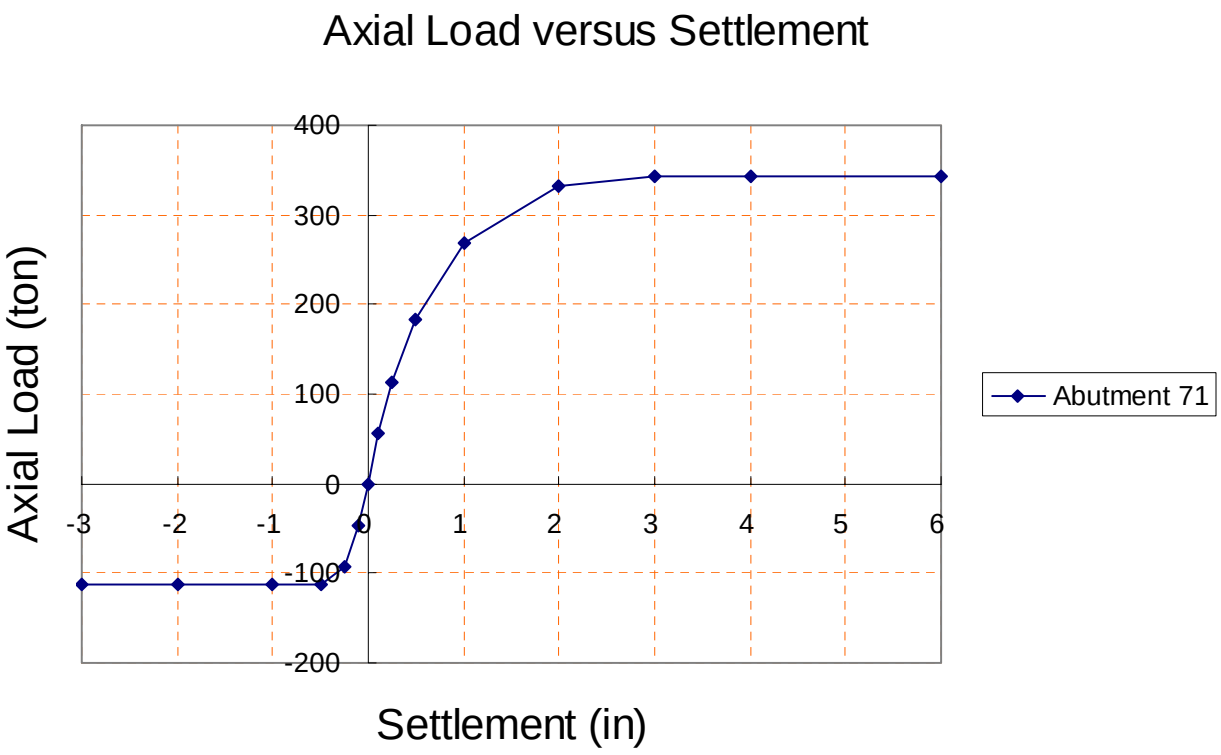


FIGURE C-50: ABUTMENT 71 - Q-δ CURVES



11.0 APPENDIX D: *P-Y* CURVES

TABLE D-1: ABUTMENT 1 – *p-y* CURVES

Node #	Elevation (ft)	Soil Type	p_u (lb/in)	y_u (in)	p_1 (lb/in)	y_1 (in)	p_2 (lb/in)	y_2 (in)	p_3 (lb/in)	y_3 (in)	p_4 (lb/in)	y_4 (in)	p_5 (lb/in)	y_5 (in)
1	15.0	Sand	326.4	0.47	32.6	0.01	150.1	0.08	248.0	0.15	297.0	0.23	326.4	0.47
2	10.0	Sand	1156.0	0.83	115.6	0.02	531.7	0.14	878.5	0.27	1051.9	0.41	1156.0	0.83
3	5.0	Sand	2597.4	1.09	259.7	0.03	1194.8	0.19	1974.0	0.36	2363.6	0.55	2597.4	1.09
4	0.0	Sand	4213.6	1.76	421.4	0.05	1938.3	0.30	3202.4	0.58	3834.4	0.88	4213.6	1.76
5	-5.0	Sand	4765.2	1.59	476.5	0.05	2192.0	0.27	3621.5	0.52	4336.3	0.79	4765.2	1.59
6	-10.0	Sand	5316.7	1.48	531.7	0.04	2445.7	0.25	4040.7	0.49	4838.2	0.74	5316.7	1.48
7	-15.0	Sand	5868.3	1.40	586.8	0.04	2699.4	0.24	4459.9	0.46	5340.1	0.70	5868.3	1.40
8	-20.0	Sand	6419.8	1.34	642.0	0.04	2953.1	0.23	4879.1	0.44	5842.1	0.67	6419.8	1.34
9	-25.0	Sand	6971.4	1.29	697.1	0.04	3206.8	0.22	5298.3	0.43	6344.0	0.65	6971.4	1.29
10	-30.0	Sand	7522.9	1.25	752.3	0.04	3460.6	0.21	5717.4	0.41	6845.9	0.63	7522.9	1.25

TABLE D-2: PIER 2 – *p-y* CURVES

Node #	Elevation (ft)	Soil Type	p_u (lb/in)	y_u (in)	p_1 (lb/in)	y_1 (in)	p_2 (lb/in)	y_2 (in)	p_3 (lb/in)	y_3 (in)	p_4 (lb/in)	y_4 (in)	p_5 (lb/in)	y_5 (in)
1	0.5	Sand	952.2	0.80	95.2	0.02	438.0	0.14	723.7	0.26	866.5	0.40	952.2	0.80
2	-3.0	Sand	1550.3	1.29	155.0	0.04	713.1	0.22	1178.2	0.43	1410.8	0.65	1550.3	1.29
3	-6.0	Sand	2135.4	1.42	213.5	0.04	982.3	0.24	1622.9	0.47	1943.3	0.71	2135.4	1.42
4	-10.0	Sand	1753.4	4.40	175.3	0.13	806.6	0.75	1332.6	1.45	1595.6	2.20	1753.4	4.40
5	-14.0	Clay	450.0	7.20	112.5	0.12	225.0	0.90	324.0	2.70	450.0	7.20	450.0	14.40
6	-19.0	Clay	3269.5	4.51	817.4	0.07	1634.8	0.56	2354.1	1.69	3269.5	4.51	3269.5	9.01
7	-22.0	Sand	7240.8	1.95	724.1	0.06	3330.8	0.33	5503.0	0.64	6589.1	0.97	7240.8	1.95
8	-26.0	Sand	8199.8	1.95	820.0	0.06	3771.9	0.33	6231.8	0.64	7461.8	0.98	8199.8	1.95
9	-30.0	Sand	4703.1	4.56	470.3	0.14	2163.4	0.77	3574.3	1.50	4279.8	2.28	4703.1	4.56
10	-35.0	Clay	5134.8	4.53	1283.7	0.07	2567.4	0.57	3697.1	1.70	5134.8	4.53	5134.8	9.06
11	-40.0	Sand	10765.1	1.83	1076.5	0.05	4952.0	0.31	8181.5	0.60	9796.3	0.92	10765.1	1.83

TABLE D-3: PIER 3 – *p-y* CURVES

Node #	Elevation (ft)	Soil Type	p_u (lb/in)	y_u (in)	p_1 (lb/in)	y_1 (in)	p_2 (lb/in)	y_2 (in)	p_3 (lb/in)	y_3 (in)	p_4 (lb/in)	y_4 (in)	p_5 (lb/in)	y_5 (in)
1	-1.0	Clay	339.8	7.20	85.0	0.12	169.9	0.90	244.7	2.70	339.8	7.20	339.8	14.40
2	-5.0	Clay	405.8	7.20	101.5	0.12	202.9	0.90	292.2	2.70	405.8	7.20	405.8	14.40
3	-10.0	Clay	450.0	7.20	112.5	0.12	225.0	0.90	324.0	2.70	450.0	7.20	450.0	14.40
4	-15.0	Clay	450.0	7.20	112.5	0.12	225.0	0.90	324.0	2.70	450.0	7.20	450.0	14.40
5	-20.0	Clay	450.0	7.20	112.5	0.12	225.0	0.90	324.0	2.70	450.0	7.20	450.0	14.40
6	-25.0	Clay	3639.4	4.46	909.8	0.07	1819.7	0.56	2620.3	1.67	3639.4	4.46	3639.4	8.92
7	-29.0	Sand	7524.8	1.69	752.5	0.05	3461.4	0.29	5718.8	0.56	6847.5	0.85	7524.8	1.69
8	-33.0	Sand	8220.8	1.67	822.1	0.05	3781.5	0.28	6247.8	0.55	7480.9	0.84	8220.8	1.67
9	-38.0	Sand	11176.7	1.62	1117.7	0.05	5141.3	0.28	8494.3	0.54	10170.8	0.81	11176.7	1.62
10	-41.0	Sand	14167.8	1.61	1416.8	0.05	6517.2	0.27	10767.5	0.53	12892.7	0.80	14167.8	1.61
11	-45.0	Sand	15374.8	1.61	1537.5	0.05	7072.4	0.27	11684.8	0.53	13991.0	0.81	15374.8	1.61

TABLE D-4: PIER 4 – *p-y* CURVES

Node #	Elevation (ft)	Soil Type	p_u (lb/in)	y_u (in)	p_1 (lb/in)	y_1 (in)	p_2 (lb/in)	y_2 (in)	p_3 (lb/in)	y_3 (in)	p_4 (lb/in)	y_4 (in)	p_5 (lb/in)	y_5 (in)
1	-2.0	Clay	404.6	7.20	101.2	0.12	202.3	0.90	291.3	2.70	404.6	7.20	404.6	14.40
2	-7.0	Clay	450.0	7.20	112.5	0.12	225.0	0.90	324.0	2.70	450.0	7.20	450.0	14.40
3	-12.0	Clay	2304.1	4.39	576.0	0.07	1152.0	0.55	1658.9	1.65	2304.1	4.39	2304.1	8.78
4	-16.0	Sand	5464.2	1.75	546.4	0.05	2513.5	0.30	4152.8	0.58	4972.4	0.88	5464.2	1.75
5	-20.0	Sand	6946.3	1.93	694.6	0.06	3195.3	0.33	5279.2	0.64	6321.1	0.96	6946.3	1.93
6	-25.0	Sand	8306.1	1.98	830.6	0.06	3820.8	0.34	6312.7	0.65	7558.6	0.99	8306.1	1.98
7	-30.0	Sand	4850.8	4.56	485.1	0.14	2231.4	0.78	3686.6	1.51	4414.2	2.28	4850.8	4.56
8	-33.0	Clay	5109.9	4.55	1277.5	0.07	2554.9	0.57	3679.1	1.71	5109.9	4.55	5109.9	9.09
9	-37.0	Sand	10526.1	1.87	1052.6	0.06	4842.0	0.32	7999.8	0.62	9578.8	0.93	10526.1	1.87
10	-41.0	Sand	11282.5	1.84	1128.3	0.06	5190.0	0.31	8574.7	0.61	10267.1	0.92	11282.5	1.84
11	-45.0	Sand	14801.3	1.80	1480.1	0.05	6808.6	0.31	11249.0	0.59	13469.2	0.90	14801.3	1.80
12	-50.0	Sand	19062.8	1.77	1906.3	0.05	8768.9	0.30	14487.7	0.58	17347.2	0.88	19062.8	1.77

TABLE D-5: PIER 5 – *p-y* CURVES

Node #	Elevation (ft)	Soil Type	p_u (lb/in)	y_u (in)	p_1 (lb/in)	y_1 (in)	p_2 (lb/in)	y_2 (in)	p_3 (lb/in)	y_3 (in)	p_4 (lb/in)	y_4 (in)	p_5 (lb/in)	y_5 (in)
1	-2.0	Clay	382.5	7.20	95.6	0.12	191.3	0.90	275.4	2.70	382.5	7.20	382.5	14.40
2	-7.0	Clay	450.0	7.20	112.5	0.12	225.0	0.90	324.0	2.70	450.0	7.20	450.0	14.40
3	-12.0	Clay	450.0	7.20	112.5	0.12	225.0	0.90	324.0	2.70	450.0	7.20	450.0	14.40
4	-17.0	Clay	2845.2	4.44	711.3	0.07	1422.6	0.55	2048.5	1.66	2845.2	4.44	2845.2	8.88
5	-21.0	Sand	6691.0	1.86	669.1	0.06	3077.9	0.32	5085.1	0.61	6088.8	0.93	6691.0	1.86
6	-25.0	Sand	7846.5	1.92	784.6	0.06	3609.4	0.33	5963.3	0.63	7140.3	0.96	7846.5	1.92
7	-30.0	Sand	4621.0	4.54	462.1	0.14	2125.7	0.77	3512.0	1.50	4205.1	2.27	4621.0	4.54
8	-34.0	Clay	4966.4	4.52	1241.6	0.07	2483.2	0.56	3575.8	1.69	4966.4	4.52	4966.4	9.04
9	-38.0	Sand	10239.2	1.82	1023.9	0.05	4710.0	0.31	7781.8	0.60	9317.7	0.91	10239.2	1.82
10	-43.0	Sand	13751.0	1.77	1375.1	0.05	6325.5	0.30	10450.8	0.58	12513.4	0.88	13751.0	1.77
11	-45.0	Sand	16917.0	1.74	1691.7	0.05	7781.8	0.30	12857.0	0.57	15394.5	0.87	16917.0	1.74

TABLE D-6: PIER 6 – *p-y* CURVES

Node #	Elevation (ft)	Soil Type	p_u (lb/in)	y_u (in)	p_1 (lb/in)	y_1 (in)	p_2 (lb/in)	y_2 (in)	p_3 (lb/in)	y_3 (in)	p_4 (lb/in)	y_4 (in)	p_5 (lb/in)	y_5 (in)
1	-1.0	Clay	343.6	7.20	85.9	0.12	171.8	0.90	247.4	2.70	343.6	7.20	343.6	14.40
2	-5.0	Clay	411.1	7.20	102.8	0.12	205.5	0.90	296.0	2.70	411.1	7.20	411.1	14.40
3	-9.0	Clay	450.0	7.20	112.5	0.12	225.0	0.90	324.0	2.70	450.0	7.20	450.0	14.40
4	-14.0	Clay	2158.4	4.33	539.6	0.07	1079.2	0.54	1554.0	1.62	2158.4	4.33	2158.4	8.66
5	-18.0	Sand	5125.2	1.64	512.5	0.05	2357.6	0.28	3895.2	0.54	4663.9	0.82	5125.2	1.64
6	-23.0	Sand	6945.7	1.87	694.6	0.06	3195.0	0.32	5278.7	0.62	6320.6	0.93	6945.7	1.87
7	-28.0	Sand	8085.5	1.87	808.6	0.06	3719.3	0.32	6145.0	0.62	7357.8	0.94	8085.5	1.87
8	-33.0	Sand	9031.0	1.84	903.1	0.06	4154.3	0.31	6863.6	0.61	8218.2	0.92	9031.0	1.84
9	-38.0	Sand	12265.7	1.78	1226.6	0.05	5642.2	0.30	9321.9	0.59	11161.8	0.89	12265.7	1.78
10	-43.0	Sand	16054.0	1.75	1605.4	0.05	7384.8	0.30	12201.0	0.58	14609.1	0.87	16054.0	1.75
11	-48.0	Sand	9151.6	3.27	915.2	0.10	4209.7	0.56	6955.2	1.08	8327.9	1.64	9151.6	3.27
12	-51.0	Clay	750.0	4.80	187.5	0.08	375.0	0.60	540.0	1.80	750.0	4.80	750.0	9.60
13	-55.0	Clay	750.0	4.80	187.5	0.08	375.0	0.60	540.0	1.80	750.0	4.80	750.0	9.60

TABLE D-7: PIER 7 – *p-y* CURVES

Node #	Elevation (ft)	Soil Type	p_u (lb/in)	y_u (in)	p_1 (lb/in)	y_1 (in)	p_2 (lb/in)	y_2 (in)	p_3 (lb/in)	y_3 (in)	p_4 (lb/in)	y_4 (in)	p_5 (lb/in)	y_5 (in)
1	-6.0	Clay	150.0	7.20	37.5	0.12	75.0	0.90	108.0	2.70	150.0	7.20	150.0	14.40
2	-10.0	Clay	217.5	7.20	54.4	0.12	108.8	0.90	156.6	2.70	217.5	7.20	217.5	14.40
3	-14.0	Clay	352.5	3.82	88.1	0.06	176.2	0.48	253.8	1.43	352.5	3.82	352.5	7.64
4	-19.0	Sand	1045.6	0.67	104.6	0.02	481.0	0.11	794.7	0.22	951.5	0.34	1045.6	0.67
5	-24.0	Sand	1946.3	0.90	194.6	0.03	895.3	0.15	1479.2	0.30	1771.1	0.45	1946.3	0.90
6	-29.0	Sand	3122.0	1.13	312.2	0.03	1436.1	0.19	2372.7	0.37	2841.0	0.57	3122.0	1.13
7	-34.0	Sand	2661.3	3.08	266.1	0.09	1224.2	0.52	2022.6	1.02	2421.8	1.54	2661.3	3.08
8	-38.0	Clay	750.0	4.80	187.5	0.08	375.0	0.60	540.0	1.80	750.0	4.80	750.0	9.60
9	-43.0	Clay	750.0	4.80	187.5	0.08	375.0	0.60	540.0	1.80	750.0	4.80	750.0	9.60
10	-48.0	Clay	7870.0	3.18	1967.5	0.05	3935.0	0.40	5666.4	1.19	7870.0	3.18	7870.0	6.35
11	-51.0	Sand	16230.0	1.57	1623.0	0.05	7465.8	0.27	12334.8	0.52	14769.3	0.78	16230.0	1.57
12	-55.0	Sand	17883.2	1.59	1788.3	0.05	8226.3	0.27	13591.2	0.52	16273.7	0.79	17883.2	1.59

TABLE D-8: PIER 8 – *p-y* CURVES

Node #	Elevation (ft)	Soil Type	p_u (lb/in)	y_u (in)	p_1 (lb/in)	y_1 (in)	p_2 (lb/in)	y_2 (in)	p_3 (lb/in)	y_3 (in)	p_4 (lb/in)	y_4 (in)	p_5 (lb/in)	y_5 (in)
1	-16.0	Sand	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00
2	-18.0	Sand	98.8	0.56	9.9	0.02	45.5	0.10	75.1	0.19	89.9	0.28	98.8	0.56
3	-23.0	Sand	354.8	0.42	35.5	0.01	163.2	0.07	269.6	0.14	322.9	0.21	354.8	0.42
4	-28.0	Sand	748.3	2.73	74.8	0.08	344.2	0.46	568.7	0.90	681.0	1.36	748.3	2.73
5	-31.0	Clay	633.7	4.80	158.4	0.08	316.8	0.60	456.2	1.80	633.7	4.80	633.7	9.60
6	-34.0	Clay	710.6	4.80	177.6	0.08	355.3	0.60	511.6	1.80	710.6	4.80	710.6	9.60
7	-39.0	Clay	750.0	4.80	187.5	0.08	375.0	0.60	540.0	1.80	750.0	4.80	750.0	9.60
8	-44.0	Clay	750.0	4.80	187.5	0.08	375.0	0.60	540.0	1.80	750.0	4.80	750.0	9.60
9	-49.0	Clay	5291.3	3.05	1322.8	0.05	2645.6	0.38	3809.7	1.14	5291.3	3.05	5291.3	6.10
10	-52.0	Sand	11786.0	1.42	1178.6	0.04	5421.5	0.24	8957.3	0.47	10725.2	0.71	11786.0	1.42
11	-56.0	Sand	14663.3	1.59	1466.3	0.05	6745.1	0.27	11144.1	0.53	13343.6	0.80	14663.3	1.59
12	-60.0	Sand	16459.3	1.63	1645.9	0.05	7571.3	0.28	12509.1	0.54	14978.0	0.81	16459.3	1.63

TABLE D-9: PIER 9 – *p-y* CURVES

Node #	Elevation (ft)	Soil Type	p_u (lb/in)	y_u (in)	p_1 (lb/in)	y_1 (in)	p_2 (lb/in)	y_2 (in)	p_3 (lb/in)	y_3 (in)	p_4 (lb/in)	y_4 (in)	p_5 (lb/in)	y_5 (in)
1	-18.0	Sand	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00
2	-23.0	Sand	185.5	0.42	18.6	0.01	85.3	0.07	141.0	0.14	168.8	0.21	185.5	0.42
3	-27.0	Sand	539.4	0.50	53.9	0.01	248.1	0.08	410.0	0.16	490.9	0.25	539.4	0.50
4	-31.0	Sand	824.4	2.74	82.4	0.08	379.2	0.47	626.6	0.90	750.2	1.37	824.4	2.74
5	-36.0	Clay	709.3	4.80	177.3	0.08	354.7	0.60	510.7	1.80	709.3	4.80	709.3	9.60
6	-41.0	Clay	750.0	4.80	187.5	0.08	375.0	0.60	540.0	1.80	750.0	4.80	750.0	9.60
7	-46.0	Clay	750.0	4.80	187.5	0.08	375.0	0.60	540.0	1.80	750.0	4.80	750.0	9.60
8	-51.0	Clay	5252.3	3.04	1313.1	0.05	2626.1	0.38	3781.6	1.14	5252.3	3.04	5252.3	6.09
9	-55.0	Sand	12389.2	1.46	1238.9	0.04	5699.0	0.25	9415.8	0.48	11274.1	0.73	12389.2	1.46
10	-60.0	Sand	15538.2	1.61	1553.8	0.05	7147.6	0.27	11809.0	0.53	14139.7	0.80	15538.2	1.61

TABLE D-10: PIER 10 – *p-y* CURVES

Node #	Elevation (ft)	Soil Type	p_u (lb/in)	y_u (in)	p_1 (lb/in)	y_1 (in)	p_2 (lb/in)	y_2 (in)	p_3 (lb/in)	y_3 (in)	p_4 (lb/in)	y_4 (in)	p_5 (lb/in)	y_5 (in)
1	-16.0	Sand	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00
2	-20.0	Sand	159.3	0.60	15.9	0.02	73.3	0.10	121.1	0.20	145.0	0.30	159.3	0.60
3	-24.0	Sand	325.4	0.62	32.5	0.02	149.7	0.10	247.3	0.20	296.1	0.31	325.4	0.62
4	-28.0	Sand	769.9	0.72	77.0	0.02	354.1	0.12	585.1	0.24	700.6	0.36	769.9	0.72
5	-33.0	Sand	1707.0	0.84	170.7	0.03	785.2	0.14	1297.3	0.28	1553.4	0.42	1707.0	0.84
6	-38.0	Sand	2818.2	1.07	281.8	0.03	1296.3	0.18	2141.8	0.35	2564.5	0.53	2818.2	1.07
7	-43.0	Sand	2477.1	3.05	247.7	0.09	1139.5	0.52	1882.6	1.01	2254.2	1.52	2477.1	3.05
8	-46.0	Clay	750.0	4.80	187.5	0.08	375.0	0.60	540.0	1.80	750.0	4.80	750.0	9.60
9	-50.0	Clay	5452.0	3.05	1363.0	0.05	2726.0	0.38	3925.4	1.14	5452.0	3.05	5452.0	6.10
10	-54.0	Sand	12841.0	1.47	1284.1	0.04	5906.9	0.25	9759.2	0.48	11685.3	0.73	12841.0	1.47
11	-58.0	Sand	15267.3	1.58	1526.7	0.05	7022.9	0.27	11603.1	0.52	13893.2	0.79	15267.3	1.58
12	-63.0	Sand	17333.8	1.60	1733.4	0.05	7973.5	0.27	13173.7	0.53	15773.8	0.80	17333.8	1.60

TABLE D-11: PIER 11 – *p-y* CURVES

Node #	Elevation (ft)	Soil Type	p_u (lb/in)	y_u (in)	p_1 (lb/in)	y_1 (in)	p_2 (lb/in)	y_2 (in)	p_3 (lb/in)	y_3 (in)	p_4 (lb/in)	y_4 (in)	p_5 (lb/in)	y_5 (in)
1	-19.0	Sand	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00
2	-23.0	Sand	159.3	0.60	15.9	0.02	73.3	0.10	121.1	0.20	145.0	0.30	159.3	0.60
3	-27.0	Sand	325.4	0.62	32.5	0.02	149.7	0.10	247.3	0.20	296.1	0.31	325.4	0.62
4	-31.0	Sand	769.9	0.72	77.0	0.02	354.1	0.12	585.1	0.24	700.6	0.36	769.9	0.72
5	-35.0	Sand	1517.8	0.79	151.8	0.02	698.2	0.13	1153.5	0.26	1381.2	0.40	1517.8	0.79
6	-40.0	Sand	1662.0	2.91	166.2	0.09	764.5	0.49	1263.1	0.96	1512.4	1.46	1662.0	2.91
7	-43.0	Clay	750.0	4.80	187.5	0.08	375.0	0.60	540.0	1.80	750.0	4.80	750.0	9.60
8	-46.0	Clay	3596.6	2.92	899.1	0.05	1798.3	0.36	2589.5	1.09	3596.6	2.92	3596.6	5.84
9	-49.0	Sand	8045.0	1.17	804.5	0.03	3700.7	0.20	6114.2	0.38	7320.9	0.58	8045.0	1.17
10	-53.0	Sand	10453.5	1.34	1045.4	0.04	4808.6	0.23	7944.7	0.44	9512.7	0.67	10453.5	1.34
11	-58.0	Sand	13902.6	1.55	1390.3	0.05	6395.2	0.26	10565.9	0.51	12651.3	0.77	13902.6	1.55
12	-63.0	Sand	16446.7	1.63	1644.7	0.05	7565.5	0.28	12499.5	0.54	14966.5	0.81	16446.7	1.63

TABLE D-12: PIER 12 – *p-y* CURVES

Node #	Elevation (ft)	Soil Type	p_u (lb/in)	y_u (in)	p_1 (lb/in)	y_1 (in)	p_2 (lb/in)	y_2 (in)	p_3 (lb/in)	y_3 (in)	p_4 (lb/in)	y_4 (in)	p_5 (lb/in)	y_5 (in)
1	-19.0	Sand	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00
2	-23.0	Sand	160.5	0.61	16.1	0.02	73.8	0.10	122.0	0.20	146.1	0.30	160.5	0.61
3	-27.0	Sand	327.9	0.62	32.8	0.02	150.8	0.11	249.2	0.20	298.4	0.31	327.9	0.62
4	-32.0	Sand	858.5	0.81	85.8	0.02	394.9	0.14	652.4	0.27	781.2	0.41	858.5	0.81
5	-35.0	Sand	1400.8	0.88	140.1	0.03	644.4	0.15	1064.6	0.29	1274.7	0.44	1400.8	0.88
6	-39.0	Sand	1455.4	2.94	145.5	0.09	669.5	0.50	1106.1	0.97	1324.4	1.47	1455.4	2.94
7	-44.0	Clay	3103.3	2.87	775.8	0.05	1551.7	0.36	2234.4	1.08	3103.3	2.87	3103.3	5.75
8	-48.0	Sand	7480.5	1.12	748.0	0.03	3441.0	0.19	5685.2	0.37	6807.2	0.56	7480.5	1.12
9	-52.0	Sand	9818.0	1.29	981.8	0.04	4516.3	0.22	7461.7	0.43	8934.4	0.65	9818.0	1.29
10	-56.0	Sand	12469.1	1.47	1246.9	0.04	5735.8	0.25	9476.5	0.48	11346.9	0.73	12469.1	1.47
11	-60.0	Sand	15221.9	1.61	1522.2	0.05	7002.1	0.27	11568.6	0.53	13851.9	0.81	15221.9	1.61

TABLE D-13: PIER 13 – *p-y* CURVES

Node #	Elevation (ft)	Soil Type	p_u (lb/in)	y_u (in)	p_1 (lb/in)	y_1 (in)	p_2 (lb/in)	y_2 (in)	p_3 (lb/in)	y_3 (in)	p_4 (lb/in)	y_4 (in)	p_5 (lb/in)	y_5 (in)
1	-22.0	Sand	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00
2	-27.0	Sand	163.2	0.49	16.3	0.01	75.1	0.08	124.0	0.16	148.5	0.25	163.2	0.49
3	-32.0	Sand	482.1	0.73	48.2	0.02	221.8	0.12	366.4	0.24	438.7	0.37	482.1	0.73
4	-37.0	Sand	1160.1	0.87	116.0	0.03	533.7	0.15	881.7	0.29	1055.7	0.44	1160.1	0.87
5	-40.0	Sand	1878.0	0.87	187.8	0.03	863.9	0.15	1427.2	0.29	1708.9	0.43	1878.0	0.87
6	-44.0	Sand	2783.1	1.05	278.3	0.03	1280.2	0.18	2115.2	0.35	2532.6	0.53	2783.1	1.05
7	-48.0	Sand	2307.1	3.02	230.7	0.09	1061.3	0.51	1753.4	1.00	2099.5	1.51	2307.1	3.02
8	-51.0	Clay	750.0	4.80	187.5	0.08	375.0	0.60	540.0	1.80	750.0	4.80	750.0	9.60
9	-54.0	Clay	4841.2	3.01	1210.3	0.05	2420.6	0.38	3485.7	1.13	4841.2	3.01	4841.2	6.01
10	-58.0	Sand	11464.2	1.38	1146.4	0.04	5273.5	0.24	8712.8	0.46	10432.4	0.69	11464.2	1.38
11	-62.0	Sand	14307.6	1.56	1430.8	0.05	6581.5	0.26	10873.8	0.51	13019.9	0.78	14307.6	1.56
12	-66.0	Sand	16100.2	1.59	1610.0	0.05	7406.1	0.27	12236.1	0.52	14651.2	0.80	16100.2	1.59

TABLE D-14: PIER 14 – *p-y* CURVES

Node #	Elevation (ft)	Soil Type	p_u (lb/in)	y_u (in)	p_1 (lb/in)	y_1 (in)	p_2 (lb/in)	y_2 (in)	p_3 (lb/in)	y_3 (in)	p_4 (lb/in)	y_4 (in)	p_5 (lb/in)	y_5 (in)
1	-20.0	Sand	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00
2	-24.0	Sand	159.3	0.60	15.9	0.02	73.3	0.10	121.1	0.20	145.0	0.30	159.3	0.60
3	-28.0	Sand	325.4	0.62	32.5	0.02	149.7	0.10	247.3	0.20	296.1	0.31	325.4	0.62
4	-32.0	Sand	769.9	0.72	77.0	0.02	354.1	0.12	585.1	0.24	700.6	0.36	769.9	0.72
5	-36.0	Sand	1517.8	0.79	151.8	0.02	698.2	0.13	1153.5	0.26	1381.2	0.40	1517.8	0.79
6	-41.0	Sand	1662.0	2.91	166.2	0.09	764.5	0.49	1263.1	0.96	1512.4	1.46	1662.0	2.91
7	-45.0	Clay	3143.4	2.88	785.9	0.05	1571.7	0.36	2263.3	1.08	3143.4	2.88	3143.4	5.76
8	-50.0	Sand	8121.0	1.18	812.1	0.04	3735.7	0.20	6172.0	0.39	7390.1	0.59	8121.0	1.18
9	-55.0	Sand	11192.3	1.39	1119.2	0.04	5148.5	0.24	8506.1	0.46	10185.0	0.70	11192.3	1.39
10	-60.0	Sand	14750.7	1.60	1475.1	0.05	6785.3	0.27	11210.5	0.53	13423.1	0.80	14750.7	1.60

TABLE D-15: PIER 15 – *p-y* CURVES

Node #	Elevation (ft)	Soil Type	p_u (lb/in)	y_u (in)	p_1 (lb/in)	y_1 (in)	p_2 (lb/in)	y_2 (in)	p_3 (lb/in)	y_3 (in)	p_4 (lb/in)	y_4 (in)	p_5 (lb/in)	y_5 (in)
1	-24.0	Sand	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00
2	-27.0	Sand	131.0	0.66	13.1	0.02	60.3	0.11	99.6	0.22	119.2	0.33	131.0	0.66
3	-31.0	Sand	295.3	0.48	29.5	0.01	135.8	0.08	224.4	0.16	268.7	0.24	295.3	0.48
4	-35.0	Sand	768.7	0.58	76.9	0.02	353.6	0.10	584.2	0.19	699.6	0.29	768.7	0.58
5	-40.0	Sand	1109.5	2.81	111.0	0.08	510.4	0.48	843.2	0.93	1009.7	1.40	1109.5	2.81
6	-45.0	Clay	2382.5	2.82	595.6	0.05	1191.3	0.35	1715.4	1.06	2382.5	2.82	2382.5	5.63
7	-50.0	Sand	6251.9	1.05	625.2	0.03	2875.9	0.18	4751.4	0.35	5689.2	0.52	6251.9	1.05
8	-55.0	Sand	8975.8	1.26	897.6	0.04	4128.9	0.21	6821.6	0.42	8168.0	0.63	8975.8	1.26
9	-60.0	Sand	12186.8	1.47	1218.7	0.04	5605.9	0.25	9262.0	0.49	11090.0	0.74	12186.8	1.47
10	-65.0	Sand	15666.7	1.66	1566.7	0.05	7206.7	0.28	11906.7	0.55	14256.7	0.83	15666.7	1.66

TABLE D-16: PIER 16 – *p-y* CURVES

Node #	Elevation (ft)	Soil Type	p_u (lb/in)	y_u (in)	p_1 (lb/in)	y_1 (in)	p_2 (lb/in)	y_2 (in)	p_3 (lb/in)	y_3 (in)	p_4 (lb/in)	y_4 (in)	p_5 (lb/in)	y_5 (in)
1	-26.0	Sand	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00
2	-30.0	Sand	159.3	0.60	15.9	0.02	73.3	0.10	121.1	0.20	145.0	0.30	159.3	0.60
3	-34.0	Sand	372.6	0.53	37.3	0.02	171.4	0.09	283.2	0.17	339.1	0.26	372.6	0.53
4	-38.0	Sand	898.5	0.62	89.8	0.02	413.3	0.11	682.8	0.21	817.6	0.31	898.5	0.62
5	-42.0	Sand	1104.9	2.80	110.5	0.08	508.3	0.48	839.7	0.93	1005.5	1.40	1104.9	2.80
6	-46.0	Clay	2193.0	2.80	548.2	0.04	1096.5	0.35	1578.9	1.05	2193.0	2.80	2193.0	5.59
7	-50.0	Sand	5310.3	0.96	531.0	0.03	2442.7	0.16	4035.8	0.32	4832.3	0.48	5310.3	0.96
8	-55.0	Sand	7841.6	1.18	784.2	0.04	3607.1	0.20	5959.6	0.39	7135.8	0.59	7841.6	1.18
9	-60.0	Sand	10860.0	1.39	1086.0	0.04	4995.6	0.24	8253.6	0.46	9882.6	0.69	10860.0	1.39
10	-65.0	Sand	14365.5	1.60	1436.5	0.05	6608.1	0.27	10917.8	0.53	13072.6	0.80	14365.5	1.60
11	-70.0	Sand	16925.5	1.67	1692.6	0.05	7785.7	0.28	12863.4	0.55	15402.2	0.84	16925.5	1.67

TABLE D-17: PIER 17 – *p-y* CURVES

Node #	Elevation (ft)	Soil Type	p_u (lb/in)	y_u (in)	p_1 (lb/in)	y_1 (in)	p_2 (lb/in)	y_2 (in)	p_3 (lb/in)	y_3 (in)	p_4 (lb/in)	y_4 (in)	p_5 (lb/in)	y_5 (in)
1	-34.0	Sand	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00
2	-37.0	Sand	330.3	1.17	33.0	0.04	151.9	0.20	251.0	0.39	300.6	0.59	330.3	1.17
3	-42.0	Sand	1077.9	0.96	107.8	0.03	495.8	0.16	819.2	0.32	980.9	0.48	1077.9	0.96
4	-47.0	Sand	1391.5	0.76	139.2	0.02	640.1	0.13	1057.6	0.25	1266.3	0.38	1391.5	0.76
5	-52.0	Sand	2466.1	0.98	246.6	0.03	1134.4	0.17	1874.2	0.32	2244.1	0.49	2466.1	0.98
6	-57.0	Sand	3838.5	1.19	383.8	0.04	1765.7	0.20	2917.2	0.39	3493.0	0.60	3838.5	1.19
7	-62.0	Sand	5508.8	1.41	550.9	0.04	2534.0	0.24	4186.7	0.46	5013.0	0.70	5508.8	1.41
8	-67.0	Sand	7476.9	1.62	747.7	0.05	3439.4	0.28	5682.4	0.53	6804.0	0.81	7476.9	1.62
9	-72.0	Sand	11737.8	1.70	1173.8	0.05	5399.4	0.29	8920.7	0.56	10681.4	0.85	11737.8	1.70
10	-77.0	Sand	17662.3	1.79	1766.2	0.05	8124.6	0.30	13423.3	0.59	16072.7	0.89	17662.3	1.79
11	-82.0	Sand	22079.0	2.00	2207.9	0.06	10156.3	0.34	16780.1	0.66	20091.9	1.00	22079.0	2.00
12	-87.0	Sand	26982.9	2.21	2698.3	0.07	12412.1	0.38	20507.0	0.73	24554.4	1.11	26982.9	2.21
13	-92.0	Sand	32373.8	2.43	3237.4	0.07	14891.9	0.41	24604.1	0.80	29460.1	1.21	32373.8	2.43

TABLE D-18: PIER 18 – *p-y* CURVES

Node #	Elevation (ft)	Soil Type	p_u (lb/in)	y_u (in)	p_1 (lb/in)	y_1 (in)	p_2 (lb/in)	y_2 (in)	p_3 (lb/in)	y_3 (in)	p_4 (lb/in)	y_4 (in)	p_5 (lb/in)	y_5 (in)
1	-34.0	Sand	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00
2	-37.0	Sand	287.8	1.45	28.8	0.04	132.4	0.25	218.7	0.48	261.9	0.73	287.8	1.45
3	-40.0	Sand	596.8	1.51	59.7	0.05	274.5	0.26	453.6	0.50	543.1	0.75	596.8	1.51
4	-45.0	Sand	831.6	1.15	83.2	0.03	382.5	0.19	632.0	0.38	756.7	0.57	831.6	1.15
5	-50.0	Sand	1343.7	1.27	134.4	0.04	618.1	0.22	1021.2	0.42	1222.7	0.64	1343.7	1.27
6	-55.0	Sand	2159.2	1.56	215.9	0.05	993.2	0.26	1641.0	0.51	1964.8	0.78	2159.2	1.56
7	-60.0	Sand	3797.6	1.53	379.8	0.05	1746.9	0.26	2886.2	0.51	3455.8	0.77	3797.6	1.53
8	-63.0	Sand	5470.2	1.35	547.0	0.04	2516.3	0.23	4157.3	0.44	4977.9	0.67	5470.2	1.35
9	-66.0	Sand	6615.4	1.48	661.5	0.04	3043.1	0.25	5027.7	0.49	6020.0	0.74	6615.4	1.48
10	-71.0	Sand	8762.3	1.69	876.2	0.05	4030.7	0.29	6659.4	0.56	7973.7	0.85	8762.3	1.69
11	-76.0	Sand	11207.2	1.91	1120.7	0.06	5155.3	0.32	8517.4	0.63	10198.5	0.95	11207.2	1.91
12	-81.0	Sand	13949.8	2.12	1395.0	0.06	6416.9	0.36	10601.9	0.70	12694.4	1.06	13949.8	2.12
13	-86.0	Sand	20523.8	2.17	2052.4	0.07	9440.9	0.37	15598.1	0.72	18676.6	1.09	20523.8	2.17
14	-89.0	Sand	27073.7	2.14	2707.4	0.06	12453.9	0.36	20576.0	0.71	24637.0	1.07	27073.7	2.14
15	-92.0	Sand	30265.5	2.27	3026.6	0.07	13922.1	0.39	23001.8	0.75	27541.6	1.13	30265.5	2.27

TABLE D-19: PIER 19 – *p-y* CURVES

Node #	Elevation (ft)	Soil Type	p_u (lb/in)	y_u (in)	p_1 (lb/in)	y_1 (in)	p_2 (lb/in)	y_2 (in)	p_3 (lb/in)	y_3 (in)	p_4 (lb/in)	y_4 (in)	p_5 (lb/in)	y_5 (in)
1	-40.0	Sand	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00
2	-44.0	Sand	359.9	1.36	36.0	0.04	165.6	0.23	273.5	0.45	327.5	0.68	359.9	1.36
3	-48.0	Sand	689.1	1.31	68.9	0.04	317.0	0.22	523.7	0.43	627.0	0.65	689.1	1.31
4	-53.0	Sand	862.2	1.00	86.2	0.03	396.6	0.17	655.2	0.33	784.6	0.50	862.2	1.00
5	-58.0	Sand	1794.2	1.05	179.4	0.03	825.3	0.18	1363.6	0.35	1632.7	0.52	1794.2	1.05
6	-61.0	Sand	2827.2	0.96	282.7	0.03	1300.5	0.16	2148.7	0.32	2572.8	0.48	2827.2	0.96
7	-65.0	Sand	3984.6	1.14	398.5	0.03	1832.9	0.19	3028.3	0.38	3625.9	0.57	3984.6	1.14
8	-70.0	Sand	5701.1	1.36	570.1	0.04	2622.5	0.23	4332.9	0.45	5188.0	0.68	5701.1	1.36
9	-75.0	Sand	9290.3	1.46	929.0	0.04	4273.5	0.25	7060.6	0.48	8454.1	0.73	9290.3	1.46
10	-78.0	Sand	12937.9	1.48	1293.8	0.04	5951.4	0.25	9832.8	0.49	11773.5	0.74	12937.9	1.48
11	-83.0	Sand	16788.3	1.70	1678.8	0.05	7722.6	0.29	12759.1	0.56	15277.3	0.85	16788.3	1.70
12	-88.0	Sand	21128.7	1.91	2112.9	0.06	9719.2	0.33	16057.8	0.63	19227.1	0.96	21128.7	1.91
13	-93.0	Sand	25959.2	2.13	2595.9	0.06	11941.2	0.36	19729.0	0.70	23622.9	1.06	25959.2	2.13
14	-98.0	Sand	31279.7	2.34	3128.0	0.07	14388.7	0.40	23772.6	0.77	28464.5	1.17	31279.7	2.34

TABLE D-20: PIER 20 – *p-y* CURVES

Node #	Elevation (ft)	Soil Type	p_u (lb/in)	y_u (in)	p_1 (lb/in)	y_1 (in)	p_2 (lb/in)	y_2 (in)	p_3 (lb/in)	y_3 (in)	p_4 (lb/in)	y_4 (in)	p_5 (lb/in)	y_5 (in)
1	-44.0	Clay	168.8	21.60	42.2	0.35	84.4	2.70	121.5	8.10	168.8	21.60	168.8	43.20
2	-49.0	Clay	244.6	21.60	61.2	0.35	122.3	2.70	176.1	8.10	244.6	21.60	244.6	43.20
3	-54.0	Clay	320.5	21.60	80.1	0.35	160.3	2.70	230.8	8.10	320.5	21.60	320.5	43.20
4	-59.0	Clay	396.4	21.60	99.1	0.35	198.2	2.70	285.4	8.10	396.4	21.60	396.4	43.20
5	-64.0	Clay	472.3	21.60	118.1	0.35	236.1	2.70	340.0	8.10	472.3	21.60	472.3	43.20
6	-69.0	Clay	2119.9	11.33	530.0	0.18	1060.0	1.42	1526.3	4.25	2119.9	11.33	2119.9	22.67
7	-73.0	Sand	5044.0	1.24	504.4	0.04	2320.3	0.21	3833.5	0.41	4590.1	0.62	5044.0	1.24
8	-78.0	Sand	6950.2	1.46	695.0	0.04	3197.1	0.25	5282.2	0.48	6324.7	0.73	6950.2	1.46
9	-83.0	Sand	11031.3	1.56	1103.1	0.05	5074.4	0.26	8383.8	0.51	10038.5	0.78	11031.3	1.56
10	-86.0	Sand	15157.9	1.57	1515.8	0.05	6972.6	0.27	11520.0	0.52	13793.7	0.78	15157.9	1.57
11	-90.0	Sand	18430.1	1.74	1843.0	0.05	8477.8	0.30	14006.9	0.57	16771.4	0.87	18430.1	1.74
12	-95.0	Sand	22958.7	1.96	2295.9	0.06	10561.0	0.33	17448.6	0.65	20892.4	0.98	22958.7	1.96
13	-100.0	Sand	27974.3	2.17	2797.4	0.07	12868.2	0.37	21260.5	0.72	25456.6	1.09	27974.3	2.17

TABLE D-21: PIER 21 – *p-y* CURVES

Node #	Elevation (ft)	Soil Type	p_u (lb/in)	y_u (in)	p_1 (lb/in)	y_1 (in)	p_2 (lb/in)	y_2 (in)	p_3 (lb/in)	y_3 (in)	p_4 (lb/in)	y_4 (in)	p_5 (lb/in)	y_5 (in)
1	-20.0	Clay	168.8	21.60	42.2	0.35	84.4	2.70	121.5	8.10	168.8	21.60	168.8	43.20
2	-25.0	Clay	245.0	21.60	61.3	0.35	122.5	2.70	176.4	8.10	245.0	21.60	245.0	43.20
3	-30.0	Clay	321.3	21.60	80.3	0.35	160.6	2.70	231.3	8.10	321.3	21.60	321.3	43.20
4	-35.0	Clay	397.5	21.60	99.4	0.35	198.8	2.70	286.2	8.10	397.5	21.60	397.5	43.20
5	-40.0	Clay	473.8	21.60	118.4	0.35	236.9	2.70	341.1	8.10	473.8	21.60	473.8	43.20
6	-45.0	Clay	506.3	21.60	126.6	0.35	253.1	2.70	364.5	8.10	506.3	21.60	506.3	43.20
7	-50.0	Clay	506.3	21.60	126.6	0.35	253.1	2.70	364.5	8.10	506.3	21.60	506.3	43.20
8	-55.0	Clay	506.3	21.60	126.6	0.35	253.1	2.70	364.5	8.10	506.3	21.60	506.3	43.20
9	-60.0	Clay	506.3	21.60	126.6	0.35	253.1	2.70	364.5	8.10	506.3	21.60	506.3	43.20
10	-65.0	Clay	506.3	21.60	126.6	0.35	253.1	2.70	364.5	8.10	506.3	21.60	506.3	43.20
11	-70.0	Clay	506.3	21.60	126.6	0.35	253.1	2.70	364.5	8.10	506.3	21.60	506.3	43.20
12	-75.0	Clay	11924.3	11.72	2981.1	0.19	5962.2	1.47	8585.5	4.40	11924.3	11.72	11924.3	23.45
13	-78.0	Sand	26357.4	1.98	2635.7	0.06	12124.4	0.34	20031.6	0.65	23985.3	0.99	26357.4	1.98
14	-83.0	Sand	31774.5	2.19	3177.4	0.07	14616.3	0.37	24148.6	0.72	28914.8	1.10	31774.5	2.19
15	-88.0	Sand	37681.6	2.41	3768.2	0.07	17333.5	0.41	28638.0	0.80	34290.2	1.20	37681.6	2.41
16	-93.0	Sand	44078.8	2.63	4407.9	0.08	20276.2	0.45	33499.9	0.87	40111.7	1.31	44078.8	2.63
17	-98.0	Sand	50966.0	2.84	5096.6	0.09	23444.3	0.48	38734.1	0.94	46379.0	1.42	50966.0	2.84

TABLE D-22: PIER 22 – *p-y* CURVES

Node #	Elevation (ft)	Soil Type	p_u (lb/in)	y_u (in)	p_1 (lb/in)	y_1 (in)	p_2 (lb/in)	y_2 (in)	p_3 (lb/in)	y_3 (in)	p_4 (lb/in)	y_4 (in)	p_5 (lb/in)	y_5 (in)
1	-14.0	Clay	126.1	9.60	31.5	0.15	63.0	1.20	90.8	3.60	126.1	9.60	126.1	19.20
2	-18.0	Clay	167.0	9.60	41.7	0.15	83.5	1.20	120.2	3.60	167.0	9.60	167.0	19.20
3	-23.0	Clay	218.0	9.60	54.5	0.15	109.0	1.20	157.0	3.60	218.0	9.60	218.0	19.20
4	-28.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
5	-33.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
6	-38.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
7	-43.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
8	-48.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
9	-53.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
10	-58.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
11	-63.0	Clay	4814.6	5.42	1203.7	0.09	2407.3	0.68	3466.5	2.03	4814.6	5.42	4814.6	10.84
12	-66.0	Sand	10036.4	1.26	1003.6	0.04	4616.7	0.21	7627.7	0.42	9133.1	0.63	10036.4	1.26
13	-69.0	Sand	10668.6	1.27	1066.9	0.04	4907.6	0.22	8108.2	0.42	9708.4	0.64	10668.6	1.27
14	-74.0	Sand	11722.3	1.29	1172.2	0.04	5392.3	0.22	8909.0	0.43	10667.3	0.64	11722.3	1.29
15	-79.0	Sand	12776.0	1.30	1277.6	0.04	5877.0	0.22	9709.8	0.43	11626.2	0.65	12776.0	1.30
16	-84.0	Sand	13829.7	1.32	1383.0	0.04	6361.7	0.22	10510.6	0.43	12585.0	0.66	13829.7	1.32
17	-89.0	Sand	20256.8	1.36	2025.7	0.04	9318.1	0.23	15395.2	0.45	18433.7	0.68	20256.8	1.36
18	-93.0	Sand	27283.5	1.41	2728.3	0.04	12550.4	0.24	20735.4	0.47	24828.0	0.71	27283.5	1.41
19	-98.0	Sand	29350.0	1.43	2935.0	0.04	13501.0	0.24	22306.0	0.47	26708.5	0.72	29350.0	1.43

TABLE D-23: PIER 23 – *p-y* CURVES

Node #	Elevation (ft)	Soil Type	p_u (lb/in)	y_u (in)	p_1 (lb/in)	y_1 (in)	p_2 (lb/in)	y_2 (in)	p_3 (lb/in)	y_3 (in)	p_4 (lb/in)	y_4 (in)	p_5 (lb/in)	y_5 (in)
1	-16.0	Clay	115.9	9.60	29.0	0.15	57.9	1.20	83.4	3.60	115.9	9.60	115.9	19.20
2	-21.0	Clay	167.0	9.60	41.7	0.15	83.5	1.20	120.2	3.60	167.0	9.60	167.0	19.20
3	-26.0	Clay	218.0	9.60	54.5	0.15	109.0	1.20	157.0	3.60	218.0	9.60	218.0	19.20
4	-31.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
5	-36.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
6	-41.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
7	-46.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
8	-51.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
9	-56.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
10	-61.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
11	-66.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
12	-71.0	Clay	5250.0	5.42	1312.5	0.09	2625.0	0.68	3780.0	2.03	5250.0	5.42	5250.0	10.84
13	-75.0	Sand	11117.9	1.26	1111.8	0.04	5114.2	0.21	8449.6	0.42	10117.3	0.63	11117.9	1.26
14	-79.0	Sand	11960.9	1.28	1196.1	0.04	5502.0	0.22	9090.3	0.42	10884.4	0.64	11960.9	1.28
15	-84.0	Sand	13014.6	1.29	1301.5	0.04	5986.7	0.22	9891.1	0.43	11843.2	0.65	13014.6	1.29
16	-89.0	Sand	19147.4	1.34	1914.7	0.04	8807.8	0.23	14552.0	0.44	17424.1	0.67	19147.4	1.34
17	-93.0	Sand	25879.7	1.39	2588.0	0.04	11904.7	0.24	19668.6	0.46	23550.6	0.69	25879.7	1.39
18	-98.0	Sand	27946.3	1.41	2794.6	0.04	12855.3	0.24	21239.2	0.47	25431.1	0.71	27946.3	1.41
19	-103.0	Sand	30012.8	1.43	3001.3	0.04	13805.9	0.24	22809.7	0.47	27311.7	0.72	30012.8	1.43

TABLE D-24: PIER 24 – *p-y* CURVES

Node #	Elevation (ft)	Soil Type	p_u (lb/in)	y_u (in)	p_1 (lb/in)	y_1 (in)	p_2 (lb/in)	y_2 (in)	p_3 (lb/in)	y_3 (in)	p_4 (lb/in)	y_4 (in)	p_5 (lb/in)	y_5 (in)
1	-17.0	Clay	115.9	9.60	29.0	0.15	57.9	1.20	83.4	3.60	115.9	9.60	115.9	19.20
2	-20.0	Clay	146.5	9.60	36.6	0.15	73.3	1.20	105.5	3.60	146.5	9.60	146.5	19.20
3	-24.0	Clay	187.4	9.60	46.8	0.15	93.7	1.20	134.9	3.60	187.4	9.60	187.4	19.20
4	-29.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
5	-34.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
6	-39.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
7	-44.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
8	-49.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
9	-54.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
10	-59.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
11	-64.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
12	-69.0	Clay	4988.8	5.42	1247.2	0.09	2494.4	0.68	3591.9	2.03	4988.8	5.42	4988.8	10.84
13	-72.0	Sand	10384.7	1.26	1038.5	0.04	4777.0	0.21	7892.4	0.41	9450.1	0.63	10384.7	1.26
14	-76.0	Sand	11227.7	1.27	1122.8	0.04	5164.7	0.22	8533.0	0.42	10217.2	0.64	11227.7	1.27
15	-81.0	Sand	12281.4	1.29	1228.1	0.04	5649.4	0.22	9333.8	0.43	11176.0	0.65	12281.4	1.29
16	-86.0	Sand	18149.5	1.34	1814.9	0.04	8348.8	0.23	13793.6	0.44	16516.0	0.67	18149.5	1.34
17	-90.0	Sand	24617.1	1.39	2461.7	0.04	11323.9	0.24	18709.0	0.46	22401.6	0.70	24617.1	1.39
18	-95.0	Sand	26683.7	1.41	2668.4	0.04	12274.5	0.24	20279.6	0.47	24282.1	0.71	26683.7	1.41
19	-100.0	Sand	28750.2	1.44	2875.0	0.04	13225.1	0.24	21850.2	0.47	26162.7	0.72	28750.2	1.44
20	-105.0	Sand	30816.8	1.46	3081.7	0.04	14175.7	0.25	23420.7	0.48	28043.3	0.73	30816.8	1.46

TABLE D-25: PIER 25 – *p-y* CURVES

Node #	Elevation (ft)	Soil Type	p_u (lb/in)	y_u (in)	p_1 (lb/in)	y_1 (in)	p_2 (lb/in)	y_2 (in)	p_3 (lb/in)	y_3 (in)	p_4 (lb/in)	y_4 (in)	p_5 (lb/in)	y_5 (in)
1	-18.0	Clay	126.1	9.60	31.5	0.15	63.0	1.20	90.8	3.60	126.1	9.60	126.1	19.20
2	-21.0	Clay	156.7	9.60	39.2	0.15	78.4	1.20	112.8	3.60	156.7	9.60	156.7	19.20
3	-25.0	Clay	197.6	9.60	49.4	0.15	98.8	1.20	142.3	3.60	197.6	9.60	197.6	19.20
4	-30.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
5	-35.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
6	-40.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
7	-45.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
8	-50.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
9	-55.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
10	-60.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
11	-65.0	Clay	4640.5	5.42	1160.1	0.09	2320.2	0.68	3341.1	2.03	4640.5	5.42	4640.5	10.84
12	-69.0	Sand	9898.8	1.26	989.9	0.04	4553.5	0.21	7523.1	0.42	9007.9	0.63	9898.8	1.26
13	-73.0	Sand	10741.8	1.28	1074.2	0.04	4941.2	0.22	8163.8	0.42	9775.0	0.64	10741.8	1.28
14	-77.0	Sand	11584.8	1.29	1158.5	0.04	5329.0	0.22	8804.4	0.43	10542.1	0.65	11584.8	1.29
15	-81.0	Sand	16914.5	1.34	1691.5	0.04	7780.7	0.23	12855.1	0.44	15392.2	0.67	16914.5	1.34
16	-84.0	Sand	22641.3	1.39	2264.1	0.04	10415.0	0.24	17207.4	0.46	20603.6	0.69	22641.3	1.39
17	-87.0	Sand	23881.2	1.40	2388.1	0.04	10985.4	0.24	18149.7	0.46	21731.9	0.70	23881.2	1.40
18	-92.0	Sand	25947.8	1.43	2594.8	0.04	11936.0	0.24	19720.3	0.47	23612.5	0.71	25947.8	1.43
19	-97.0	Sand	28014.3	1.45	2801.4	0.04	12886.6	0.25	21290.9	0.48	25493.0	0.73	28014.3	1.45
20	-102.0	Sand	17846.0	1.79	1784.6	0.05	8209.2	0.30	13563.0	0.59	16239.9	0.89	17846.0	1.79
21	-103.0	Sand	5684.7	2.11	568.5	0.06	2615.0	0.36	4320.4	0.69	5173.1	1.05	5684.7	2.11

TABLE D-26: PIER 26 – *p-y* CURVES

Node #	Elevation (ft)	Soil Type	p_u (lb/in)	y_u (in)	p_1 (lb/in)	y_1 (in)	p_2 (lb/in)	y_2 (in)	p_3 (lb/in)	y_3 (in)	p_4 (lb/in)	y_4 (in)	p_5 (lb/in)	y_5 (in)
1	-18.5	Clay	131.2	9.60	32.8	0.15	65.6	1.20	94.5	3.60	131.2	9.60	131.2	19.20
2	-23.0	Clay	177.2	9.60	44.3	0.15	88.6	1.20	127.6	3.60	177.2	9.60	177.2	19.20
3	-28.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
4	-33.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
5	-38.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
6	-43.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
7	-48.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
8	-53.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
9	-58.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
10	-63.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
11	-68.0	Clay	4901.7	5.42	1225.4	0.09	2450.8	0.68	3529.2	2.03	4901.7	5.42	4901.7	10.84
12	-73.0	Sand	10632.0	1.27	1063.2	0.04	4890.7	0.22	8080.4	0.42	9675.2	0.63	10632.0	1.27
13	-78.0	Sand	15904.7	1.32	1590.5	0.04	7316.2	0.22	12087.6	0.43	14473.3	0.66	15904.7	1.32
14	-81.0	Sand	21363.6	1.37	2136.4	0.04	9827.2	0.23	16236.3	0.45	19440.8	0.68	21363.6	1.37
15	-85.0	Sand	23016.8	1.39	2301.7	0.04	10587.7	0.24	17492.8	0.46	20945.3	0.69	23016.8	1.39
16	-90.0	Sand	25083.4	1.42	2508.3	0.04	11538.3	0.24	19063.3	0.47	22825.8	0.71	25083.4	1.42
17	-95.0	Sand	27149.9	1.44	2715.0	0.04	12489.0	0.24	20633.9	0.48	24706.4	0.72	27149.9	1.44
18	-100.0	Sand	17333.2	1.77	1733.3	0.05	7973.3	0.30	13173.2	0.59	15773.2	0.89	17333.2	1.77
19	-105.0	Sand	5817.7	2.11	581.8	0.06	2676.2	0.36	4421.5	0.70	5294.1	1.05	5817.7	2.11

TABLE D-27: PIER 27 – *p-y* CURVES

Node #	Elevation (ft)	Soil Type	p_u (lb/in)	y_u (in)	p_1 (lb/in)	y_1 (in)	p_2 (lb/in)	y_2 (in)	p_3 (lb/in)	y_3 (in)	p_4 (lb/in)	y_4 (in)	p_5 (lb/in)	y_5 (in)
1	-19.5	Clay	131.2	9.60	32.8	0.15	65.6	1.20	94.5	3.60	131.2	9.60	131.2	19.20
2	-23.5	Clay	172.1	9.60	43.0	0.15	86.0	1.20	123.9	3.60	172.1	9.60	172.1	19.20
3	-28.0	Clay	218.0	9.60	54.5	0.15	109.0	1.20	157.0	3.60	218.0	9.60	218.0	19.20
4	-33.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
5	-38.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
6	-43.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
7	-48.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
8	-53.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
9	-58.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
10	-63.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
11	-68.0	Clay	4814.6	5.42	1203.7	0.09	2407.3	0.68	3466.5	2.03	4814.6	5.42	4814.6	10.84
12	-71.0	Sand	10036.4	1.26	1003.6	0.04	4616.7	0.21	7627.7	0.42	9133.1	0.63	10036.4	1.26
13	-75.0	Sand	10879.4	1.27	1087.9	0.04	5004.5	0.22	8268.3	0.42	9900.2	0.64	10879.4	1.27
14	-80.0	Sand	11933.1	1.29	1193.3	0.04	5489.2	0.22	9069.1	0.43	10859.1	0.65	11933.1	1.29
15	-85.0	Sand	12986.7	1.31	1298.7	0.04	5973.9	0.22	9869.9	0.43	11817.9	0.65	12986.7	1.31
16	-90.0	Sand	14040.4	1.32	1404.0	0.04	6458.6	0.22	10670.7	0.44	12776.8	0.66	14040.4	1.32
17	-95.0	Sand	15094.1	1.33	1509.4	0.04	6943.3	0.23	11471.5	0.44	13735.7	0.67	15094.1	1.33
18	-100.0	Sand	16147.8	1.34	1614.8	0.04	7428.0	0.23	12272.3	0.44	14694.5	0.67	16147.8	1.34
19	-105.0	Sand	17201.5	1.35	1720.2	0.04	7912.7	0.23	13073.1	0.45	15653.4	0.68	17201.5	1.35

TABLE D-28: PIER 28 – *p-y* CURVES

Node #	Elevation (ft)	Soil Type	p_u (lb/in)	y_u (in)	p_1 (lb/in)	y_1 (in)	p_2 (lb/in)	y_2 (in)	p_3 (lb/in)	y_3 (in)	p_4 (lb/in)	y_4 (in)	p_5 (lb/in)	y_5 (in)
1	-20.0	Clay	136.3	9.60	34.1	0.15	68.2	1.20	98.1	3.60	136.3	9.60	136.3	19.20
2	-24.0	Clay	177.2	9.60	44.3	0.15	88.6	1.20	127.6	3.60	177.2	9.60	177.2	19.20
3	-29.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
4	-34.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
5	-39.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
6	-44.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
7	-49.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
8	-54.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
9	-59.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
10	-64.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
11	-69.0	Clay	4901.7	5.42	1225.4	0.09	2450.8	0.68	3529.2	2.03	4901.7	5.42	4901.7	10.84
12	-73.0	Sand	10421.3	1.26	1042.1	0.04	4793.8	0.21	7920.2	0.42	9483.4	0.63	10421.3	1.26
13	-78.0	Sand	11475.0	1.28	1147.5	0.04	5278.5	0.22	8721.0	0.42	10442.2	0.64	11475.0	1.28
14	-83.0	Sand	12528.7	1.30	1252.9	0.04	5763.2	0.22	9521.8	0.43	11401.1	0.65	12528.7	1.30
15	-88.0	Sand	13582.4	1.31	1358.2	0.04	6247.9	0.22	10322.6	0.43	12360.0	0.66	13582.4	1.31
16	-93.0	Sand	14636.1	1.32	1463.6	0.04	6732.6	0.22	11123.4	0.44	13318.8	0.66	14636.1	1.32
17	-98.0	Sand	15689.8	1.33	1569.0	0.04	7217.3	0.23	11924.2	0.44	14277.7	0.67	15689.8	1.33
18	-103.0	Sand	16743.5	1.34	1674.3	0.04	7702.0	0.23	12725.0	0.44	15236.5	0.67	16743.5	1.34

TABLE D-29: PIER 29 – *p-y* CURVES

Node #	Elevation (ft)	Soil Type	p_u (lb/in)	y_u (in)	p_1 (lb/in)	y_1 (in)	p_2 (lb/in)	y_2 (in)	p_3 (lb/in)	y_3 (in)	p_4 (lb/in)	y_4 (in)	p_5 (lb/in)	y_5 (in)
1	-21.0	Clay	136.3	9.60	34.1	0.15	68.2	1.20	98.1	3.60	136.3	9.60	136.3	19.20
2	-24.0	Clay	167.0	9.60	41.7	0.15	83.5	1.20	120.2	3.60	167.0	9.60	167.0	19.20
3	-28.0	Clay	207.8	9.60	52.0	0.15	103.9	1.20	149.6	3.60	207.8	9.60	207.8	19.20
4	-33.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
5	-38.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
6	-43.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
7	-48.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
8	-53.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
9	-58.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
10	-63.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
11	-68.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
12	-73.0	Clay	5162.9	5.42	1290.7	0.09	2581.5	0.68	3717.3	2.03	5162.9	5.42	5162.9	10.84
13	-76.0	Sand	10733.0	1.26	1073.3	0.04	4937.2	0.21	8157.1	0.41	9767.0	0.63	10733.0	1.26
14	-80.0	Sand	11576.0	1.27	1157.6	0.04	5324.9	0.22	8797.7	0.42	10534.1	0.64	11576.0	1.27
15	-85.0	Sand	12629.7	1.29	1263.0	0.04	5809.6	0.22	9598.5	0.43	11493.0	0.64	12629.7	1.29
16	-90.0	Sand	13683.4	1.30	1368.3	0.04	6294.3	0.22	10399.3	0.43	12451.8	0.65	13683.4	1.30
17	-95.0	Sand	14737.0	1.32	1473.7	0.04	6779.0	0.22	11200.2	0.43	13410.7	0.66	14737.0	1.32
18	-100.0	Sand	15790.7	1.33	1579.1	0.04	7263.7	0.23	12001.0	0.44	14369.6	0.66	15790.7	1.33
19	-105.0	Sand	16844.4	1.34	1684.4	0.04	7748.4	0.23	12801.8	0.44	15328.4	0.67	16844.4	1.34

TABLE D-30: PIER 30 – *p-y* CURVES

Node #	Elevation (ft)	Soil Type	p_u (lb/in)	y_u (in)	p_1 (lb/in)	y_1 (in)	p_2 (lb/in)	y_2 (in)	p_3 (lb/in)	y_3 (in)	p_4 (lb/in)	y_4 (in)	p_5 (lb/in)	y_5 (in)
1	-21.0	Clay	126.3	9.60	31.6	0.15	63.1	1.20	90.9	3.60	126.3	9.60	126.3	19.20
2	-25.0	Clay	167.3	9.60	41.8	0.15	83.6	1.20	120.4	3.60	167.3	9.60	167.3	19.20
3	-30.0	Clay	218.5	9.60	54.6	0.15	109.3	1.20	157.3	3.60	218.5	9.60	218.5	19.20
4	-35.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
5	-40.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
6	-45.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
7	-50.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
8	-55.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
9	-60.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
10	-65.0	Clay	4415.1	5.43	1103.8	0.09	2207.5	0.68	3178.9	2.04	4415.1	5.43	4415.1	10.85
11	-68.0	Sand	9241.8	1.27	924.2	0.04	4251.2	0.22	7023.7	0.42	8410.0	0.63	9241.8	1.27
12	-72.0	Sand	10090.6	1.29	1009.1	0.04	4641.7	0.22	7668.8	0.42	9182.4	0.64	10090.6	1.29
13	-77.0	Sand	11151.6	1.31	1115.2	0.04	5129.7	0.22	8475.2	0.43	10147.9	0.65	11151.6	1.31
14	-82.0	Sand	12212.6	1.32	1221.3	0.04	5617.8	0.22	9281.6	0.44	11113.4	0.66	12212.6	1.32
15	-87.0	Sand	13273.6	1.34	1327.4	0.04	6105.8	0.23	10087.9	0.44	12079.0	0.67	13273.6	1.34
16	-92.0	Sand	14334.6	1.35	1433.5	0.04	6593.9	0.23	10894.3	0.44	13044.5	0.67	14334.6	1.35
17	-97.0	Sand	15395.6	1.36	1539.6	0.04	7082.0	0.23	11700.7	0.45	14010.0	0.68	15395.6	1.36
18	-102.0	Sand	10871.4	1.71	1087.1	0.05	5000.9	0.29	8262.3	0.56	9893.0	0.85	10871.4	1.71
19	-107.0	Sand	5654.1	2.07	565.4	0.06	2600.9	0.35	4297.1	0.68	5145.3	1.04	5654.1	2.07
20	-112.0	Sand	6022.0	2.09	602.2	0.06	2770.1	0.36	4576.7	0.69	5480.0	1.05	6022.0	2.09

TABLE D-31: PIER 31 – *p-y* CURVES

Node #	Elevation (ft)	Soil Type	p_u (lb/in)	y_u (in)	p_1 (lb/in)	y_1 (in)	p_2 (lb/in)	y_2 (in)	p_3 (lb/in)	y_3 (in)	p_4 (lb/in)	y_4 (in)	p_5 (lb/in)	y_5 (in)
1	-19.0	Clay	105.7	9.60	26.4	0.15	52.8	1.20	76.1	3.60	105.7	9.60	105.7	19.20
2	-24.0	Clay	156.7	9.60	39.2	0.15	78.4	1.20	112.8	3.60	156.7	9.60	156.7	19.20
3	-29.0	Clay	207.8	9.60	52.0	0.15	103.9	1.20	149.6	3.60	207.8	9.60	207.8	19.20
4	-34.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
5	-39.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
6	-44.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
7	-49.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
8	-54.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
9	-59.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
10	-64.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
11	-69.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
12	-74.0	Clay	5162.9	5.42	1290.7	0.09	2581.5	0.68	3717.3	2.03	5162.9	5.42	5162.9	10.84
13	-77.0	Sand	10733.0	1.26	1073.3	0.04	4937.2	0.21	8157.1	0.41	9767.0	0.63	10733.0	1.26
14	-81.0	Sand	11576.0	1.27	1157.6	0.04	5324.9	0.22	8797.7	0.42	10534.1	0.64	11576.0	1.27
15	-86.0	Sand	12629.7	1.29	1263.0	0.04	5809.6	0.22	9598.5	0.43	11493.0	0.64	12629.7	1.29
16	-91.0	Sand	13683.4	1.30	1368.3	0.04	6294.3	0.22	10399.3	0.43	12451.8	0.65	13683.4	1.30
17	-96.0	Sand	14737.0	1.32	1473.7	0.04	6779.0	0.22	11200.2	0.43	13410.7	0.66	14737.0	1.32
18	-101.0	Sand	15790.7	1.33	1579.1	0.04	7263.7	0.23	12001.0	0.44	14369.6	0.66	15790.7	1.33
19	-106.0	Sand	11127.6	1.67	1112.8	0.05	5118.7	0.28	8457.0	0.55	10126.2	0.84	11127.6	1.67
20	-112.0	Sand	5852.3	2.03	585.2	0.06	2692.0	0.35	4447.7	0.67	5325.6	1.02	5852.3	2.03

TABLE D-32: PIER 32 – *p-y* CURVES

Node #	Elevation (ft)	Soil Type	p_u (lb/in)	y_u (in)	p_1 (lb/in)	y_1 (in)	p_2 (lb/in)	y_2 (in)	p_3 (lb/in)	y_3 (in)	p_4 (lb/in)	y_4 (in)	p_5 (lb/in)	y_5 (in)
1	-19.0	Clay	95.4	9.60	23.9	0.15	47.7	1.20	68.7	3.60	95.4	9.60	95.4	19.20
2	-23.0	Clay	136.3	9.60	34.1	0.15	68.2	1.20	98.1	3.60	136.3	9.60	136.3	19.20
3	-27.0	Clay	177.2	9.60	44.3	0.15	88.6	1.20	127.6	3.60	177.2	9.60	177.2	19.20
4	-32.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
5	-37.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
6	-42.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
7	-47.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
8	-52.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
9	-57.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
10	-62.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
11	-67.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
12	-72.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
13	-77.0	Clay	5337.1	5.42	1334.3	0.09	2668.5	0.68	3842.7	2.03	5337.1	5.42	5337.1	10.84
14	-81.0	Sand	11292.1	1.26	1129.2	0.04	5194.3	0.21	8582.0	0.42	10275.8	0.63	11292.1	1.26
15	-86.0	Sand	12345.8	1.28	1234.6	0.04	5679.0	0.22	9382.8	0.42	11234.6	0.64	12345.8	1.28
16	-91.0	Sand	13399.4	1.29	1339.9	0.04	6163.7	0.22	10183.6	0.43	12193.5	0.65	13399.4	1.29
17	-96.0	Sand	14453.1	1.31	1445.3	0.04	6648.4	0.22	10984.4	0.43	13152.3	0.65	14453.1	1.31
18	-101.0	Sand	21105.3	1.35	2110.5	0.04	9708.4	0.23	16040.0	0.45	19205.8	0.68	21105.3	1.35
19	-107.0	Sand	17313.7	1.71	1731.4	0.05	7964.3	0.29	13158.4	0.57	15755.5	0.86	17313.7	1.71
20	-112.0	Sand	5811.6	2.04	581.2	0.06	2673.3	0.35	4416.8	0.67	5288.6	1.02	5811.6	2.04

TABLE D-33: PIER 33 – *p-y* CURVES

Node #	Elevation (ft)	Soil Type	t_{max} (lb/in)	z_c (in)	t_1 (lb/in)	z_1 (in)	t_2 (lb/in)	z_2 (in)	t_3 (lb/in)	z_3 (in)	t_4 (lb/in)	z_4 (in)	t_5 (lb/in)	z_5 (in)	t_6 (lb/in)	z_6 (in)	t_7 (lb/in)	z_7 (in)
1	-19.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
2	-21.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
3	-24.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
4	-29.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
5	-34.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
6	-39.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
7	-44.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
8	-49.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
9	-54.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
10	-59.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
11	-64.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
12	-69.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
13	-74.0	Clay	200.0	0.24	79.4	0.01	106.4	0.024	138.8	0.048	159.0	0.072	173.0	0.096	189.8	0.144	200.0	0.24
14	-79.0	Clay	583.0	0.22	231.4	0.01	310.1	0.022	404.6	0.044	463.4	0.066	504.3	0.088	553.2	0.132	583.0	0.22
15	-82.0	Sand	993.4	0.20	394.4	0.01	528.5	0.02	689.4	0.04	789.7	0.06	859.3	0.08	942.7	0.12	993.4	0.20
16	-85.0	Sand	1057.5	0.20	419.8	0.01	562.6	0.02	733.9	0.04	840.7	0.06	914.7	0.08	1003.6	0.12	1057.5	0.20
17	-90.0	Sand	1139.9	0.20	452.5	0.01	606.4	0.02	791.1	0.04	906.2	0.06	986.0	0.08	1081.8	0.12	1139.9	0.20
18	-95.0	Sand	1231.5	0.20	488.9	0.01	655.2	0.02	854.7	0.04	979.0	0.06	1065.2	0.08	1168.7	0.12	1231.5	0.20
19	-100.0	Sand	1415.4	0.20	561.9	0.01	753.0	0.02	982.3	0.04	1125.3	0.06	1224.3	0.08	1343.2	0.12	1415.4	0.20
20	-104.0	Sand	1601.1	0.20	635.6	0.01	851.8	0.02	1111.1	0.04	1272.8	0.06	1384.9	0.08	1519.4	0.12	1601.1	0.20
21	-108.0	Sand	1368.6	0.20	543.3	0.01	728.1	0.02	949.8	0.04	1088.1	0.06	1183.9	0.08	1298.8	0.12	1368.6	0.20
22	-112.0	Sand	1117.0	0.20	443.5	0.01	594.3	0.02	775.2	0.04	888.0	0.06	966.2	0.08	1060.1	0.12	1117.0	0.20

q_{max} (kips)	u_c (in)	q_1 (kips)	u_1 (in)	q_2 (kips)	u_2 (in)	q_3 (kips)	u_3 (in)	q_4 (kips)	u_4 (in)
789.8	2.40	355.4	0.24	497.5	0.60	623.9	1.20	789.8	2.40

TABLE D-34: PIER 34 – *p-y* CURVES

Node #	Elevation (ft)	Soil Type	p_u (lb/in)	y_u (in)	p_1 (lb/in)	y_1 (in)	p_2 (lb/in)	y_2 (in)	p_3 (lb/in)	y_3 (in)	p_4 (lb/in)	y_4 (in)	p_5 (lb/in)	y_5 (in)
1	-18.0	Clay	85.2	9.60	21.3	0.15	42.6	1.20	61.4	3.60	85.2	9.60	85.2	19.20
2	-21.0	Clay	115.9	9.60	29.0	0.15	57.9	1.20	83.4	3.60	115.9	9.60	115.9	19.20
3	-24.0	Clay	146.5	9.60	36.6	0.15	73.3	1.20	105.5	3.60	146.5	9.60	146.5	19.20
4	-29.0	Clay	197.6	9.60	49.4	0.15	98.8	1.20	142.3	3.60	197.6	9.60	197.6	19.20
5	-34.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
6	-39.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
7	-44.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
8	-49.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
9	-54.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
10	-59.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
11	-64.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
12	-69.0	Clay	4640.5	5.42	1160.1	0.09	2320.2	0.68	3341.1	2.03	4640.5	5.42	4640.5	10.84
13	-74.0	Sand	10109.6	1.27	1011.0	0.04	4650.4	0.22	7683.3	0.42	9199.7	0.63	10109.6	1.27
14	-79.0	Sand	11163.3	1.29	1116.3	0.04	5135.1	0.22	8484.1	0.42	10158.6	0.64	11163.3	1.29
15	-84.0	Sand	12217.0	1.30	1221.7	0.04	5619.8	0.22	9284.9	0.43	11117.4	0.65	12217.0	1.30
16	-89.0	Sand	13270.7	1.32	1327.1	0.04	6104.5	0.22	10085.7	0.43	12076.3	0.66	13270.7	1.32
17	-94.0	Sand	16538.4	1.34	1653.8	0.04	7607.7	0.23	12569.2	0.44	15049.9	0.67	16538.4	1.34
18	-98.0	Sand	19951.8	1.37	1995.2	0.04	9177.8	0.23	15163.3	0.45	18156.1	0.68	19951.8	1.37
19	-103.0	Sand	21450.9	1.39	2145.1	0.04	9867.4	0.24	16302.7	0.46	19520.3	0.69	21450.9	1.39
20	-108.0	Sand	14290.7	1.73	1429.1	0.05	6573.7	0.29	10860.9	0.57	13004.5	0.87	14290.7	1.73
21	-112.0	Sand	5925.6	2.08	592.6	0.06	2725.8	0.35	4503.5	0.69	5392.3	1.04	5925.6	2.08

TABLE D-35: PIER 35 – *p-y* CURVES

Node #	Elevation (ft)	Soil Type	p_u (lb/in)	y_u (in)	p_1 (lb/in)	y_1 (in)	p_2 (lb/in)	y_2 (in)	p_3 (lb/in)	y_3 (in)	p_4 (lb/in)	y_4 (in)	p_5 (lb/in)	y_5 (in)
1	-18.0	Clay	85.2	9.60	21.3	0.15	42.6	1.20	61.4	3.60	85.2	9.60	85.2	19.20
2	-21.0	Clay	115.9	9.60	29.0	0.15	57.9	1.20	83.4	3.60	115.9	9.60	115.9	19.20
3	-25.0	Clay	156.7	9.60	39.2	0.15	78.4	1.20	112.8	3.60	156.7	9.60	156.7	19.20
4	-30.0	Clay	207.8	9.60	52.0	0.15	103.9	1.20	149.6	3.60	207.8	9.60	207.8	19.20
5	-35.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
6	-40.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
7	-45.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
8	-50.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
9	-55.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
10	-60.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
11	-65.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
12	-70.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
13	-75.0	Clay	5162.9	5.42	1290.7	0.09	2581.5	0.68	3717.3	2.03	5162.9	5.42	5162.9	10.84
14	-80.0	Sand	11154.5	1.26	1115.4	0.04	5131.1	0.21	8477.4	0.42	10150.6	0.63	11154.5	1.26
15	-85.0	Sand	12208.2	1.28	1220.8	0.04	5615.8	0.22	9278.2	0.42	11109.4	0.64	12208.2	1.28
16	-90.0	Sand	13261.9	1.30	1326.2	0.04	6100.5	0.22	10079.0	0.43	12068.3	0.65	13261.9	1.30
17	-95.0	Sand	16528.3	1.32	1652.8	0.04	7603.0	0.22	12561.5	0.44	15040.7	0.66	16528.3	1.32
18	-100.0	Sand	20240.1	1.35	2024.0	0.04	9310.4	0.23	15382.5	0.45	18418.5	0.68	20240.1	1.35
19	-105.0	Sand	21739.3	1.37	2173.9	0.04	10000.1	0.23	16521.8	0.45	19782.7	0.69	21739.3	1.37
20	-110.0	Sand	14470.3	1.72	1447.0	0.05	6656.3	0.29	10997.4	0.57	13167.9	0.86	14470.3	1.72
21	-112.0	Sand	5849.2	2.05	584.9	0.06	2690.6	0.35	4445.4	0.68	5322.8	1.03	5849.2	2.05

TABLE D-36: PIER 36 – *p-y* CURVES

Node #	Elevation (ft)	Soil Type	p_u (lb/in)	y_u (in)	p_1 (lb/in)	y_1 (in)	p_2 (lb/in)	y_2 (in)	p_3 (lb/in)	y_3 (in)	p_4 (lb/in)	y_4 (in)	p_5 (lb/in)	y_5 (in)
1	-18.0	Clay	85.2	9.60	21.3	0.15	42.6	1.20	61.4	3.60	85.2	9.60	85.2	19.20
2	-21.0	Clay	115.9	9.60	29.0	0.15	57.9	1.20	83.4	3.60	115.9	9.60	115.9	19.20
3	-25.0	Clay	156.7	9.60	39.2	0.15	78.4	1.20	112.8	3.60	156.7	9.60	156.7	19.20
4	-30.0	Clay	207.8	9.60	52.0	0.15	103.9	1.20	149.6	3.60	207.8	9.60	207.8	19.20
5	-35.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
6	-40.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
7	-45.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
8	-50.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
9	-55.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
10	-60.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
11	-65.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
12	-70.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
13	-75.0	Clay	5162.9	5.42	1290.7	0.09	2581.5	0.68	3717.3	2.03	5162.9	5.42	5162.9	10.84
14	-79.0	Sand	10943.8	1.26	1094.4	0.04	5034.1	0.21	8317.3	0.42	9958.8	0.63	10943.8	1.26
15	-83.0	Sand	11786.7	1.28	1178.7	0.04	5421.9	0.22	8957.9	0.42	10725.9	0.64	11786.7	1.28
16	-88.0	Sand	12840.4	1.29	1284.0	0.04	5906.6	0.22	9758.7	0.43	11684.8	0.65	12840.4	1.29
17	-93.0	Sand	18910.3	1.34	1891.0	0.04	8698.8	0.23	14371.9	0.44	17208.4	0.67	18910.3	1.34
18	-97.0	Sand	25579.8	1.39	2558.0	0.04	11766.7	0.24	19440.7	0.46	23277.6	0.70	25579.8	1.39
19	-101.0	Sand	27233.1	1.41	2723.3	0.04	12527.2	0.24	20697.1	0.47	24782.1	0.70	27233.1	1.41
20	-106.0	Sand	29299.6	1.43	2930.0	0.04	13477.8	0.24	22267.7	0.47	26662.6	0.72	29299.6	1.43

TABLE D-37: PIER 37 – *p-y* CURVES

Node #	Elevation (ft)	Soil Type	p_u (lb/in)	y_u (in)	p_1 (lb/in)	y_1 (in)	p_2 (lb/in)	y_2 (in)	p_3 (lb/in)	y_3 (in)	p_4 (lb/in)	y_4 (in)	p_5 (lb/in)	y_5 (in)
1	-18.5	Clay	100.5	9.60	25.1	0.15	50.3	1.20	72.4	3.60	100.5	9.60	100.5	19.20
2	-21.0	Clay	126.1	9.60	31.5	0.15	63.0	1.20	90.8	3.60	126.1	9.60	126.1	19.20
3	-24.0	Clay	156.7	9.60	39.2	0.15	78.4	1.20	112.8	3.60	156.7	9.60	156.7	19.20
4	-29.0	Clay	207.8	9.60	52.0	0.15	103.9	1.20	149.6	3.60	207.8	9.60	207.8	19.20
5	-34.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
6	-39.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
7	-44.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
8	-49.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
9	-54.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
10	-59.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
11	-64.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
12	-69.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
13	-74.0	Clay	5162.9	5.42	1290.7	0.09	2581.5	0.68	3717.3	2.03	5162.9	5.42	5162.9	10.84
14	-78.0	Sand	10943.8	1.26	1094.4	0.04	5034.1	0.21	8317.3	0.42	9958.8	0.63	10943.8	1.26
15	-83.0	Sand	11997.5	1.28	1199.7	0.04	5518.8	0.22	9118.1	0.42	10917.7	0.64	11997.5	1.28
16	-88.0	Sand	13051.1	1.29	1305.1	0.04	6003.5	0.22	9918.9	0.43	11876.5	0.65	13051.1	1.29
17	-93.0	Sand	19197.2	1.34	1919.7	0.04	8830.7	0.23	14589.8	0.44	17469.4	0.67	19197.2	1.34
18	-97.0	Sand	25942.7	1.39	2594.3	0.04	11933.7	0.24	19716.5	0.46	23607.9	0.70	25942.7	1.39
19	-101.0	Sand	27596.0	1.41	2759.6	0.04	12694.1	0.24	20972.9	0.47	25112.3	0.71	27596.0	1.41
20	-106.0	Sand	29662.5	1.43	2966.3	0.04	13644.8	0.24	22543.5	0.47	26992.9	0.72	29662.5	1.43
21	-111.0	Sand	31729.1	1.45	3172.9	0.04	14595.4	0.25	24114.1	0.48	28873.5	0.73	31729.1	1.45

TABLE D-38: PIER 38 – *p-y* CURVES

Node #	Elevation (ft)	Soil Type	p_u (lb/in)	y_u (in)	p_1 (lb/in)	y_1 (in)	p_2 (lb/in)	y_2 (in)	p_3 (lb/in)	y_3 (in)	p_4 (lb/in)	y_4 (in)	p_5 (lb/in)	y_5 (in)
1	-19.0	Clay	115.9	9.60	29.0	0.15	57.9	1.20	83.4	3.60	115.9	9.60	115.9	19.20
2	-22.0	Clay	146.5	9.60	36.6	0.15	73.3	1.20	105.5	3.60	146.5	9.60	146.5	19.20
3	-27.0	Clay	197.6	9.60	49.4	0.15	98.8	1.20	142.3	3.60	197.6	9.60	197.6	19.20
4	-32.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
5	-37.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
6	-42.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
7	-47.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
8	-52.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
9	-57.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
10	-62.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
11	-67.0	Clay	225.0	9.60	56.3	0.15	112.5	1.20	162.0	3.60	225.0	9.60	225.0	19.20
12	-72.0	Clay	5075.8	5.42	1269.0	0.09	2537.9	0.68	3654.6	2.03	5075.8	5.42	5075.8	10.84
13	-77.0	Sand	10980.3	1.27	1098.0	0.04	5051.0	0.22	8345.1	0.42	9992.1	0.63	10980.3	1.27
14	-82.0	Sand	12034.0	1.28	1203.4	0.04	5535.7	0.22	9145.9	0.42	10951.0	0.64	12034.0	1.28
15	-87.0	Sand	13087.7	1.30	1308.8	0.04	6020.4	0.22	9946.7	0.43	11909.8	0.65	13087.7	1.30
16	-92.0	Sand	14141.4	1.31	1414.1	0.04	6505.0	0.22	10747.5	0.43	12868.7	0.66	14141.4	1.31
17	-97.0	Sand	20681.1	1.36	2068.1	0.04	9513.3	0.23	15717.6	0.45	18819.8	0.68	20681.1	1.36
18	-101.0	Sand	27820.3	1.41	2782.0	0.04	12797.3	0.24	21143.4	0.46	25316.4	0.70	27820.3	1.41
19	-106.0	Sand	29886.8	1.43	2988.7	0.04	13747.9	0.24	22714.0	0.47	27197.0	0.71	29886.8	1.43
20	-111.0	Sand	31953.4	1.45	3195.3	0.04	14698.5	0.25	24284.6	0.48	29077.6	0.72	31953.4	1.45

TABLE D-39: PIER 39 – *p-y* CURVES

Node #	Elevation (ft)	Soil Type	p_u (lb/in)	y_u (in)	p_1 (lb/in)	y_1 (in)	p_2 (lb/in)	y_2 (in)	p_3 (lb/in)	y_3 (in)	p_4 (lb/in)	y_4 (in)	p_5 (lb/in)	y_5 (in)
1	-10.0	Clay	93.8	12.00	23.4	0.19	46.9	1.50	67.5	4.50	93.8	12.00	93.8	24.00
2	-15.0	Clay	147.4	12.00	36.9	0.19	73.7	1.50	106.1	4.50	147.4	12.00	147.4	24.00
3	-20.0	Clay	201.0	12.00	50.3	0.19	100.5	1.50	144.7	4.50	201.0	12.00	201.0	24.00
4	-25.0	Clay	254.7	12.00	63.7	0.19	127.3	1.50	183.4	4.50	254.7	12.00	254.7	24.00
5	-30.0	Clay	281.3	12.00	70.3	0.19	140.6	1.50	202.5	4.50	281.3	12.00	281.3	24.00
6	-35.0	Clay	281.3	12.00	70.3	0.19	140.6	1.50	202.5	4.50	281.3	12.00	281.3	24.00
7	-40.0	Clay	281.3	12.00	70.3	0.19	140.6	1.50	202.5	4.50	281.3	12.00	281.3	24.00
8	-45.0	Clay	281.3	12.00	70.3	0.19	140.6	1.50	202.5	4.50	281.3	12.00	281.3	24.00
9	-50.0	Clay	281.3	12.00	70.3	0.19	140.6	1.50	202.5	4.50	281.3	12.00	281.3	24.00
10	-55.0	Clay	281.3	12.00	70.3	0.19	140.6	1.50	202.5	4.50	281.3	12.00	281.3	24.00
11	-60.0	Clay	281.3	12.00	70.3	0.19	140.6	1.50	202.5	4.50	281.3	12.00	281.3	24.00
12	-65.0	Clay	4438.2	6.78	1109.6	0.11	2219.1	0.85	3195.5	2.54	4438.2	6.78	4438.2	13.56
13	-68.0	Sand	9173.0	1.58	917.3	0.05	4219.6	0.27	6971.5	0.52	8347.4	0.79	9173.0	1.58
14	-73.0	Sand	10136.1	1.61	1013.6	0.05	4662.6	0.27	7703.4	0.53	9223.9	0.80	10136.1	1.61
15	-78.0	Sand	12533.0	1.55	1253.3	0.05	5765.2	0.26	9525.1	0.51	11405.1	0.77	12533.0	1.55
16	-82.0	Sand	15027.9	1.49	1502.8	0.04	6912.8	0.25	11421.2	0.49	13675.4	0.75	15027.9	1.49
17	-87.0	Sand	16354.2	1.52	1635.4	0.05	7522.9	0.26	12429.2	0.50	14882.3	0.76	16354.2	1.52
18	-92.0	Sand	20413.2	1.55	2041.3	0.05	9390.1	0.26	15514.0	0.51	18576.0	0.78	20413.2	1.55
19	-97.0	Sand	25031.9	1.60	2503.2	0.05	11514.7	0.27	19024.3	0.53	22779.0	0.80	25031.9	1.60
20	-103.0	Sand	27295.0	1.63	2729.5	0.05	12555.7	0.28	20744.2	0.54	24838.5	0.82	27295.0	1.63

TABLE D-40: PIER 40 – *p-y* CURVES

Node #	Elevation (ft)	Soil Type	p_u (lb/in)	y_u (in)	p_1 (lb/in)	y_1 (in)	p_2 (lb/in)	y_2 (in)	p_3 (lb/in)	y_3 (in)	p_4 (lb/in)	y_4 (in)	p_5 (lb/in)	y_5 (in)
1	-12.0	Clay	93.8	12.00	23.4	0.19	46.9	1.50	67.5	4.50	93.8	12.00	93.8	24.00
2	-15.0	Clay	127.4	12.00	31.8	0.19	63.7	1.50	91.7	4.50	127.4	12.00	127.4	24.00
3	-18.0	Clay	161.0	12.00	40.3	0.19	80.5	1.50	115.9	4.50	161.0	12.00	161.0	24.00
4	-23.0	Clay	217.0	12.00	54.3	0.19	108.5	1.50	156.3	4.50	217.0	12.00	217.0	24.00
5	-28.0	Clay	273.1	12.00	68.3	0.19	136.5	1.50	196.6	4.50	273.1	12.00	273.1	24.00
6	-33.0	Clay	281.3	12.00	70.3	0.19	140.6	1.50	202.5	4.50	281.3	12.00	281.3	24.00
7	-38.0	Clay	281.3	12.00	70.3	0.19	140.6	1.50	202.5	4.50	281.3	12.00	281.3	24.00
8	-43.0	Clay	281.3	12.00	70.3	0.19	140.6	1.50	202.5	4.50	281.3	12.00	281.3	24.00
9	-48.0	Clay	281.3	12.00	70.3	0.19	140.6	1.50	202.5	4.50	281.3	12.00	281.3	24.00
10	-53.0	Clay	281.3	12.00	70.3	0.19	140.6	1.50	202.5	4.50	281.3	12.00	281.3	24.00
11	-58.0	Clay	281.3	12.00	70.3	0.19	140.6	1.50	202.5	4.50	281.3	12.00	281.3	24.00
12	-63.0	Clay	281.3	12.00	70.3	0.19	140.6	1.50	202.5	4.50	281.3	12.00	281.3	24.00
13	-68.0	Clay	6235.9	6.78	1559.0	0.11	3118.0	0.85	4489.9	2.54	6235.9	6.78	6235.9	13.56
14	-72.0	Sand	13244.3	1.58	1324.4	0.05	6092.4	0.27	10065.7	0.52	12052.3	0.79	13244.3	1.58
15	-77.0	Sand	14561.4	1.60	1456.1	0.05	6698.3	0.27	11066.7	0.53	13250.9	0.80	14561.4	1.60
16	-82.0	Sand	15878.5	1.62	1587.9	0.05	7304.1	0.28	12067.7	0.53	14449.5	0.81	15878.5	1.62
17	-87.0	Sand	23403.9	1.68	2340.4	0.05	10765.8	0.29	17786.9	0.55	21297.5	0.84	23403.9	1.68
18	-91.0	Sand	31678.7	1.74	3167.9	0.05	14572.2	0.30	24075.8	0.58	28827.6	0.87	31678.7	1.74
19	-95.0	Sand	33745.2	1.77	3374.5	0.05	15522.8	0.30	25646.4	0.58	30708.1	0.88	33745.2	1.77
20	-99.0	Sand	35811.8	1.79	3581.2	0.05	16473.4	0.30	27216.9	0.59	32588.7	0.89	35811.8	1.79
21	-103.0	Sand	37878.3	1.81	3787.8	0.05	17424.0	0.31	28787.5	0.60	34469.3	0.90	37878.3	1.81

TABLE D-41: PIER 41 – *p-y* CURVES

Node #	Elevation (ft)	Soil Type	p_u (lb/in)	y_u (in)	p_1 (lb/in)	y_1 (in)	p_2 (lb/in)	y_2 (in)	p_3 (lb/in)	y_3 (in)	p_4 (lb/in)	y_4 (in)	p_5 (lb/in)	y_5 (in)
1	-13.0	Clay	95.1	5.60	23.8	0.09	47.6	0.70	68.5	2.10	95.1	5.60	95.1	11.20
2	-16.0	Clay	120.8	5.60	30.2	0.09	60.4	0.70	87.0	2.10	120.8	5.60	120.8	11.20
3	-19.0	Clay	131.3	5.60	32.8	0.09	65.6	0.70	94.5	2.10	131.3	5.60	131.3	11.20
4	-24.0	Clay	131.3	5.60	32.8	0.09	65.6	0.70	94.5	2.10	131.3	5.60	131.3	11.20
5	-29.0	Clay	131.3	5.60	32.8	0.09	65.6	0.70	94.5	2.10	131.3	5.60	131.3	11.20
6	-34.0	Clay	131.3	5.60	32.8	0.09	65.6	0.70	94.5	2.10	131.3	5.60	131.3	11.20
7	-39.0	Clay	131.3	5.60	32.8	0.09	65.6	0.70	94.5	2.10	131.3	5.60	131.3	11.20
8	-44.0	Clay	131.3	5.60	32.8	0.09	65.6	0.70	94.5	2.10	131.3	5.60	131.3	11.20
9	-49.0	Clay	131.3	5.60	32.8	0.09	65.6	0.70	94.5	2.10	131.3	5.60	131.3	11.20
10	-54.0	Clay	131.3	5.60	32.8	0.09	65.6	0.70	94.5	2.10	131.3	5.60	131.3	11.20
11	-59.0	Clay	131.3	5.60	32.8	0.09	65.6	0.70	94.5	2.10	131.3	5.60	131.3	11.20
12	-64.0	Clay	131.3	5.60	32.8	0.09	65.6	0.70	94.5	2.10	131.3	5.60	131.3	11.20
13	-69.0	Clay	3214.9	3.16	803.7	0.05	1607.4	0.40	2314.7	1.19	3214.9	3.16	3214.9	6.33
14	-73.0	Sand	6790.2	0.73	679.0	0.02	3123.5	0.12	5160.6	0.24	6179.1	0.37	6790.2	0.73
15	-77.0	Sand	7281.9	0.74	728.2	0.02	3349.7	0.13	5534.3	0.25	6626.6	0.37	7281.9	0.74
16	-81.0	Sand	7773.7	0.75	777.4	0.02	3575.9	0.13	5908.0	0.25	7074.0	0.38	7773.7	0.75
17	-85.0	Sand	11249.5	0.78	1124.9	0.02	5174.8	0.13	8549.6	0.26	10237.0	0.39	11249.5	0.78
18	-90.0	Sand	15439.0	0.81	1543.9	0.02	7102.0	0.14	11733.7	0.27	14049.5	0.40	15439.0	0.81
19	-95.0	Sand	16644.5	0.82	1664.5	0.02	7656.5	0.14	12649.8	0.27	15146.5	0.41	16644.5	0.82

TABLE D-42: PIERS 42~46 – *p-y* CURVES

Node #	Elevation (ft)	Soil Type	p_u (lb/in)	y_u (in)	p_1 (lb/in)	y_1 (in)	p_2 (lb/in)	y_2 (in)	p_3 (lb/in)	y_3 (in)	p_4 (lb/in)	y_4 (in)	p_5 (lb/in)	y_5 (in)
1	-12.0	Clay	70.4	4.80	17.6	0.08	35.2	0.60	50.7	1.80	70.4	4.80	70.4	9.60
2	-16.0	Clay	103.4	4.80	25.8	0.08	51.7	0.60	74.4	1.80	103.4	4.80	103.4	9.60
3	-21.0	Clay	112.5	4.80	28.1	0.08	56.3	0.60	81.0	1.80	112.5	4.80	112.5	9.60
4	-26.0	Clay	112.5	4.80	28.1	0.08	56.3	0.60	81.0	1.80	112.5	4.80	112.5	9.60
5	-31.0	Clay	112.5	4.80	28.1	0.08	56.3	0.60	81.0	1.80	112.5	4.80	112.5	9.60
6	-36.0	Clay	112.5	4.80	28.1	0.08	56.3	0.60	81.0	1.80	112.5	4.80	112.5	9.60
7	-41.0	Clay	112.5	4.80	28.1	0.08	56.3	0.60	81.0	1.80	112.5	4.80	112.5	9.60
8	-46.0	Clay	112.5	4.80	28.1	0.08	56.3	0.60	81.0	1.80	112.5	4.80	112.5	9.60
9	-51.0	Clay	112.5	4.80	28.1	0.08	56.3	0.60	81.0	1.80	112.5	4.80	112.5	9.60
10	-56.0	Clay	112.5	4.80	28.1	0.08	56.3	0.60	81.0	1.80	112.5	4.80	112.5	9.60
11	-61.0	Clay	112.5	4.80	28.1	0.08	56.3	0.60	81.0	1.80	112.5	4.80	112.5	9.60
12	-66.0	Clay	2581.5	2.71	645.4	0.04	1290.7	0.34	1858.6	1.02	2581.5	2.71	2581.5	5.42
13	-70.0	Sand	5471.9	0.63	547.2	0.02	2517.1	0.11	4158.6	0.21	4979.4	0.32	5471.9	0.63
14	-75.0	Sand	5998.7	0.64	599.9	0.02	2759.4	0.11	4559.0	0.21	5458.8	0.32	5998.7	0.64
15	-80.0	Sand	6525.6	0.65	652.6	0.02	3001.8	0.11	4959.4	0.21	5938.3	0.32	6525.6	0.65
16	-85.0	Sand	9598.6	0.67	959.9	0.02	4415.3	0.11	7294.9	0.22	8734.7	0.34	9598.6	0.67
17	-90.0	Sand	13178.0	0.70	1317.8	0.02	6061.9	0.12	10015.3	0.23	11992.0	0.35	13178.0	0.70

TABLE D-43: PIERS 47~51 – *p-y* CURVES

Node #	Elevation (ft)	Soil Type	p_u (lb/in)	y_u (in)	p_1 (lb/in)	y_1 (in)	p_2 (lb/in)	y_2 (in)	p_3 (lb/in)	y_3 (in)	p_4 (lb/in)	y_4 (in)	p_5 (lb/in)	y_5 (in)
1	-12.0	Clay	62.2	4.80	15.6	0.08	31.1	0.60	44.8	1.80	62.2	4.80	62.2	9.60
2	-15.0	Clay	86.9	4.80	21.7	0.08	43.5	0.60	62.6	1.80	86.9	4.80	86.9	9.60
3	-18.0	Clay	111.6	4.80	27.9	0.08	55.8	0.60	80.4	1.80	111.6	4.80	111.6	9.60
4	-23.0	Clay	112.5	4.80	28.1	0.08	56.3	0.60	81.0	1.80	112.5	4.80	112.5	9.60
5	-28.0	Clay	112.5	4.80	28.1	0.08	56.3	0.60	81.0	1.80	112.5	4.80	112.5	9.60
6	-33.0	Clay	112.5	4.80	28.1	0.08	56.3	0.60	81.0	1.80	112.5	4.80	112.5	9.60
7	-38.0	Clay	1318.9	2.71	329.7	0.04	659.4	0.34	949.6	1.02	1318.9	2.71	1318.9	5.42
8	-42.0	Sand	3052.1	0.64	305.2	0.02	1403.9	0.11	2319.6	0.21	2777.4	0.32	3052.1	0.64
9	-47.0	Sand	1793.0	2.73	179.3	0.08	824.8	0.46	1362.7	0.90	1631.6	1.36	1793.0	2.73
10	-51.0	Clay	112.5	4.80	28.1	0.08	56.3	0.60	81.0	1.80	112.5	4.80	112.5	9.60
11	-55.0	Clay	112.5	4.80	28.1	0.08	56.3	0.60	81.0	1.80	112.5	4.80	112.5	9.60
12	-59.0	Clay	2315.5	2.72	578.9	0.04	1157.7	0.34	1667.1	1.02	2315.5	2.72	2315.5	5.45
13	-62.0	Sand	4834.5	0.65	483.5	0.02	2223.9	0.11	3674.3	0.22	4399.4	0.33	4834.5	0.65
14	-65.0	Sand	5150.7	0.66	515.1	0.02	2369.3	0.11	3914.5	0.22	4687.1	0.33	5150.7	0.66
15	-70.0	Sand	5677.5	0.66	567.7	0.02	2611.6	0.11	4314.9	0.22	5166.5	0.33	5677.5	0.66
16	-75.0	Sand	6204.3	0.67	620.4	0.02	2854.0	0.11	4715.3	0.22	5645.9	0.34	6204.3	0.67
17	-80.0	Sand	6731.2	0.68	673.1	0.02	3096.3	0.12	5115.7	0.22	6125.4	0.34	6731.2	0.68
18	-85.0	Sand	9878.4	0.70	987.8	0.02	4544.1	0.12	7507.6	0.23	8989.4	0.35	9878.4	0.70
19	-90.0	Sand	13532.1	0.73	1353.2	0.02	6224.8	0.12	10284.4	0.24	12314.2	0.36	13532.1	0.73

TABLE D-44: PIERS 52 AND 53 – *p-y* CURVES

Node #	Elevation (ft)	Soil Type	p_u (lb/in)	y_u (in)	p_1 (lb/in)	y_1 (in)	p_2 (lb/in)	y_2 (in)	p_3 (lb/in)	y_3 (in)	p_4 (lb/in)	y_4 (in)	p_5 (lb/in)	y_5 (in)
1	-12.0	Clay	54.0	4.80	13.5	0.08	27.0	0.60	38.9	1.80	54.0	4.80	54.0	9.60
2	-15.0	Clay	78.7	4.80	19.7	0.08	39.3	0.60	56.6	1.80	78.7	4.80	78.7	9.60
3	-19.0	Clay	111.6	4.80	27.9	0.08	55.8	0.60	80.4	1.80	111.6	4.80	111.6	9.60
4	-24.0	Clay	112.5	4.80	28.1	0.08	56.3	0.60	81.0	1.80	112.5	4.80	112.5	9.60
5	-29.0	Clay	112.5	4.80	28.1	0.08	56.3	0.60	81.0	1.80	112.5	4.80	112.5	9.60
6	-34.0	Clay	112.5	4.80	28.1	0.08	56.3	0.60	81.0	1.80	112.5	4.80	112.5	9.60
7	-39.0	Clay	112.5	4.80	28.1	0.08	56.3	0.60	81.0	1.80	112.5	4.80	112.5	9.60
8	-44.0	Clay	112.5	4.80	28.1	0.08	56.3	0.60	81.0	1.80	112.5	4.80	112.5	9.60
9	-49.0	Clay	1754.2	2.71	438.6	0.04	877.1	0.34	1263.0	1.02	1754.2	2.71	1754.2	5.42
10	-54.0	Sand	3922.8	0.64	392.3	0.02	1804.5	0.11	2981.3	0.21	3569.7	0.32	3922.8	0.64
11	-59.0	Sand	4449.7	0.65	445.0	0.02	2046.8	0.11	3381.7	0.21	4049.2	0.32	4449.7	0.65
12	-64.0	Sand	4976.5	0.66	497.7	0.02	2289.2	0.11	3782.1	0.22	4528.6	0.33	4976.5	0.66
13	-69.0	Sand	5503.3	0.67	550.3	0.02	2531.5	0.11	4182.5	0.22	5008.0	0.33	5503.3	0.67
14	-74.0	Sand	6030.2	0.67	603.0	0.02	2773.9	0.11	4582.9	0.22	5487.5	0.34	6030.2	0.67
15	-79.0	Sand	6557.0	0.68	655.7	0.02	3016.2	0.12	4983.3	0.22	5966.9	0.34	6557.0	0.68
16	-85.0	Sand	7189.3	0.68	718.9	0.02	3307.1	0.12	5463.8	0.23	6542.2	0.34	7189.3	0.68

TABLE D-45: PIERS 54~56 – *p-y* CURVES

Node #	Elevation (ft)	Soil Type	p_u (lb/in)	y_u (in)	p_1 (lb/in)	y_1 (in)	p_2 (lb/in)	y_2 (in)	p_3 (lb/in)	y_3 (in)	p_4 (lb/in)	y_4 (in)	p_5 (lb/in)	y_5 (in)
1	-13.0	Clay	54.0	4.80	13.5	0.08	27.0	0.60	38.9	1.80	54.0	4.80	54.0	9.60
2	-16.0	Clay	78.7	4.80	19.7	0.08	39.3	0.60	56.6	1.80	78.7	4.80	78.7	9.60
3	-20.0	Clay	111.6	4.80	27.9	0.08	55.8	0.60	80.4	1.80	111.6	4.80	111.6	9.60
4	-25.0	Clay	112.5	4.80	28.1	0.08	56.3	0.60	81.0	1.80	112.5	4.80	112.5	9.60
5	-30.0	Clay	112.5	4.80	28.1	0.08	56.3	0.60	81.0	1.80	112.5	4.80	112.5	9.60
6	-35.0	Clay	1101.2	2.71	275.3	0.04	550.6	0.34	792.8	1.02	1101.2	2.71	1101.2	5.42
7	-40.0	Sand	2616.7	0.64	261.7	0.02	1203.7	0.11	1988.7	0.21	2381.2	0.32	2616.7	0.64
8	-45.0	Sand	3143.5	0.66	314.4	0.02	1446.0	0.11	2389.1	0.22	2860.6	0.33	3143.5	0.66
9	-50.0	Sand	3670.4	0.67	367.0	0.02	1688.4	0.11	2789.5	0.22	3340.0	0.34	3670.4	0.67
10	-55.0	Sand	4197.2	0.68	419.7	0.02	1930.7	0.12	3189.9	0.22	3819.5	0.34	4197.2	0.68
11	-60.0	Sand	4724.1	0.69	472.4	0.02	2173.1	0.12	3590.3	0.23	4298.9	0.34	4724.1	0.69
12	-65.0	Sand	5250.9	0.69	525.1	0.02	2415.4	0.12	3990.7	0.23	4778.3	0.35	5250.9	0.69
13	-70.0	Sand	5777.7	0.70	577.8	0.02	2657.8	0.12	4391.1	0.23	5257.7	0.35	5777.7	0.70
14	-75.0	Sand	6304.6	0.70	630.5	0.02	2900.1	0.12	4791.5	0.23	5737.2	0.35	6304.6	0.70
15	-80.0	Sand	6831.4	0.71	683.1	0.02	3142.5	0.12	5191.9	0.23	6216.6	0.35	6831.4	0.71

TABLE D-46: PIERS 57 AND 58 – *p-y* CURVES

Node #	Elevation (ft)	Soil Type	p_u (lb/in)	y_u (in)	p_1 (lb/in)	y_1 (in)	p_2 (lb/in)	y_2 (in)	p_3 (lb/in)	y_3 (in)	p_4 (lb/in)	y_4 (in)	p_5 (lb/in)	y_5 (in)
1	-13.0	Clay	54.0	4.80	13.5	0.08	27.0	0.60	38.9	1.80	54.0	4.80	54.0	9.60
2	-16.0	Clay	78.7	4.80	19.7	0.08	39.3	0.60	56.6	1.80	78.7	4.80	78.7	9.60
3	-20.0	Clay	111.6	4.80	27.9	0.08	55.8	0.60	80.4	1.80	111.6	4.80	111.6	9.60
4	-24.0	Clay	510.2	2.65	127.5	0.04	255.1	0.33	367.3	0.99	510.2	2.65	510.2	5.30
5	-29.0	Sand	1658.8	0.66	165.9	0.02	763.1	0.11	1260.7	0.22	1509.5	0.33	1658.8	0.66
6	-34.0	Sand	2185.7	0.68	218.6	0.02	1005.4	0.12	1661.1	0.22	1989.0	0.34	2185.7	0.68
7	-39.0	Sand	2712.5	0.69	271.3	0.02	1247.8	0.12	2061.5	0.23	2468.4	0.35	2712.5	0.69
8	-44.0	Sand	3239.4	0.70	323.9	0.02	1490.1	0.12	2461.9	0.23	2947.8	0.35	3239.4	0.70
9	-49.0	Sand	3766.2	0.71	376.6	0.02	1732.5	0.12	2862.3	0.23	3427.3	0.35	3766.2	0.71
10	-54.0	Sand	4293.1	0.71	429.3	0.02	1974.8	0.12	3262.7	0.24	3906.7	0.36	4293.1	0.71
11	-59.0	Sand	4819.9	0.72	482.0	0.02	2217.2	0.12	3663.1	0.24	4386.1	0.36	4819.9	0.72
12	-64.0	Sand	5346.8	0.72	534.7	0.02	2459.5	0.12	4063.5	0.24	4865.5	0.36	5346.8	0.72
13	-69.0	Sand	5873.6	0.72	587.4	0.02	2701.9	0.12	4463.9	0.24	5345.0	0.36	5873.6	0.72
14	-75.0	Sand	3309.2	2.76	330.9	0.08	1522.2	0.47	2515.0	0.91	3011.3	1.38	3309.2	2.76
15	-80.0	Clay	112.5	4.80	28.1	0.08	56.3	0.60	81.0	1.80	112.5	4.80	112.5	9.60

TABLE D-47: PIERS 59~62 – *p-y* CURVES

Node #	Elevation (ft)	Soil Type	p_u (lb/in)	y_u (in)	p_1 (lb/in)	y_1 (in)	p_2 (lb/in)	y_2 (in)	p_3 (lb/in)	y_3 (in)	p_4 (lb/in)	y_4 (in)	p_5 (lb/in)	y_5 (in)
1	-13.0	Clay	45.7	4.80	11.4	0.08	22.9	0.60	32.9	1.80	45.7	4.80	45.7	9.60
2	-16.0	Clay	70.4	4.80	17.6	0.08	35.2	0.60	50.7	1.80	70.4	4.80	70.4	9.60
3	-20.0	Clay	103.4	4.80	25.8	0.08	51.7	0.60	74.4	1.80	103.4	4.80	103.4	9.60
4	-24.0	Clay	445.7	2.63	111.4	0.04	222.9	0.33	320.9	0.99	445.7	2.63	445.7	5.26
5	-28.0	Sand	1424.8	0.64	142.5	0.02	655.4	0.11	1082.8	0.21	1296.5	0.32	1424.8	0.64
6	-33.0	Sand	1993.2	0.68	199.3	0.02	916.9	0.12	1514.9	0.22	1813.8	0.34	1993.2	0.68
7	-38.0	Sand	2520.1	0.69	252.0	0.02	1159.2	0.12	1915.3	0.23	2293.3	0.35	2520.1	0.69
8	-43.0	Sand	3046.9	0.70	304.7	0.02	1401.6	0.12	2315.7	0.23	2772.7	0.35	3046.9	0.70
9	-48.0	Sand	3573.8	0.71	357.4	0.02	1643.9	0.12	2716.1	0.23	3252.1	0.35	3573.8	0.71
10	-53.0	Sand	4100.6	0.71	410.1	0.02	1886.3	0.12	3116.5	0.24	3731.6	0.36	4100.6	0.71
11	-58.0	Sand	4627.5	0.72	462.7	0.02	2128.6	0.12	3516.9	0.24	4211.0	0.36	4627.5	0.72
12	-63.0	Sand	5154.3	0.72	515.4	0.02	2371.0	0.12	3917.3	0.24	4690.4	0.36	5154.3	0.72
13	-68.0	Sand	5681.2	0.72	568.1	0.02	2613.3	0.12	4317.7	0.24	5169.8	0.36	5681.2	0.72
14	-73.0	Sand	6208.0	0.73	620.8	0.02	2855.7	0.12	4718.1	0.24	5649.3	0.36	6208.0	0.73
15	-78.0	Sand	9166.4	0.75	916.6	0.02	4216.5	0.13	6966.4	0.25	8341.4	0.37	9166.4	0.75
16	-80.0	Sand	12011.2	0.77	1201.1	0.02	5525.1	0.13	9128.5	0.25	10930.2	0.38	12011.2	0.77

TABLE D-48: PIERS 63~67 – *p-y* CURVES

Node #	Elevation (ft)	Soil Type	p_u (lb/in)	y_u (in)	p_1 (lb/in)	y_1 (in)	p_2 (lb/in)	y_2 (in)	p_3 (lb/in)	y_3 (in)	p_4 (lb/in)	y_4 (in)	p_5 (lb/in)	y_5 (in)
1	-15.0	Clay	54.0	4.80	13.5	0.08	27.0	0.60	38.9	1.80	54.0	4.80	54.0	9.60
2	-20.0	Clay	95.1	4.80	23.8	0.08	47.6	0.60	68.5	1.80	95.1	4.80	95.1	9.60
3	-25.0	Clay	445.7	2.63	111.4	0.04	222.9	0.33	320.9	0.99	445.7	2.63	445.7	5.26
4	-28.0	Sand	1245.5	0.59	124.5	0.02	572.9	0.10	946.5	0.20	1133.4	0.30	1245.5	0.59
5	-32.0	Sand	1782.5	0.67	178.2	0.02	819.9	0.11	1354.7	0.22	1622.1	0.34	1782.5	0.67
6	-37.0	Sand	2309.3	0.69	230.9	0.02	1062.3	0.12	1755.1	0.23	2101.5	0.34	2309.3	0.69
7	-42.0	Sand	2836.2	0.70	283.6	0.02	1304.6	0.12	2155.5	0.23	2580.9	0.35	2836.2	0.70
8	-47.0	Sand	3363.0	0.71	336.3	0.02	1547.0	0.12	2555.9	0.23	3060.4	0.35	3363.0	0.71
9	-52.0	Sand	3889.9	0.71	389.0	0.02	1789.3	0.12	2956.3	0.24	3539.8	0.36	3889.9	0.71
10	-57.0	Sand	4416.7	0.72	441.7	0.02	2031.7	0.12	3356.7	0.24	4019.2	0.36	4416.7	0.72
11	-62.0	Sand	4943.6	0.72	494.4	0.02	2274.0	0.12	3757.1	0.24	4498.6	0.36	4943.6	0.72
12	-67.0	Sand	5470.4	0.72	547.0	0.02	2516.4	0.12	4157.5	0.24	4978.1	0.36	5470.4	0.72
13	-72.0	Sand	5997.3	0.73	599.7	0.02	2758.7	0.12	4557.9	0.24	5457.5	0.36	5997.3	0.73
14	-77.0	Sand	8879.5	0.75	888.0	0.02	4084.6	0.13	6748.4	0.25	8080.4	0.37	8879.5	0.75
15	-80.0	Sand	11854.9	0.77	1185.5	0.02	5453.3	0.13	9009.7	0.25	10788.0	0.38	11854.9	0.77

TABLE D-49: PIERS 68~70 – *p-y* CURVES

Node #	Elevation (ft)	Soil Type	p_u (lb/in)	y_u (in)	p_1 (lb/in)	y_1 (in)	p_2 (lb/in)	y_2 (in)	p_3 (lb/in)	y_3 (in)	p_4 (lb/in)	y_4 (in)	p_5 (lb/in)	y_5 (in)
1	-15.0	Clay	62.2	4.80	15.6	0.08	31.1	0.60	44.8	1.80	62.2	4.80	62.2	9.60
2	-19.0	Clay	95.1	4.80	23.8	0.08	47.6	0.60	68.5	1.80	95.1	4.80	95.1	9.60
3	-24.0	Clay	445.7	2.63	111.4	0.04	222.9	0.33	320.9	0.99	445.7	2.63	445.7	5.26
4	-29.0	Sand	1571.8	0.66	157.2	0.02	723.0	0.11	1194.5	0.22	1430.3	0.33	1571.8	0.66
5	-34.0	Sand	2098.6	0.68	209.9	0.02	965.4	0.12	1594.9	0.22	1909.7	0.34	2098.6	0.68
6	-39.0	Sand	2625.5	0.69	262.5	0.02	1207.7	0.12	1995.3	0.23	2389.2	0.35	2625.5	0.69
7	-44.0	Sand	3152.3	0.70	315.2	0.02	1450.1	0.12	2395.7	0.23	2868.6	0.35	3152.3	0.70
8	-49.0	Sand	3679.1	0.71	367.9	0.02	1692.4	0.12	2796.1	0.23	3348.0	0.36	3679.1	0.71
9	-54.0	Sand	4206.0	0.72	420.6	0.02	1934.8	0.12	3196.5	0.24	3827.4	0.36	4206.0	0.72
10	-59.0	Sand	4732.8	0.72	473.3	0.02	2177.1	0.12	3597.0	0.24	4306.9	0.36	4732.8	0.72
11	-64.0	Sand	5259.7	0.72	526.0	0.02	2419.5	0.12	3997.4	0.24	4786.3	0.36	5259.7	0.72
12	-69.0	Sand	5786.5	0.73	578.7	0.02	2661.8	0.12	4397.8	0.24	5265.7	0.36	5786.5	0.73
13	-74.0	Sand	6313.4	0.73	631.3	0.02	2904.2	0.12	4798.2	0.24	5745.2	0.36	6313.4	0.73
14	-80.0	Sand	6945.6	0.73	694.6	0.02	3195.0	0.12	5278.6	0.24	6320.5	0.36	6945.6	0.73

TABLE D-50: ABUTMENT 71 – *p-y* CURVES

Node #	Elevation (ft)	Soil Type	p_u (lb/in)	y_u (in)	p_1 (lb/in)	y_1 (in)	p_2 (lb/in)	y_2 (in)	p_3 (lb/in)	y_3 (in)	p_4 (lb/in)	y_4 (in)	p_5 (lb/in)	y_5 (in)
1	-8.0	Sand	144.4	0.29	14.4	0.01	66.4	0.05	109.7	0.10	131.4	0.14	144.4	0.29
2	-12.0	Sand	269.1	2.64	26.9	0.08	123.8	0.45	204.5	0.87	244.9	1.32	269.1	2.64
3	-16.0	Clay	112.5	4.80	28.1	0.08	56.3	0.60	81.0	1.80	112.5	4.80	112.5	9.60
4	-20.0	Clay	112.5	4.80	28.1	0.08	56.3	0.60	81.0	1.80	112.5	4.80	112.5	9.60
5	-24.0	Clay	1011.7	2.73	252.9	0.04	505.9	0.34	728.4	1.02	1011.7	2.73	1011.7	5.45
6	-29.0	Sand	2437.8	0.67	243.8	0.02	1121.4	0.11	1852.7	0.22	2218.4	0.33	2437.8	0.67
7	-34.0	Sand	2964.6	0.68	296.5	0.02	1363.7	0.12	2253.1	0.23	2697.8	0.34	2964.6	0.68
8	-39.0	Sand	3491.5	0.69	349.1	0.02	1606.1	0.12	2653.5	0.23	3177.2	0.35	3491.5	0.69
9	-44.0	Sand	4018.3	0.70	401.8	0.02	1848.4	0.12	3053.9	0.23	3656.7	0.35	4018.3	0.70
10	-49.0	Sand	4545.1	0.71	454.5	0.02	2090.8	0.12	3454.3	0.23	4136.1	0.35	4545.1	0.71
11	-54.0	Sand	5072.0	0.71	507.2	0.02	2333.1	0.12	3854.7	0.23	4615.5	0.36	5072.0	0.71
12	-59.0	Sand	5598.8	0.71	559.9	0.02	2575.5	0.12	4255.1	0.24	5094.9	0.36	5598.8	0.71
13	-64.0	Sand	6125.7	0.72	612.6	0.02	2817.8	0.12	4655.5	0.24	5574.4	0.36	6125.7	0.72
14	-69.0	Sand	6652.5	0.72	665.3	0.02	3060.2	0.12	5055.9	0.24	6053.8	0.36	6652.5	0.72
15	-74.0	Sand	7179.4	0.72	717.9	0.02	3302.5	0.12	5456.3	0.24	6533.2	0.36	7179.4	0.72
16	-80.0	Sand	7811.6	0.72	781.2	0.02	3593.3	0.12	5936.8	0.24	7108.5	0.36	7811.6	0.72

12.0 APPENDIX E: LATERAL PUSH-OVER CURVES

FIGURE E-1: ABUTMENT 1 – LATERAL PUSH-OVER CURVES

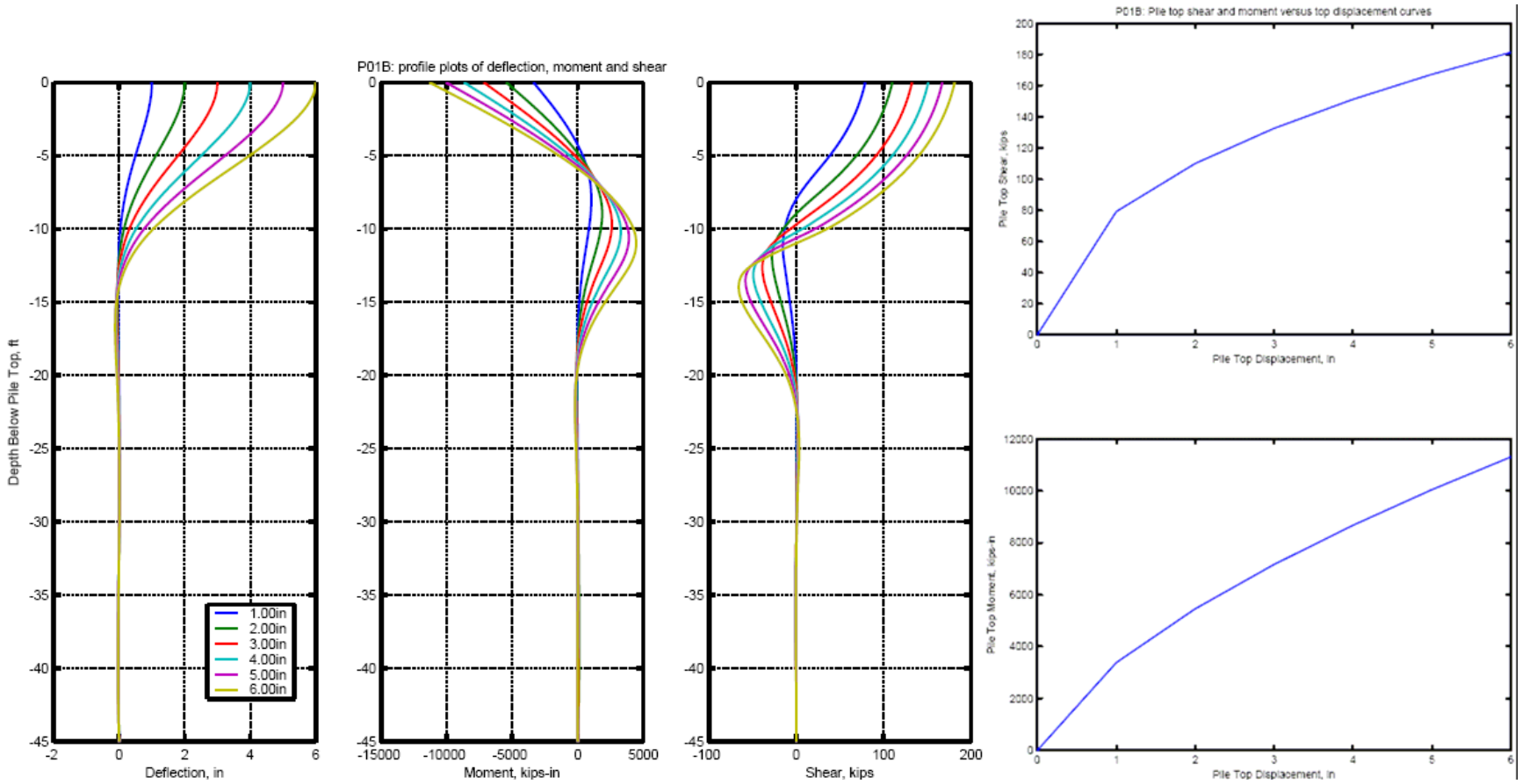


FIGURE E-2: PIER 2 – LATERAL PUSH-OVER CURVES

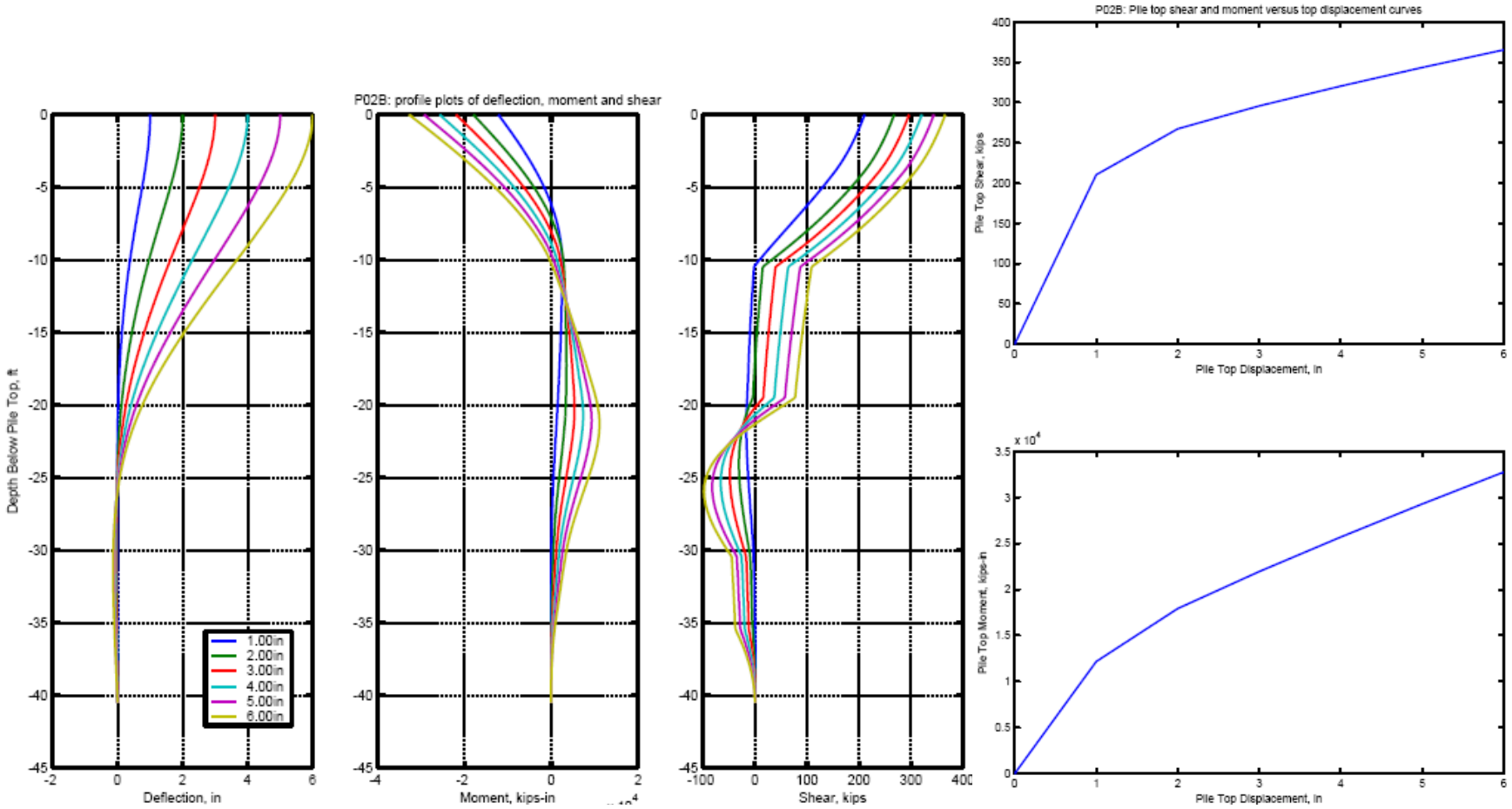


FIGURE E-3: PIER 3 – LATERAL PUSH-OVER CURVES

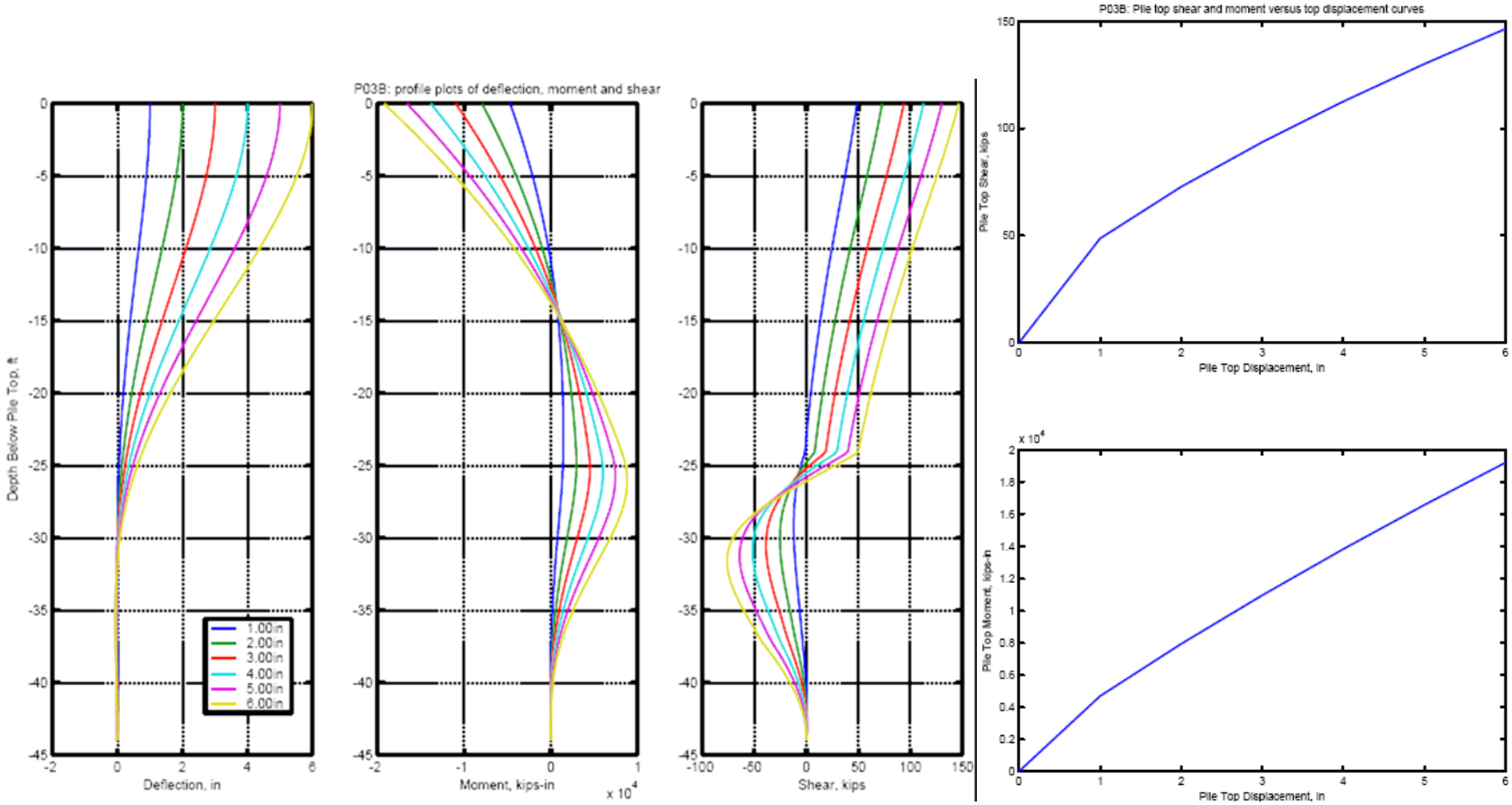


FIGURE E-4: PIER 4 – LATERAL PUSH-OVER CURVES

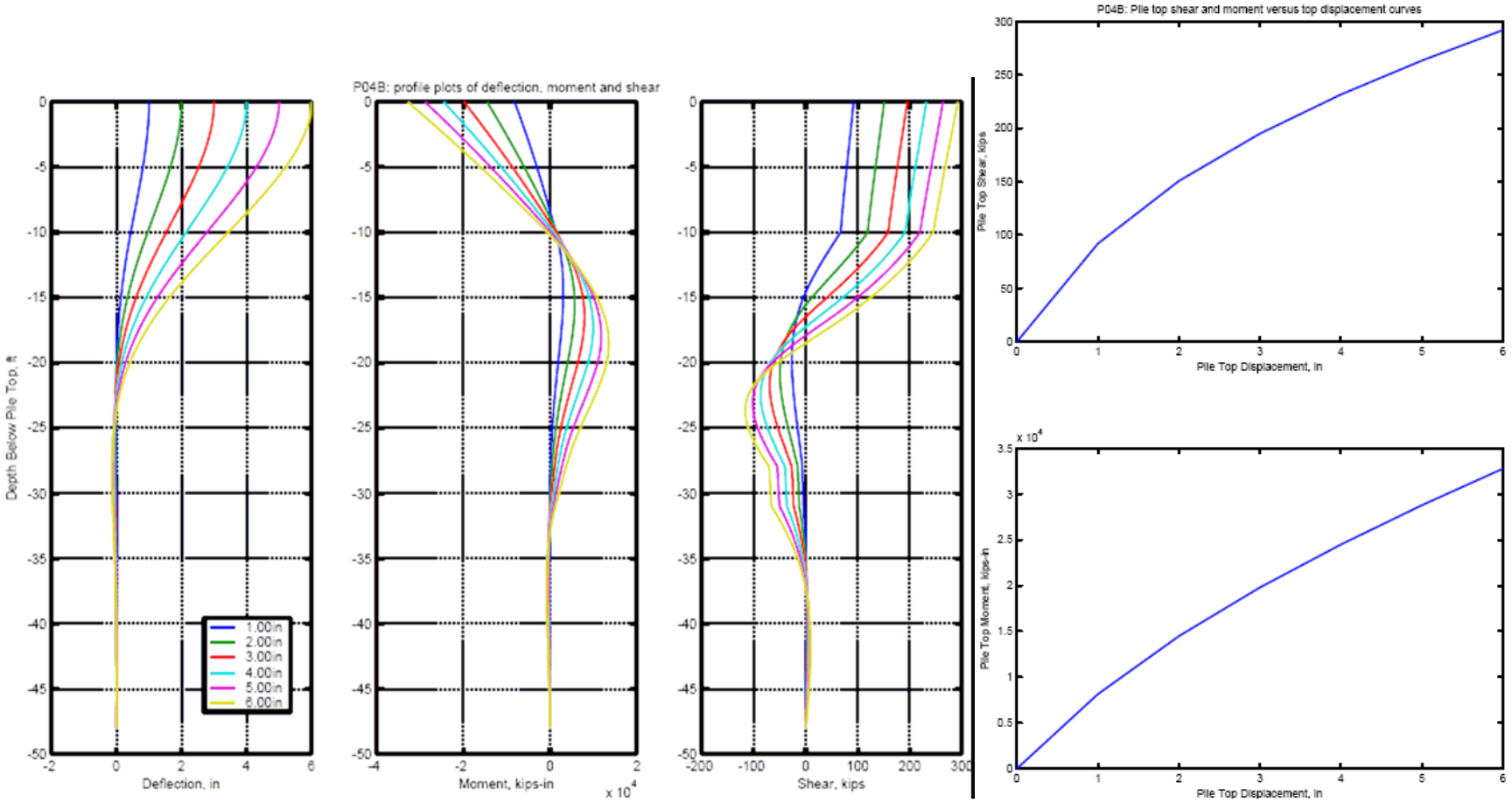


FIGURE E-5: PIER 5 – LATERAL PUSH-OVER CURVES

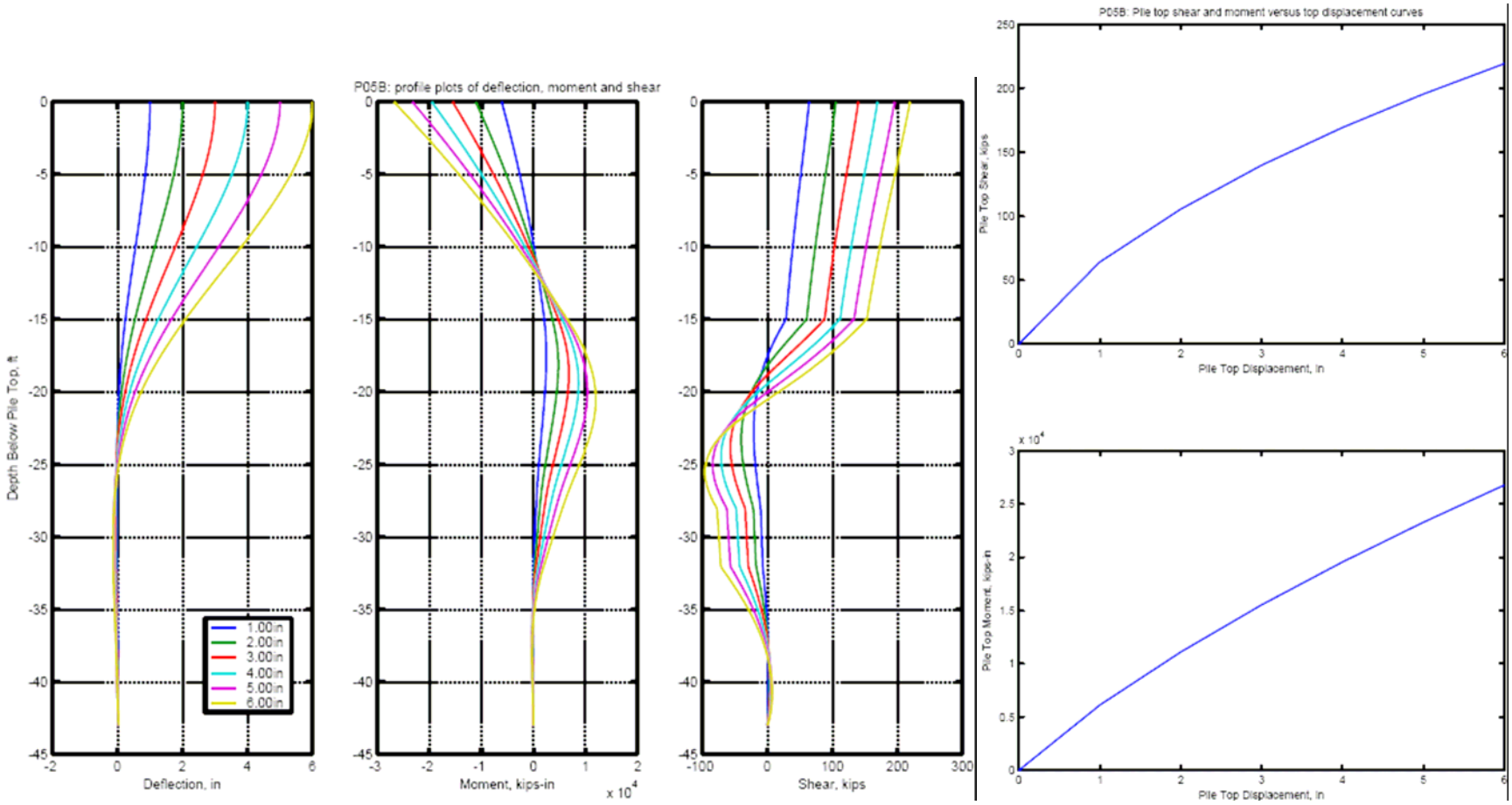


FIGURE E-6: PIER 6 – LATERAL PUSH-OVER CURVES

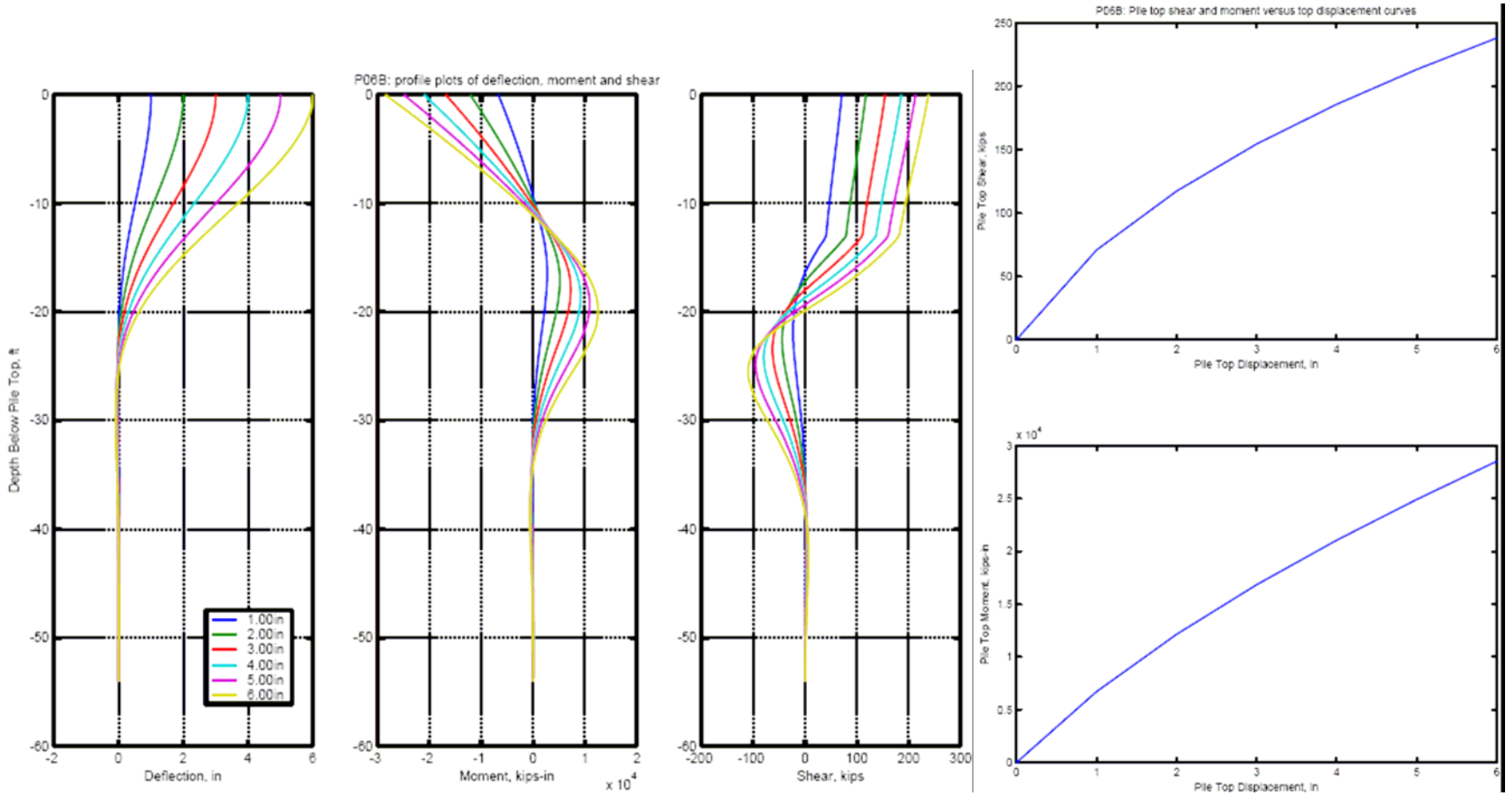


FIGURE E-7: PIER 7 – LATERAL PUSH-OVER CURVES

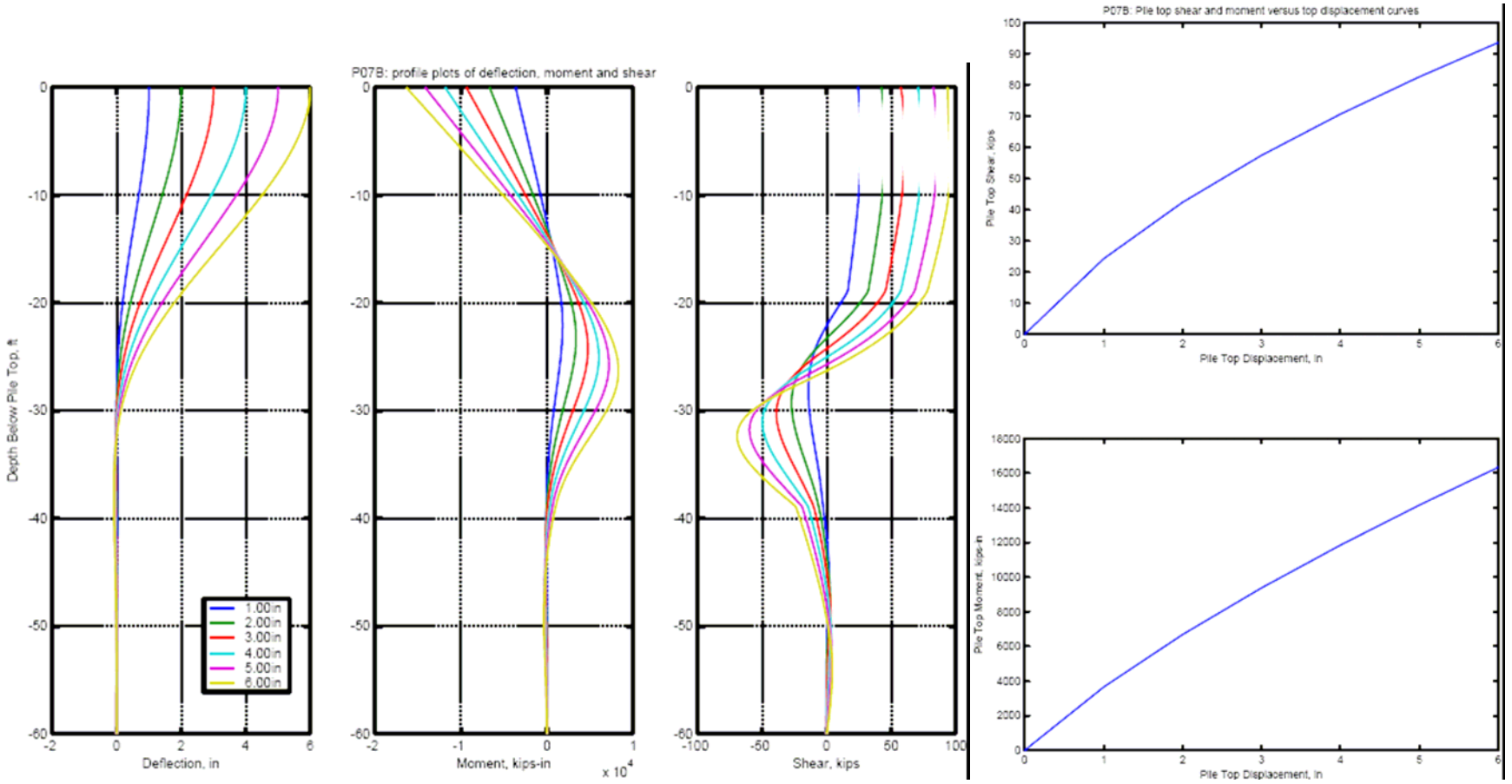


FIGURE E-8: PIER 8 – LATERAL PUSH-OVER CURVES

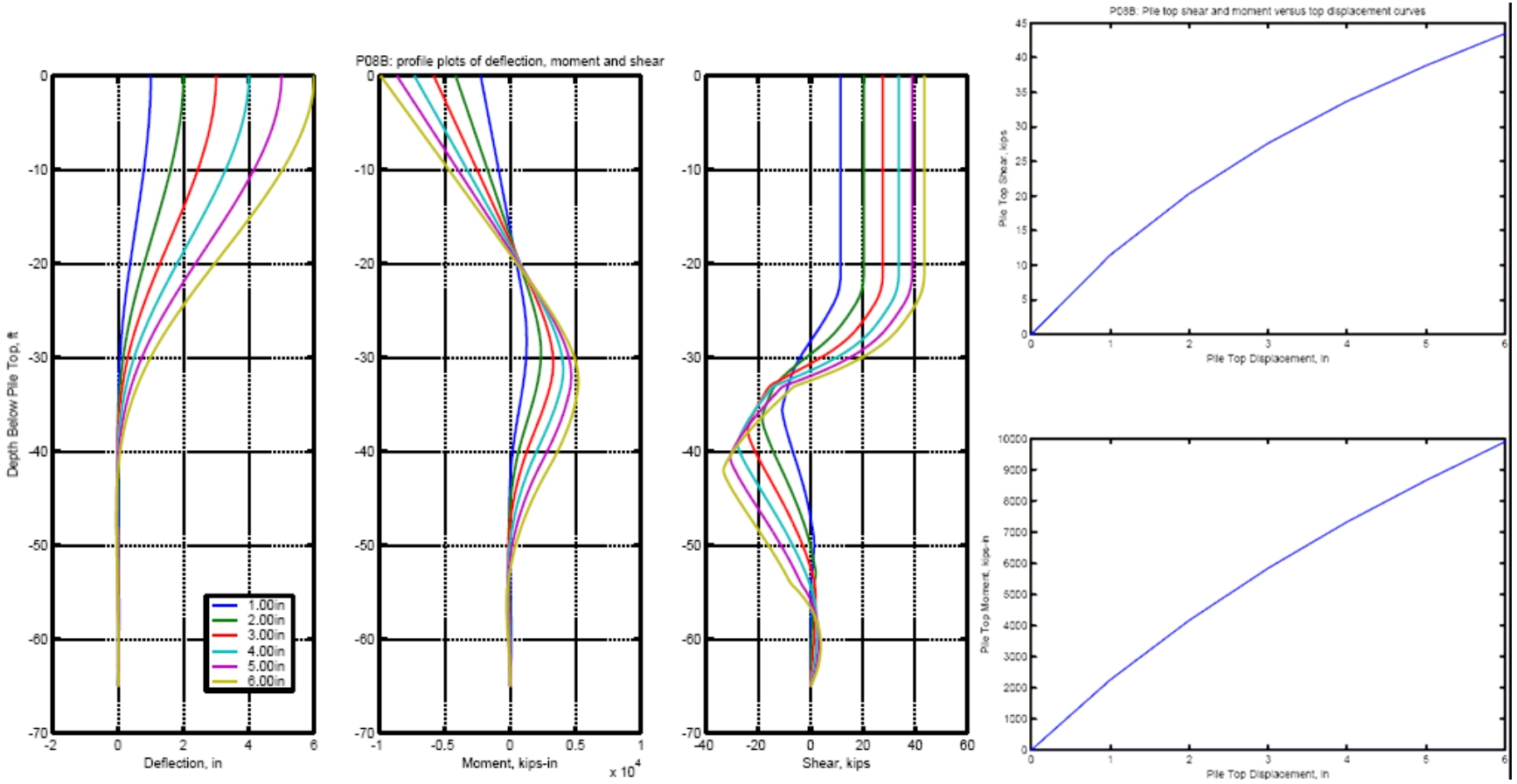


FIGURE E-9: PIER 9 – LATERAL PUSH-OVER CURVES

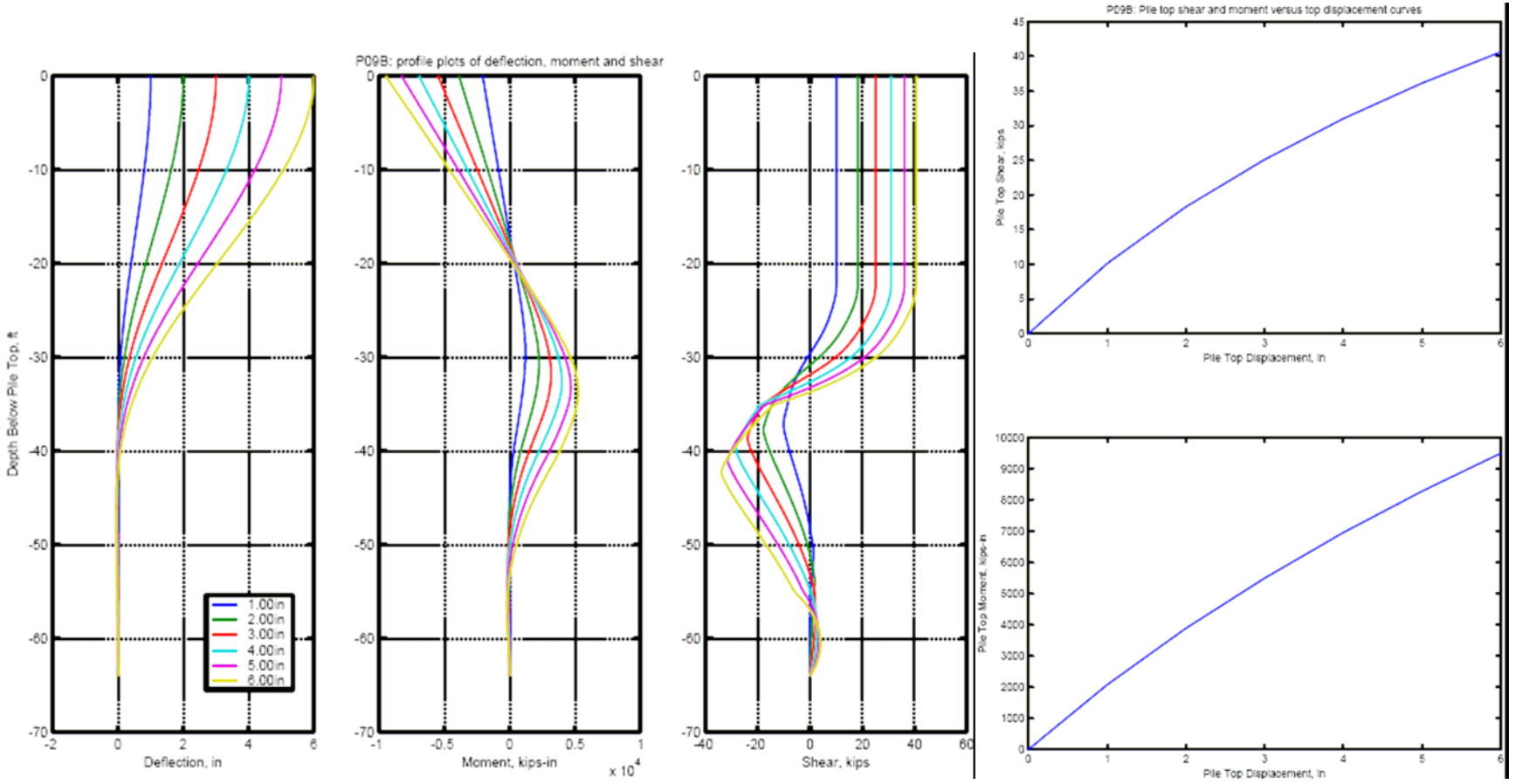


FIGURE E-10: PIER 10 – LATERAL PUSH-OVER CURVES

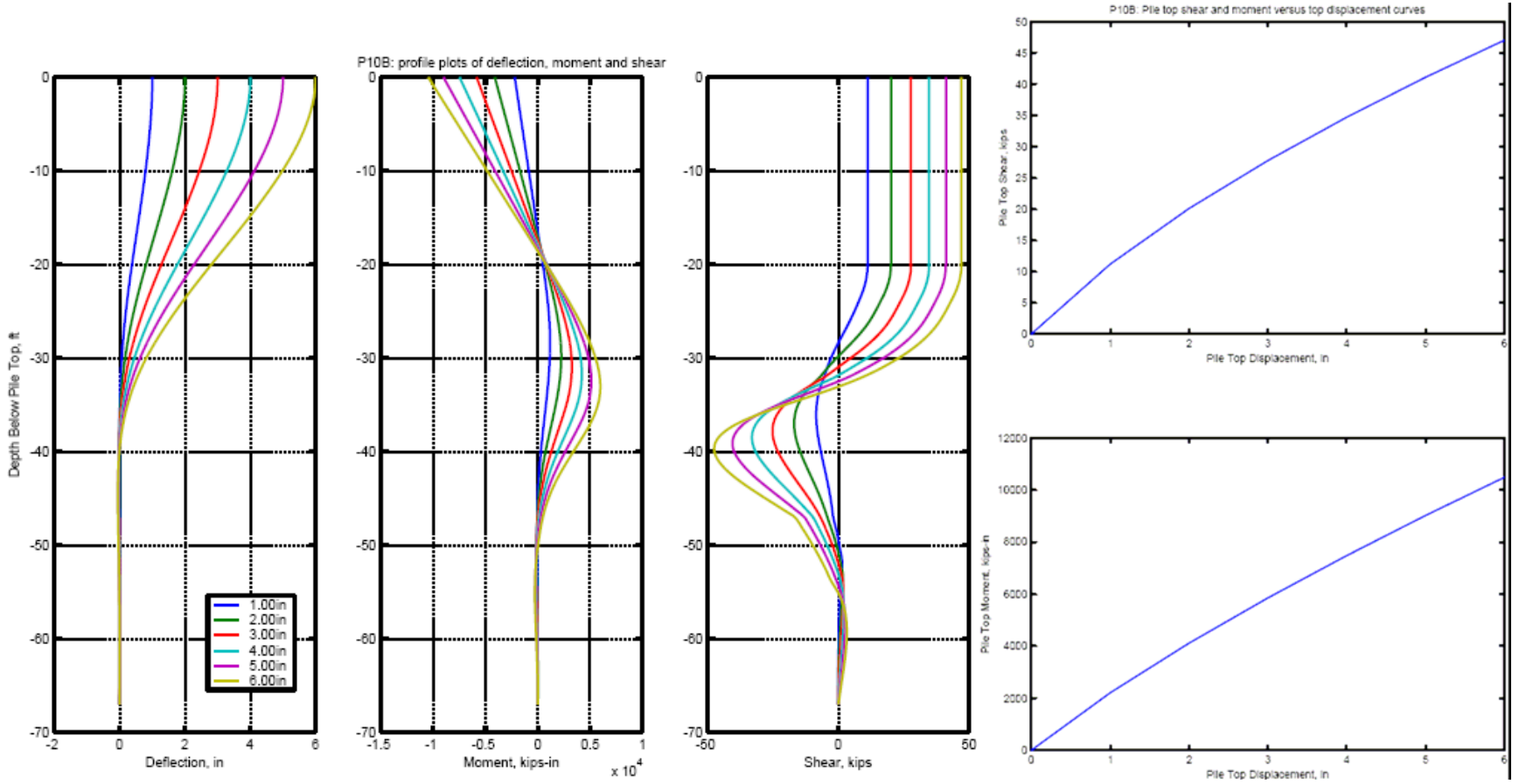


FIGURE E-11: PIER 11 – LATERAL PUSH-OVER CURVES

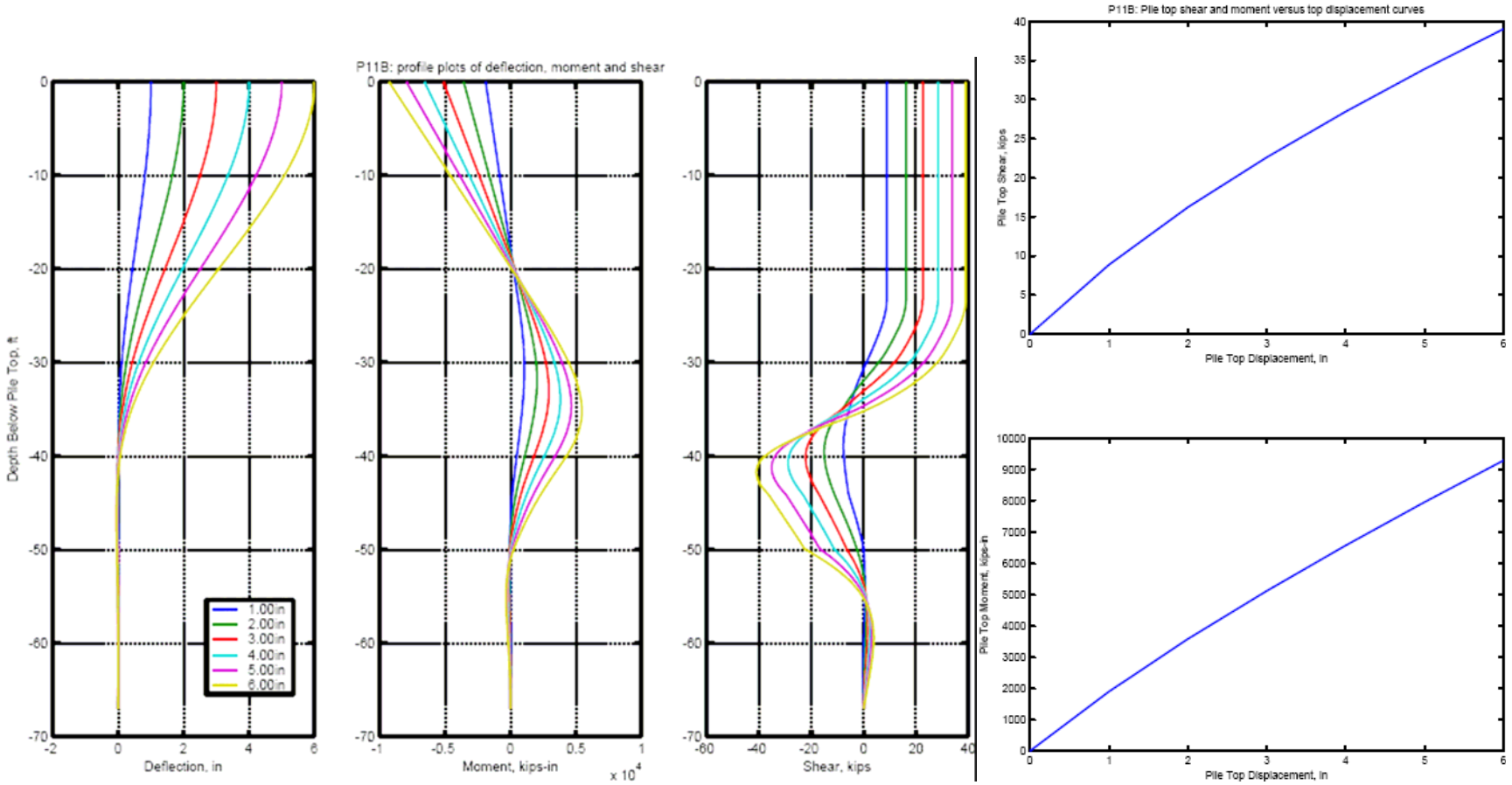


FIGURE E-12: PIER 12 – LATERAL PUSH-OVER CURVES

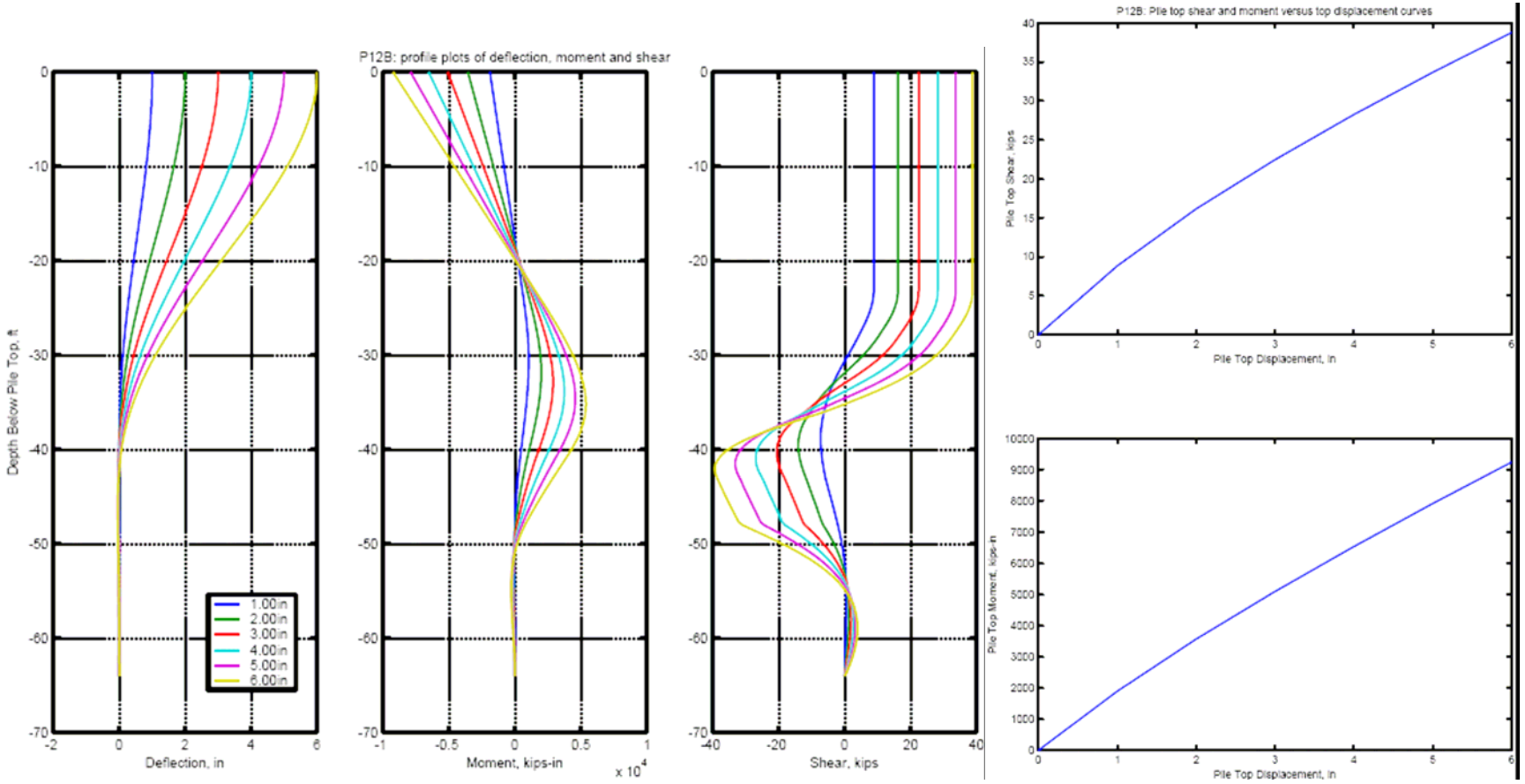


FIGURE E-13: PIER 13 – LATERAL PUSH-OVER CURVES

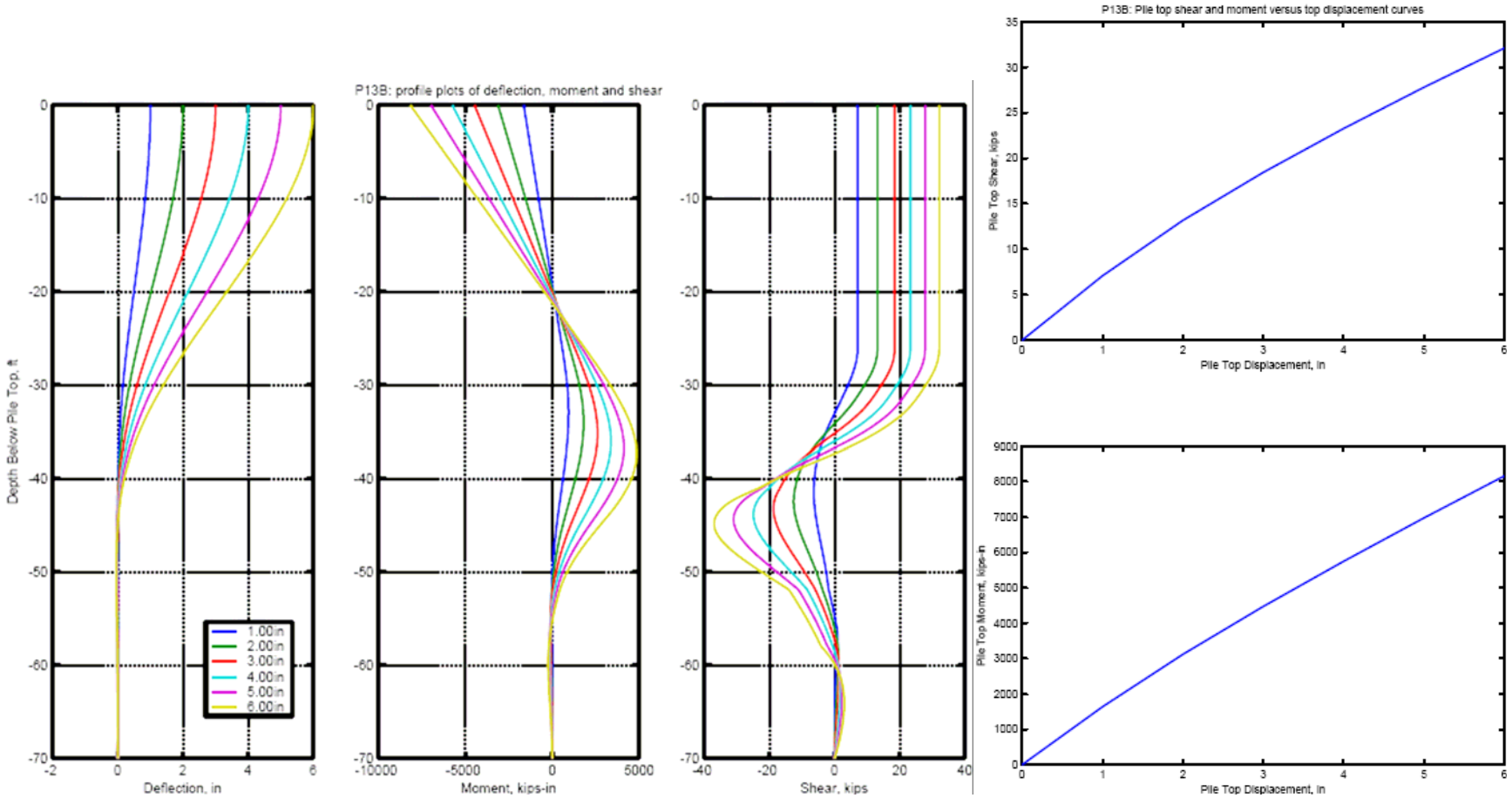


FIGURE E-14: PIER 14 – LATERAL PUSH-OVER CURVES

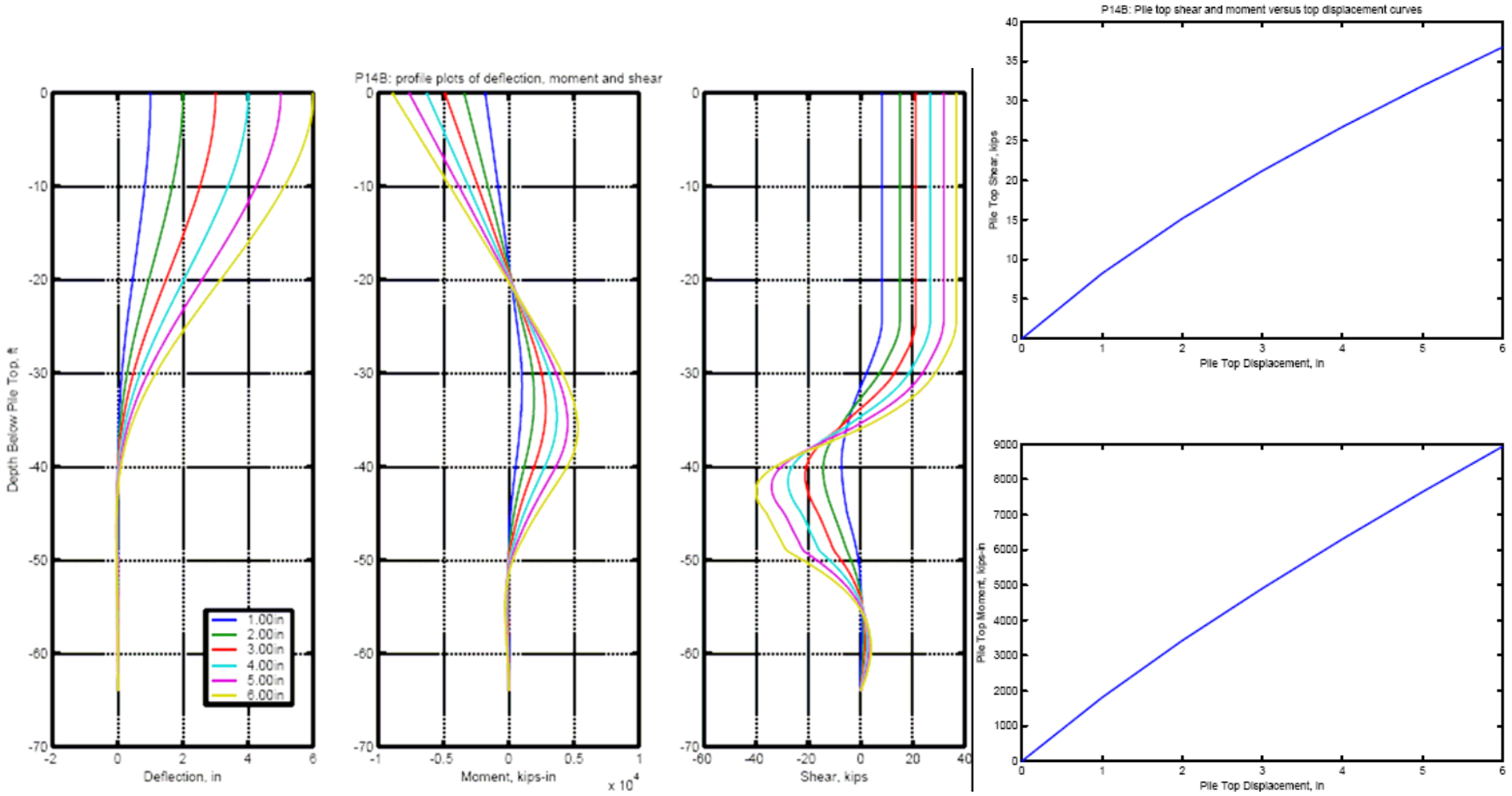


FIGURE E-15: PIER 15 – LATERAL PUSH-OVER CURVES

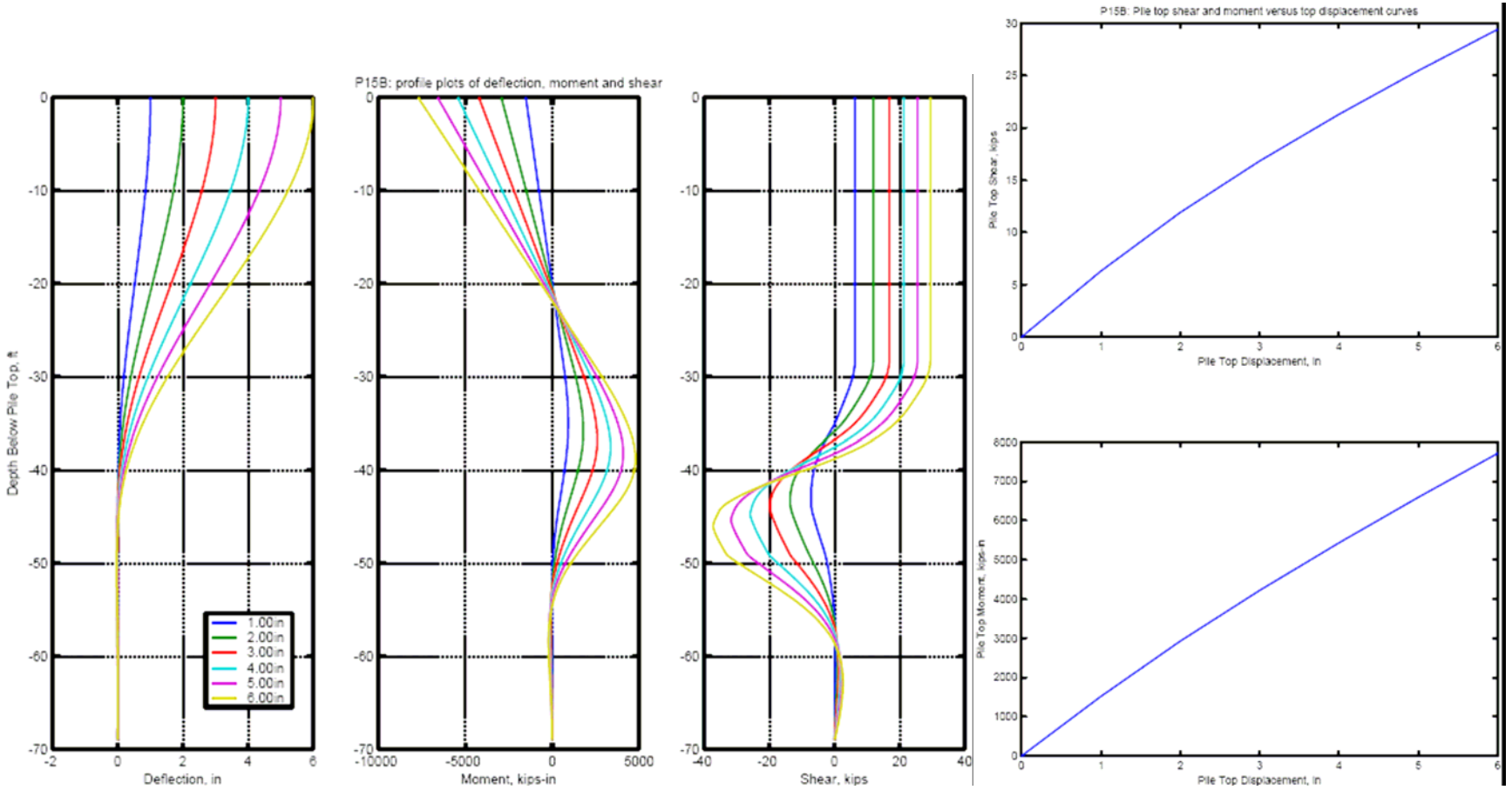


FIGURE E-16: PIER 16 – LATERAL PUSH-OVER CURVES

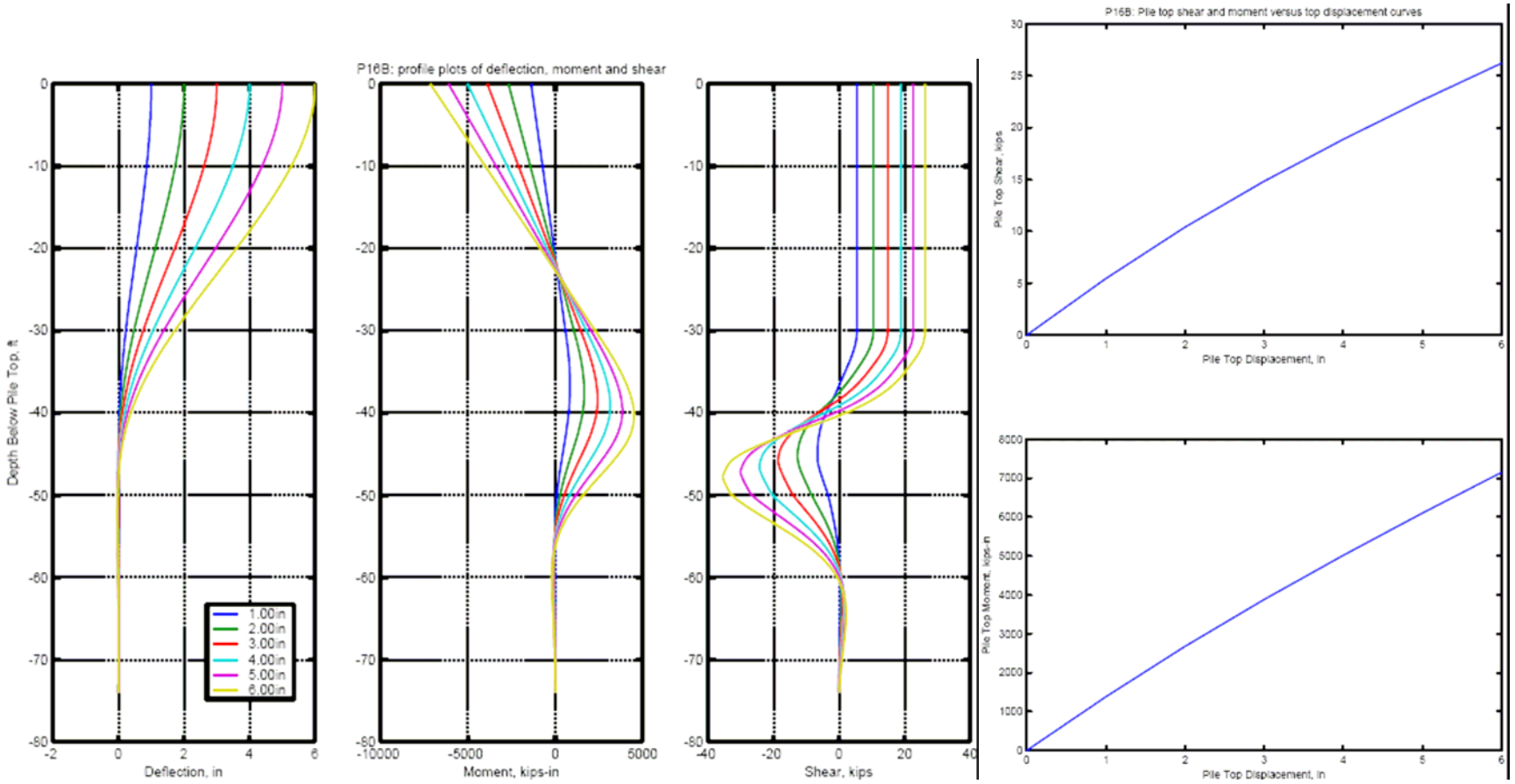


FIGURE E-17: PIER 17 – LATERAL PUSH-OVER CURVES

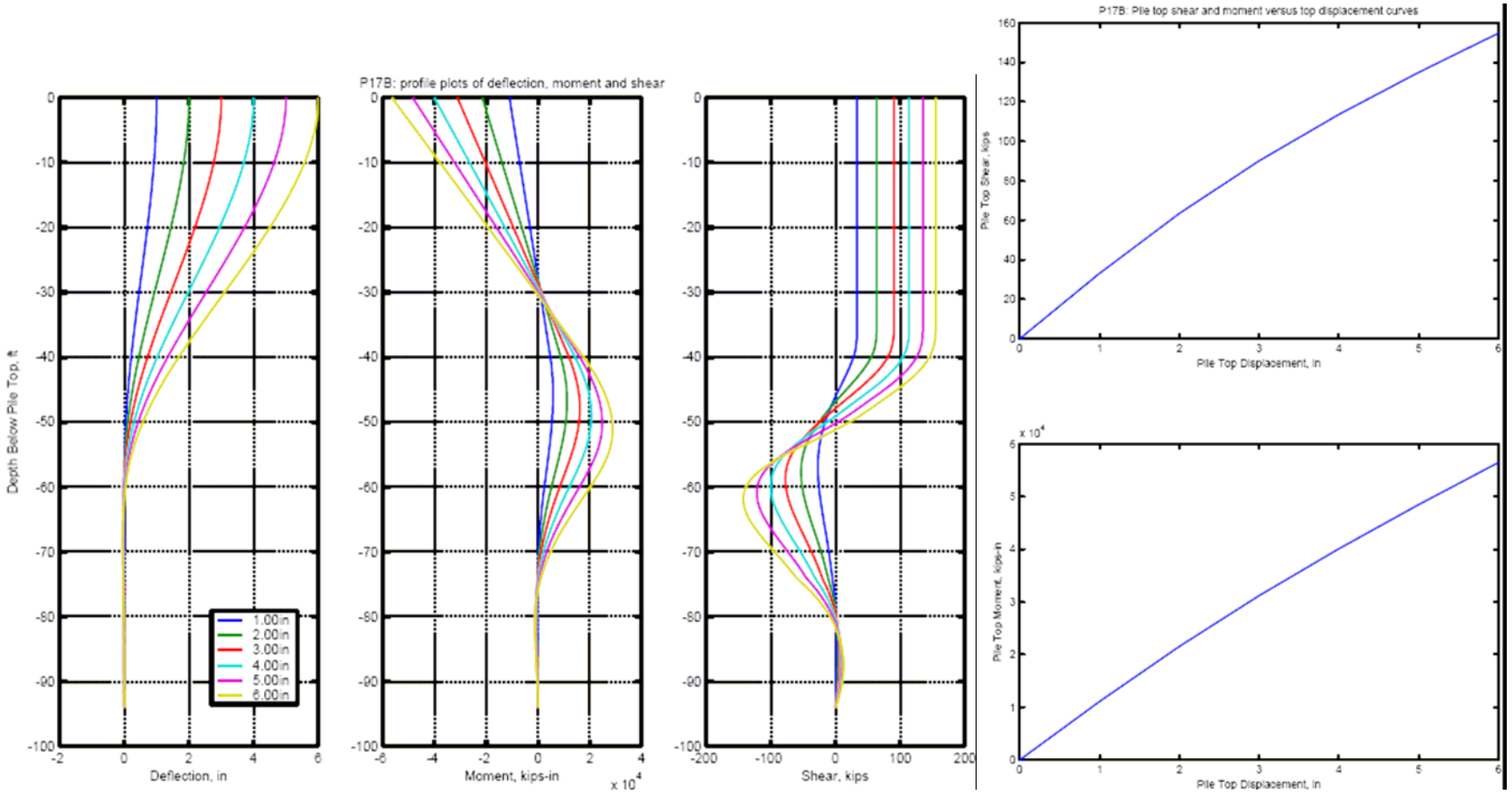


FIGURE E-18: PIER 18 – LATERAL PUSH-OVER CURVES

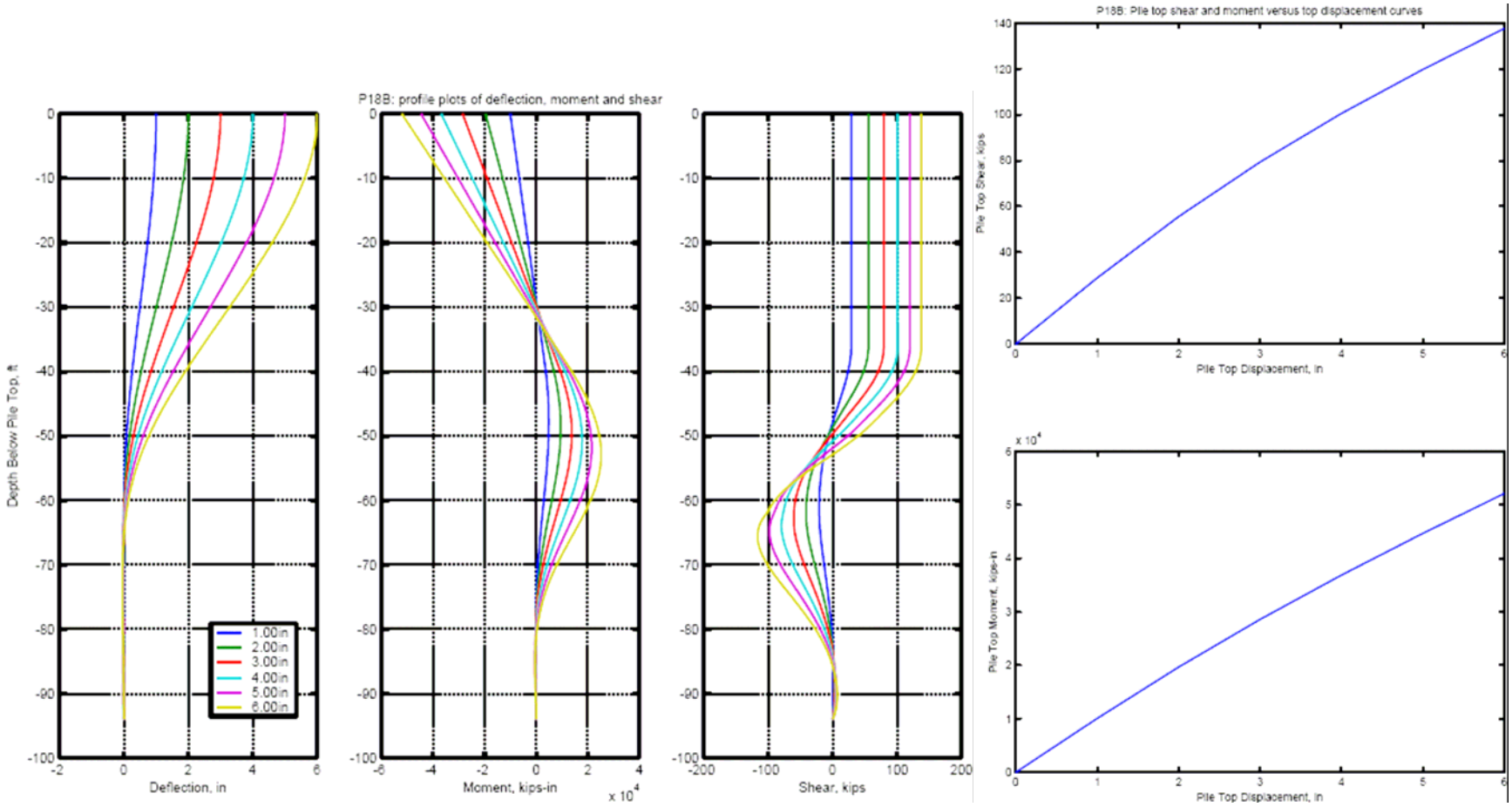


FIGURE E-19: PIER 19 – LATERAL PUSH-OVER CURVES

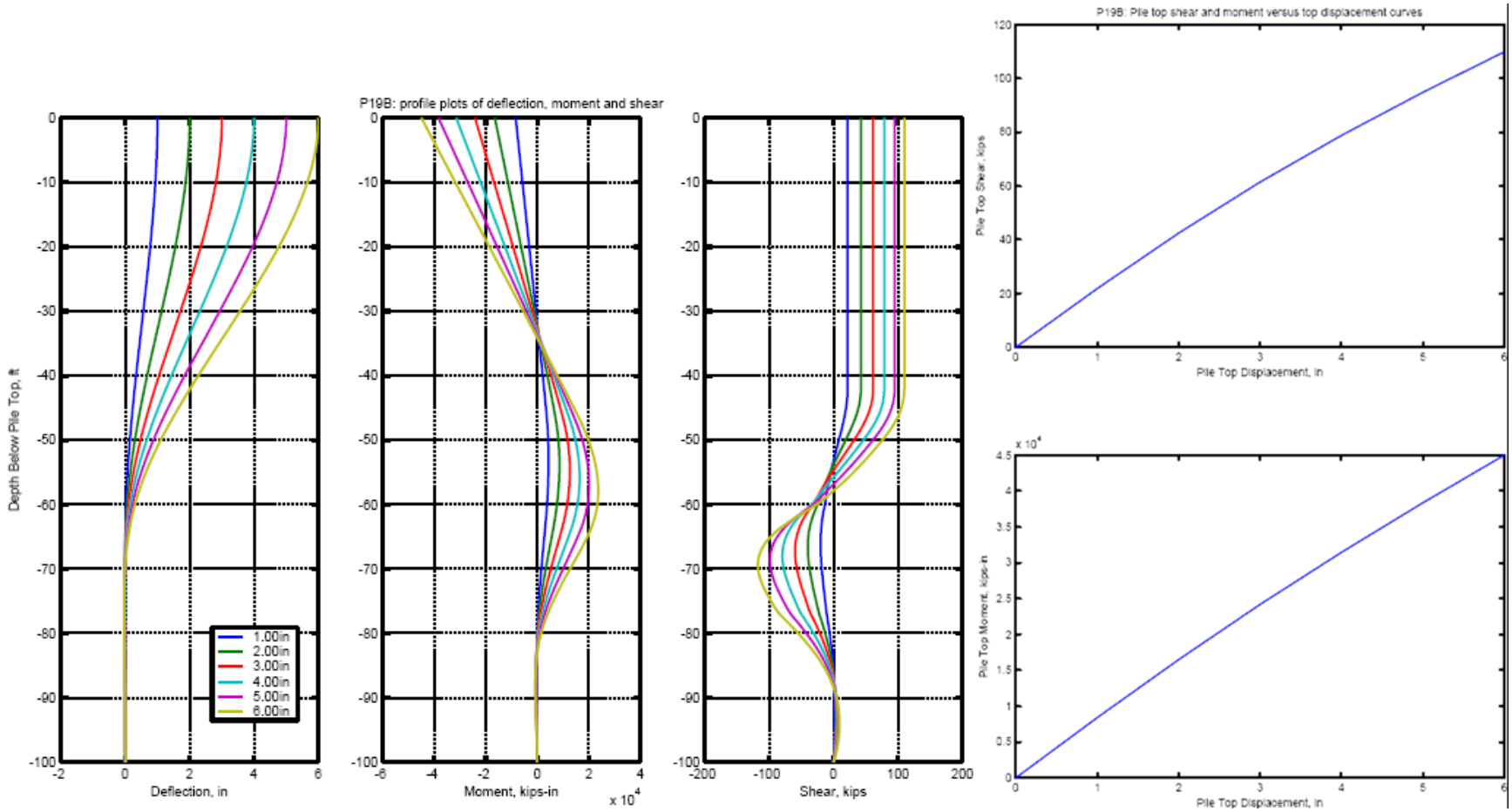


FIGURE E-20: PIER 20 – LATERAL PUSH-OVER CURVES

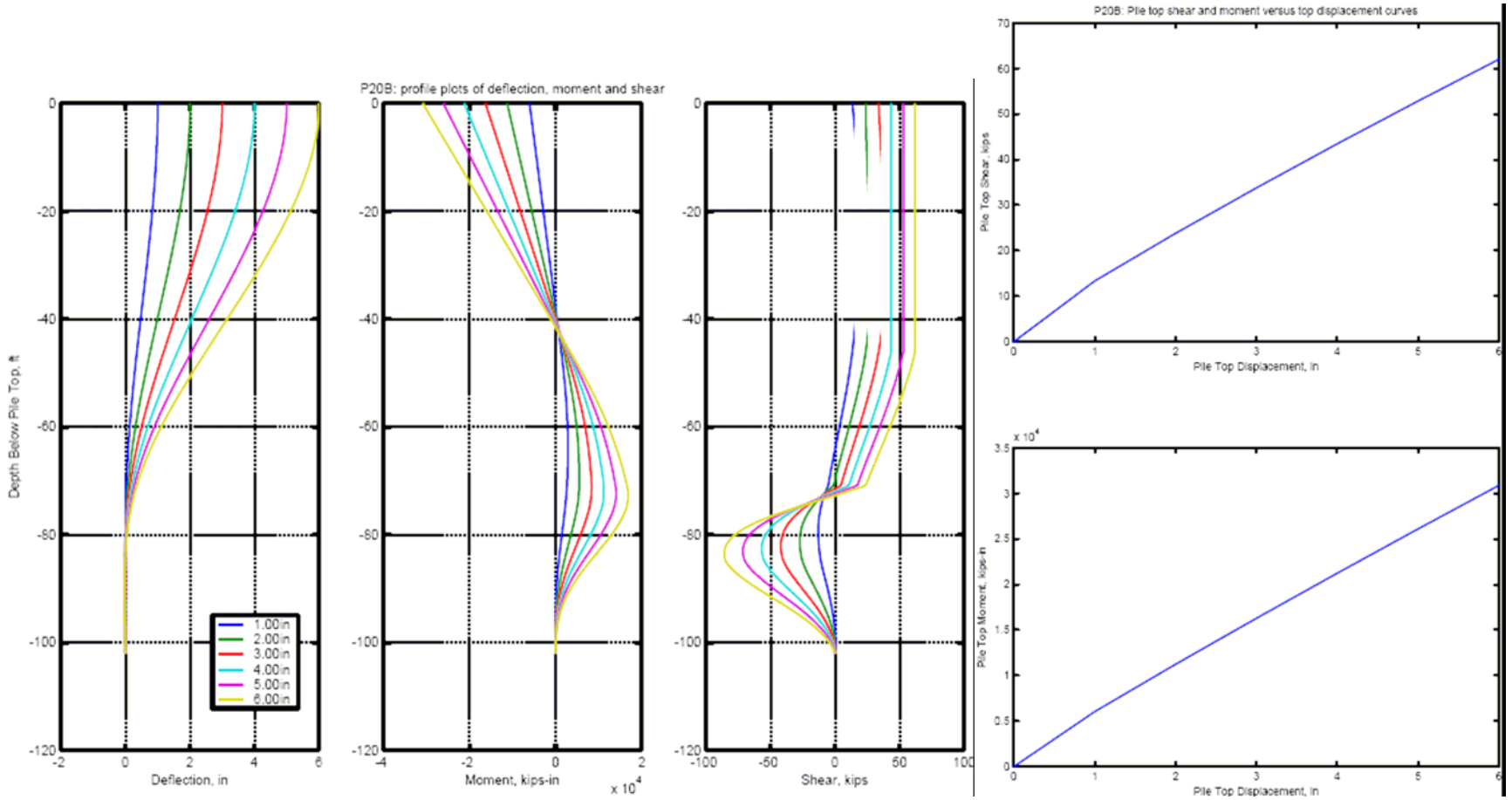


FIGURE E-21: PIER 21 – LATERAL PUSH-OVER CURVES

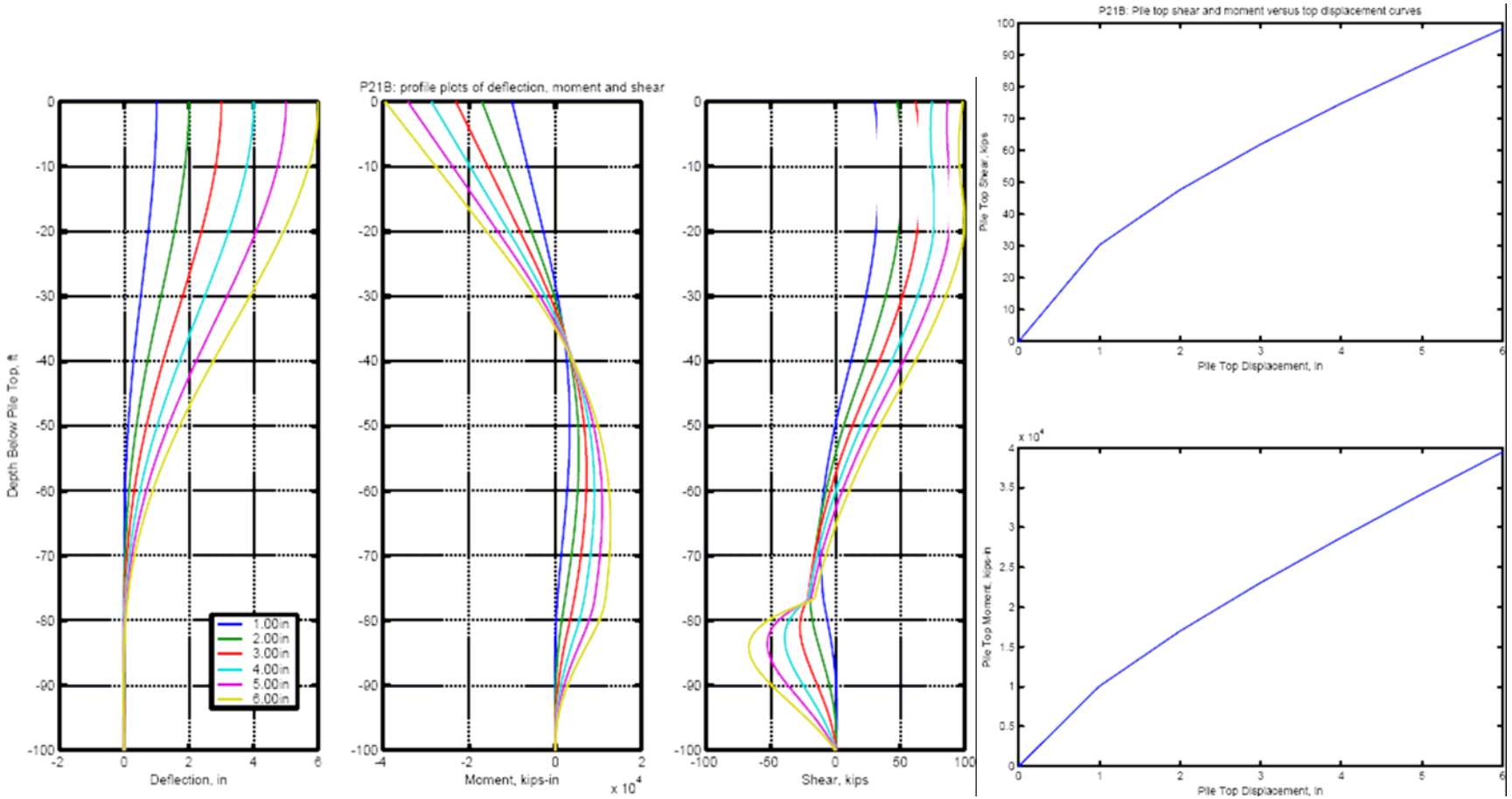


FIGURE E-22: PIER 22 – LATERAL PUSH-OVER CURVES

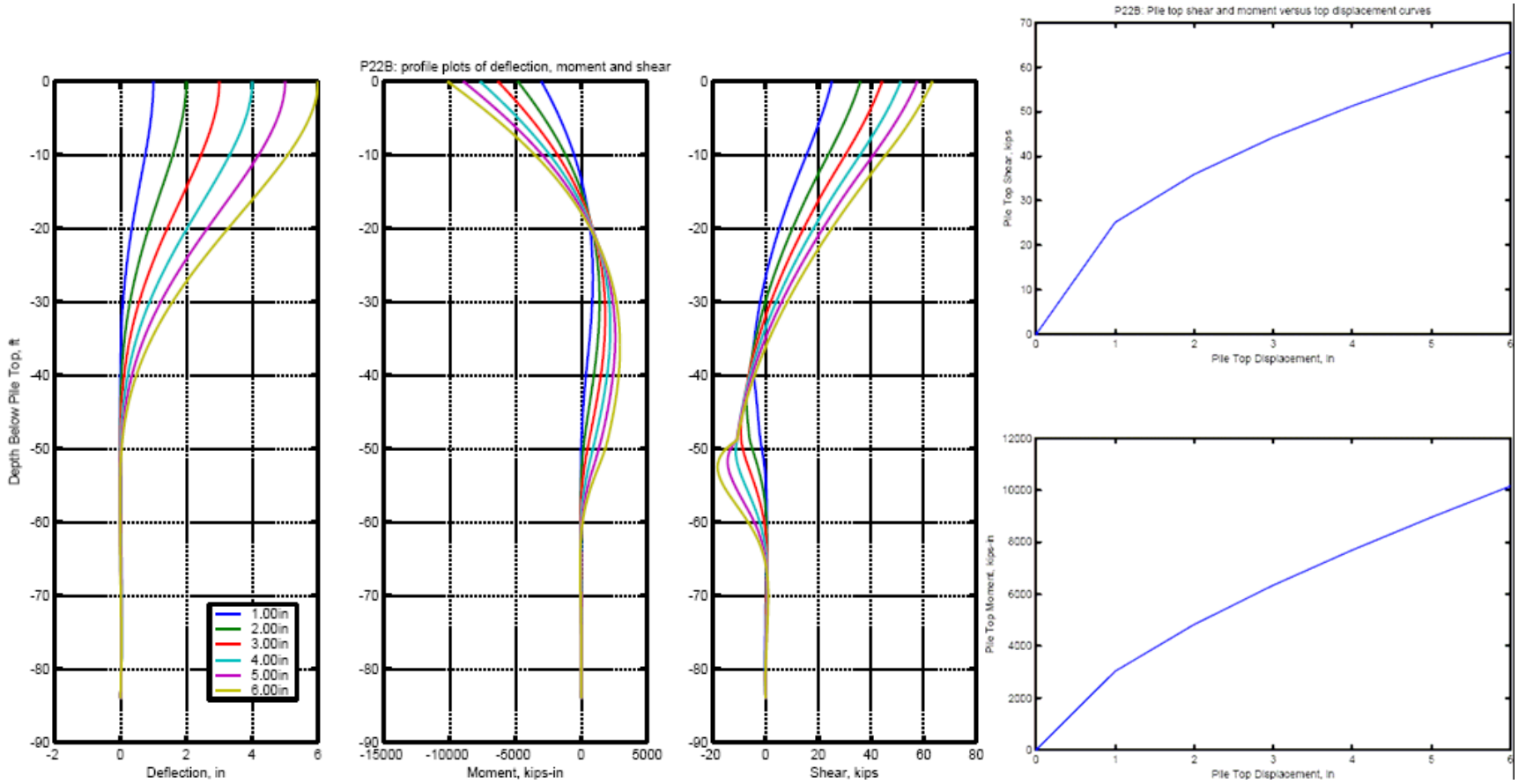


FIGURE E-23: PIER 23 – LATERAL PUSH-OVER CURVES

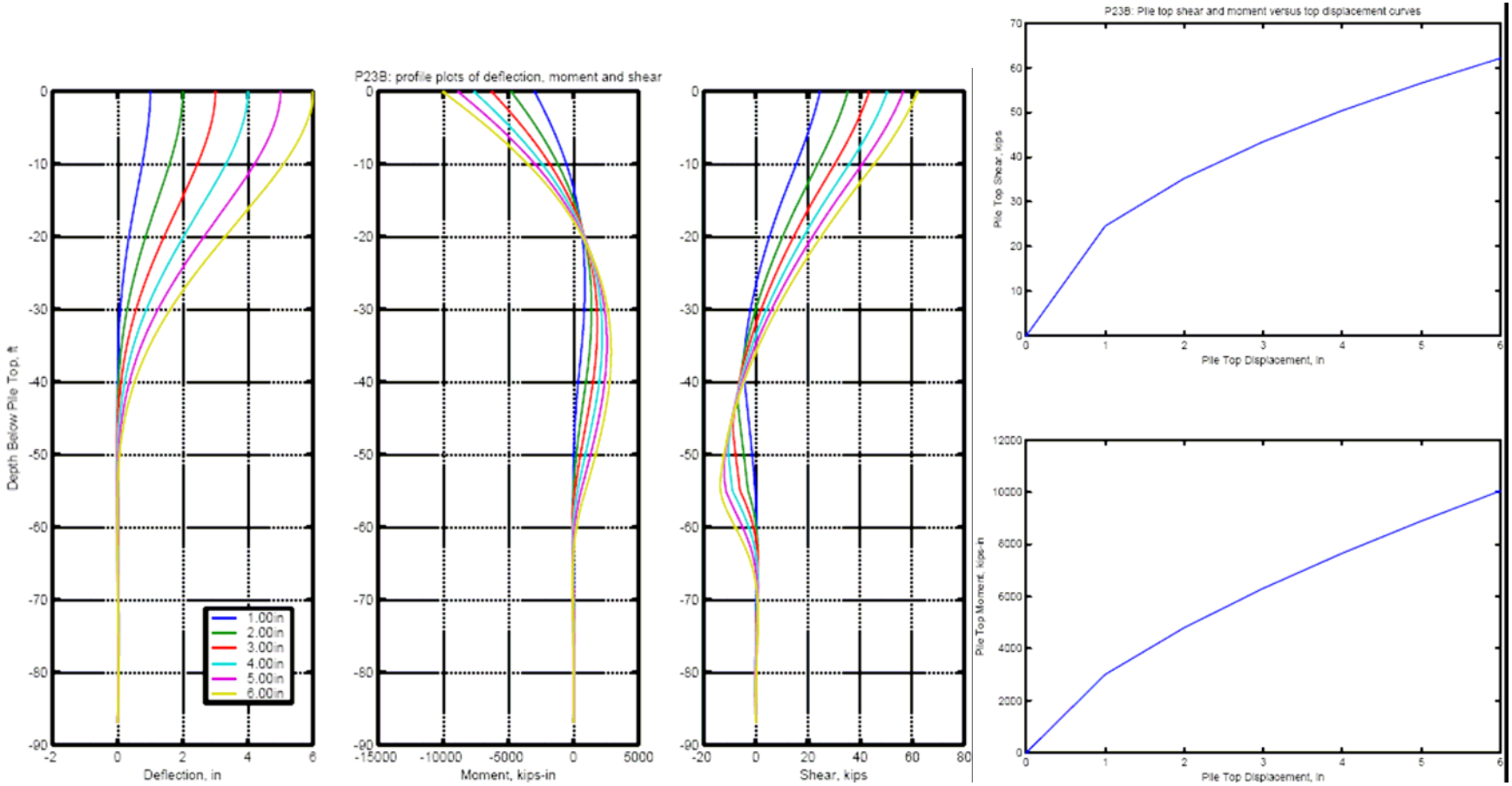


FIGURE E-24: PIER 24 – LATERAL PUSH-OVER CURVES

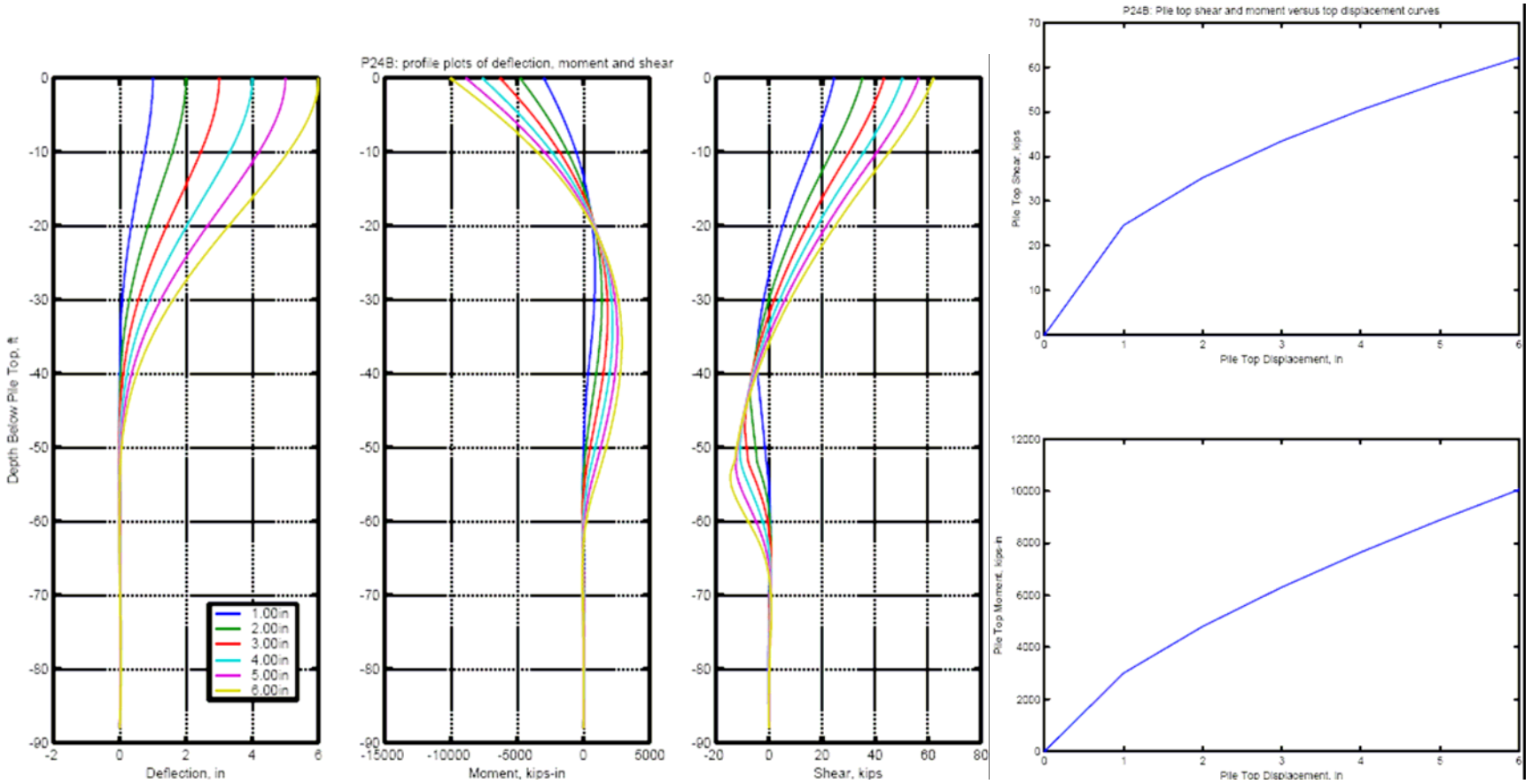


FIGURE E-25: PIER 25 – LATERAL PUSH-OVER CURVES

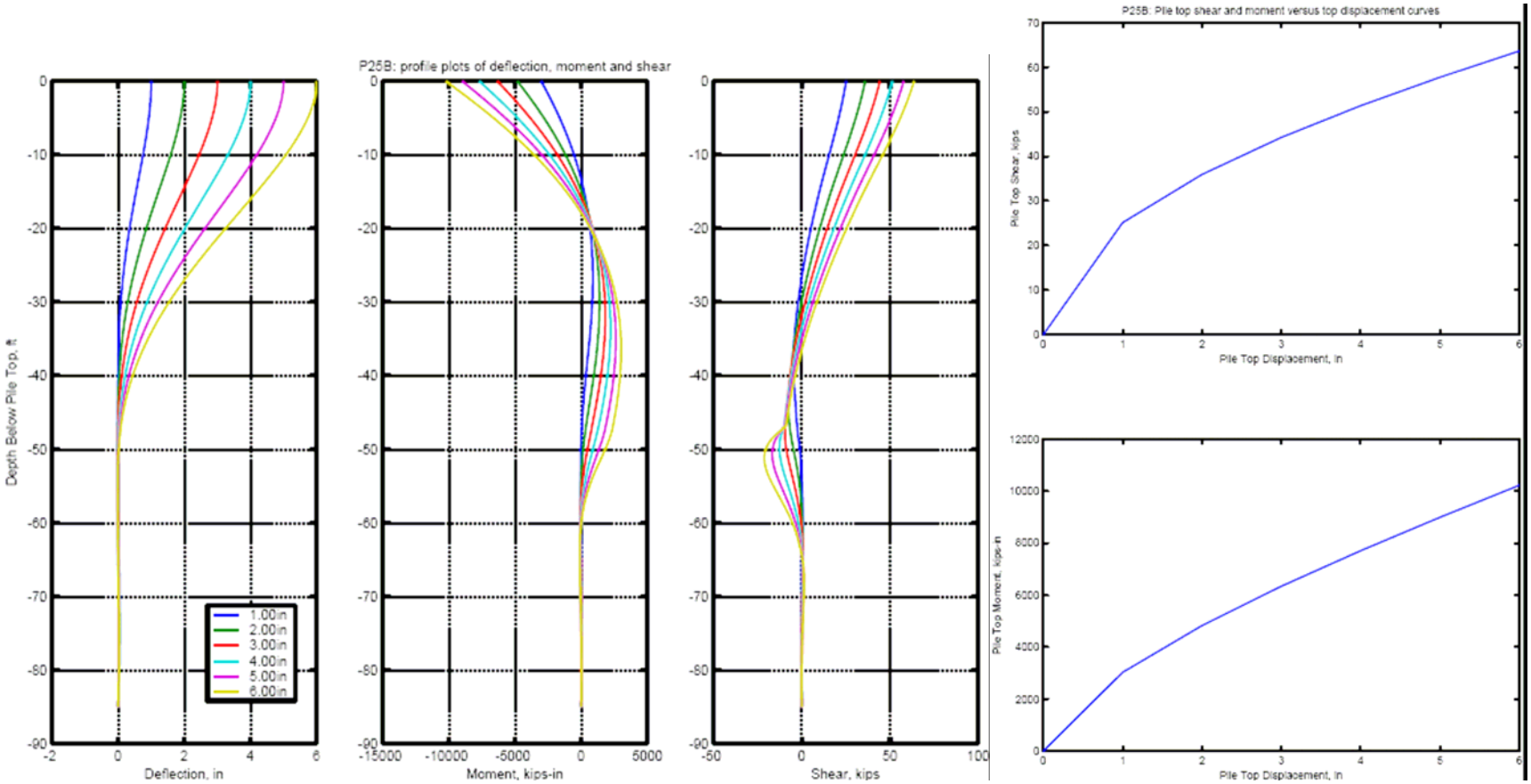


FIGURE E-26: PIER 26 – LATERAL PUSH-OVER CURVES

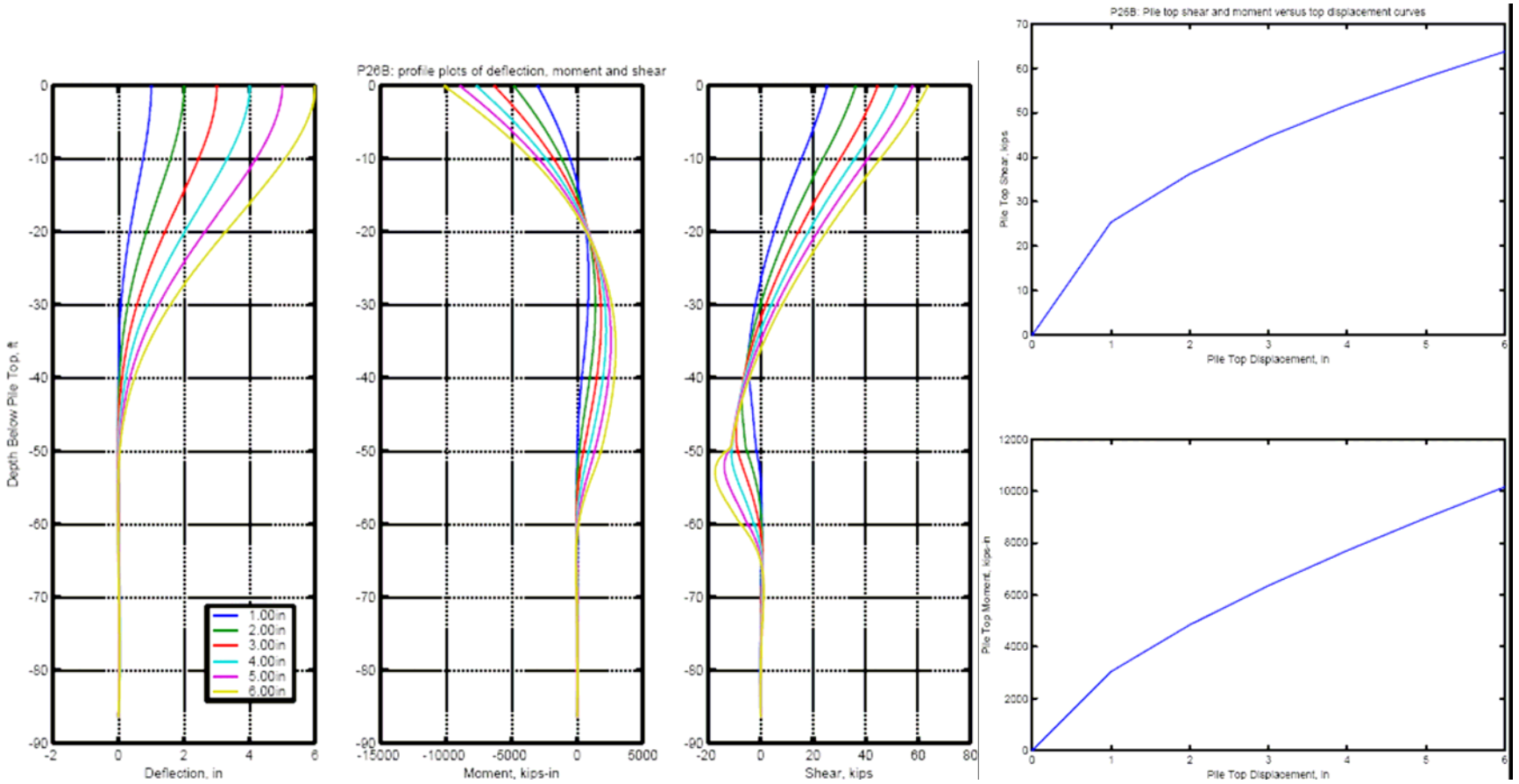


FIGURE E-27: PIER 27 – LATERAL PUSH-OVER CURVES

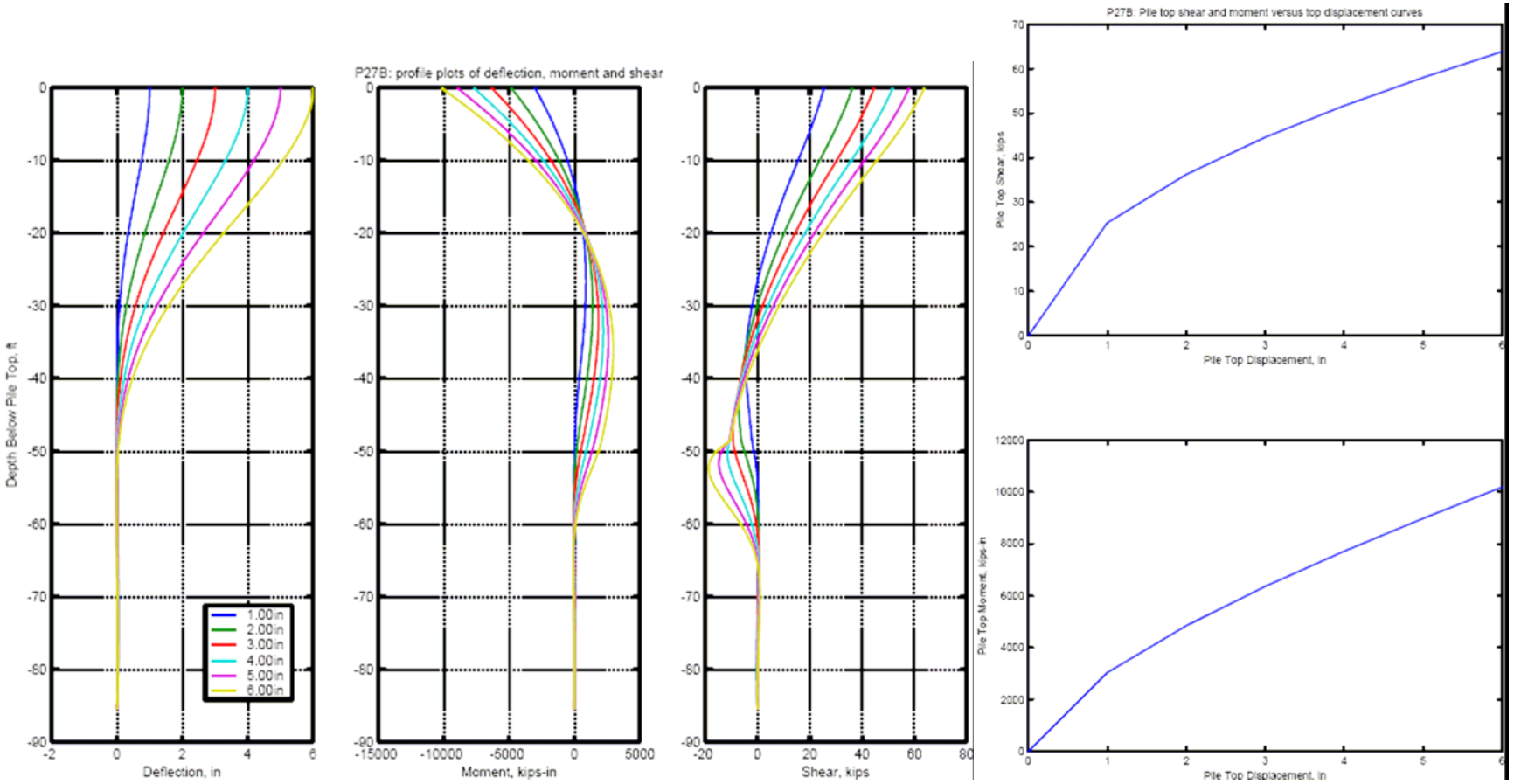


FIGURE E-28: PIER 28 – LATERAL PUSH-OVER CURVES

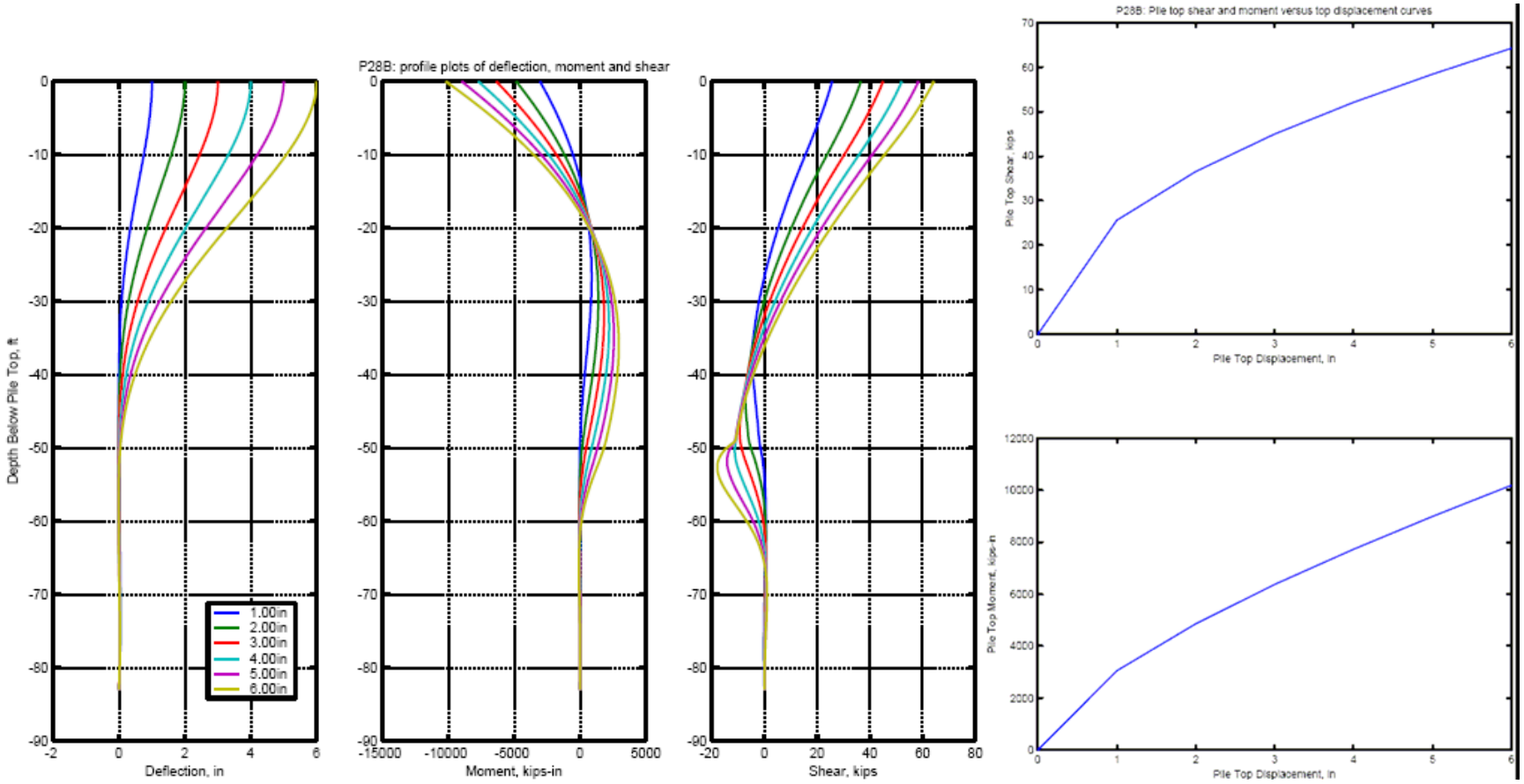


FIGURE E-29: PIER 29 – LATERAL PUSH-OVER CURVES

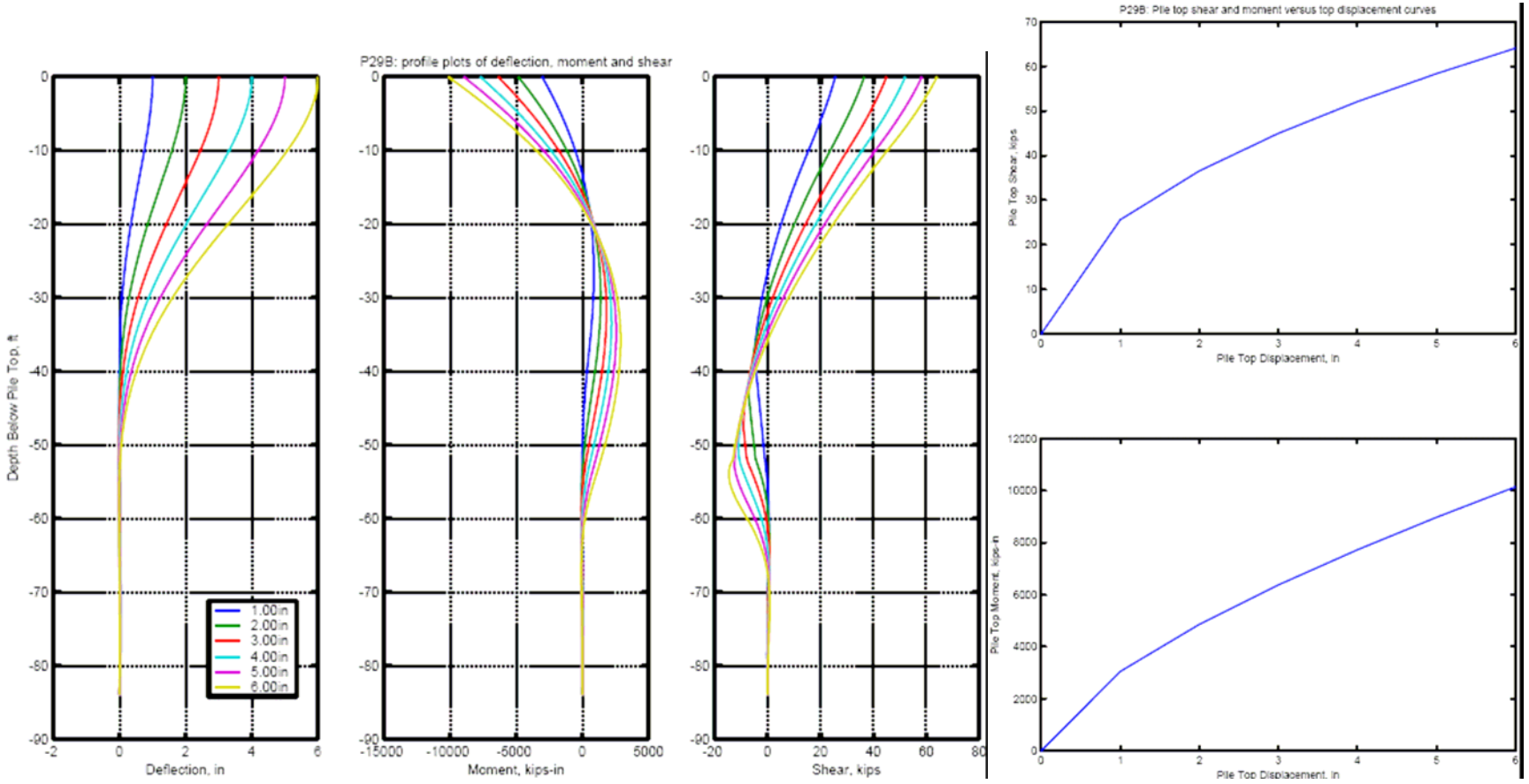


FIGURE E-30: PIER 30 – LATERAL PUSH-OVER CURVES

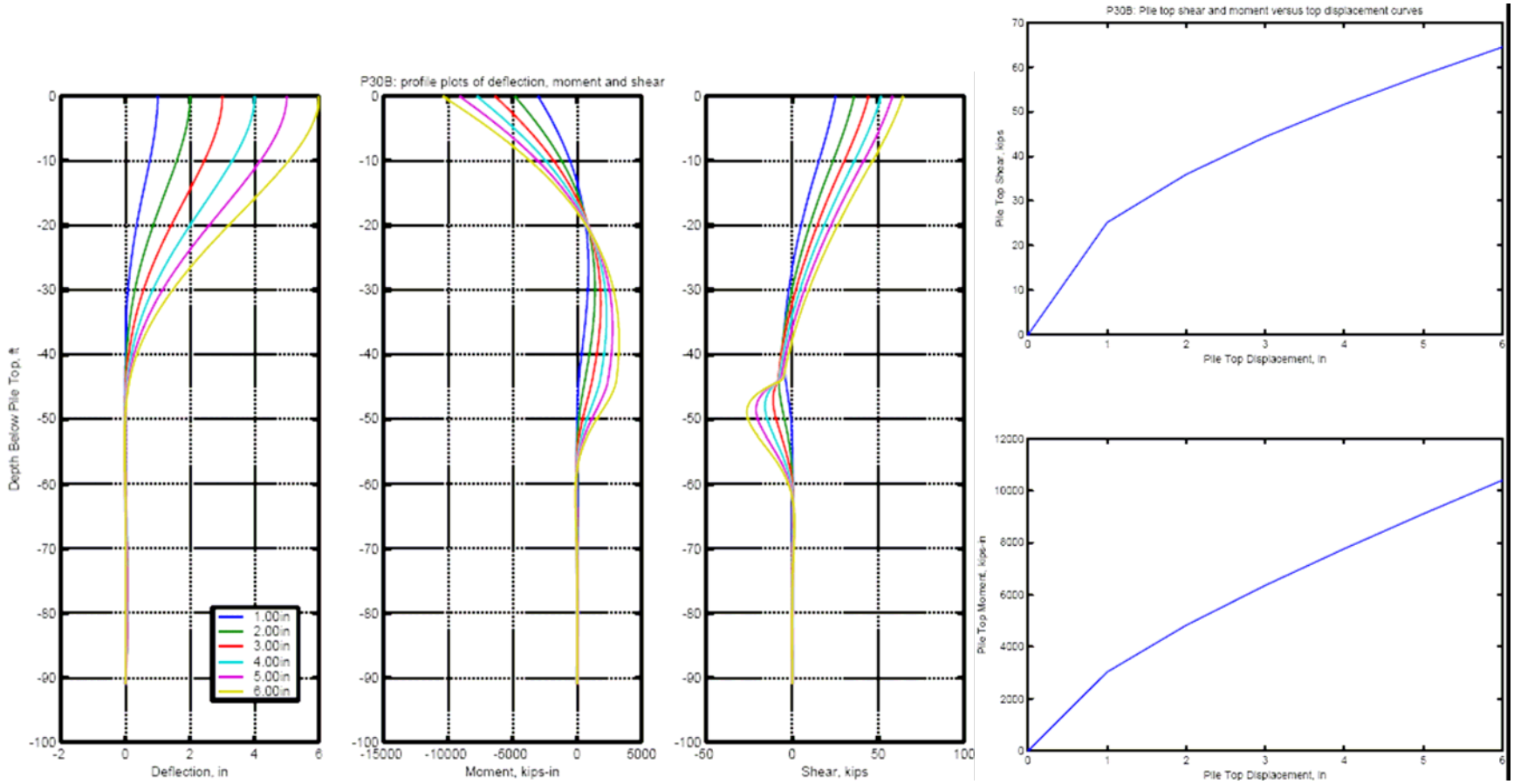


FIGURE E-31: PIER 31 – LATERAL PUSH-OVER CURVES

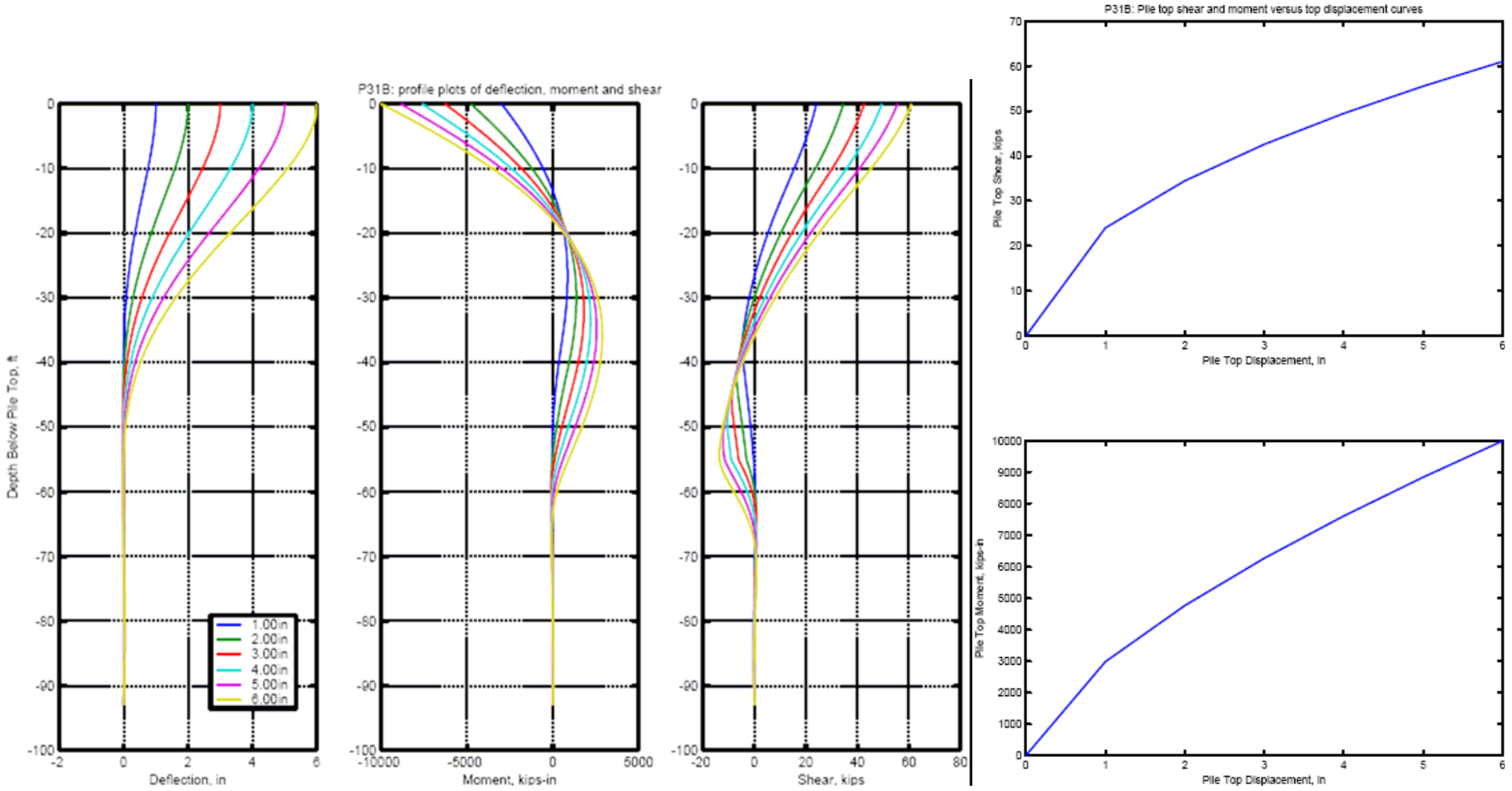


FIGURE E-32: PIER 32 – LATERAL PUSH-OVER CURVES

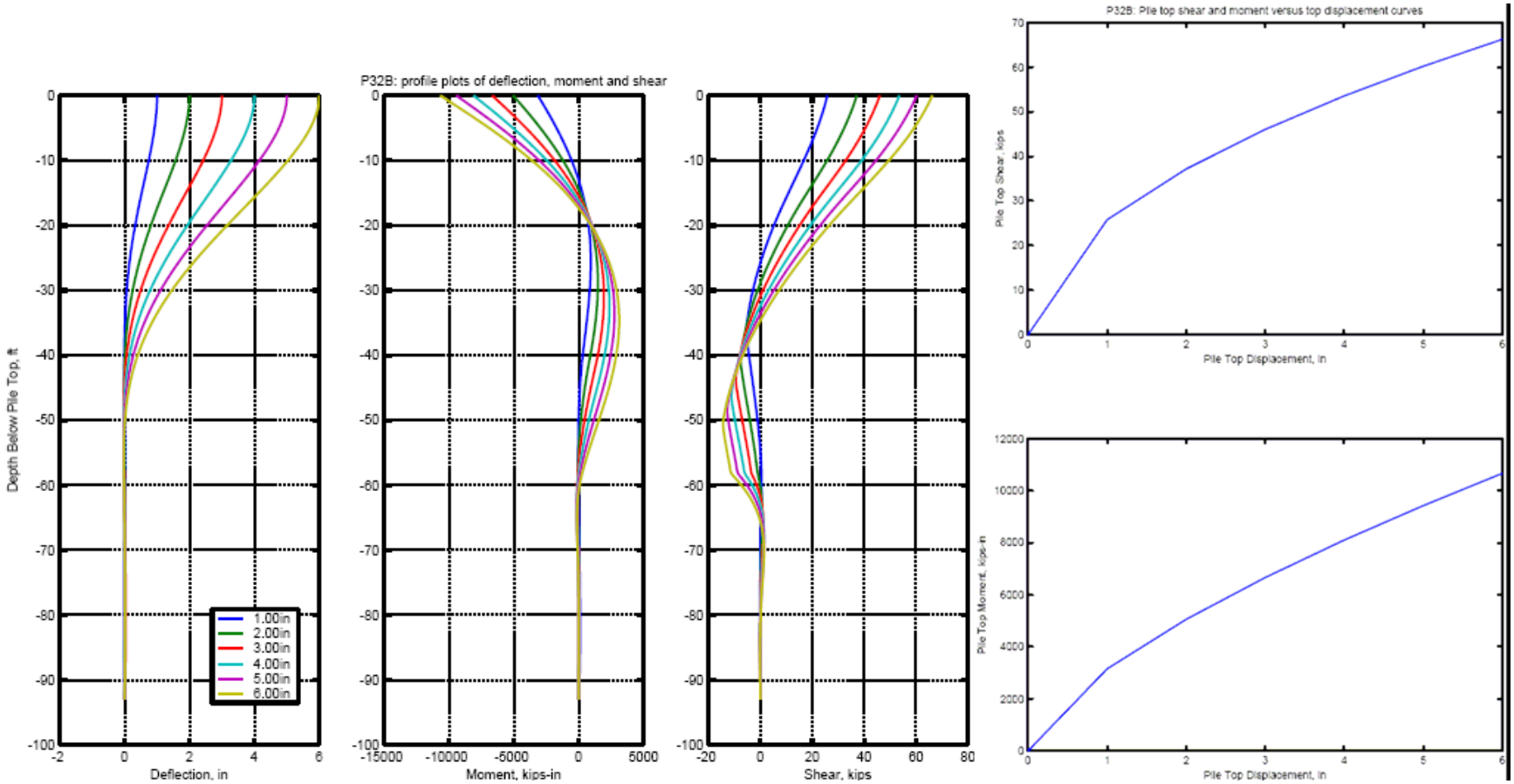


FIGURE E-33: PIER 33 – LATERAL PUSH-OVER CURVES

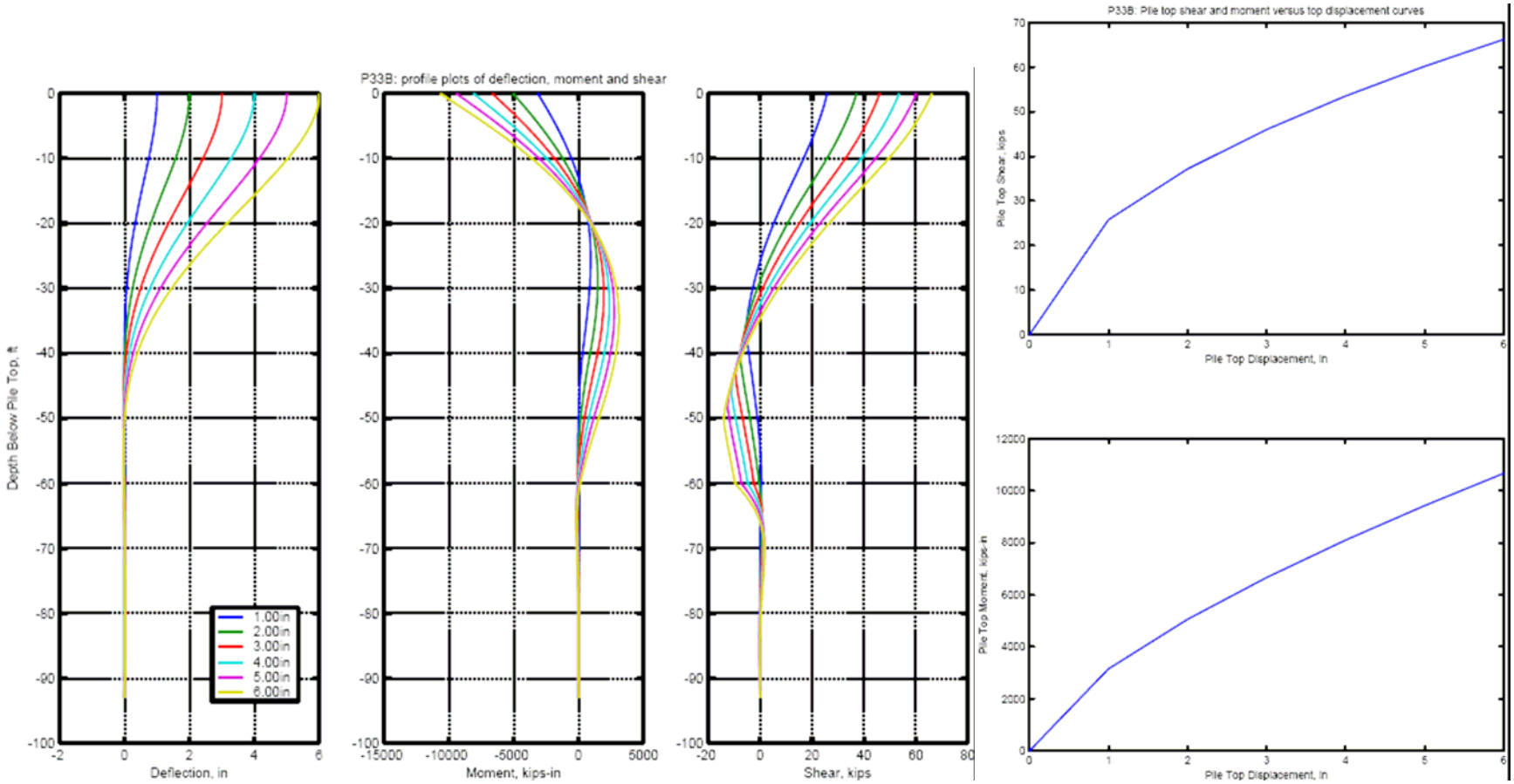


FIGURE E-34: PIER 34 – LATERAL PUSH-OVER CURVES

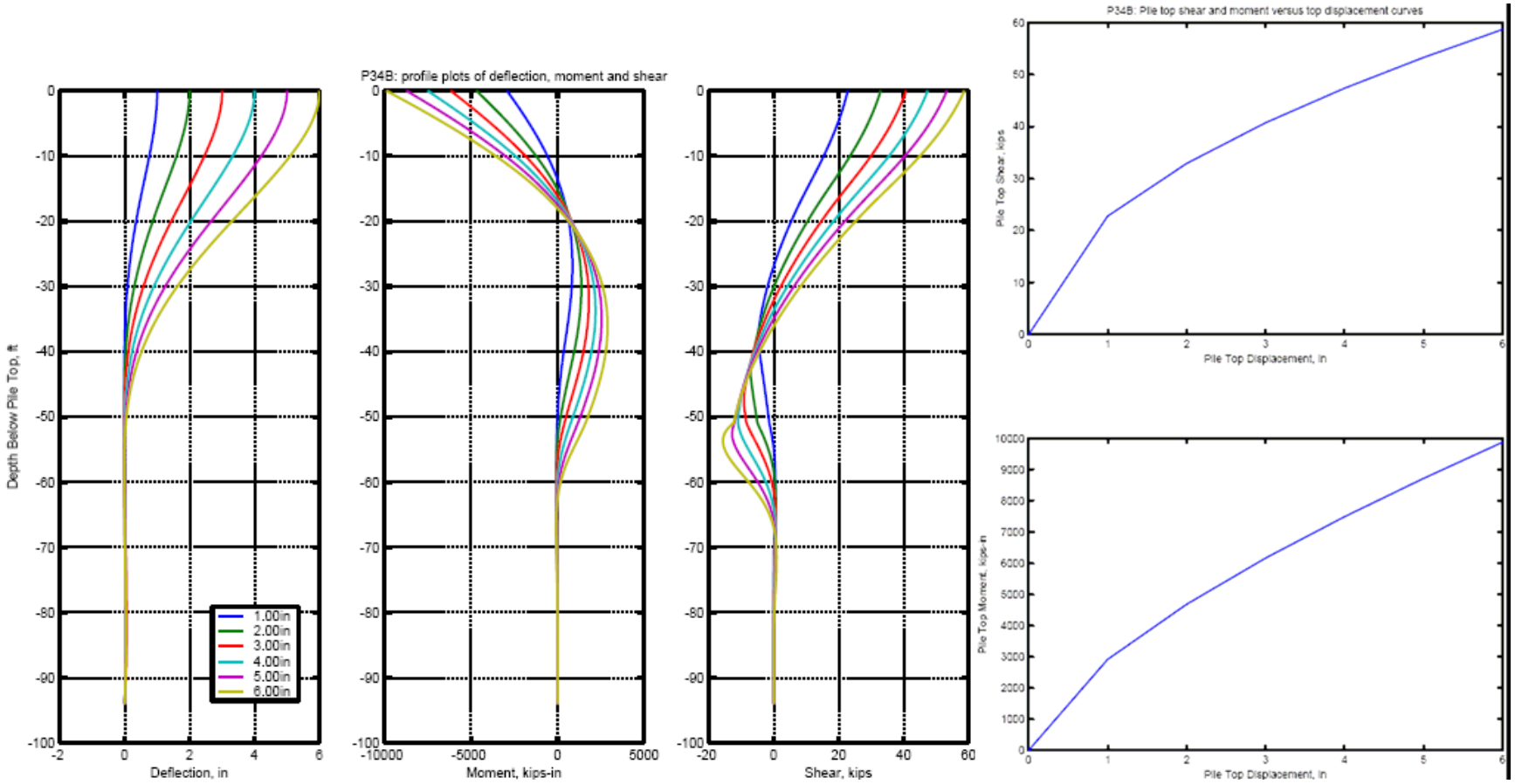


FIGURE E-35: PIER 35 – LATERAL PUSH-OVER CURVES

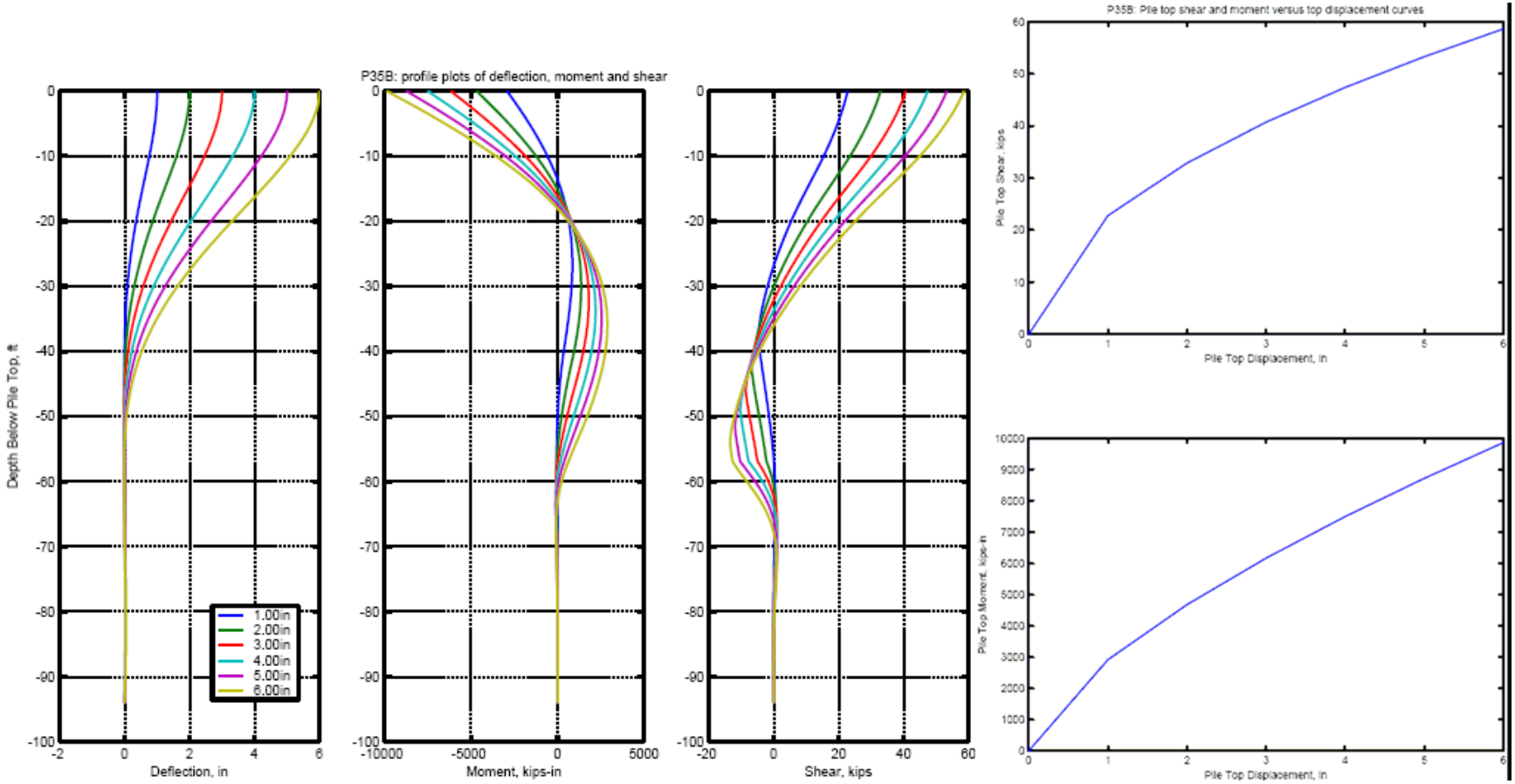


FIGURE E-36: PIER 36 – LATERAL PUSH-OVER CURVES

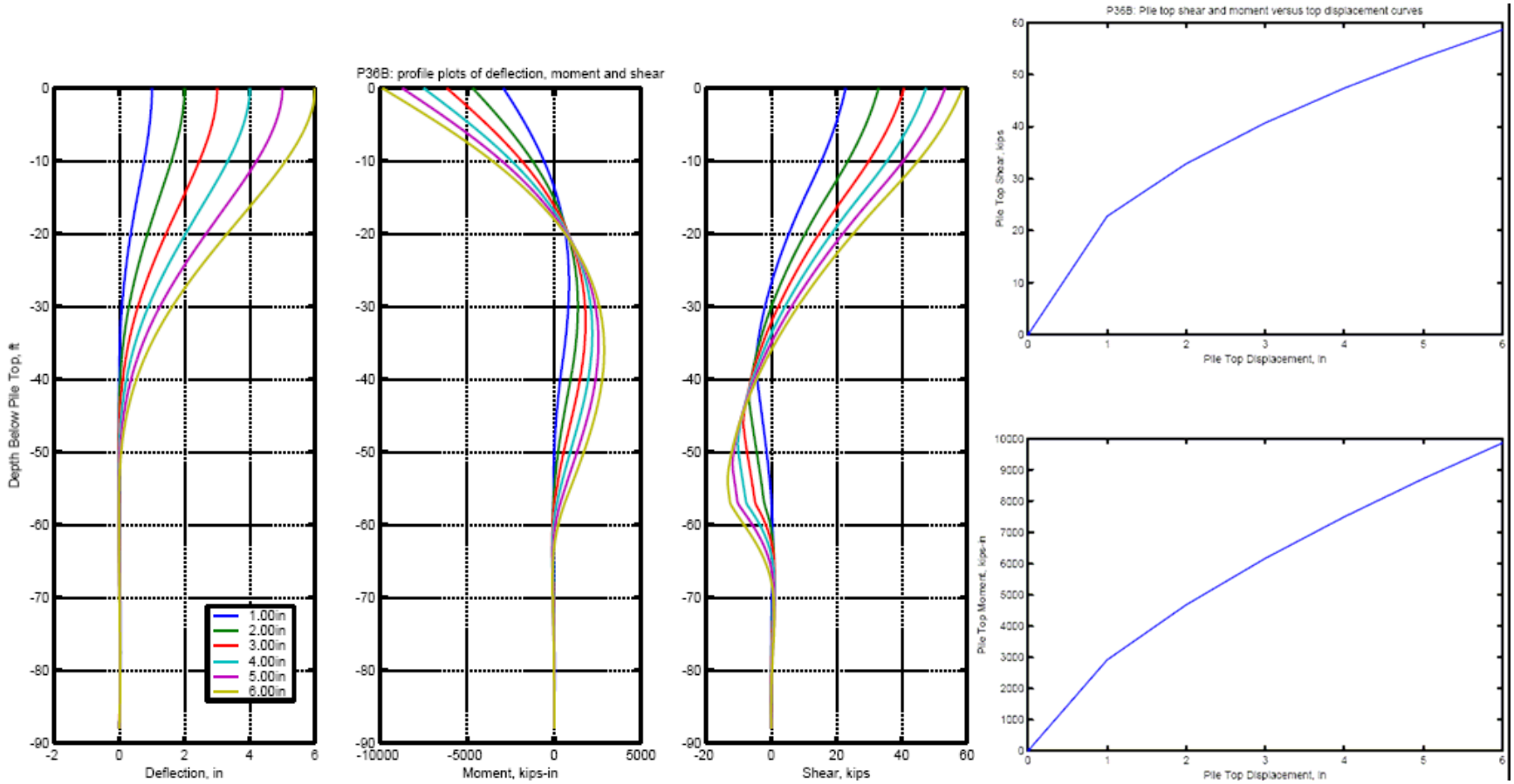


FIGURE E-37: PIER 37 – LATERAL PUSH-OVER CURVES

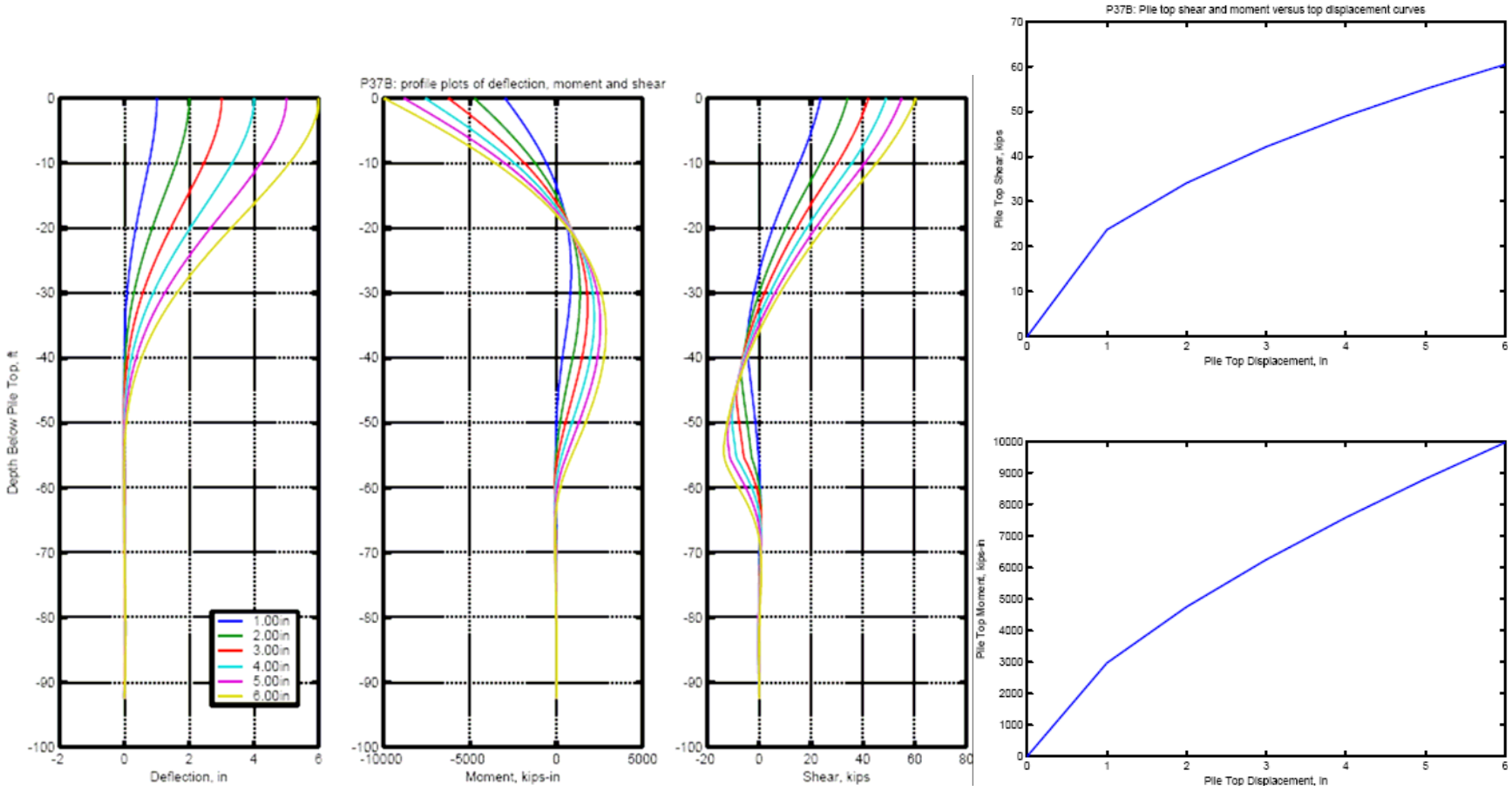


FIGURE E-38: PIER 38 – LATERAL PUSH-OVER CURVES

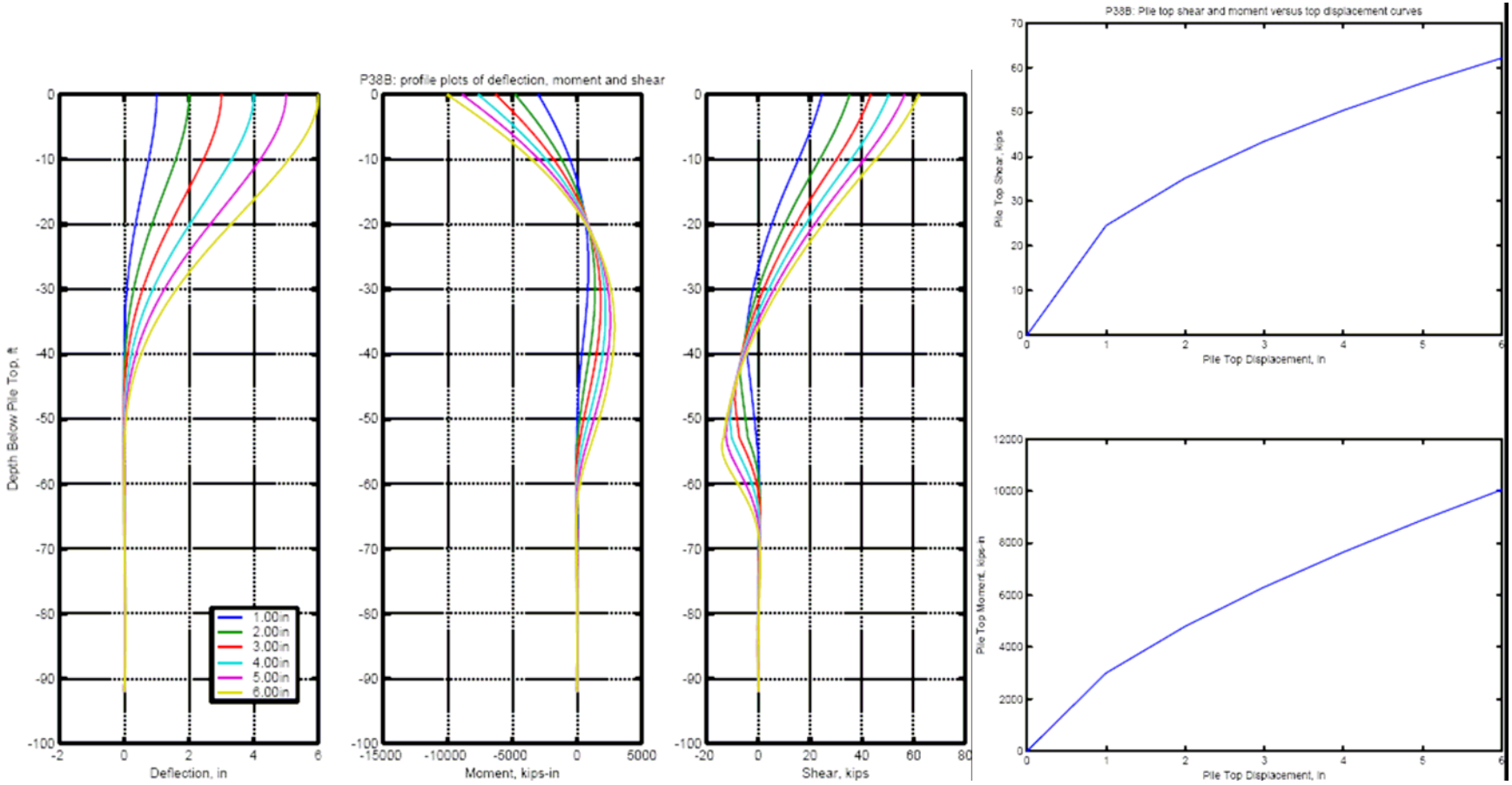


FIGURE E-39: PIER 39 – LATERAL PUSH-OVER CURVES

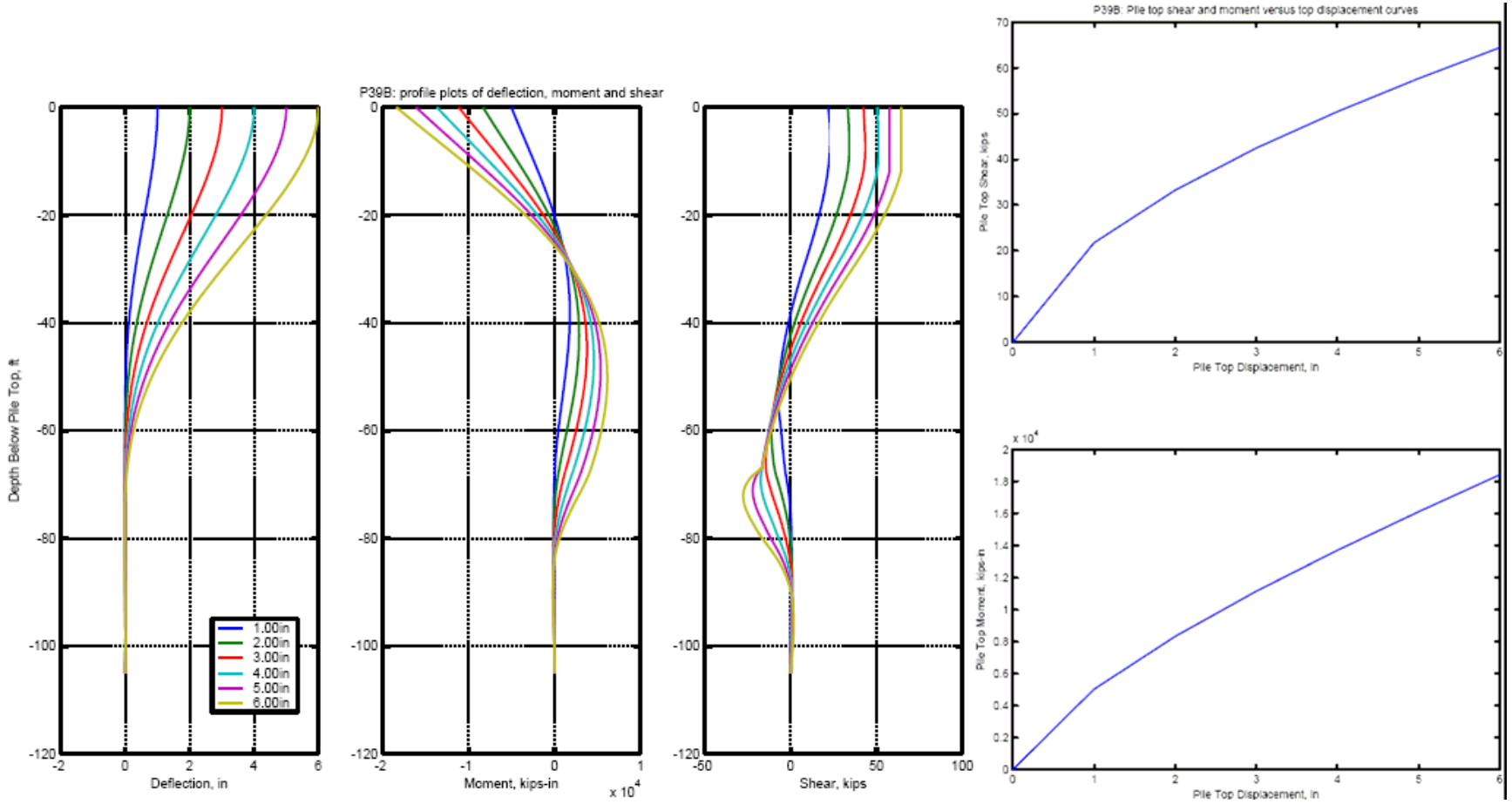


FIGURE E-40: PIER 40 – LATERAL PUSH-OVER CURVES

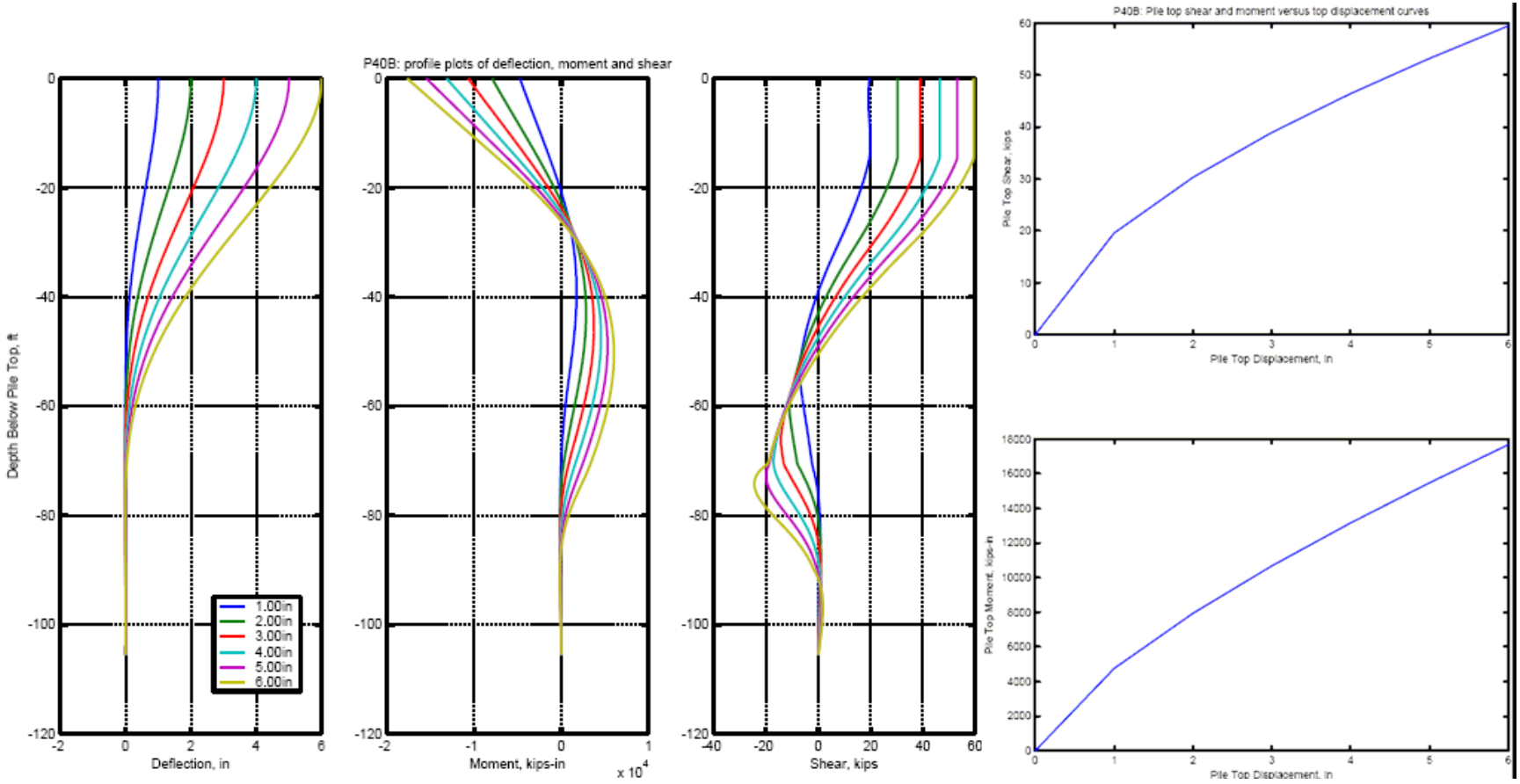


FIGURE E-41: PIER 41 – LATERAL PUSH-OVER CURVES

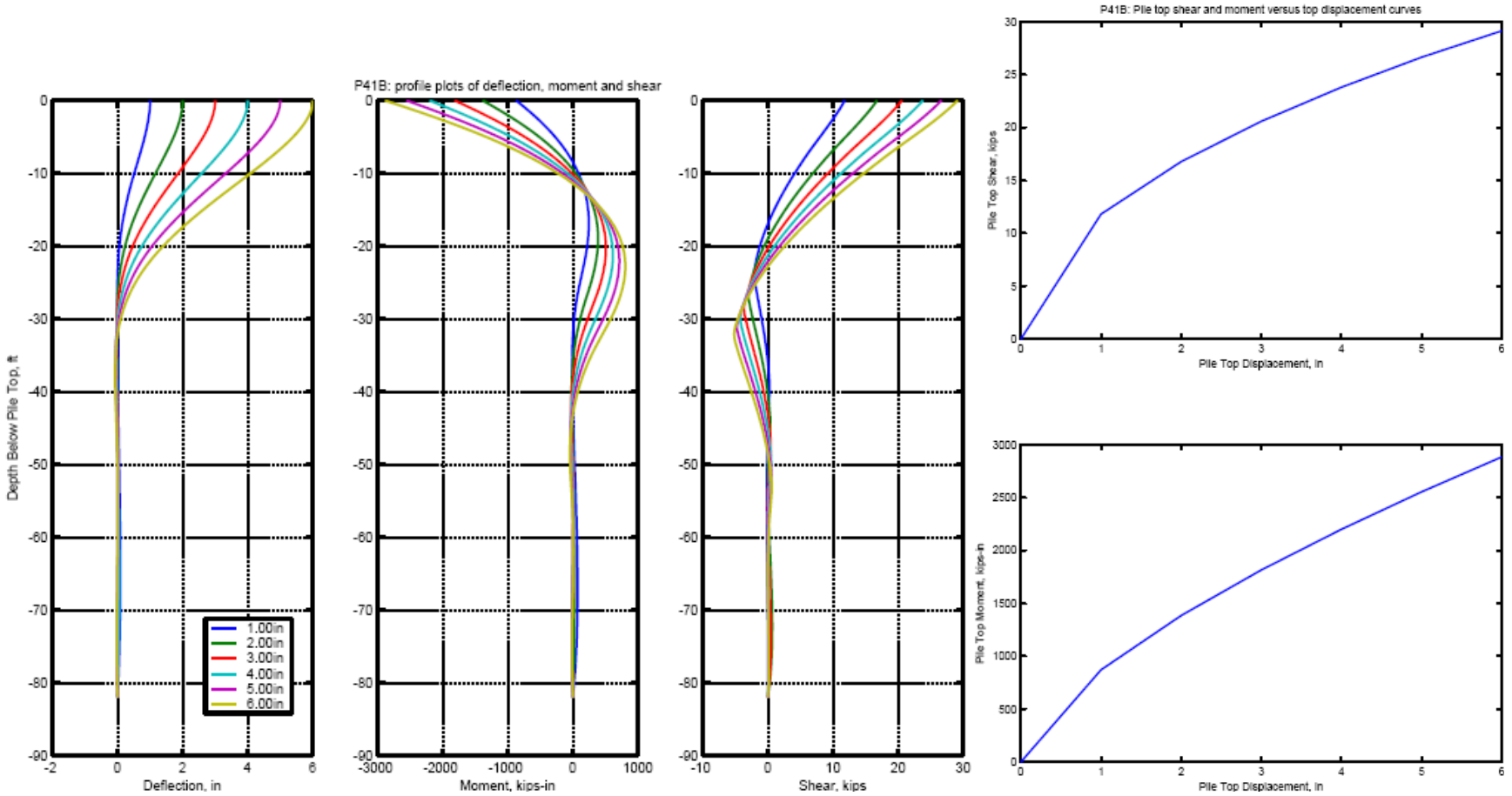


FIGURE E-42: PIERS 42~46 – LATERAL PUSH-OVER CURVES

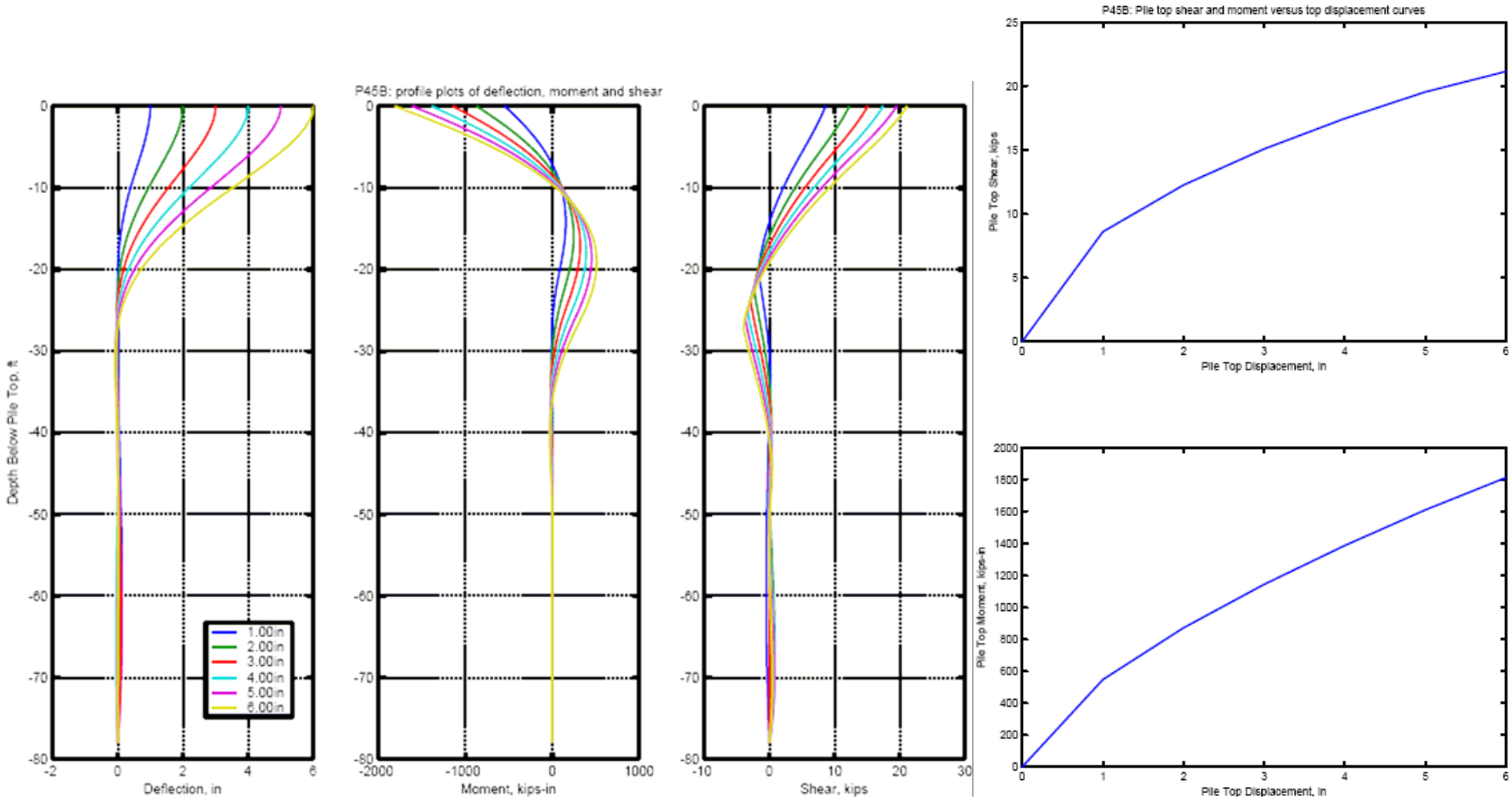


FIGURE E-43: PIERS 47~51 – LATERAL PUSH-OVER CURVES

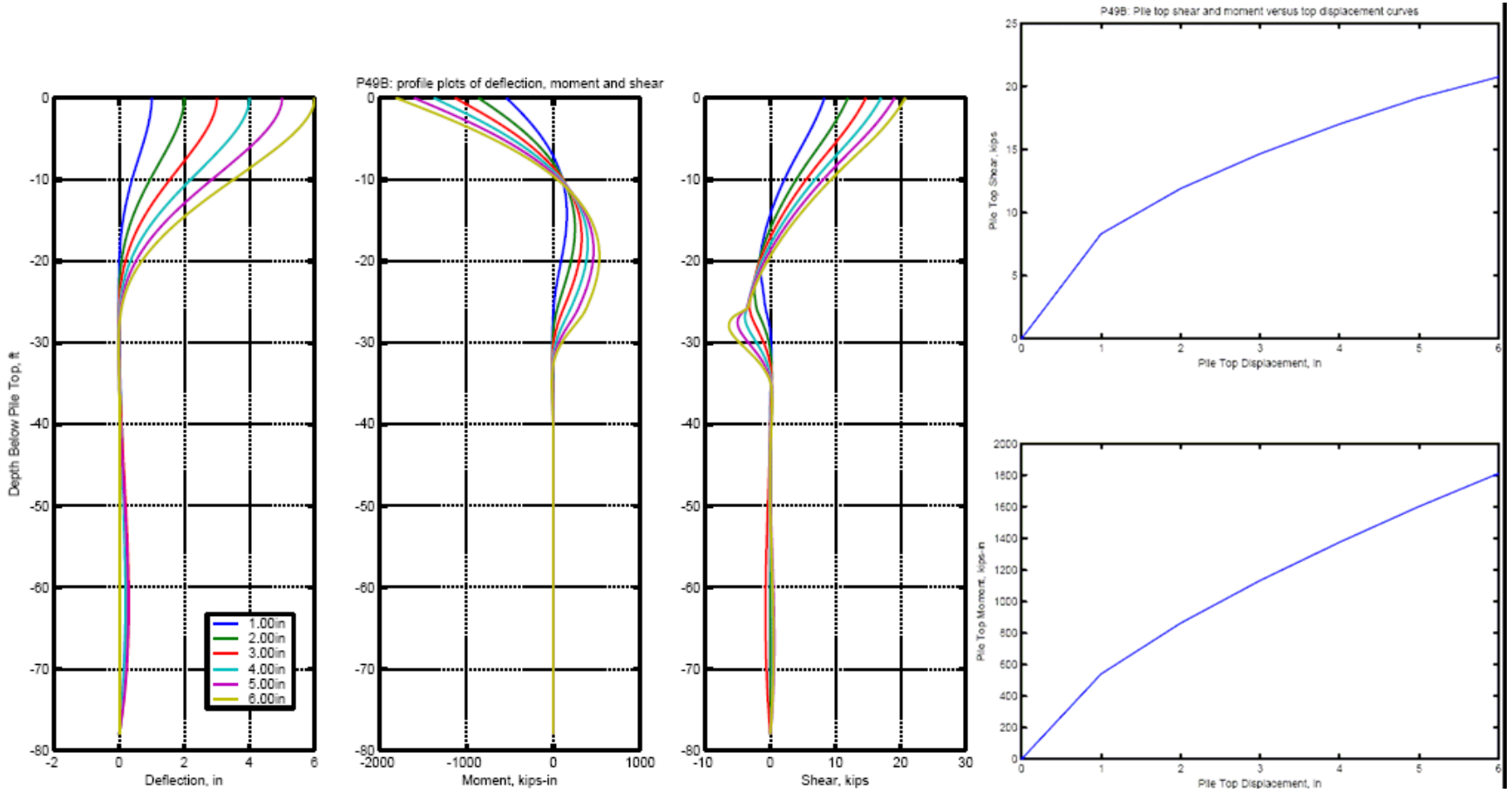


FIGURE E-44: PIERS 52 AND 53 – LATERAL PUSH-OVER CURVES

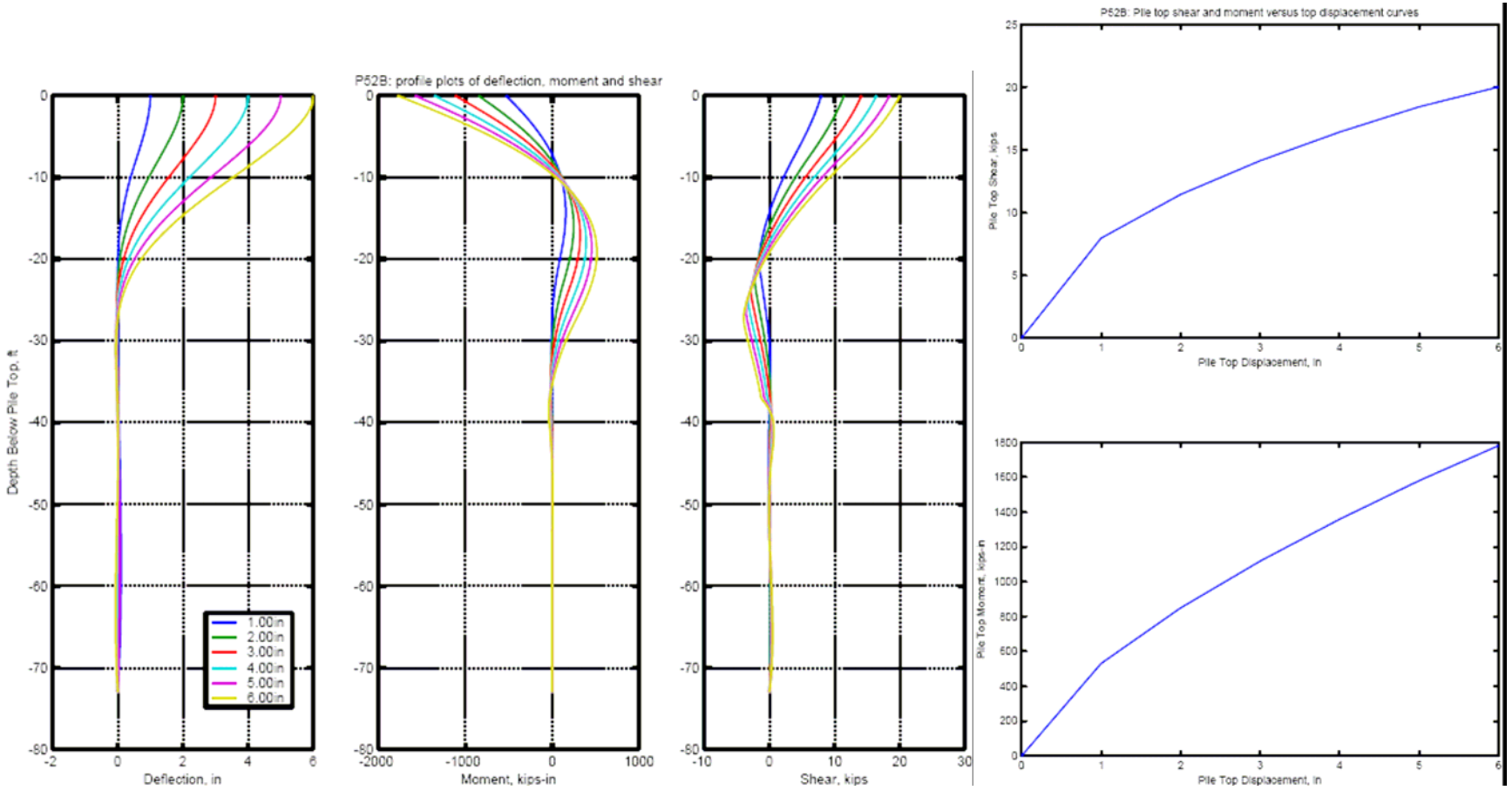


FIGURE E-45: PIERS 54~56 – LATERAL PUSH-OVER CURVES

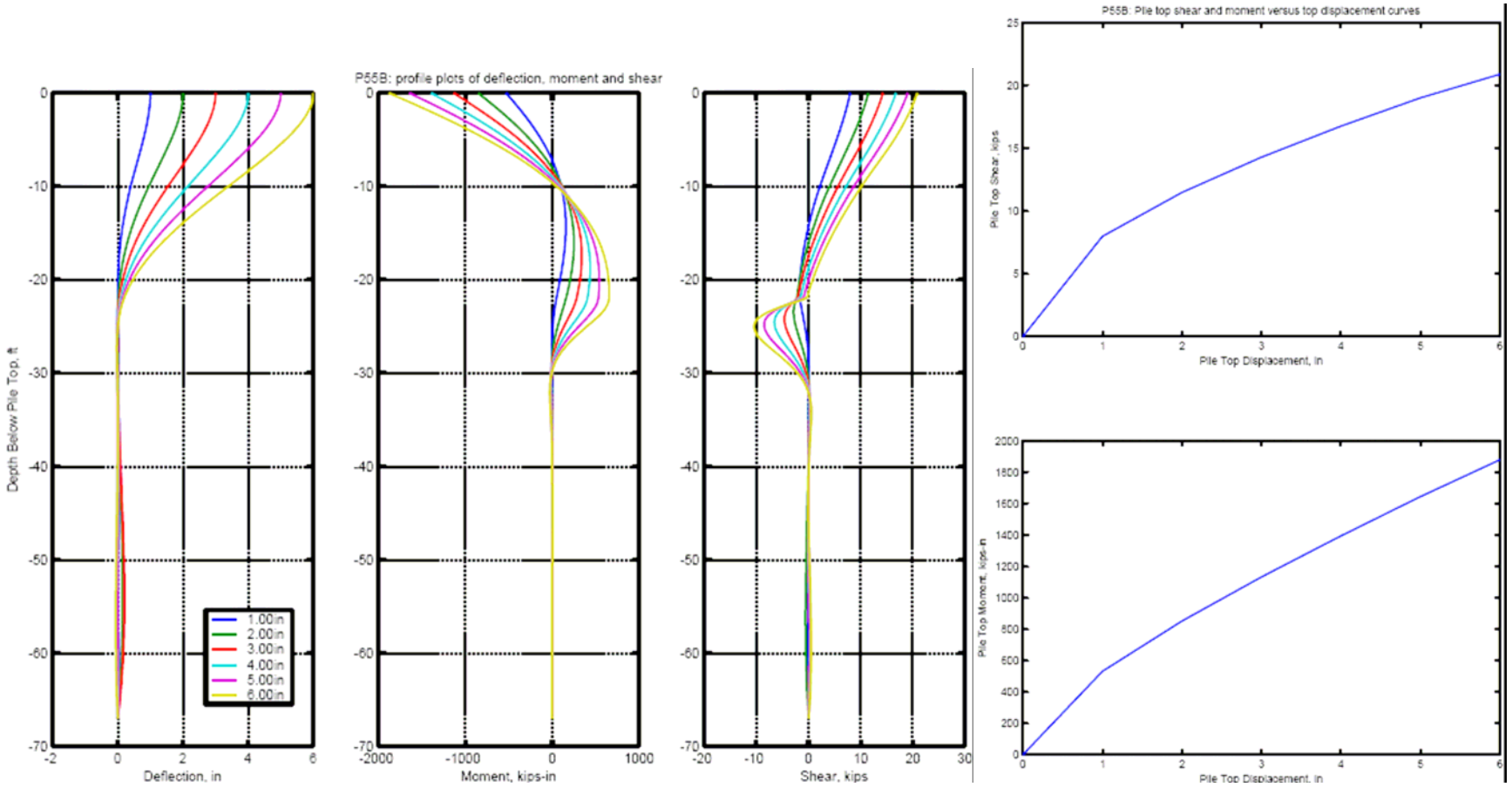


FIGURE E-46: PIERS 57 AND 58 – LATERAL PUSH-OVER CURVES

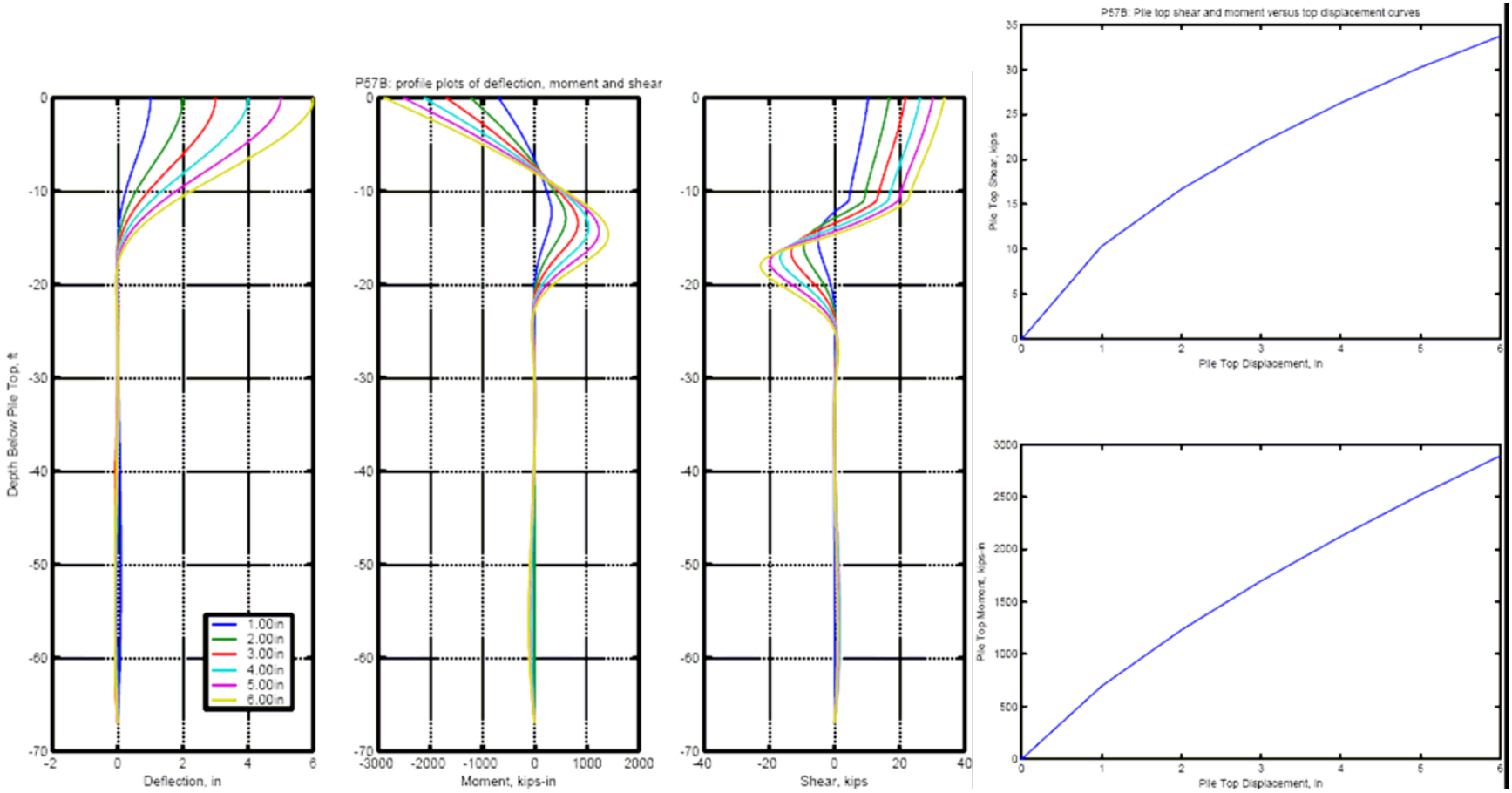


FIGURE E-47: PIERS 59~62 – LATERAL PUSH-OVER CURVES

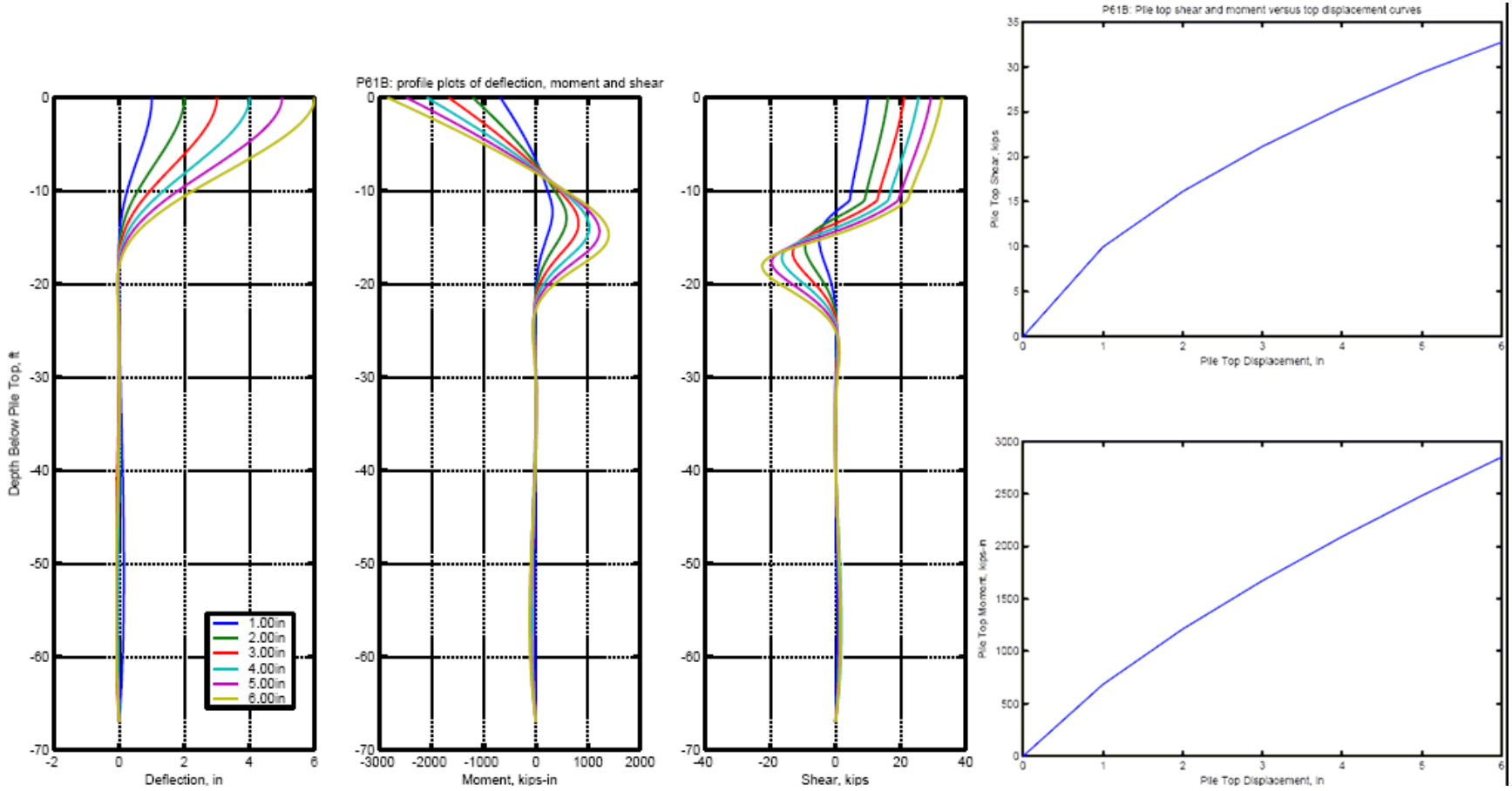


FIGURE E-48: PIERS 63~67 – LATERAL PUSH-OVER CURVES

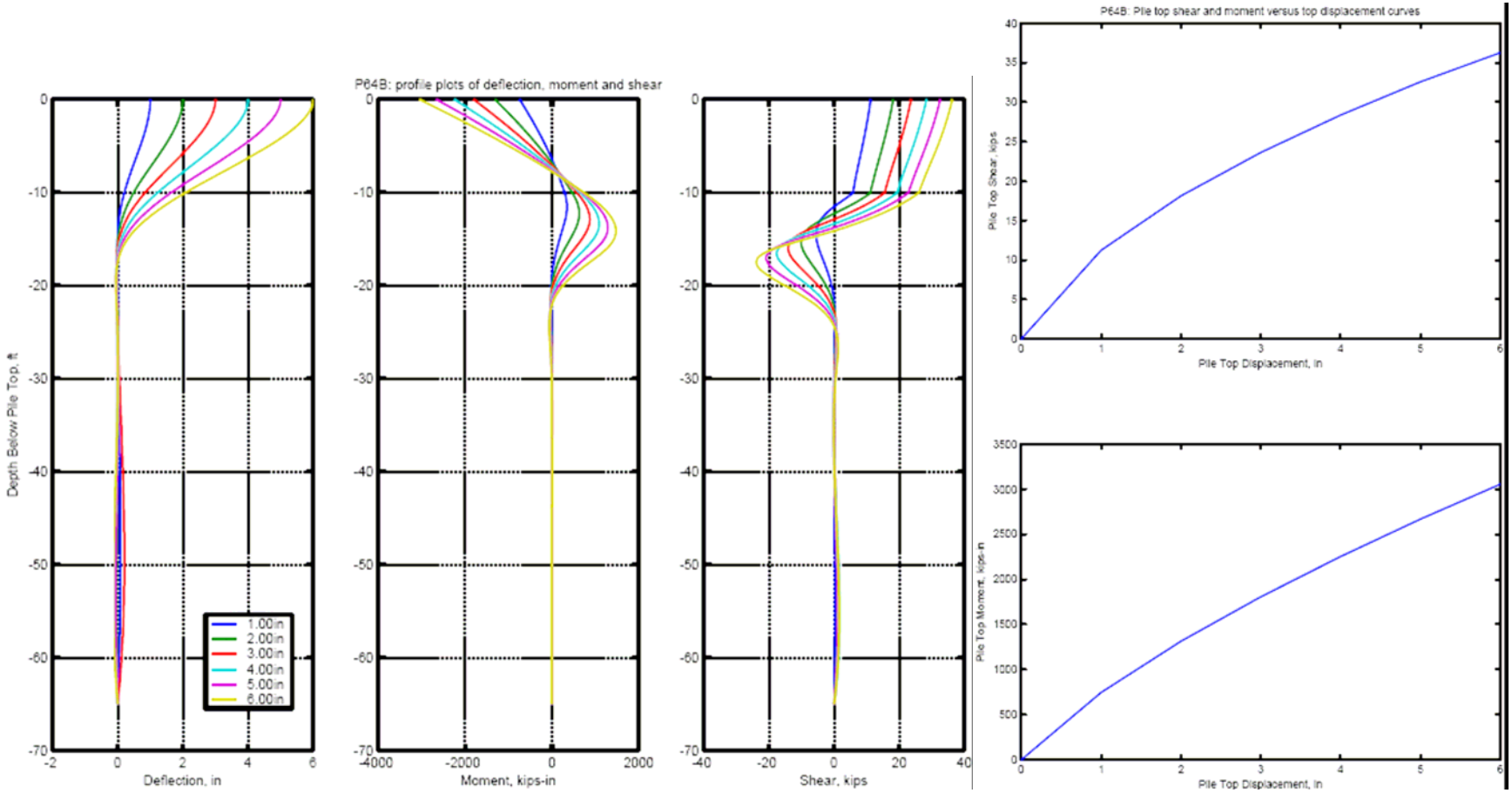


FIGURE E-49: PIERS 68~70 – LATERAL PUSH-OVER CURVES

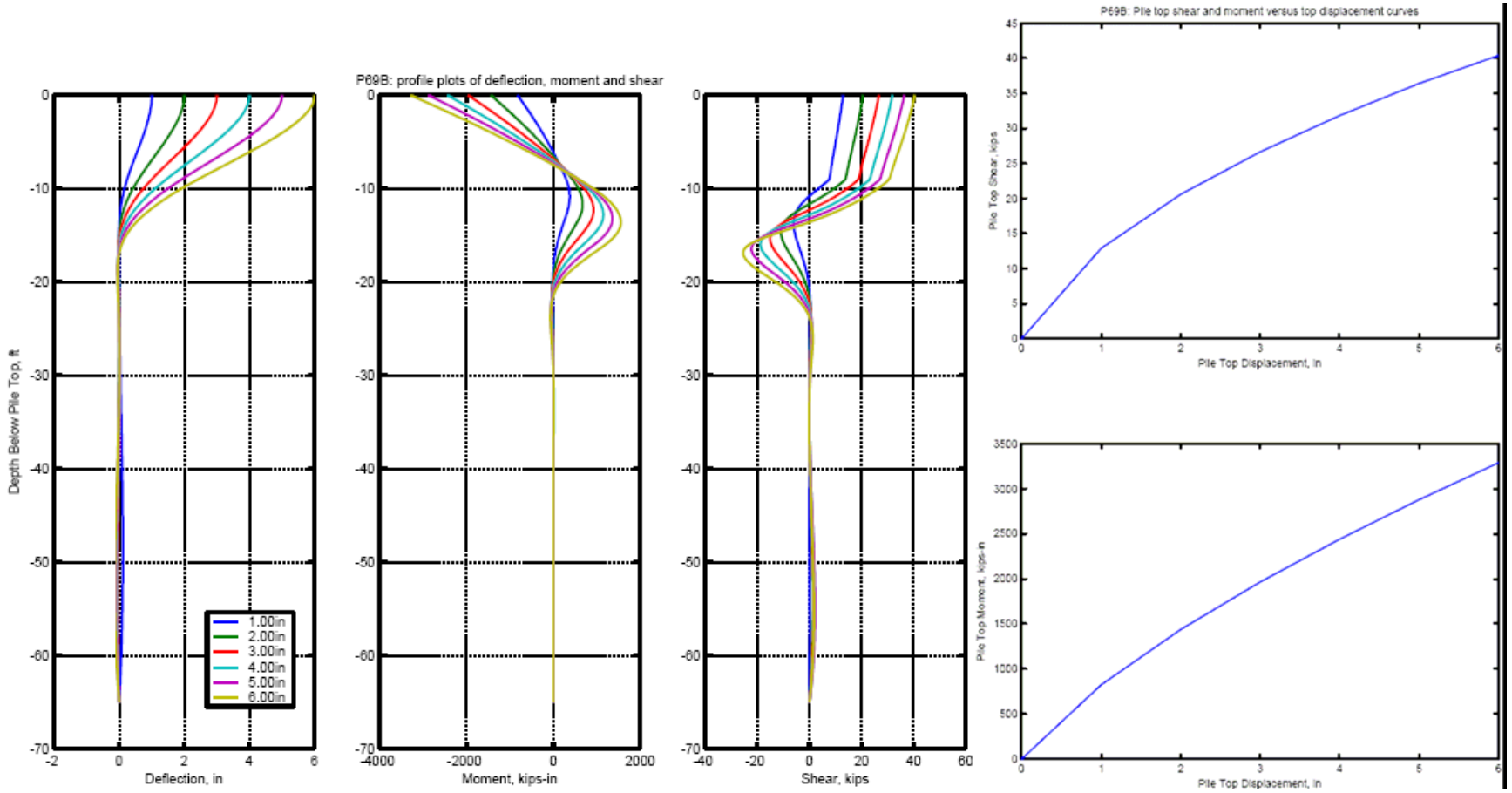
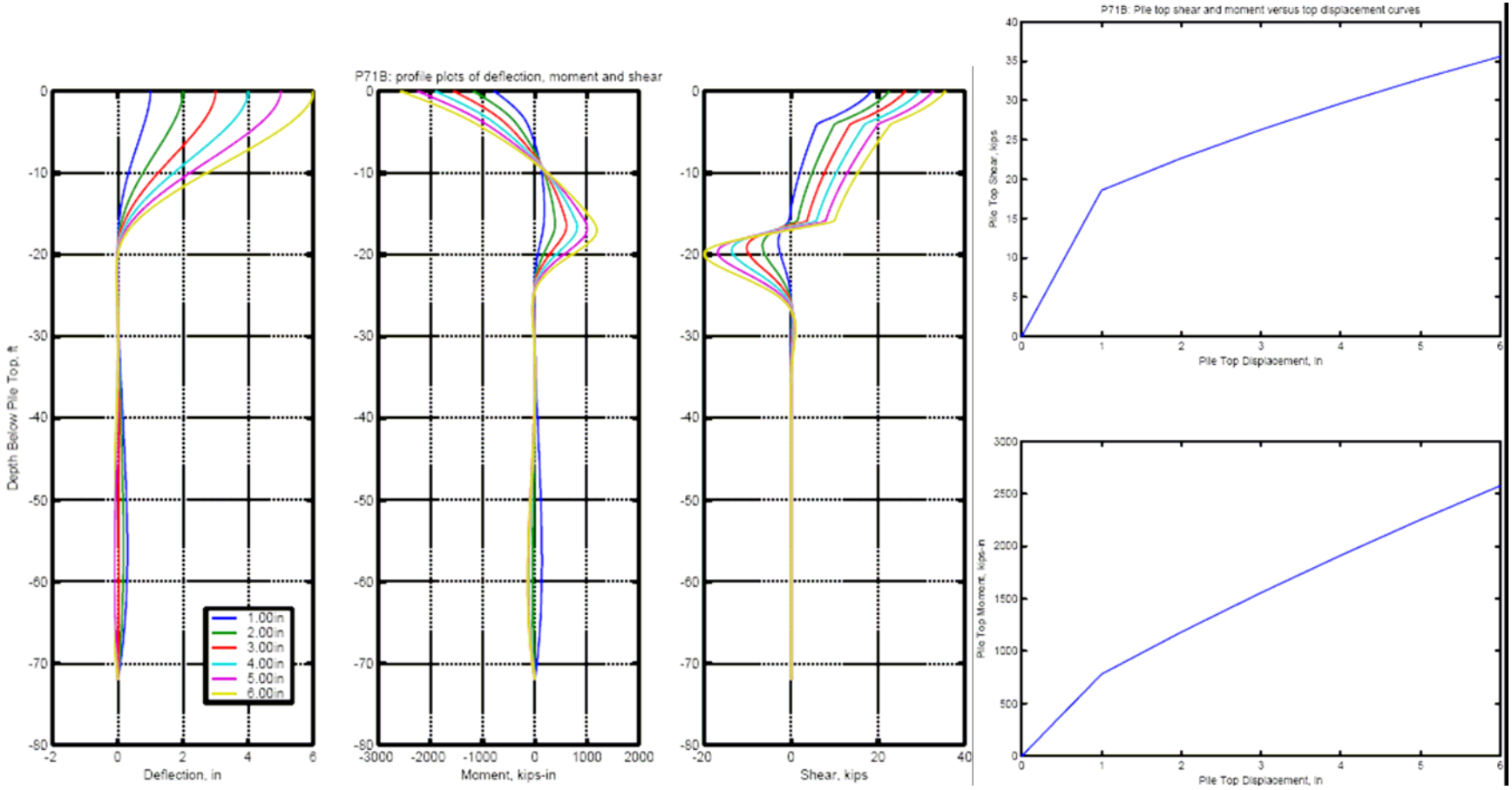


FIGURE E-50: ABUTMENT 71 – LATERAL PUSH-OVER CURVES



13.0 APPENDIX F: Q-δ CURVES AT LIQUEFIED STATE

FIGURE F-1: PIER 10 - Q-δ CURVES AT LIQUEFIED STATE

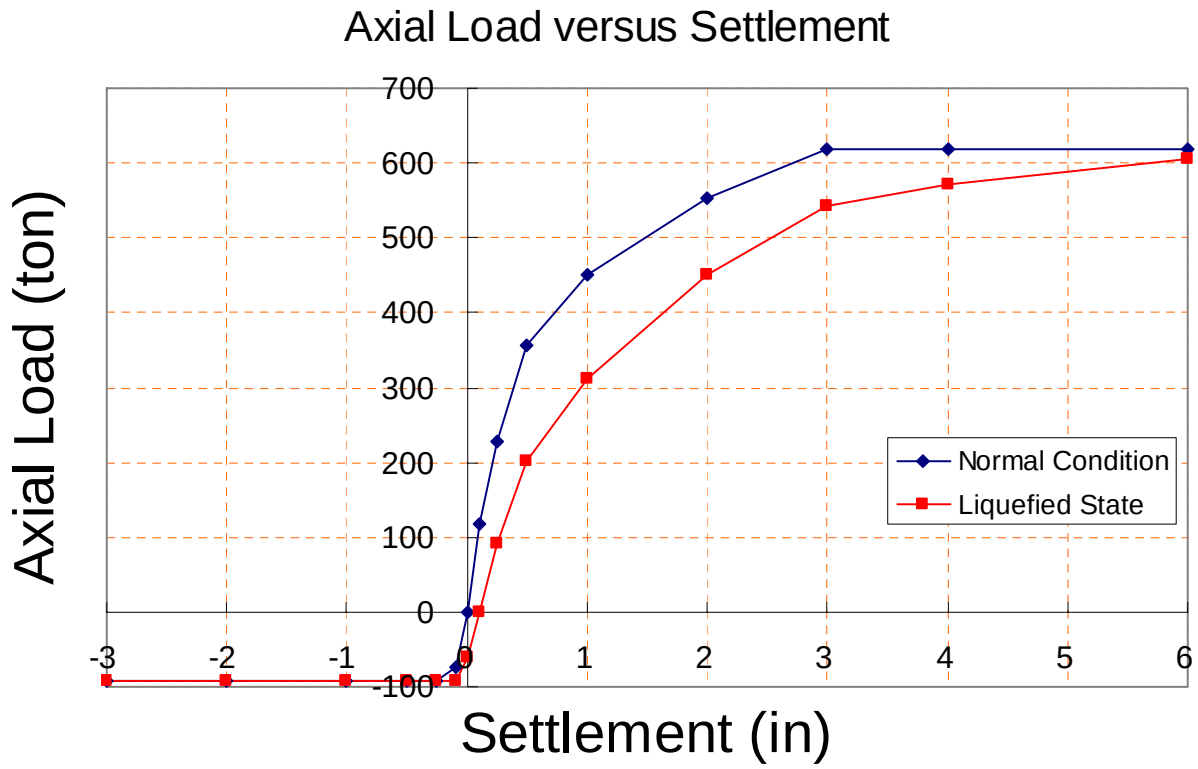


FIGURE F-2: PIER 11 - Q-δ CURVES AT LIQUEFIED STATE

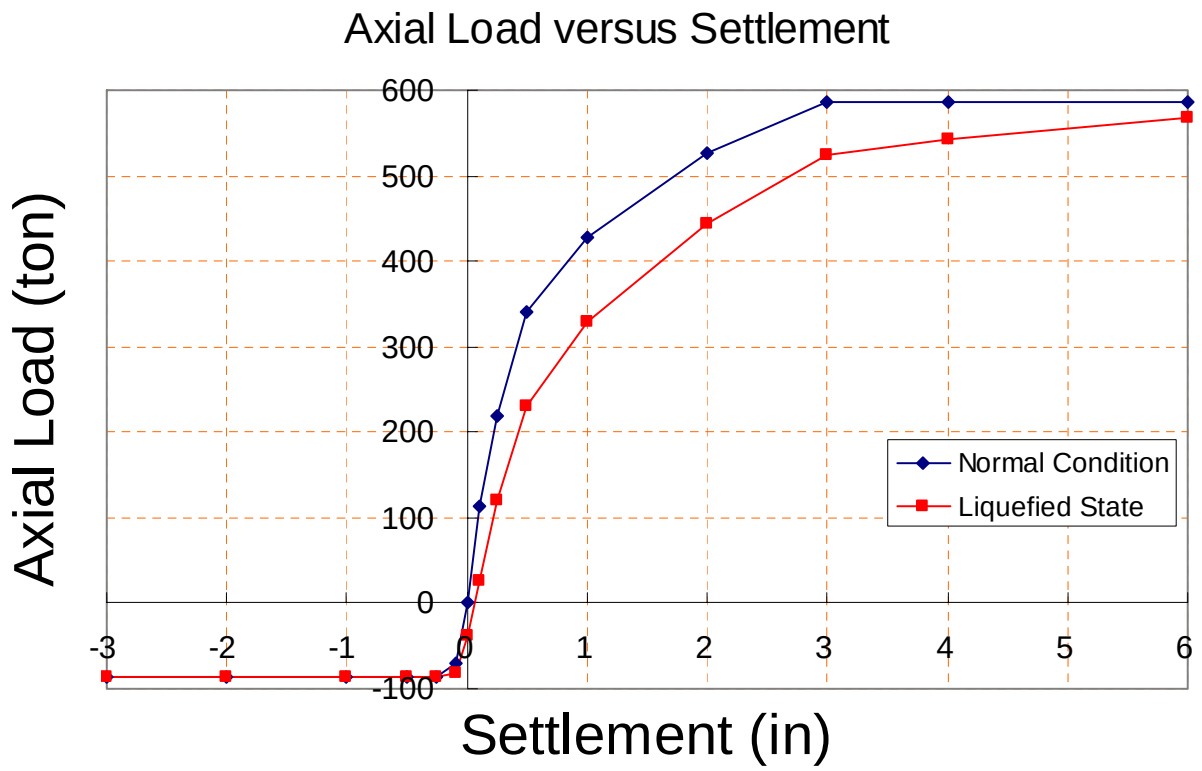


FIGURE F-3: PIER 17 - Q-δ CURVES AT LIQUEFIED STATE

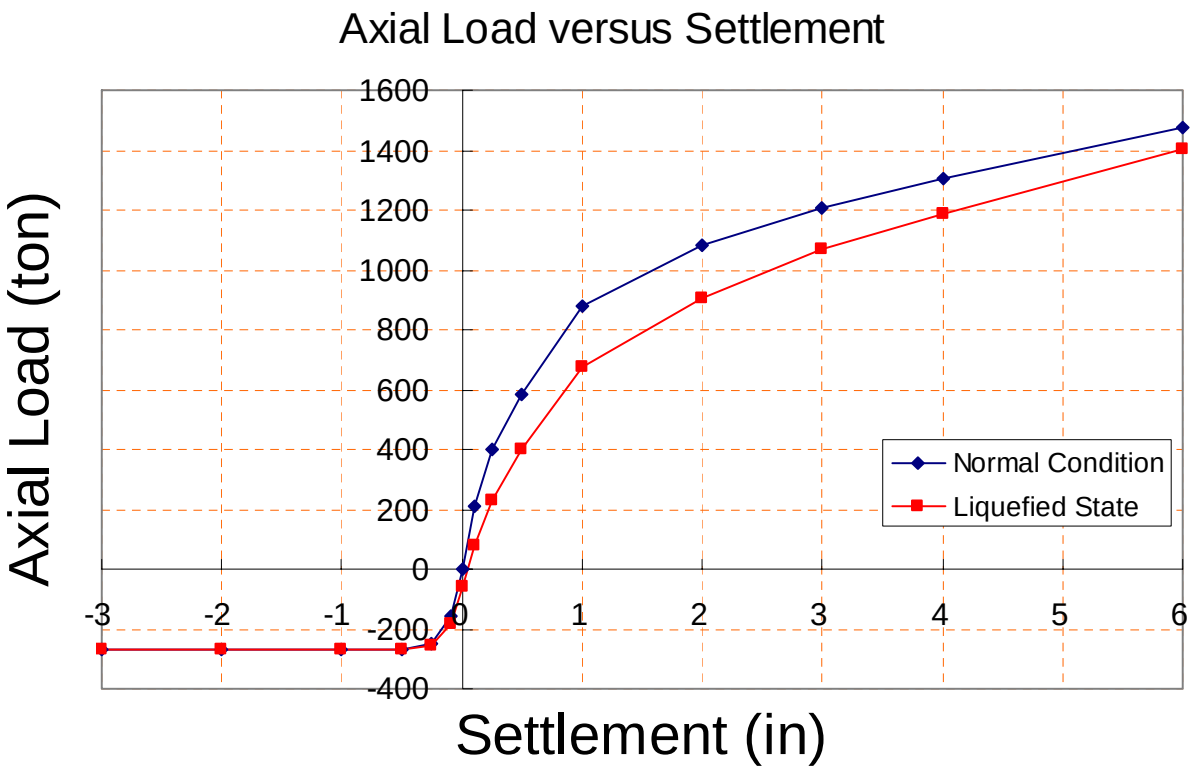


FIGURE F-4: PIER 18- *Q*-δ CURVES AT LIQUEFIED STATE

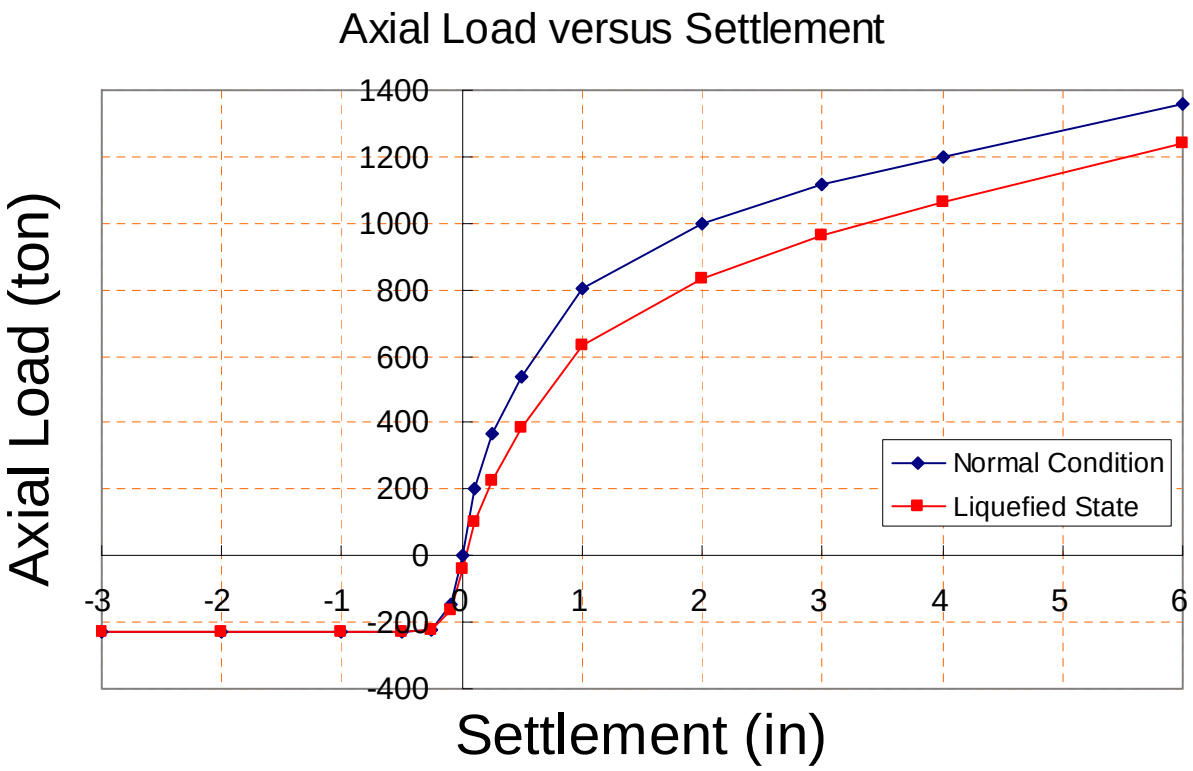


FIGURE F-5: PIER 19- *Q*-δ CURVES AT LIQUEFIED STATE

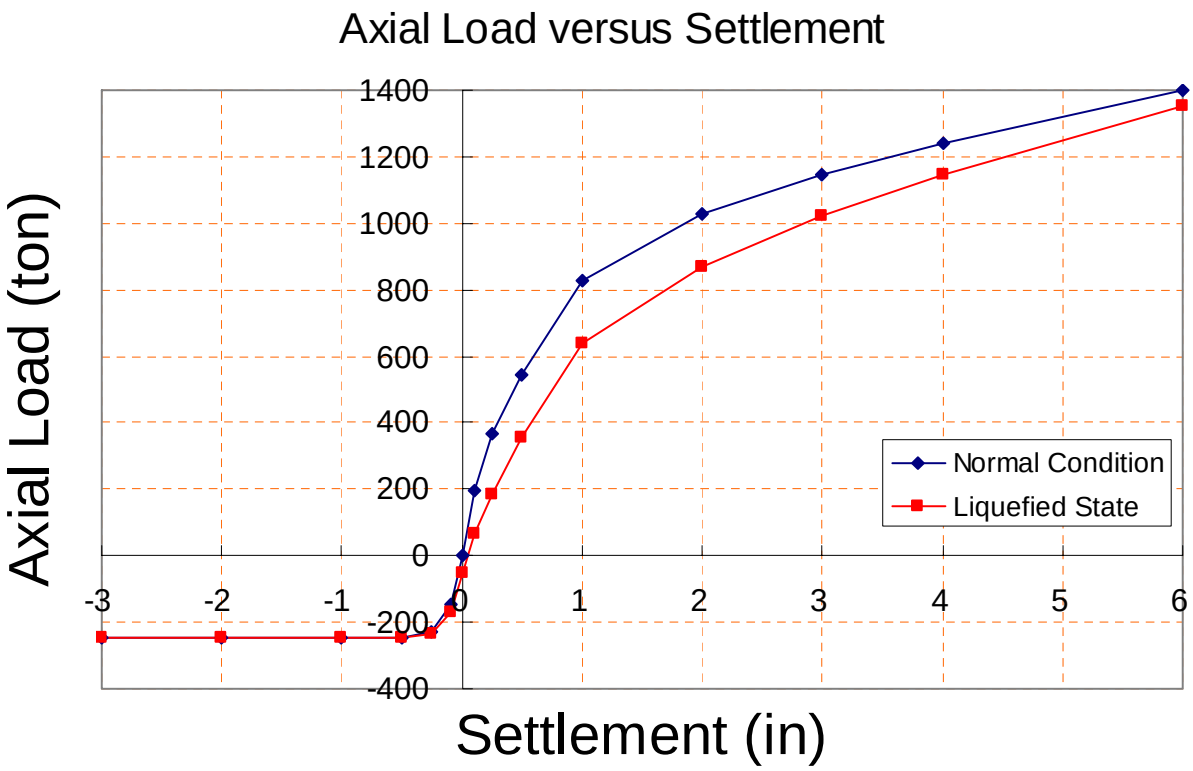


FIGURE F-6: PIER 64 - Q-δ CURVES AT LIQUEFIED STATE

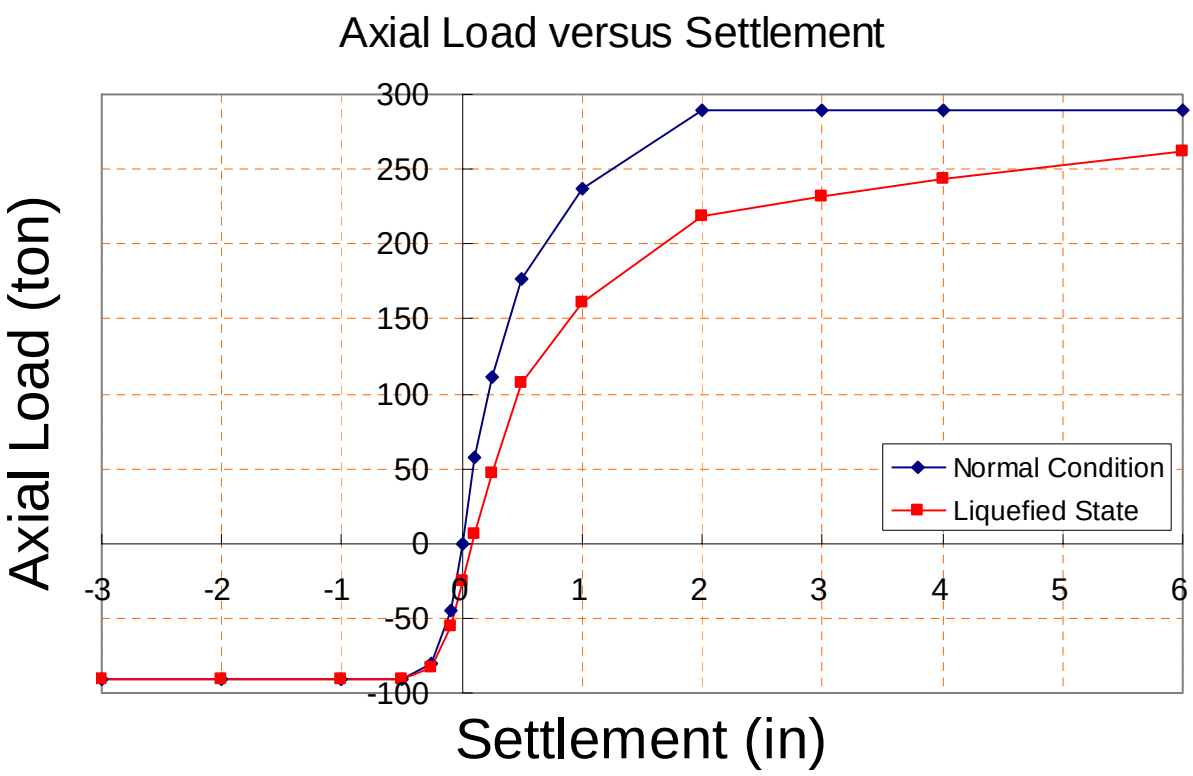
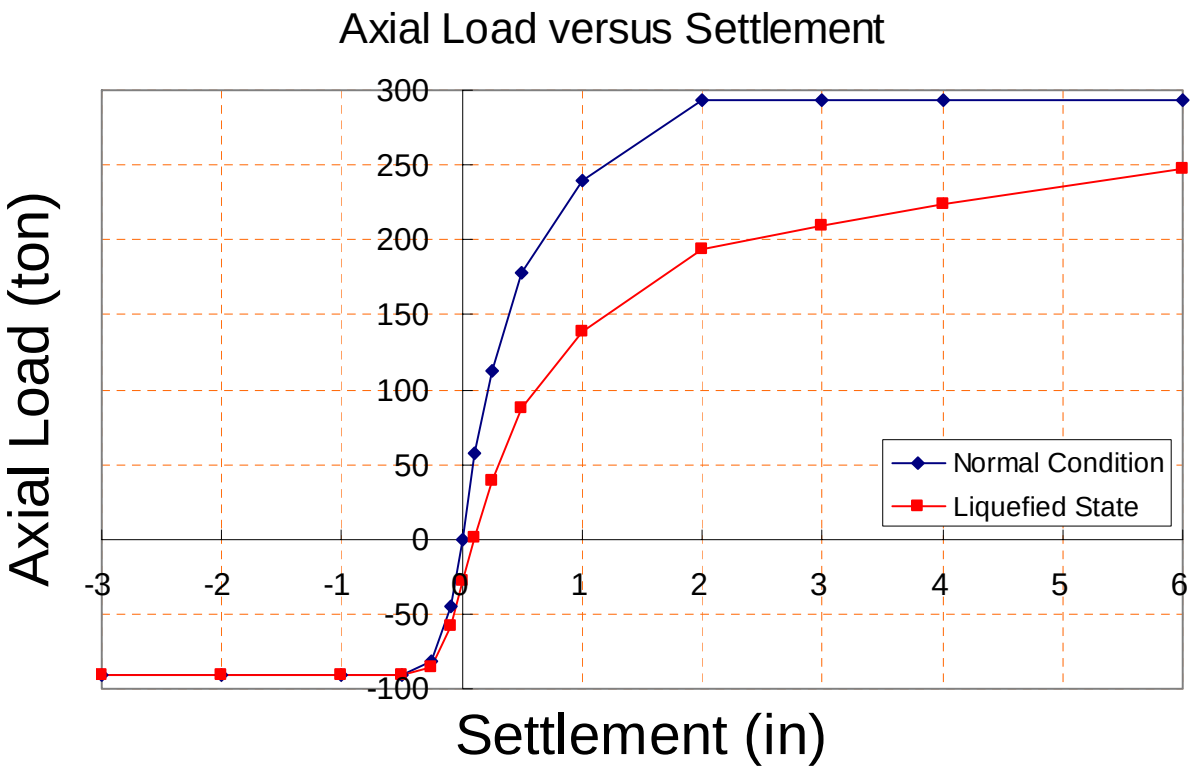


FIGURE F-7: PIER 69 - Q-δ CURVES AT LIQUEFIED STATE



14.0 APPENDIX G: 6×6 MATRICES

TABLE G-1: ABUTMENT 1 - PILE GROUP CONDENSED MATRICES AT PILE-CAP

Number of Piles = 11 Pile Cross-Section = 14x14 inch Footing Bottom El = +15'

6x6 Stiffness Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
8.1290E+05	0.0000E+00	-5.4540E+05	0.0000E+00	-1.2480E+07	0.0000E+00
0.0000E+00	6.3110E+05	0.0000E+00	2.8840E+07	0.0000E+00	6.0260E+06
-5.4540E+05	0.0000E+00	3.7750E+06	0.0000E+00	-9.8660E+06	0.0000E+00
0.0000E+00	2.8840E+07	0.0000E+00	1.0410E+11	0.0000E+00	1.6960E+10
-1.2480E+07	0.0000E+00	-9.8660E+06	0.0000E+00	6.0340E+09	0.0000E+00
0.0000E+00	6.0260E+06	0.0000E+00	1.6960E+10	0.0000E+00	2.3570E+10

6x6 Mass Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
3.5570E+01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	2.4740E+01	0.0000E+00	0.0000E+00	0.0000E+00	5.8580E+01
0.0000E+00	0.0000E+00	2.1320E+02	0.0000E+00	-2.5250E+02	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	5.7510E+06	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	-2.5250E+02	0.0000E+00	1.9190E+05	0.0000E+00
0.0000E+00	5.8580E+01	0.0000E+00	0.0000E+00	0.0000E+00	1.0220E+06

6x6 Damping Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
5.7551E+03	0.0000E+00	-3.8579E+03	0.0000E+00	-8.8279E+04	0.0000E+00
0.0000E+00	4.4676E+03	0.0000E+00	2.0400E+05	0.0000E+00	4.2634E+04
-3.8579E+03	0.0000E+00	2.6733E+04	0.0000E+00	-6.9823E+04	0.0000E+00
0.0000E+00	2.0400E+05	0.0000E+00	7.3716E+08	0.0000E+00	1.1997E+08
-8.8279E+04	0.0000E+00	-6.9823E+04	0.0000E+00	4.2709E+07	0.0000E+00
0.0000E+00	4.2634E+04	0.0000E+00	1.1997E+08	0.0000E+00	1.6687E+08

Note: units = lb,in,sec; stiffness (translation=lb/in, rotation=lb-in/rad); mass (translation=lb-sec^2/in, rotation=lb-in-sec^2/rad); damping (translation=lb-sec/in, rotation=lb-in-sec/rad).

TABLE G-2: PIER 2 - PILE GROUP CONDENSED MATRICES AT PILE-CAP

Number of Piles = 12 Pile Cross-Section = 24x24 inch Footing Bottom El = +0.5'

6x6 Stiffness Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
1.8500E+06	0.0000E+00	0.0000E+00	0.0000E+00	1.4660E+07	0.0000E+00
0.0000E+00	1.7470E+06	0.0000E+00	-4.8360E+07	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	7.1890E+06	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-4.8360E+07	0.0000E+00	1.7180E+11	0.0000E+00	0.0000E+00
1.4660E+07	0.0000E+00	0.0000E+00	0.0000E+00	7.1200E+10	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	5.7220E+10

6x6 Mass Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
1.6970E+02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	1.6010E+02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	6.6850E+02	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	1.4380E+07	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	5.1180E+06	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	4.7130E+06

6x6 Damping Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
1.3110E+04	0.0000E+00	0.0000E+00	0.0000E+00	1.0370E+05	0.0000E+00
0.0000E+00	1.2380E+04	0.0000E+00	-3.4208E+05	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	5.0945E+04	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-3.4208E+05	0.0000E+00	1.2173E+09	0.0000E+00	0.0000E+00
1.0370E+05	0.0000E+00	0.0000E+00	0.0000E+00	5.0435E+08	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	4.0541E+08

Note: units = lb,in,sec; stiffness (translation=lb/in, rotation=lb-in/rad); mass (translation=lb-sec^2/in, rotation=lb-in-sec^2/rad); damping (translation=lb-sec/in, rotation=lb-in-sec/rad).

TABLE G-3: PIER 3 - PILE GROUP CONDENSED MATRICES AT PILE-CAP

Number of Piles = 12 Pile Cross-Section = 24x24 inch Footing Bottom El = -1.0'

6x6 Stiffness Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
7.8050E+05	0.0000E+00	0.0000E+00	0.0000E+00	8.9120E+07	0.0000E+00
0.0000E+00	6.6030E+05	0.0000E+00	-1.2850E+08	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	7.0330E+06	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-1.2850E+08	0.0000E+00	1.6160E+11	0.0000E+00	0.0000E+00
8.9120E+07	0.0000E+00	0.0000E+00	0.0000E+00	6.4000E+10	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	1.9090E+10

6x6 Mass Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
2.2740E+02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	2.1790E+02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	7.2090E+02	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	1.5520E+07	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	5.5250E+06	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	6.4280E+06

6x6 Damping Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
5.5527E+03	0.0000E+00	0.0000E+00	0.0000E+00	6.3040E+05	0.0000E+00
0.0000E+00	4.7011E+03	0.0000E+00	-9.0896E+05	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	4.9849E+04	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-9.0896E+05	0.0000E+00	1.1453E+09	0.0000E+00	0.0000E+00
6.3040E+05	0.0000E+00	0.0000E+00	0.0000E+00	4.5348E+08	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	1.3593E+08

Note: units = lb,in,sec; stiffness (translation=lb/in, rotation=lb-in/rad); mass (translation=lb-sec^2/in, rotation=lb-in-sec^2/rad); damping (translation=lb-sec/in, rotation=lb-in-sec/rad).

TABLE G-4: PIER 4 - PILE GROUP CONDENSED MATRICES AT PILE-CAP

Number of Piles = 20 Pile Cross-Section = 24x24 inch Footing Bottom El = -2'

6x6 Stiffness Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
1.8350E+06	0.0000E+00	0.0000E+00	0.0000E+00	7.3980E+07	0.0000E+00
0.0000E+00	1.9580E+06	0.0000E+00	-1.9850E+08	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	1.2800E+07	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-1.9850E+08	0.0000E+00	3.2530E+11	0.0000E+00	0.0000E+00
7.3980E+07	0.0000E+00	0.0000E+00	0.0000E+00	2.0180E+11	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	7.2100E+10

6x6 Mass Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
2.6830E+02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	2.7970E+02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	1.2950E+03	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	3.0130E+07	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	1.7930E+07	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	9.9140E+06

6x6 Damping Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
1.3018E+04	0.0000E+00	0.0000E+00	0.0000E+00	5.2330E+05	0.0000E+00
0.0000E+00	1.3889E+04	0.0000E+00	-1.4041E+06	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	9.0723E+04	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-1.4041E+06	0.0000E+00	2.3052E+09	0.0000E+00	0.0000E+00
5.2330E+05	0.0000E+00	0.0000E+00	0.0000E+00	1.4300E+09	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	5.1139E+08

Note: units = lb,in,sec; stiffness (translation=lb/in, rotation=lb-in/rad); mass (translation=lb-sec^2/in, rotation=lb-in-sec^2/rad); damping (translation=lb-sec/in, rotation=lb-in-sec/rad).

TABLE G-5: PIER 5 - PILE GROUP CONDENSED MATRICES AT PILE-CAP

Number of Piles = 15 Pile Cross-Section = 24x24 inch Footing Bottom El = -2'

6x6 Stiffness Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
1.2550E+06	0.0000E+00	0.0000E+00	0.0000E+00	9.8640E+07	0.0000E+00
0.0000E+00	1.0090E+06	0.0000E+00	-1.1510E+08	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	9.2380E+06	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-1.1510E+08	0.0000E+00	2.2870E+11	0.0000E+00	0.0000E+00
9.8640E+07	0.0000E+00	0.0000E+00	0.0000E+00	8.6610E+10	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	3.5460E+10

6x6 Mass Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
2.4090E+02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	2.2120E+02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	8.8050E+02	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	2.0290E+07	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	6.7230E+06	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	7.0550E+06

6x6 Damping Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
8.9110E+03	0.0000E+00	0.0000E+00	0.0000E+00	6.9774E+05	0.0000E+00
0.0000E+00	7.1681E+03	0.0000E+00	-8.1417E+05	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	6.5469E+04	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-8.1417E+05	0.0000E+00	1.6206E+09	0.0000E+00	0.0000E+00
6.9774E+05	0.0000E+00	0.0000E+00	0.0000E+00	6.1358E+08	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	2.5181E+08

Note: units = lb,in,sec; stiffness (translation=lb/in, rotation=lb-in/rad); mass (translation=lb-sec^2/in, rotation=lb-in-sec^2/rad); damping (translation=lb-sec/in, rotation=lb-in-sec/rad).

TABLE G-6: PIER 6 - PILE GROUP CONDENSED MATRICES AT PILE-CAP

Number of Piles = 12 Pile Cross-Section = 24x24 inch Footing Bottom El = -1'

6x6 Stiffness Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
1.0690E+06	0.0000E+00	0.0000E+00	0.0000E+00	7.4230E+07	0.0000E+00
0.0000E+00	9.4030E+05	0.0000E+00	-1.1630E+08	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	7.7490E+06	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-1.1630E+08	0.0000E+00	1.8060E+11	0.0000E+00	0.0000E+00
7.4230E+07	0.0000E+00	0.0000E+00	0.0000E+00	7.2840E+10	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	2.9290E+10

6x6 Mass Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
1.9180E+02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	1.7930E+02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	8.4220E+02	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	1.8100E+07	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	6.4420E+06	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	5.2920E+06

6x6 Damping Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
7.5885E+03	0.0000E+00	0.0000E+00	0.0000E+00	5.2507E+05	0.0000E+00
0.0000E+00	6.6763E+03	0.0000E+00	-8.2266E+05	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	5.4931E+04	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-8.2266E+05	0.0000E+00	1.2800E+09	0.0000E+00	0.0000E+00
5.2507E+05	0.0000E+00	0.0000E+00	0.0000E+00	5.1614E+08	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	2.0792E+08

Note: units = lb,in,sec; stiffness (translation=lb/in, rotation=lb-in/rad); mass (translation=lb-sec^2/in, rotation=lb-in-sec^2/rad); damping (translation=lb-sec/in, rotation=lb-in-sec/rad).

TABLE G-7: PIER 7 - PILE GROUP CONDENSED MATRICES AT PILE-CAP

Number of Piles = 12 Pile Cross-Section = 24x24 inch Footing Bottom El = +5'

6x6 Stiffness Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
5.5940E+05	0.0000E+00	0.0000E+00	0.0000E+00	9.1470E+07	0.0000E+00
0.0000E+00	4.4540E+05	0.0000E+00	-1.2880E+08	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	6.4890E+06	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-1.2880E+08	0.0000E+00	1.4880E+11	0.0000E+00	0.0000E+00
9.1470E+07	0.0000E+00	0.0000E+00	0.0000E+00	5.8840E+10	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	1.2100E+10

6x6 Mass Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
2.3960E+02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	2.2620E+02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	9.3880E+02	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	2.0190E+07	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	7.1850E+06	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	6.6770E+06

6x6 Damping Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
3.9904E+03	0.0000E+00	0.0000E+00	0.0000E+00	6.4702E+05	0.0000E+00
0.0000E+00	3.1822E+03	0.0000E+00	-9.1108E+05	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	4.6032E+04	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-9.1108E+05	0.0000E+00	1.0554E+09	0.0000E+00	0.0000E+00
6.4702E+05	0.0000E+00	0.0000E+00	0.0000E+00	4.1721E+08	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	8.6523E+07

Note: units = lb,in,sec; stiffness (translation=lb/in, rotation=lb-in/rad); mass (translation=lb-sec^2/in, rotation=lb-in-sec^2/rad); damping (translation=lb-sec/in, rotation=lb-in-sec/rad).

TABLE G-8: PIER 8 - PILE GROUP CONDENSED MATRICES AT PILE-CAP

Number of Piles = 12 Pile Cross-Section = 24x24 inch Footing Bottom El = +5'

6x6 Stiffness Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
4.4820E+05	0.0000E+00	0.0000E+00	0.0000E+00	1.0630E+08	0.0000E+00
0.0000E+00	3.3290E+05	0.0000E+00	-1.4400E+08	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	6.4480E+06	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-1.4400E+08	0.0000E+00	1.4550E+11	0.0000E+00	0.0000E+00
1.0630E+08	0.0000E+00	0.0000E+00	0.0000E+00	5.6290E+10	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	7.3980E+09

6x6 Mass Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
3.0410E+02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	2.9070E+02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	1.0030E+03	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	2.1580E+07	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	7.6800E+06	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	8.5850E+06

6x6 Damping Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
3.2128E+03	0.0000E+00	0.0000E+00	0.0000E+00	7.5192E+05	0.0000E+00
0.0000E+00	2.3954E+03	0.0000E+00	-1.0186E+06	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	4.5751E+04	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-1.0186E+06	0.0000E+00	1.0322E+09	0.0000E+00	0.0000E+00
7.5192E+05	0.0000E+00	0.0000E+00	0.0000E+00	3.9925E+08	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	5.3529E+07

Note: units = lb,in,sec; stiffness (translation=lb/in, rotation=lb-in/rad); mass (translation=lb-sec^2/in, rotation=lb-in-sec^2/rad); damping (translation=lb-sec/in, rotation=lb-in-sec/rad).

TABLE G-9: PIER 9 - PILE GROUP CONDENSED MATRICES AT PILE-CAP

Number of Piles = 25 Pile Cross-Section = 24x24 inch Footing Bottom El = +4'

6x6 Stiffness Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
6.5200E+05	0.0000E+00	0.0000E+00	0.0000E+00	2.1050E+08	0.0000E+00
0.0000E+00	6.5200E+05	0.0000E+00	-2.8280E+08	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	1.3540E+07	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-2.8280E+08	0.0000E+00	3.2200E+11	0.0000E+00	0.0000E+00
2.1050E+08	0.0000E+00	0.0000E+00	0.0000E+00	2.0020E+11	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	1.6160E+10

6x6 Mass Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
6.2390E+02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	6.2390E+02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	2.1050E+03	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	4.8090E+07	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	2.9090E+07	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	2.2810E+07

6x6 Damping Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
4.6991E+03	0.0000E+00	0.0000E+00	0.0000E+00	1.4890E+06	0.0000E+00
0.0000E+00	4.6991E+03	0.0000E+00	-2.0004E+06	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	9.6070E+04	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-2.0004E+06	0.0000E+00	2.2844E+09	0.0000E+00	0.0000E+00
1.4890E+06	0.0000E+00	0.0000E+00	0.0000E+00	1.4202E+09	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	1.1749E+08

Note: units = lb,in,sec; stiffness (translation=lb/in, rotation=lb-in/rad); mass (translation=lb-sec^2/in, rotation=lb-in-sec^2/rad); damping (translation=lb-sec/in, rotation=lb-in-sec/rad).

TABLE G-10: PIER 10 - PILE GROUP CONDENSED MATRICES AT PILE-CAP

Number of Piles = 25 Pile Cross-Section = 24x24 inch Footing Bottom El = +4'

6x6 Stiffness Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
6.7490E+05	0.0000E+00	0.0000E+00	0.0000E+00	2.0770E+08	0.0000E+00
0.0000E+00	6.7490E+05	0.0000E+00	-2.8010E+08	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	1.3580E+07	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-2.8010E+08	0.0000E+00	3.2350E+11	0.0000E+00	0.0000E+00
2.0770E+08	0.0000E+00	0.0000E+00	0.0000E+00	2.0130E+11	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	1.7270E+10

6x6 Mass Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
6.0160E+02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	6.0160E+02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	2.1810E+03	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	4.9790E+07	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	3.0120E+07	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	2.1940E+07

6x6 Damping Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
4.8580E+03	0.0000E+00	0.0000E+00	0.0000E+00	1.4692E+06	0.0000E+00
0.0000E+00	4.8580E+03	0.0000E+00	-1.9813E+06	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	9.6364E+04	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-1.9813E+06	0.0000E+00	2.2953E+09	0.0000E+00	0.0000E+00
1.4692E+06	0.0000E+00	0.0000E+00	0.0000E+00	1.4281E+09	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	1.2522E+08

Note: units = lb,in,sec; stiffness (translation=lb/in, rotation=lb-in/rad); mass (translation=lb-sec^2/in, rotation=lb-in-sec^2/rad); damping (translation=lb-sec/in, rotation=lb-in-sec/rad).

TABLE G-11: PIER 11 - PILE GROUP CONDENSED MATRICES AT PILE-CAP

Number of Piles = 20 Pile Cross-Section = 24x24 inch Footing Bottom El = +4'

6x6 Stiffness Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
4.8740E+05	0.0000E+00	0.0000E+00	0.0000E+00	1.6750E+08	0.0000E+00
0.0000E+00	6.0300E+05	0.0000E+00	-2.8540E+08	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	1.0920E+07	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-2.8540E+08	0.0000E+00	2.6440E+11	0.0000E+00	0.0000E+00
1.6750E+08	0.0000E+00	0.0000E+00	0.0000E+00	1.6140E+11	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	1.1770E+10

6x6 Mass Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
5.1550E+02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	5.2890E+02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	1.7320E+03	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	4.0370E+07	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	2.4020E+07	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	1.9250E+07

6x6 Damping Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
3.5197E+03	0.0000E+00	0.0000E+00	0.0000E+00	1.1848E+06	0.0000E+00
0.0000E+00	4.3392E+03	0.0000E+00	-2.0188E+06	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	7.7486E+04	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-2.0188E+06	0.0000E+00	1.8759E+09	0.0000E+00	0.0000E+00
1.1848E+06	0.0000E+00	0.0000E+00	0.0000E+00	1.1450E+09	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	8.5944E+07

Note: units = lb,in,sec; stiffness (translation=lb/in, rotation=lb-in/rad); mass (translation=lb-sec^2/in, rotation=lb-in-sec^2/rad); damping (translation=lb-sec/in, rotation=lb-in-sec/rad).

TABLE G-12: PIER 12 - PILE GROUP CONDENSED MATRICES AT PILE-CAP

Number of Piles = 20 Pile Cross-Section = 24x24 inch Footing Bottom El = +4.0'

6x6 Stiffness Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
4.7620E+05	0.0000E+00	0.0000E+00	0.0000E+00	1.6130E+08	0.0000E+00
0.0000E+00	5.8820E+05	0.0000E+00	-2.7560E+08	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	1.0580E+07	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-2.7560E+08	0.0000E+00	2.5650E+11	0.0000E+00	0.0000E+00
1.6130E+08	0.0000E+00	0.0000E+00	0.0000E+00	1.5670E+11	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	1.1660E+10

6x6 Mass Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
5.0730E+02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	5.2030E+02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	1.6810E+03	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	3.9190E+07	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	2.3320E+07	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	1.8940E+07

6x6 Damping Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
3.4393E+03	0.0000E+00	0.0000E+00	0.0000E+00	1.1410E+06	0.0000E+00
0.0000E+00	4.2333E+03	0.0000E+00	-1.9495E+06	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	7.5073E+04	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-1.9495E+06	0.0000E+00	1.8199E+09	0.0000E+00	0.0000E+00
1.1410E+06	0.0000E+00	0.0000E+00	0.0000E+00	1.1117E+09	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	8.5123E+07

Note: units = lb,in,sec; stiffness (translation=lb/in, rotation=lb-in/rad); mass (translation=lb-sec^2/in, rotation=lb-in-sec^2/rad); damping (translation=lb-sec/in, rotation=lb-in-sec/rad).

TABLE G-13: PIER 13 - PILE GROUP CONDENSED MATRICES AT PILE-CAP

Number of Piles = 20 Pile Cross-Section = 24x24 inch Footing Bottom El = +4'

6x6 Stiffness Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
4.5910E+05	0.0000E+00	0.0000E+00	0.0000E+00	1.6990E+08	0.0000E+00
0.0000E+00	5.7380E+05	0.0000E+00	-2.8690E+08	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	1.0810E+07	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-2.8690E+08	0.0000E+00	2.6100E+11	0.0000E+00	0.0000E+00
1.6990E+08	0.0000E+00	0.0000E+00	0.0000E+00	1.5910E+11	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	1.0390E+10

6x6 Mass Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
5.4290E+02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	5.5680E+02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	1.7970E+03	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	4.1890E+07	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	2.4920E+07	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	2.0270E+07

6x6 Damping Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
3.3233E+03	0.0000E+00	0.0000E+00	0.0000E+00	1.2018E+06	0.0000E+00
0.0000E+00	4.1366E+03	0.0000E+00	-2.0294E+06	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	7.6717E+04	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-2.0294E+06	0.0000E+00	1.8521E+09	0.0000E+00	0.0000E+00
1.2018E+06	0.0000E+00	0.0000E+00	0.0000E+00	1.1289E+09	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	7.6325E+07

Note: units = lb,in,sec; stiffness (translation=lb/in, rotation=lb-in/rad); mass (translation=lb-sec^2/in, rotation=lb-in-sec^2/rad); damping (translation=lb-sec/in, rotation=lb-in-sec/rad).

TABLE G-14: PIER 14 - PILE GROUP CONDENSED MATRICES AT PILE-CAP

Number of Piles = 18 Pile Cross-Section = 24x24 inch Footing Bottom El = +4'

6x6 Stiffness Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
6.8950E+05	0.0000E+00	0.0000E+00	0.0000E+00	1.7400E+08	0.0000E+00
0.0000E+00	3.4620E+05	0.0000E+00	-1.7220E+08	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	9.6350E+06	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-1.7220E+08	0.0000E+00	2.6470E+11	0.0000E+00	0.0000E+00
1.7400E+08	0.0000E+00	0.0000E+00	0.0000E+00	8.2850E+10	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	1.4180E+10

6x6 Mass Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
4.9350E+02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	4.5500E+02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	1.4980E+03	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	3.9810E+07	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	1.1420E+07	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	1.6340E+07

6x6 Damping Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
4.9462E+03	0.0000E+00	0.0000E+00	0.0000E+00	1.2308E+06	0.0000E+00
0.0000E+00	2.5124E+03	0.0000E+00	-1.2181E+06	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	6.8363E+04	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-1.2181E+06	0.0000E+00	1.8779E+09	0.0000E+00	0.0000E+00
1.2308E+06	0.0000E+00	0.0000E+00	0.0000E+00	5.8764E+08	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	1.0259E+08

Note: units = lb,in,sec; stiffness (translation=lb/in, rotation=lb-in/rad); mass (translation=lb-sec^2/in, rotation=lb-in-sec^2/rad); damping (translation=lb-sec/in, rotation=lb-in-sec/rad).

TABLE G-15: PIER 15 - PILE GROUP CONDENSED MATRICES AT PILE-CAP

Number of Piles = 18 Pile Cross-Section = 24x24 inch Footing Bottom El = +4'

6x6 Stiffness Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
6.7330E+05	0.0000E+00	0.0000E+00	0.0000E+00	1.8040E+08	0.0000E+00
0.0000E+00	3.2530E+05	0.0000E+00	-1.7850E+08	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	9.7400E+06	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-1.7850E+08	0.0000E+00	2.6670E+11	0.0000E+00	0.0000E+00
1.8040E+08	0.0000E+00	0.0000E+00	0.0000E+00	8.2850E+10	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	1.3100E+10

6x6 Mass Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
5.3170E+02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	4.9130E+02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	1.5860E+03	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	4.2160E+07	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	1.2100E+07	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	1.7620E+07

6x6 Damping Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
4.8369E+03	0.0000E+00	0.0000E+00	0.0000E+00	1.2761E+06	0.0000E+00
0.0000E+00	2.3696E+03	0.0000E+00	-1.2626E+06	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	6.9118E+04	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-1.2626E+06	0.0000E+00	1.8924E+09	0.0000E+00	0.0000E+00
1.2761E+06	0.0000E+00	0.0000E+00	0.0000E+00	5.8774E+08	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	9.5124E+07

Note: units = lb,in,sec; stiffness (translation=lb/in, rotation=lb-in/rad); mass (translation=lb-sec^2/in, rotation=lb-in-sec^2/rad); damping (translation=lb-sec/in, rotation=lb-in-sec/rad).

TABLE G-16: PIER 16 - PILE GROUP CONDENSED MATRICES AT PILE-CAP

Number of Piles = 18 Pile Cross-Section = 24x24 inch Footing Bottom El = +4'

6x6 Stiffness Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
6.6650E+05	0.0000E+00	0.0000E+00	0.0000E+00	1.8400E+08	0.0000E+00
0.0000E+00	3.1560E+05	0.0000E+00	-1.8220E+08	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	9.8120E+06	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-1.8220E+08	0.0000E+00	2.6820E+11	0.0000E+00	0.0000E+00
1.8400E+08	0.0000E+00	0.0000E+00	0.0000E+00	8.2950E+10	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	1.2580E+10

6x6 Mass Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
5.5900E+02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	5.1640E+02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	1.6710E+03	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	4.4430E+07	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	1.2740E+07	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	1.8530E+07

6x6 Damping Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
4.7926E+03	0.0000E+00	0.0000E+00	0.0000E+00	1.3015E+06	0.0000E+00
0.0000E+00	2.3045E+03	0.0000E+00	-1.2888E+06	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	6.9639E+04	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-1.2888E+06	0.0000E+00	1.9033E+09	0.0000E+00	0.0000E+00
1.3015E+06	0.0000E+00	0.0000E+00	0.0000E+00	5.8853E+08	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	9.1573E+07

Note: units = lb,in,sec; stiffness (translation=lb/in, rotation=lb-in/rad); mass (translation=lb-sec^2/in, rotation=lb-in-sec^2/rad); damping (translation=lb-sec/in, rotation=lb-in-sec/rad).

TABLE G-17: PIER 17 - PILE GROUP CONDENSED MATRICES AT PILE-CAP

Number of Piles = 25 Pile Diameter = 54 inch Footing Bottom El = +2'

6x6 Stiffness Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
1.5410E+06	0.0000E+00	0.0000E+00	0.0000E+00	3.6130E+08	0.0000E+00
0.0000E+00	1.5410E+06	0.0000E+00	-3.6130E+08	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	2.5360E+07	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-3.6130E+08	0.0000E+00	7.0110E+11	0.0000E+00	0.0000E+00
3.6130E+08	0.0000E+00	0.0000E+00	0.0000E+00	7.0110E+11	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	7.2100E+10

6x6 Mass Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
3.6940E+03	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	3.6940E+03	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	9.6580E+03	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	2.2120E+08	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	2.2120E+08	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	1.6940E+08

6x6 Damping Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
1.1416E+04	0.0000E+00	0.0000E+00	0.0000E+00	2.5557E+06	0.0000E+00
0.0000E+00	1.1416E+04	0.0000E+00	-2.5557E+06	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	1.8074E+05	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-2.5557E+06	0.0000E+00	4.9902E+09	0.0000E+00	0.0000E+00
2.5557E+06	0.0000E+00	0.0000E+00	0.0000E+00	4.9902E+09	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	5.3366E+08

Note: units = lb,in,sec; stiffness (translation=lb/in, rotation=lb-in/rad); mass (translation=lb-sec^2/in, rotation=lb-in-sec^2/rad); damping (translation=lb-sec/in, rotation=lb-in-sec/rad).

TABLE G-18: PIER 18 - PILE GROUP CONDENSED MATRICES AT PILE-CAP

Number of Piles = 25 Pile Diameter = 54 inch Footing Bottom El = +2'

6x6 Stiffness Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
1.4300E+06	0.0000E+00	0.0000E+00	0.0000E+00	3.5590E+08	0.0000E+00
0.0000E+00	1.4300E+06	0.0000E+00	-3.5590E+08	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	2.4270E+07	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-3.5590E+08	0.0000E+00	6.7060E+11	0.0000E+00	0.0000E+00
3.5590E+08	0.0000E+00	0.0000E+00	0.0000E+00	6.7060E+11	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	6.6120E+10

6x6 Mass Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
3.8490E+03	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	3.8490E+03	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	9.7480E+03	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	2.2340E+08	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	2.2340E+08	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	1.7660E+08

6x6 Damping Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
1.0653E+04	0.0000E+00	0.0000E+00	0.0000E+00	2.5175E+06	0.0000E+00
0.0000E+00	1.0653E+04	0.0000E+00	-2.5175E+06	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	1.7304E+05	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-2.5175E+06	0.0000E+00	4.7747E+09	0.0000E+00	0.0000E+00
2.5175E+06	0.0000E+00	0.0000E+00	0.0000E+00	4.7747E+09	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	4.9237E+08

Note: units = lb,in,sec; stiffness (translation=lb/in, rotation=lb-in/rad); mass (translation=lb-sec^2/in, rotation=lb-in-sec^2/rad); damping (translation=lb-sec/in, rotation=lb-in-sec/rad).

TABLE G-19: PIER 19 - PILE GROUP CONDENSED MATRICES AT PILE-CAP

Number of Piles = 30 Pile Diameter = 54 inch Footing Bottom El = +2.0'

6x6 Stiffness Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
1.5750E+06	0.0000E+00	0.0000E+00	0.0000E+00	4.7910E+08	0.0000E+00
0.0000E+00	1.3740E+06	0.0000E+00	-4.9260E+08	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	2.8920E+07	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-4.9260E+08	0.0000E+00	1.0900E+12	0.0000E+00	0.0000E+00
4.7910E+08	0.0000E+00	0.0000E+00	0.0000E+00	7.8640E+11	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	7.8340E+10

6x6 Mass Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
5.0470E+03	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	4.9910E+03	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	1.2650E+04	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	4.2320E+08	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	2.8940E+08	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	2.8400E+08

6x6 Damping Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
1.1846E+04	0.0000E+00	0.0000E+00	0.0000E+00	3.3890E+06	0.0000E+00
0.0000E+00	1.0416E+04	0.0000E+00	-3.4845E+06	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	2.0633E+05	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-3.4845E+06	0.0000E+00	7.7693E+09	0.0000E+00	0.0000E+00
3.3890E+06	0.0000E+00	0.0000E+00	0.0000E+00	5.6031E+09	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	5.9380E+08

Note: units = lb,in,sec; stiffness (translation=lb/in, rotation=lb-in/rad); mass (translation=lb-sec^2/in, rotation=lb-in-sec^2/rad); damping (translation=lb-sec/in, rotation=lb-in-sec/rad).

TABLE G-20: PIER 20 - PILE GROUP CONDENSED MATRICES AT PILE-CAP

Number of Piles = 30 Pile Diameter = 54 inch Footing Bottom El = +2'

6x6 Stiffness Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
1.3290E+06	0.0000E+00	0.0000E+00	0.0000E+00	5.5870E+08	0.0000E+00
0.0000E+00	1.1260E+06	0.0000E+00	-5.7230E+08	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	2.8950E+07	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-5.7230E+08	0.0000E+00	1.0650E+12	0.0000E+00	0.0000E+00
5.5870E+08	0.0000E+00	0.0000E+00	0.0000E+00	7.6170E+11	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	5.5760E+10

6x6 Mass Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
6.0420E+03	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	5.9900E+03	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	1.3160E+04	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	4.4090E+08	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	3.0150E+08	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	3.4130E+08

6x6 Damping Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
1.0244E+04	0.0000E+00	0.0000E+00	0.0000E+00	3.9520E+06	0.0000E+00
0.0000E+00	8.8013E+03	0.0000E+00	-4.0482E+06	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	2.0662E+05	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-4.0482E+06	0.0000E+00	7.5949E+09	0.0000E+00	0.0000E+00
3.9520E+06	0.0000E+00	0.0000E+00	0.0000E+00	5.4301E+09	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	4.4208E+08

Note: units = lb,in,sec; stiffness (translation=lb/in, rotation=lb-in/rad); mass (translation=lb-sec^2/in, rotation=lb-in-sec^2/rad); damping (translation=lb-sec/in, rotation=lb-in-sec/rad).

TABLE G-21: PIER 21 - PILE GROUP CONDENSED MATRICES AT PILE-CAP

Number of Piles = 25 Pile Diameter = 54 inch Footing Bottom El = +2.0'

6x6 Stiffness Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
1.2870E+06	0.0000E+00	0.0000E+00	0.0000E+00	3.9250E+08	0.0000E+00
0.0000E+00	1.2870E+06	0.0000E+00	-3.9250E+08	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	2.3940E+07	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-3.9250E+08	0.0000E+00	6.4660E+11	0.0000E+00	0.0000E+00
3.9250E+08	0.0000E+00	0.0000E+00	0.0000E+00	6.4660E+11	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	5.5200E+10

6x6 Mass Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
4.1120E+03	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	4.1120E+03	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	9.0900E+03	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	2.0860E+08	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	2.0860E+08	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	1.8900E+08

6x6 Damping Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
9.6779E+03	0.0000E+00	0.0000E+00	0.0000E+00	2.7764E+06	0.0000E+00
0.0000E+00	9.6779E+03	0.0000E+00	-2.7764E+06	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	1.7061E+05	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-2.7764E+06	0.0000E+00	4.6029E+09	0.0000E+00	0.0000E+00
2.7764E+06	0.0000E+00	0.0000E+00	0.0000E+00	4.6029E+09	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	4.1685E+08

Note: units = lb,in,sec; stiffness (translation=lb/in, rotation=lb-in/rad); mass (translation=lb-sec^2/in, rotation=lb-in-sec^2/rad); damping (translation=lb-sec/in, rotation=lb-in-sec/rad).

TABLE G-22: PIER 22 - PILE GROUP CONDENSED MATRICES AT PILE-CAP

Number of Piles = 49 Pile Cross-Section = 24x24 inch Footing Bottom El = -14'

6x6 Stiffness Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
1.4020E+06	0.0000E+00	0.0000E+00	0.0000E+00	4.6320E+08	0.0000E+00
0.0000E+00	1.4020E+06	0.0000E+00	-4.6320E+08	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	2.7820E+07	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-4.6320E+08	0.0000E+00	7.9240E+11	0.0000E+00	0.0000E+00
4.6320E+08	0.0000E+00	0.0000E+00	0.0000E+00	7.9240E+11	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	6.5170E+10

6x6 Mass Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
1.2540E+03	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	1.2540E+03	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	5.2050E+03	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	1.4340E+08	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	1.4340E+08	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	6.9090E+07

6x6 Damping Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
1.0092E+04	0.0000E+00	0.0000E+00	0.0000E+00	3.2765E+06	0.0000E+00
0.0000E+00	1.0092E+04	0.0000E+00	-3.2765E+06	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	1.9751E+05	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-3.2765E+06	0.0000E+00	5.6251E+09	0.0000E+00	0.0000E+00
3.2765E+06	0.0000E+00	0.0000E+00	0.0000E+00	5.6251E+09	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	4.7063E+08

Note: units = lb,in,sec; stiffness (translation=lb/in, rotation=lb-in/rad); mass (translation=lb-sec^2/in, rotation=lb-in-sec^2/rad); damping (translation=lb-sec/in, rotation=lb-in-sec/rad).

TABLE G-23: PIER 23 - PILE GROUP CONDENSED MATRICES AT PILE-CAP

Number of Piles = 20 Pile Cross-Section = 24x24 inch Footing Bottom El = -16'

6x6 Stiffness Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
6.2490E+05	0.0000E+00	0.0000E+00	0.0000E+00	1.5880E+08	0.0000E+00
0.0000E+00	7.4000E+05	0.0000E+00	-2.7630E+08	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	1.1020E+07	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-2.7630E+08	0.0000E+00	2.6760E+11	0.0000E+00	0.0000E+00
1.5880E+08	0.0000E+00	0.0000E+00	0.0000E+00	1.6350E+11	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	1.7870E+10

6x6 Mass Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
5.1920E+02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	5.3720E+02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	2.1350E+03	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	4.9670E+07	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	2.9560E+07	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	1.9230E+07

6x6 Damping Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
4.4928E+03	0.0000E+00	0.0000E+00	0.0000E+00	1.1233E+06	0.0000E+00
0.0000E+00	5.3095E+03	0.0000E+00	-1.9544E+06	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	7.8249E+04	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-1.9544E+06	0.0000E+00	1.8998E+09	0.0000E+00	0.0000E+00
1.1233E+06	0.0000E+00	0.0000E+00	0.0000E+00	1.1607E+09	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	1.2909E+08

Note: units = lb,in,sec; stiffness (translation=lb/in, rotation=lb-in/rad); mass (translation=lb-sec^2/in, rotation=lb-in-sec^2/rad); damping (translation=lb-sec/in, rotation=lb-in-sec/rad).

TABLE G-24: PIER 24 - PILE GROUP CONDENSED MATRICES AT PILE-CAP

Number of Piles = 20 Pile Cross-Section = 24x24 inch Footing Bottom El = -17'

6x6 Stiffness Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
6.3070E+05	0.0000E+00	0.0000E+00	0.0000E+00	1.6190E+08	0.0000E+00
0.0000E+00	7.4760E+05	0.0000E+00	-2.8120E+08	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	1.1180E+07	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-2.8120E+08	0.0000E+00	2.7140E+11	0.0000E+00	0.0000E+00
1.6190E+08	0.0000E+00	0.0000E+00	0.0000E+00	1.6580E+11	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	1.7930E+10

6x6 Mass Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
5.2210E+02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	5.4020E+02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	2.1530E+03	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	5.0070E+07	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	2.9800E+07	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	1.9340E+07

6x6 Damping Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
4.5342E+03	0.0000E+00	0.0000E+00	0.0000E+00	1.1452E+06	0.0000E+00
0.0000E+00	5.3637E+03	0.0000E+00	-1.9891E+06	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	7.9383E+04	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-1.9891E+06	0.0000E+00	1.9268E+09	0.0000E+00	0.0000E+00
1.1452E+06	0.0000E+00	0.0000E+00	0.0000E+00	1.1770E+09	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	1.2953E+08

Note: units = lb,in,sec; stiffness (translation=lb/in, rotation=lb-in/rad); mass (translation=lb-sec^2/in, rotation=lb-in-sec^2/rad); damping (translation=lb-sec/in, rotation=lb-in-sec/rad).

TABLE G-25: PIER 25 - PILE GROUP CONDENSED MATRICES AT PILE-CAP

Number of Piles = 20 Pile Cross-Section = 24x24 inch Footing Bottom El = -18'

6x6 Stiffness Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
6.4260E+05	0.0000E+00	0.0000E+00	0.0000E+00	1.6550E+08	0.0000E+00
0.0000E+00	7.6170E+05	0.0000E+00	-3.2970E+08	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	1.1400E+07	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-3.2970E+08	0.0000E+00	3.5000E+11	0.0000E+00	0.0000E+00
1.6550E+08	0.0000E+00	0.0000E+00	0.0000E+00	1.6870E+11	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	2.1030E+10

6x6 Mass Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
5.1980E+02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	5.3730E+02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	2.0920E+03	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	6.2190E+07	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	2.8960E+07	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	2.2590E+07

6x6 Damping Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
4.6181E+03	0.0000E+00	0.0000E+00	0.0000E+00	1.1707E+06	0.0000E+00
0.0000E+00	5.4630E+03	0.0000E+00	-2.3322E+06	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	8.0931E+04	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-2.3322E+06	0.0000E+00	2.4844E+09	0.0000E+00	0.0000E+00
1.1707E+06	0.0000E+00	0.0000E+00	0.0000E+00	1.1974E+09	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	1.5191E+08

Note: units = lb,in,sec; stiffness (translation=lb/in, rotation=lb-in/rad); mass (translation=lb-sec^2/in, rotation=lb-in-sec^2/rad); damping (translation=lb-sec/in, rotation=lb-in-sec/rad).

TABLE G-26: PIER 26 - PILE GROUP CONDENSED MATRICES AT PILE-CAP

Number of Piles = 30 Pile Cross-Section = 24x24 inch Footing Bottom El = -18.5'

6x6 Stiffness Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
1.0320E+06	0.0000E+00	0.0000E+00	0.0000E+00	2.6710E+08	0.0000E+00
0.0000E+00	9.1260E+05	0.0000E+00	-2.7330E+08	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	1.7390E+07	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-2.7330E+08	0.0000E+00	3.6640E+11	0.0000E+00	0.0000E+00
2.6710E+08	0.0000E+00	0.0000E+00	0.0000E+00	2.5580E+11	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	2.6600E+10

6x6 Mass Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
7.8920E+02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	7.7150E+02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	3.2040E+03	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	6.4510E+07	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	4.4070E+07	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	2.6290E+07

6x6 Damping Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
7.4102E+03	0.0000E+00	0.0000E+00	0.0000E+00	1.8894E+06	0.0000E+00
0.0000E+00	6.5631E+03	0.0000E+00	-1.9332E+06	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	1.2346E+05	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-1.9332E+06	0.0000E+00	2.6008E+09	0.0000E+00	0.0000E+00
1.8894E+06	0.0000E+00	0.0000E+00	0.0000E+00	1.8156E+09	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	1.9183E+08

Note: units = lb,in,sec; stiffness (translation=lb/in, rotation=lb-in/rad); mass (translation=lb-sec^2/in, rotation=lb-in-sec^2/rad); damping (translation=lb-sec/in, rotation=lb-in-sec/rad).

TABLE G-27: PIER 27 - PILE GROUP CONDENSED MATRICES AT PILE-CAP

Number of Piles = 30 Pile Cross-Section = 24x24 inch Footing Bottom El = -19.5'

6x6 Stiffness Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
1.1200E+06	0.0000E+00	0.0000E+00	0.0000E+00	3.1480E+08	0.0000E+00
0.0000E+00	9.8290E+05	0.0000E+00	-3.2200E+08	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	1.9890E+07	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-3.2200E+08	0.0000E+00	4.1620E+11	0.0000E+00	0.0000E+00
3.1480E+08	0.0000E+00	0.0000E+00	0.0000E+00	2.8980E+11	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	2.7510E+10

6x6 Mass Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
7.8450E+02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	7.6800E+02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	3.0400E+03	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	6.1200E+07	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	4.1810E+07	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	2.6190E+07

6x6 Damping Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
8.0320E+03	0.0000E+00	0.0000E+00	0.0000E+00	2.2268E+06	0.0000E+00
0.0000E+00	7.0599E+03	0.0000E+00	-2.2777E+06	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	1.4112E+05	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-2.2777E+06	0.0000E+00	2.9526E+09	0.0000E+00	0.0000E+00
2.2268E+06	0.0000E+00	0.0000E+00	0.0000E+00	2.0558E+09	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	1.9825E+08

Note: units = lb,in,sec; stiffness (translation=lb/in, rotation=lb-in/rad); mass (translation=lb-sec^2/in, rotation=lb-in-sec^2/rad); damping (translation=lb-sec/in, rotation=lb-in-sec/rad).

TABLE G-28: PIER 28 - PILE GROUP CONDENSED MATRICES AT PILE-CAP

Number of Piles = 24 Pile Cross-Section = 24x24 inch Footing Bottom El = -20'

6x6 Stiffness Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
9.1880E+05	0.0000E+00	0.0000E+00	0.0000E+00	2.5250E+08	0.0000E+00
0.0000E+00	6.9060E+05	0.0000E+00	-2.6790E+08	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	1.3170E+07	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-2.6790E+08	0.0000E+00	4.5280E+11	1.1440E-05	0.0000E+00
2.5250E+08	0.0000E+00	0.0000E+00	0.0000E+00	2.0080E+11	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	3.0830E+10

6x6 Mass Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
6.4590E+02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	6.1150E+02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	2.4910E+03	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	8.3240E+07	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	3.5410E+07	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	2.9850E+07

6x6 Damping Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
6.5894E+03	0.0000E+00	0.0000E+00	0.0000E+00	1.7861E+06	0.0000E+00
0.0000E+00	4.9704E+03	0.0000E+00	-1.8950E+06	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	9.3507E+04	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-1.8950E+06	0.0000E+00	3.2145E+09	8.0922E-08	0.0000E+00
1.7861E+06	0.0000E+00	0.0000E+00	0.0000E+00	1.4253E+09	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	2.2225E+08

Note: units = lb,in,sec; stiffness (translation=lb/in, rotation=lb-in/rad); mass (translation=lb-sec^2/in, rotation=lb-in-sec^2/rad); damping (translation=lb-sec/in, rotation=lb-in-sec/rad).

TABLE G-29: PIER 29 - PILE GROUP CONDENSED MATRICES AT PILE-CAP

Number of Piles = 24 Pile Cross-Section = 24x24 inch Footing Bottom El = -21'

6x6 Stiffness Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
9.0590E+05	0.0000E+00	0.0000E+00	0.0000E+00	2.4550E+08	0.0000E+00
0.0000E+00	6.8300E+05	0.0000E+00	-2.6040E+08	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	1.2870E+07	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-2.6040E+08	0.0000E+00	4.4280E+11	0.0000E+00	0.0000E+00
2.4550E+08	0.0000E+00	0.0000E+00	0.0000E+00	1.9650E+11	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	3.0660E+10

6x6 Mass Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
6.4850E+02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	6.1340E+02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	2.5300E+03	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	8.4520E+07	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	3.5960E+07	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	2.9950E+07

6x6 Damping Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
6.4985E+03	0.0000E+00	0.0000E+00	0.0000E+00	1.7366E+06	0.0000E+00
0.0000E+00	4.9169E+03	0.0000E+00	-1.8420E+06	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	9.1390E+04	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-1.8420E+06	0.0000E+00	3.1440E+09	0.0000E+00	0.0000E+00
1.7366E+06	0.0000E+00	0.0000E+00	0.0000E+00	1.3950E+09	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	2.2106E+08

Note: units = lb,in,sec; stiffness (translation=lb/in, rotation=lb-in/rad); mass (translation=lb-sec^2/in, rotation=lb-in-sec^2/rad); damping (translation=lb-sec/in, rotation=lb-in-sec/rad).

TABLE G-30: PIER 30 - PILE GROUP CONDENSED MATRICES AT PILE-CAP

Number of Piles = 24 Pile Cross-Section = 24x24 inch Footing Bottom El = -21.0'

6x6 Stiffness Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
9.4310E+05	0.0000E+00	0.0000E+00	0.0000E+00	2.6800E+08	0.0000E+00
0.0000E+00	7.0320E+05	0.0000E+00	-2.8410E+08	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	1.3820E+07	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-2.8410E+08	0.0000E+00	4.7440E+11	0.0000E+00	0.0000E+00
2.6800E+08	0.0000E+00	0.0000E+00	0.0000E+00	2.1000E+11	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	3.1020E+10

6x6 Mass Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
6.5250E+02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	6.1510E+02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	2.6570E+03	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	8.8740E+07	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	3.7750E+07	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	3.0060E+07

6x6 Damping Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
6.7622E+03	0.0000E+00	0.0000E+00	0.0000E+00	1.8957E+06	0.0000E+00
0.0000E+00	5.0600E+03	0.0000E+00	-2.0096E+06	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	9.8128E+04	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-2.0096E+06	0.0000E+00	3.3681E+09	0.0000E+00	0.0000E+00
1.8957E+06	0.0000E+00	0.0000E+00	0.0000E+00	1.4907E+09	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	2.2362E+08

Note: units = lb,in,sec; stiffness (translation=lb/in, rotation=lb-in/rad); mass (translation=lb-sec^2/in, rotation=lb-in-sec^2/rad); damping (translation=lb-sec/in, rotation=lb-in-sec/rad).

TABLE G-31: PIER 31 - PILE GROUP CONDENSED MATRICES AT PILE-CAP

Number of Piles = 18 Pile Cross-Section = 24x24 inch Footing Bottom El = -19'

6x6 Stiffness Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
8.0710E+05	0.0000E+00	0.0000E+00	0.0000E+00	1.6220E+08	0.0000E+00
0.0000E+00	4.7000E+05	0.0000E+00	-1.6040E+08	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	9.5880E+06	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-1.6040E+08	0.0000E+00	2.6440E+11	0.0000E+00	0.0000E+00
1.6220E+08	0.0000E+00	0.0000E+00	0.0000E+00	8.3370E+10	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	1.9230E+10

6x6 Mass Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
5.1520E+02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	4.5730E+02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	2.0250E+03	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	5.3750E+07	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	1.5400E+07	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	1.6680E+07

6x6 Damping Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
5.7810E+03	0.0000E+00	0.0000E+00	0.0000E+00	1.1473E+06	0.0000E+00
0.0000E+00	3.3884E+03	0.0000E+00	-1.1346E+06	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	6.8104E+04	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-1.1346E+06	0.0000E+00	1.8778E+09	0.0000E+00	0.0000E+00
1.1473E+06	0.0000E+00	0.0000E+00	0.0000E+00	5.9188E+08	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	1.3835E+08

Note: units = lb,in,sec; stiffness (translation=lb/in, rotation=lb-in/rad); mass (translation=lb-sec^2/in, rotation=lb-in-sec^2/rad); damping (translation=lb-sec/in, rotation=lb-in-sec/rad).

TABLE G-32: PIER 32 - PILE GROUP CONDENSED MATRICES AT PILE-CAP

Number of Piles = 18 Pile Cross-Section = 24x24 inch Footing Bottom El = -19'

6x6 Stiffness Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
8.3080E+05	0.0000E+00	0.0000E+00	0.0000E+00	1.6130E+08	0.0000E+00
0.0000E+00	4.9140E+05	0.0000E+00	-1.5950E+08	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	9.6720E+06	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-1.5950E+08	0.0000E+00	2.6700E+11	0.0000E+00	0.0000E+00
1.6130E+08	0.0000E+00	0.0000E+00	0.0000E+00	8.4420E+10	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	2.0170E+10

6x6 Mass Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
5.0300E+02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	4.4470E+02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	2.0200E+03	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	5.3630E+07	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	1.5370E+07	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	1.6250E+07

6x6 Damping Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
5.9470E+03	0.0000E+00	0.0000E+00	0.0000E+00	1.1410E+06	0.0000E+00
0.0000E+00	3.5381E+03	0.0000E+00	-1.1282E+06	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	6.8698E+04	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-1.1282E+06	0.0000E+00	1.8961E+09	0.0000E+00	0.0000E+00
1.1410E+06	0.0000E+00	0.0000E+00	0.0000E+00	5.9930E+08	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	1.4494E+08

Note: units = lb,in,sec; stiffness (translation=lb/in, rotation=lb-in/rad); mass (translation=lb-sec^2/in, rotation=lb-in-sec^2/rad); damping (translation=lb-sec/in, rotation=lb-in-sec/rad).

TABLE G-33: PIER 33 - PILE GROUP CONDENSED MATRICES AT PILE-CAP

Number of Piles = 18 Pile Cross-Section = 24x24 inch Footing Bottom El = -19'

6x6 Stiffness Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
8.2210E+05	0.0000E+00	0.0000E+00	0.0000E+00	1.5830E+08	0.0000E+00
0.0000E+00	4.8800E+05	0.0000E+00	-1.5650E+08	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	9.5270E+06	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-1.5650E+08	0.0000E+00	2.6310E+11	0.0000E+00	0.0000E+00
1.5830E+08	0.0000E+00	0.0000E+00	0.0000E+00	8.3300E+10	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	2.0060E+10

6x6 Mass Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
5.0430E+02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	4.4590E+02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	2.0270E+03	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	5.3810E+07	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	1.5420E+07	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	1.6290E+07

6x6 Damping Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
5.8856E+03	0.0000E+00	0.0000E+00	0.0000E+00	1.1198E+06	0.0000E+00
0.0000E+00	3.5142E+03	0.0000E+00	-1.1070E+06	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	6.7673E+04	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-1.1070E+06	0.0000E+00	1.8686E+09	0.0000E+00	0.0000E+00
1.1198E+06	0.0000E+00	0.0000E+00	0.0000E+00	5.9138E+08	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	1.4417E+08

Note: units = lb,in,sec; stiffness (translation=lb/in, rotation=lb-in/rad); mass (translation=lb-sec^2/in, rotation=lb-in-sec^2/rad); damping (translation=lb-sec/in, rotation=lb-in-sec/rad).

TABLE G-34: PIER 34 - PILE GROUP CONDENSED MATRICES AT PILE-CAP

Number of Piles = 15 Pile Cross-Section = 24x24 inch Footing Bottom El = -18'

6x6 Stiffness Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
6.6420E+05	0.0000E+00	0.0000E+00	0.0000E+00	1.3920E+08	0.0000E+00
0.0000E+00	4.2970E+05	0.0000E+00	-1.5490E+08	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	8.3010E+06	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-1.5490E+08	0.0000E+00	1.9930E+11	0.0000E+00	0.0000E+00
1.3920E+08	0.0000E+00	0.0000E+00	0.0000E+00	7.1840E+10	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	1.3220E+10

6x6 Mass Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
4.2890E+02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	3.9050E+02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	1.6790E+03	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	3.8660E+07	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	1.2800E+07	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	1.2470E+07

6x6 Damping Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
4.7582E+03	0.0000E+00	0.0000E+00	0.0000E+00	9.8465E+05	0.0000E+00
0.0000E+00	3.0941E+03	0.0000E+00	-1.0957E+06	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	5.8952E+04	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-1.0957E+06	0.0000E+00	1.4152E+09	0.0000E+00	0.0000E+00
9.8465E+05	0.0000E+00	0.0000E+00	0.0000E+00	5.0995E+08	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	9.5254E+07

Note: units = lb,in,sec; stiffness (translation=lb/in, rotation=lb-in/rad); mass (translation=lb-sec^2/in, rotation=lb-in-sec^2/rad); damping (translation=lb-sec/in, rotation=lb-in-sec/rad).

TABLE G-35: PIER 35 - PILE GROUP CONDENSED MATRICES AT PILE-CAP

Number of Piles = 15 Pile Cross-Section = 24x24 inch Footing Bottom El = -18'

6x6 Stiffness Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
6.5560E+05	0.0000E+00	0.0000E+00	0.0000E+00	1.3610E+08	0.0000E+00
0.0000E+00	4.2540E+05	0.0000E+00	-1.5150E+08	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	8.1520E+06	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-1.5150E+08	0.0000E+00	1.9590E+11	0.0000E+00	0.0000E+00
1.3610E+08	0.0000E+00	0.0000E+00	0.0000E+00	7.0720E+10	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	1.3150E+10

6x6 Mass Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
4.2880E+02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	3.9030E+02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	1.6830E+03	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	3.8740E+07	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	1.2830E+07	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	1.2470E+07

6x6 Damping Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
4.6973E+03	0.0000E+00	0.0000E+00	0.0000E+00	9.6272E+05	0.0000E+00
0.0000E+00	3.0636E+03	0.0000E+00	-1.0717E+06	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	5.7899E+04	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-1.0717E+06	0.0000E+00	1.3911E+09	0.0000E+00	0.0000E+00
9.6272E+05	0.0000E+00	0.0000E+00	0.0000E+00	5.0204E+08	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	9.4759E+07

Note: units = lb,in,sec; stiffness (translation=lb/in, rotation=lb-in/rad); mass (translation=lb-sec^2/in, rotation=lb-in-sec^2/rad); damping (translation=lb-sec/in, rotation=lb-in-sec/rad).

TABLE G-36: PIER 36 - PILE GROUP CONDENSED MATRICES AT PILE-CAP

Number of Piles = 15 Pile Cross-Section = 24x24 inch Footing Bottom El = -18'

6x6 Stiffness Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
6.7100E+05	0.0000E+00	0.0000E+00	0.0000E+00	1.4160E+08	0.0000E+00
0.0000E+00	4.3310E+05	0.0000E+00	-1.5760E+08	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	8.4200E+06	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-1.5760E+08	0.0000E+00	2.0210E+11	0.0000E+00	0.0000E+00
1.4160E+08	0.0000E+00	0.0000E+00	0.0000E+00	7.2740E+10	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	1.3280E+10

6x6 Mass Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
4.2300E+02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	3.8730E+02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	1.5820E+03	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	3.6440E+07	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	1.2070E+07	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	1.2350E+07

6x6 Damping Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
4.8054E+03	0.0000E+00	0.0000E+00	0.0000E+00	1.0016E+06	0.0000E+00
0.0000E+00	3.1177E+03	0.0000E+00	-1.1148E+06	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	5.9781E+04	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-1.1148E+06	0.0000E+00	1.4347E+09	0.0000E+00	0.0000E+00
1.0016E+06	0.0000E+00	0.0000E+00	0.0000E+00	5.1622E+08	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	9.5662E+07

Note: units = lb,in,sec; stiffness (translation=lb/in, rotation=lb-in/rad); mass (translation=lb-sec^2/in, rotation=lb-in-sec^2/rad); damping (translation=lb-sec/in, rotation=lb-in-sec/rad).

TABLE G-37: PIER 37 - PILE GROUP CONDENSED MATRICES AT PILE-CAP

Number of Piles = 18 Pile Cross-Section = 24x24 inch Footing Bottom El = -18.5'

6x6 Stiffness Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
8.4190E+05	0.0000E+00	0.0000E+00	0.0000E+00	1.7530E+08	0.0000E+00
0.0000E+00	4.8260E+05	0.0000E+00	-1.7340E+08	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	1.0200E+07	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-1.7340E+08	0.0000E+00	2.8060E+11	0.0000E+00	0.0000E+00
1.7530E+08	0.0000E+00	0.0000E+00	0.0000E+00	8.7990E+10	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	1.9620E+10

6x6 Mass Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
5.1490E+02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	4.5870E+02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	1.9790E+03	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	5.2520E+07	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	1.5050E+07	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	1.6700E+07

6x6 Damping Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
6.0272E+03	0.0000E+00	0.0000E+00	0.0000E+00	1.2400E+06	0.0000E+00
0.0000E+00	3.4778E+03	0.0000E+00	-1.2266E+06	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	7.2427E+04	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-1.2266E+06	0.0000E+00	1.9922E+09	0.0000E+00	0.0000E+00
1.2400E+06	0.0000E+00	0.0000E+00	0.0000E+00	6.2451E+08	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	1.4112E+08

Note: units = lb,in,sec; stiffness (translation=lb/in, rotation=lb-in/rad); mass (translation=lb-sec^2/in, rotation=lb-in-sec^2/rad); damping (translation=lb-sec/in, rotation=lb-in-sec/rad).

TABLE G-38: PIER 38 - PILE GROUP CONDENSED MATRICES AT PILE-CAP

Number of Piles = 20 Pile Cross-Section = 24x24 inch Footing Bottom El = -19'

6x6 Stiffness Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
6.6060E+05	0.0000E+00	0.0000E+00	0.0000E+00	1.7920E+08	0.0000E+00
0.0000E+00	7.8760E+05	0.0000E+00	-3.0870E+08	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	1.2130E+07	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-3.0870E+08	0.0000E+00	2.9310E+11	0.0000E+00	0.0000E+00
1.7920E+08	0.0000E+00	0.0000E+00	0.0000E+00	1.7870E+11	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	1.8180E+10

6x6 Mass Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
5.2180E+02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	5.4000E+02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	2.1650E+03	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	5.0340E+07	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	2.9960E+07	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	1.9320E+07

6x6 Damping Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
4.7457E+03	0.0000E+00	0.0000E+00	0.0000E+00	1.2676E+06	0.0000E+00
0.0000E+00	5.6466E+03	0.0000E+00	-2.1836E+06	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	8.6105E+04	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-2.1836E+06	0.0000E+00	2.0803E+09	0.0000E+00	0.0000E+00
1.2676E+06	0.0000E+00	0.0000E+00	0.0000E+00	1.2682E+09	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	1.3130E+08

Note: units = lb,in,sec; stiffness (translation=lb/in, rotation=lb-in/rad); mass (translation=lb-sec^2/in, rotation=lb-in-sec^2/rad); damping (translation=lb-sec/in, rotation=lb-in-sec/rad).

TABLE G-39: PIER 39 - PILE GROUP CONDENSED MATRICES AT PILE-CAP

Number of Piles = 12 Pile Diameter = 30 inch Footing Bottom El = +2.0'

6x6 Stiffness Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
5.7010E+05	0.0000E+00	0.0000E+00	0.0000E+00	1.1060E+08	0.0000E+00
0.0000E+00	4.3310E+05	0.0000E+00	-1.5550E+08	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	7.7030E+06	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-1.5550E+08	0.0000E+00	1.8340E+11	0.0000E+00	0.0000E+00
1.1060E+08	0.0000E+00	0.0000E+00	0.0000E+00	7.6780E+10	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	1.2130E+10

6x6 Mass Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
6.3720E+02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	6.0780E+02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	2.1660E+03	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	4.6600E+07	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	1.6590E+07	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	1.7920E+07

6x6 Damping Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
4.1216E+03	0.0000E+00	0.0000E+00	0.0000E+00	7.8234E+05	0.0000E+00
0.0000E+00	3.1484E+03	0.0000E+00	-1.0999E+06	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	5.4790E+04	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-1.0999E+06	0.0000E+00	1.3038E+09	0.0000E+00	0.0000E+00
7.8234E+05	0.0000E+00	0.0000E+00	0.0000E+00	5.4543E+08	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	8.8305E+07

Note: units = lb,in,sec; stiffness (translation=lb/in, rotation=lb-in/rad); mass (translation=lb-sec^2/in, rotation=lb-in-sec^2/rad); damping (translation=lb-sec/in, rotation=lb-in-sec/rad).

TABLE G-40: PIER 40 - PILE GROUP CONDENSED MATRICES AT PILE-CAP

Number of Piles = 12 Pile Diameter = 30 inch Footing Bottom El = +2.5'

6x6 Stiffness Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
5.4130E+05	0.0000E+00	0.0000E+00	0.0000E+00	1.0670E+08	0.0000E+00
0.0000E+00	4.0950E+05	0.0000E+00	-1.4990E+08	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	7.4060E+06	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-1.4990E+08	0.0000E+00	1.7670E+11	0.0000E+00	0.0000E+00
1.0670E+08	0.0000E+00	0.0000E+00	0.0000E+00	7.4190E+10	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	1.1470E+10

6x6 Mass Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
6.4630E+02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	6.1660E+02	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	2.1940E+03	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	4.7190E+07	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	1.6800E+07	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	1.8180E+07

6x6 Damping Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
3.9192E+03	0.0000E+00	0.0000E+00	0.0000E+00	7.5475E+05	0.0000E+00
0.0000E+00	2.9827E+03	0.0000E+00	-1.0603E+06	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	5.2693E+04	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	-1.0603E+06	0.0000E+00	1.2565E+09	0.0000E+00	0.0000E+00
7.5475E+05	0.0000E+00	0.0000E+00	0.0000E+00	5.2714E+08	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	8.3673E+07

Note: units = lb,in,sec; stiffness (translation=lb/in, rotation=lb-in/rad); mass (translation=lb-sec^2/in, rotation=lb-in-sec^2/rad); damping (translation=lb-sec/in, rotation=lb-in-sec/rad).

TABLE G-41: PIER 41 - PILE GROUP CONDENSED MATRICES AT PILE-CAP

Number of Piles = 14 Pile Cross-Section = 14x14 inch Footing Bottom El = -13'

6x6 Stiffness Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
9.7540E+04	0.0000E+00	0.0000E+00	0.0000E+00	-8.4950E+06	0.0000E+00
0.0000E+00	9.7540E+04	0.0000E+00	8.4950E+06	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	4.4690E+06	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	8.4950E+06	0.0000E+00	1.4290E+11	0.0000E+00	0.0000E+00
-8.4950E+06	0.0000E+00	0.0000E+00	0.0000E+00	6.2260E+09	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	3.1950E+09

6x6 Mass Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
7.1900E+01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	7.1900E+01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	4.4590E+02	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	1.4120E+07	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	4.8560E+05	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	2.3550E+06

6x6 Damping Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
7.0000E+02	0.0000E+00	0.0000E+00	0.0000E+00	-6.0090E+04	0.0000E+00
0.0000E+00	7.0000E+02	0.0000E+00	6.0090E+04	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	3.1674E+04	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	6.0090E+04	0.0000E+00	1.0128E+09	0.0000E+00	0.0000E+00
-6.0090E+04	0.0000E+00	0.0000E+00	0.0000E+00	4.4108E+07	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	2.2929E+07

Note: units = lb,in,sec; stiffness (translation=lb/in, rotation=lb-in/rad); mass (translation=lb-sec^2/in, rotation=lb-in-sec^2/rad); damping (translation=lb-sec/in, rotation=lb-in-sec/rad).

TABLE G-42: PIERS 42~46 - PILE GROUP CONDENSED MATRICES AT PILE-CAP

Number of Piles = 4 Pile Cross-Section = 12x12 inch Footing Bottom El = -12'

6x6 Stiffness Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
2.0440E+04	0.0000E+00	0.0000E+00	0.0000E+00	-1.5160E+06	0.0000E+00
0.0000E+00	2.0440E+04	0.0000E+00	1.5160E+06	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	9.9510E+05	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	1.5160E+06	0.0000E+00	2.4820E+10	0.0000E+00	0.0000E+00
-1.5160E+06	0.0000E+00	0.0000E+00	0.0000E+00	2.0650E+08	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	5.0560E+08

6x6 Mass Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
1.3460E+01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	1.3460E+01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	8.9580E+01	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	2.2160E+06	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	3.3290E+05

6x6 Damping Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
1.4646E+02	0.0000E+00	0.0000E+00	0.0000E+00	-1.0724E+04	0.0000E+00
0.0000E+00	1.4646E+02	0.0000E+00	1.0724E+04	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	7.0514E+03	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	1.0724E+04	0.0000E+00	1.7588E+08	0.0000E+00	0.0000E+00
-1.0724E+04	0.0000E+00	0.0000E+00	0.0000E+00	1.4607E+06	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	3.6229E+06

Note: units = lb,in,sec; stiffness (translation=lb/in, rotation=lb-in/rad); mass (translation=lb-sec^2/in, rotation=lb-in-sec^2/rad); damping (translation=lb-sec/in, rotation=lb-in-sec/rad).

TABLE G-43: PIERS 47~51 - PILE GROUP CONDENSED MATRICES AT PILE-CAP

Number of Piles = 4 Pile Cross-Section = 12x12 inch Footing Bottom El = -12'

6x6 Stiffness Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
1.9990E+04	0.0000E+00	0.0000E+00	0.0000E+00	-1.5170E+06	0.0000E+00
0.0000E+00	1.9990E+04	0.0000E+00	1.5170E+06	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	1.1460E+06	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	1.5170E+06	0.0000E+00	2.8560E+10	0.0000E+00	0.0000E+00
-1.5170E+06	0.0000E+00	0.0000E+00	0.0000E+00	2.0610E+08	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	4.9430E+08

6x6 Mass Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
1.3590E+01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	1.3590E+01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	8.4660E+01	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	2.0940E+06	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	3.3620E+05

6x6 Damping Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
1.4330E+02	0.0000E+00	0.0000E+00	0.0000E+00	-1.0731E+04	0.0000E+00
0.0000E+00	1.4330E+02	0.0000E+00	1.0731E+04	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	8.1182E+03	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	1.0731E+04	0.0000E+00	2.0231E+08	0.0000E+00	0.0000E+00
-1.0731E+04	0.0000E+00	0.0000E+00	0.0000E+00	1.4579E+06	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	3.5434E+06

Note: units = lb,in,sec; stiffness (translation=lb/in, rotation=lb-in/rad); mass (translation=lb-sec^2/in, rotation=lb-in-sec^2/rad); damping (translation=lb-sec/in, rotation=lb-in-sec/rad).

TABLE G-44: PIERS 52 AND 53 - PILE GROUP CONDENSED MATRICES AT PILE-CAP

Number of Piles = 4 Pile Cross-Section = 12x12 inch Footing Bottom El = -12'

6x6 Stiffness Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
1.9320E+04	0.0000E+00	0.0000E+00	0.0000E+00	-1.5090E+06	0.0000E+00
0.0000E+00	1.9320E+04	0.0000E+00	1.5090E+06	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	1.0500E+06	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	1.5090E+06	0.0000E+00	2.6170E+10	0.0000E+00	0.0000E+00
-1.5090E+06	0.0000E+00	0.0000E+00	0.0000E+00	2.0790E+08	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	4.7790E+08

6x6 Mass Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
1.3460E+01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	1.3460E+01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	8.4560E+01	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	2.0910E+06	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	3.3300E+05

6x6 Damping Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
1.3854E+02	0.0000E+00	0.0000E+00	0.0000E+00	-1.0674E+04	0.0000E+00
0.0000E+00	1.3854E+02	0.0000E+00	1.0674E+04	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	7.4391E+03	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	1.0674E+04	0.0000E+00	1.8541E+08	0.0000E+00	0.0000E+00
-1.0674E+04	0.0000E+00	0.0000E+00	0.0000E+00	1.4706E+06	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	3.4270E+06

Note: units = lb,in,sec; stiffness (translation=lb/in, rotation=lb-in/rad); mass (translation=lb-sec^2/in, rotation=lb-in-sec^2/rad); damping (translation=lb-sec/in, rotation=lb-in-sec/rad).

TABLE G-45: PIERS 54 ~56 - PILE GROUP CONDENSED MATRICES AT PILE-CAP

Number of Piles = 4 Pile Cross-Section = 12x12 inch Footing Bottom El = -13'

6x6 Stiffness Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
1.9520E+04	0.0000E+00	0.0000E+00	0.0000E+00	-1.5250E+06	0.0000E+00
0.0000E+00	1.9520E+04	0.0000E+00	1.5250E+06	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	1.0340E+06	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	1.5250E+06	0.0000E+00	2.5790E+10	0.0000E+00	0.0000E+00
-1.5250E+06	0.0000E+00	0.0000E+00	0.0000E+00	2.0930E+08	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	4.8280E+08

6x6 Mass Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
1.3370E+01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	1.3370E+01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	8.1730E+01	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	2.0220E+06	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	3.3070E+05

6x6 Damping Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
1.3994E+02	0.0000E+00	0.0000E+00	0.0000E+00	-1.0787E+04	0.0000E+00
0.0000E+00	1.3994E+02	0.0000E+00	1.0787E+04	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	7.3255E+03	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	1.0787E+04	0.0000E+00	1.8271E+08	0.0000E+00	0.0000E+00
-1.0787E+04	0.0000E+00	0.0000E+00	0.0000E+00	1.4805E+06	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	3.4613E+06

Note: units = lb,in,sec; stiffness (translation=lb/in, rotation=lb-in/rad); mass (translation=lb-sec^2/in, rotation=lb-in-sec^2/rad); damping (translation=lb-sec/in, rotation=lb-in-sec/rad).

TABLE G-46: PIERS 57 AND 58 – PILE GROUP CONDENSED MATRICES AT PILE-CAP

Number of Piles = 4 Pile Cross-Section = 12x12 inch Footing Bottom El = -13'

6x6 Stiffness Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
3.2780E+04	0.0000E+00	0.0000E+00	0.0000E+00	-2.4480E+06	0.0000E+00
0.0000E+00	3.2780E+04	0.0000E+00	2.4480E+06	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	1.0860E+06	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	2.4480E+06	0.0000E+00	2.7140E+10	0.0000E+00	0.0000E+00
-2.4480E+06	0.0000E+00	0.0000E+00	0.0000E+00	2.7640E+08	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	8.1070E+08

6x6 Mass Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
1.0020E+01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	1.0020E+01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	8.0930E+01	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	2.0020E+06	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	2.4790E+05

6x6 Damping Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
2.3327E+02	0.0000E+00	0.0000E+00	0.0000E+00	-1.7316E+04	0.0000E+00
0.0000E+00	2.3327E+02	0.0000E+00	1.7316E+04	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	7.6932E+03	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	1.7316E+04	0.0000E+00	1.9226E+08	0.0000E+00	0.0000E+00
-1.7316E+04	0.0000E+00	0.0000E+00	0.0000E+00	1.9551E+06	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	5.7692E+06

Note: units = lb,in,sec; stiffness (translation=lb/in, rotation=lb-in/rad); mass (translation=lb-sec^2/in, rotation=lb-in-sec^2/rad); damping (translation=lb-sec/in, rotation=lb-in-sec/rad).

TABLE G-47: PIERS 59~62 – PILE GROUP CONDENSED MATRICES AT PILE-CAP

Number of Piles = 4 Pile Cross-Section = 12x12 inch Footing Bottom El = -13'

6x6 Stiffness Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
3.0270E+04	0.0000E+00	0.0000E+00	0.0000E+00	-2.3350E+06	0.0000E+00
0.0000E+00	3.0270E+04	0.0000E+00	2.3350E+06	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	1.1340E+06	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	2.3350E+06	0.0000E+00	2.8320E+10	0.0000E+00	0.0000E+00
-2.3350E+06	0.0000E+00	0.0000E+00	0.0000E+00	2.7100E+08	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	7.4870E+08

6x6 Mass Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
1.0180E+01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	1.0180E+01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	7.8960E+01	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	1.9530E+06	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	2.5190E+05

6x6 Damping Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
2.1554E+02	0.0000E+00	0.0000E+00	0.0000E+00	-1.6517E+04	0.0000E+00
0.0000E+00	2.1554E+02	0.0000E+00	1.6517E+04	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	8.0325E+03	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	1.6517E+04	0.0000E+00	2.0060E+08	0.0000E+00	0.0000E+00
-1.6517E+04	0.0000E+00	0.0000E+00	0.0000E+00	1.9169E+06	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	5.3312E+06

Note: units = lb,in,sec; stiffness (translation=lb/in, rotation=lb-in/rad); mass (translation=lb-sec^2/in, rotation=lb-in-sec^2/rad); damping (translation=lb-sec/in, rotation=lb-in-sec/rad).

TABLE G-48: PIERS 63~67 – PILE GROUP CONDENSED MATRICES AT PILE-CAP

Number of Piles = 4 Pile Cross-Section = 12x12 inch Footing Bottom El = -15'

6x6 Stiffness Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
3.3570E+04	0.0000E+00	0.0000E+00	0.0000E+00	-2.5000E+06	0.0000E+00
0.0000E+00	3.3570E+04	0.0000E+00	2.5000E+06	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	1.1240E+06	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	2.5000E+06	0.0000E+00	2.8080E+10	0.0000E+00	0.0000E+00
-2.5000E+06	0.0000E+00	0.0000E+00	0.0000E+00	2.8160E+08	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	8.3020E+08

6x6 Mass Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
9.5940E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	9.5940E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	7.7970E+01	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	1.9280E+06	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	2.3730E+05

6x6 Damping Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
2.3880E+02	0.0000E+00	0.0000E+00	0.0000E+00	-1.7684E+04	0.0000E+00
0.0000E+00	2.3880E+02	0.0000E+00	1.7684E+04	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	7.9616E+03	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	1.7684E+04	0.0000E+00	1.9890E+08	0.0000E+00	0.0000E+00
-1.7684E+04	0.0000E+00	0.0000E+00	0.0000E+00	1.9919E+06	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	5.9056E+06

Note: units = lb,in,sec; stiffness (translation=lb/in, rotation=lb-in/rad); mass (translation=lb-sec^2/in, rotation=lb-in-sec^2/rad); damping (translation=lb-sec/in, rotation=lb-in-sec/rad).

TABLE G-49: PIERS 68~70 – PILE GROUP CONDENSED MATRICES AT PILE-CAP

Number of Piles = 4 Pile Cross-Section = 12x12 inch Footing Bottom El = -15'

6x6 Stiffness Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
3.9640E+04	0.0000E+00	0.0000E+00	0.0000E+00	-2.7840E+06	0.0000E+00
0.0000E+00	3.9640E+04	0.0000E+00	2.7840E+06	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	1.1430E+06	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	2.7840E+06	0.0000E+00	2.8560E+10	0.0000E+00	0.0000E+00
-2.7840E+06	0.0000E+00	0.0000E+00	0.0000E+00	2.9500E+08	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	9.8050E+08

6x6 Mass Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
9.4500E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	9.4500E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	7.7650E+01	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	1.9200E+06	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	2.3370E+05

6x6 Damping Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
2.8172E+02	0.0000E+00	0.0000E+00	0.0000E+00	-1.9693E+04	0.0000E+00
0.0000E+00	2.8172E+02	0.0000E+00	1.9693E+04	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	8.0960E+03	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	1.9693E+04	0.0000E+00	2.0229E+08	0.0000E+00	0.0000E+00
-1.9693E+04	0.0000E+00	0.0000E+00	0.0000E+00	2.0867E+06	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	6.9683E+06

Note: units = lb,in,sec; stiffness (translation=lb/in, rotation=lb-in/rad); mass (translation=lb-sec^2/in, rotation=lb-in-sec^2/rad); damping (translation=lb-sec/in, rotation=lb-in-sec/rad).

TABLE G-50: ABUTMENT 71 - PILE GROUP CONDENSED MATRICES AT PILE-CAP

Number of Piles = 4 Pile Cross-Section = 12x12 inch Footing Bottom El = -8'

6x6 Stiffness Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
3.5750E+04	0.0000E+00	0.0000E+00	0.0000E+00	-2.1330E+06	0.0000E+00
0.0000E+00	3.5750E+04	0.0000E+00	2.1330E+06	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	1.2750E+06	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	2.1330E+06	0.0000E+00	3.7060E+10	0.0000E+00	0.0000E+00
-2.1330E+06	0.0000E+00	0.0000E+00	0.0000E+00	2.5010E+08	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	1.0320E+09

6x6 Mass Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
1.1000E+01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	1.1000E+01	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	7.8050E+01	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	2.2540E+06	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	3.1780E+05

6x6 Damping Matrix

DIS-X	DIS-Y	DIS-Z	ROT-X	ROT-Y	ROT-Z
2.5442E+02	0.0000E+00	0.0000E+00	0.0000E+00	-1.5088E+04	0.0000E+00
0.0000E+00	2.5442E+02	0.0000E+00	1.5088E+04	0.0000E+00	0.0000E+00
0.0000E+00	0.0000E+00	9.0297E+03	0.0000E+00	0.0000E+00	0.0000E+00
0.0000E+00	1.5088E+04	0.0000E+00	2.6246E+08	0.0000E+00	0.0000E+00
-1.5088E+04	0.0000E+00	0.0000E+00	0.0000E+00	1.7691E+06	0.0000E+00
0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	7.3443E+06

Pushover Analysis and Evaluation Pile Group Stiffness Antioch Bridge

Drafted: 10/23/08

Introduction

Earth Mechanics, Inc (EMI) provided CALTRANS designers pile group stiffness in a form of 6x6 stiffness matrix for the following conditions:

1. A fixed head assumption for all piles. This essentially represents the initial undamaged condition of the piles.
2. A pinned head assumption for the piles that are battered in the transverse direction. All vertical piles and those piles that are battered in the longitudinal direction remain fixed at the pile top. This approximately represents pile-top hinging at these piles that are battered in the transverse direction.
3. In addition to all scenarios described in 2, the t-z and q-u curves of the piles that are battered in the transverse direction are taken half. This effectively represents loss in axial pile capacity as well as plastic hinging for those transversely battered piles.
4. A pinned head assumption for all piles. This essentially represents plastic hinging of all the piles.

The question to be answered is which stiffness matrix is appropriate for the demand calculations of the global bridge model. To answer this, we have conducted non-linear pushover analyses and made comparisons of the pushover analysis results with the component of the stiffness coefficients used in the demand calculations.

For this study, we have chosen two different pile types at the following locations:

24” x 24” Square Concrete Piles: Piers 11 and Pier 30
54” Diameter Hollow Concrete Pile: Pier 19

Single Pile Pushover Analysis

Single pile pushover analyses were conducted with the moment-curvature relationship of the concrete pile section and the moment-rotation relationship of the pile-top/pile-cap connection provided by Professor Nigel Priestley. Soil supports were modeled by non-linear p-y curves. The analyses were performed for different axial loads as the moment-curvature and moment-rotation relationships vary with axial loads.

From our single pile pushover analysis, the solutions in terms of the pile-head shear versus pile-head deflection relationship are provided. Various limit states, such as limit-yield (LS1), serviceability (LS2), damage-control (LS3), and ultimate (LS4) are indicated on the pushover solutions. The details of the analysis as reviewed by Professor Nigel Priestley have been documented in an earlier report.

To make the comparison with the linear stiffness employed in the demand analysis, we have taken the single pile stiffness matrix for (1) the fixed head condition and (2) the pinned head condition. The linear stiffness is depicted as a straight line on the pushover solutions.

The time history analyses with isolation bearings provided the following peak displacement demands from three sets of earthquake time histories:

Pier 11: 6 inches (0.15 m)
Pier 19: 3 inches (0.08 m)
Pier 30: 1.5 inched (0.04 m)

Given the peak displacement demands, the linear stiffness with the fixed head assumption is appropriate for the demand calculations for all three piers.

Pile Group Pushover Analysis

Further pushover analyses were conducted on the pile group. A row of piles lined up the transverse direction was chosen for the pile group analysis, as follows:

Pier 11: 4 piles total (2 battered piles and 2 vertical piles)
Pier 19: 6 piles total (2 battered piles and 4 vertical piles)
Pier 30: 6 piles total (2 battered piles and 4 vertical piles)

The schematic of the pile group arrangement is provided in the attachment. It was anticipated that one of the battered pile would experience the largest axial load and the other battered pile would experience the smallest axial load during the lateral push. Hence, the moment-curvature and moment-rotation curves of the battered piles were assigned accordingly.

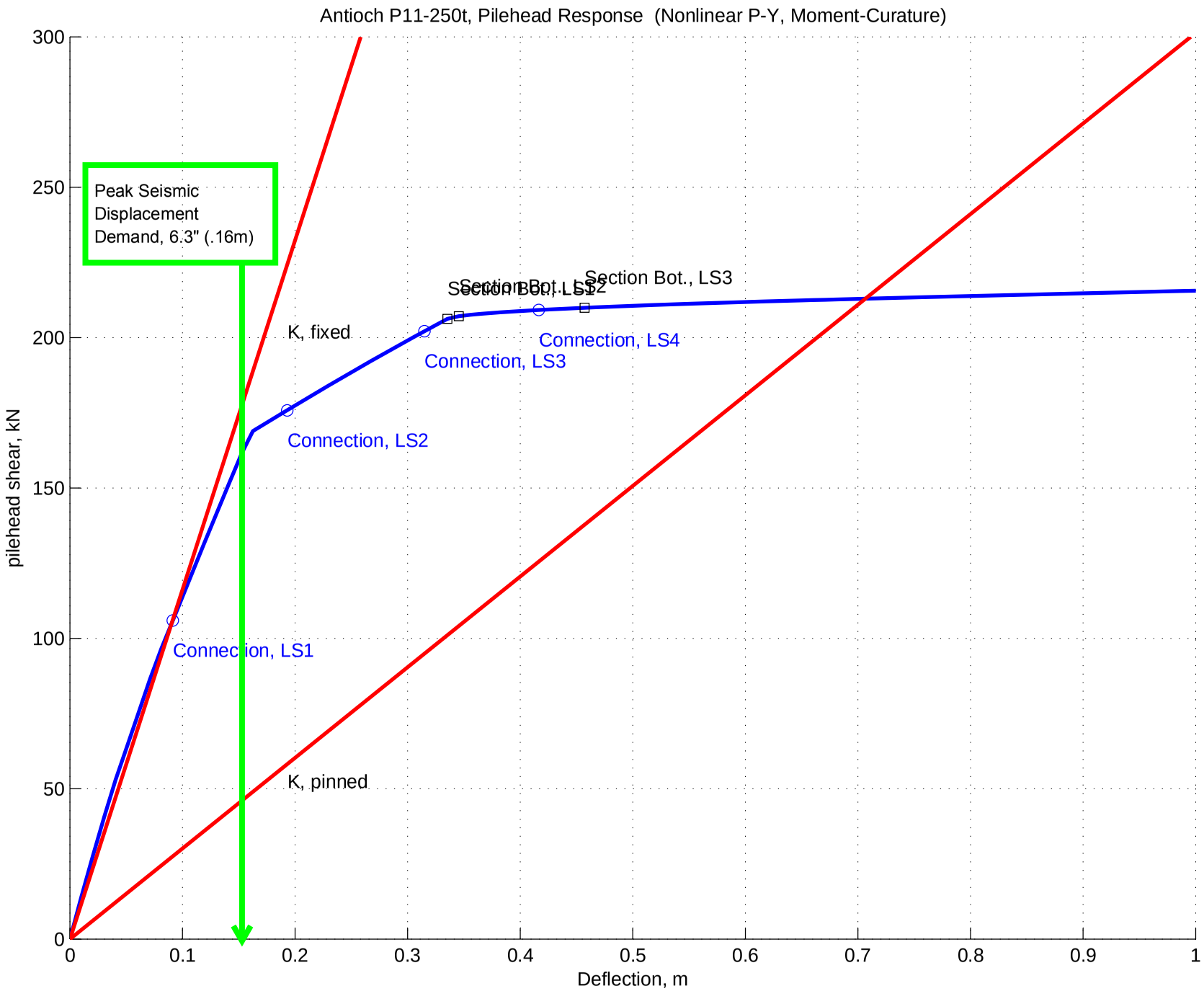
A vertical dead load was applied to the pile group prior to lateral pushing. The dead load was taken as the pile design load multiplied by the number of piles. Based on the pile group pushover analysis, the solution in terms of horizontal load versus horizontal displacement is provided. Occurrence of each limit state for each pile is noted on the solution.

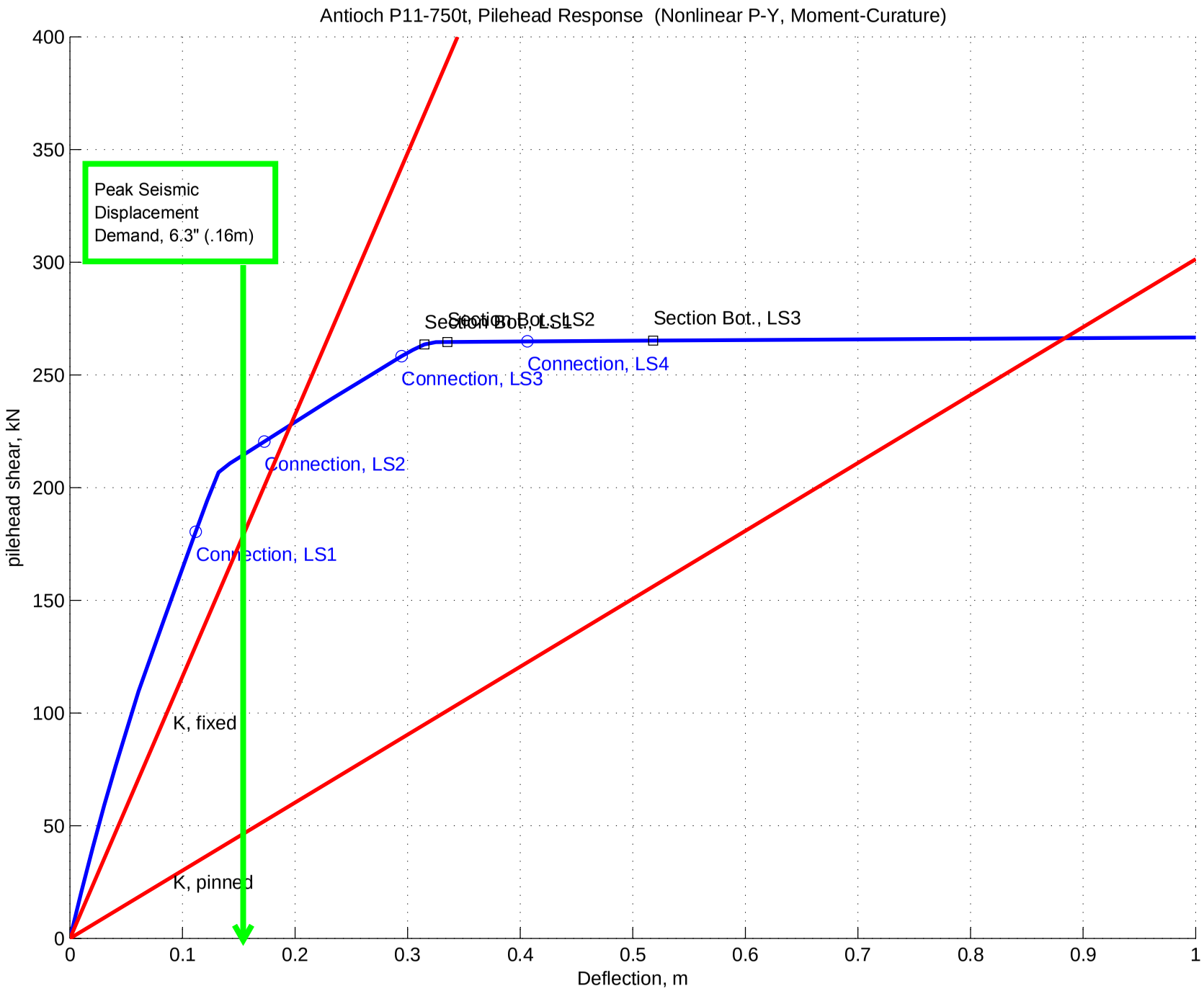
Similar to the single pile pushover analysis, a comparison of the pile group pushover analysis result with the linear pile group stiffness is illustrated on the solution. Again, judging from the peak displacement demand reported by the designers, the fixed head assumption is valid for the pile group stiffness matrix for the demand calculation.

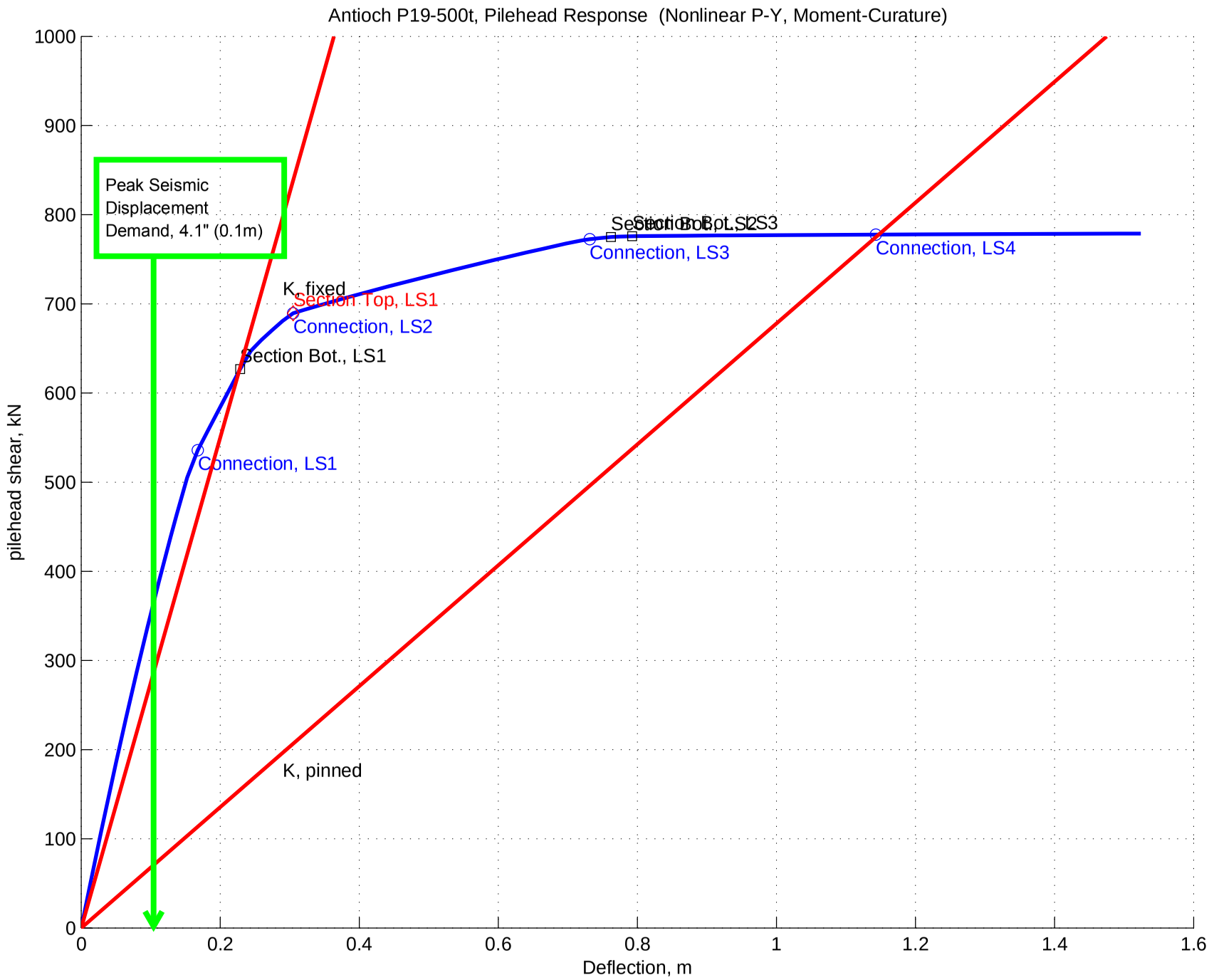
Also noted from the solutions, the displacement demands do not reach limits state LS3. Hence, pile damage is not anticipated.

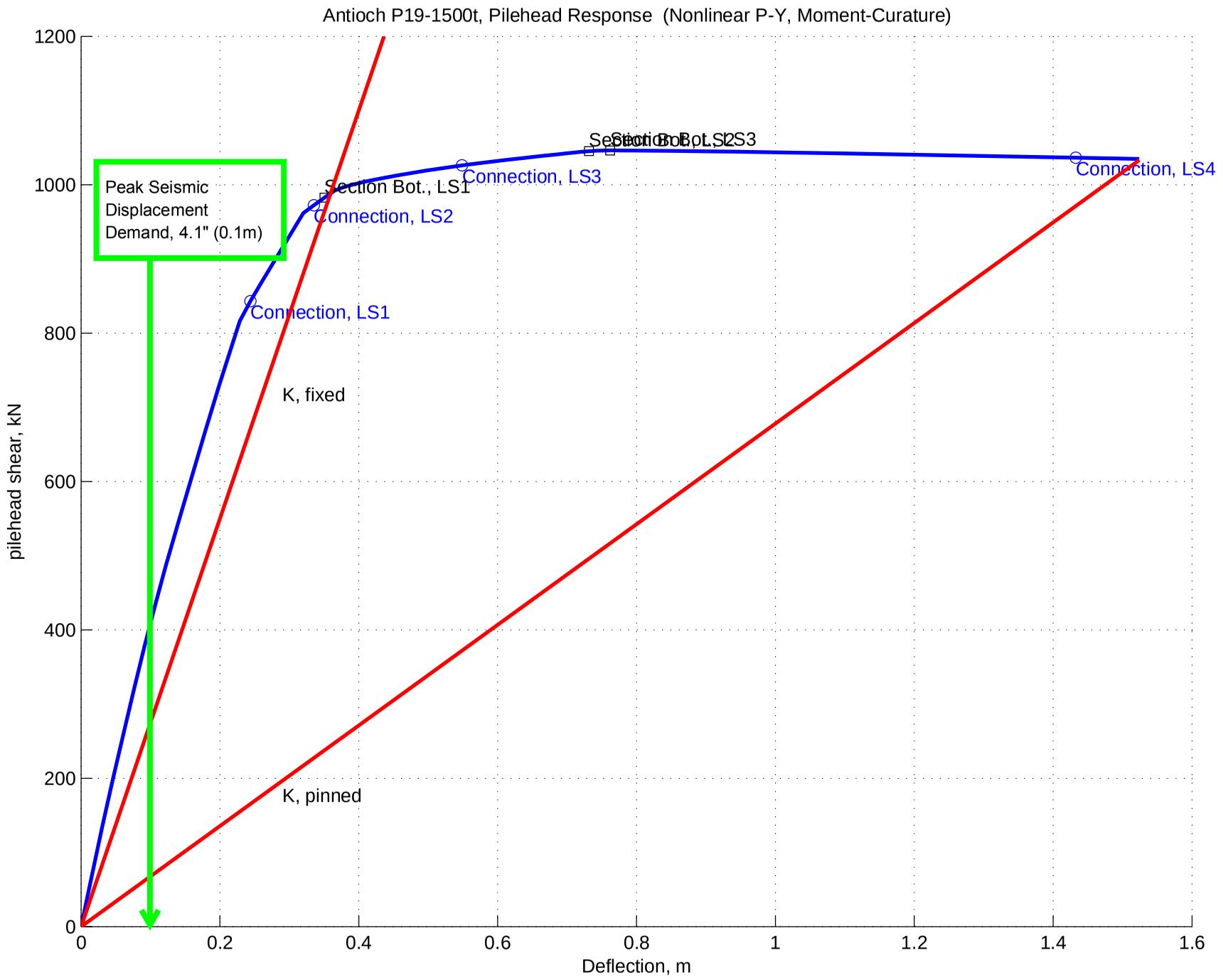
In addition to pile group response, pile deflection, moment, and curvature profiles of each pile are provided in the attachment.

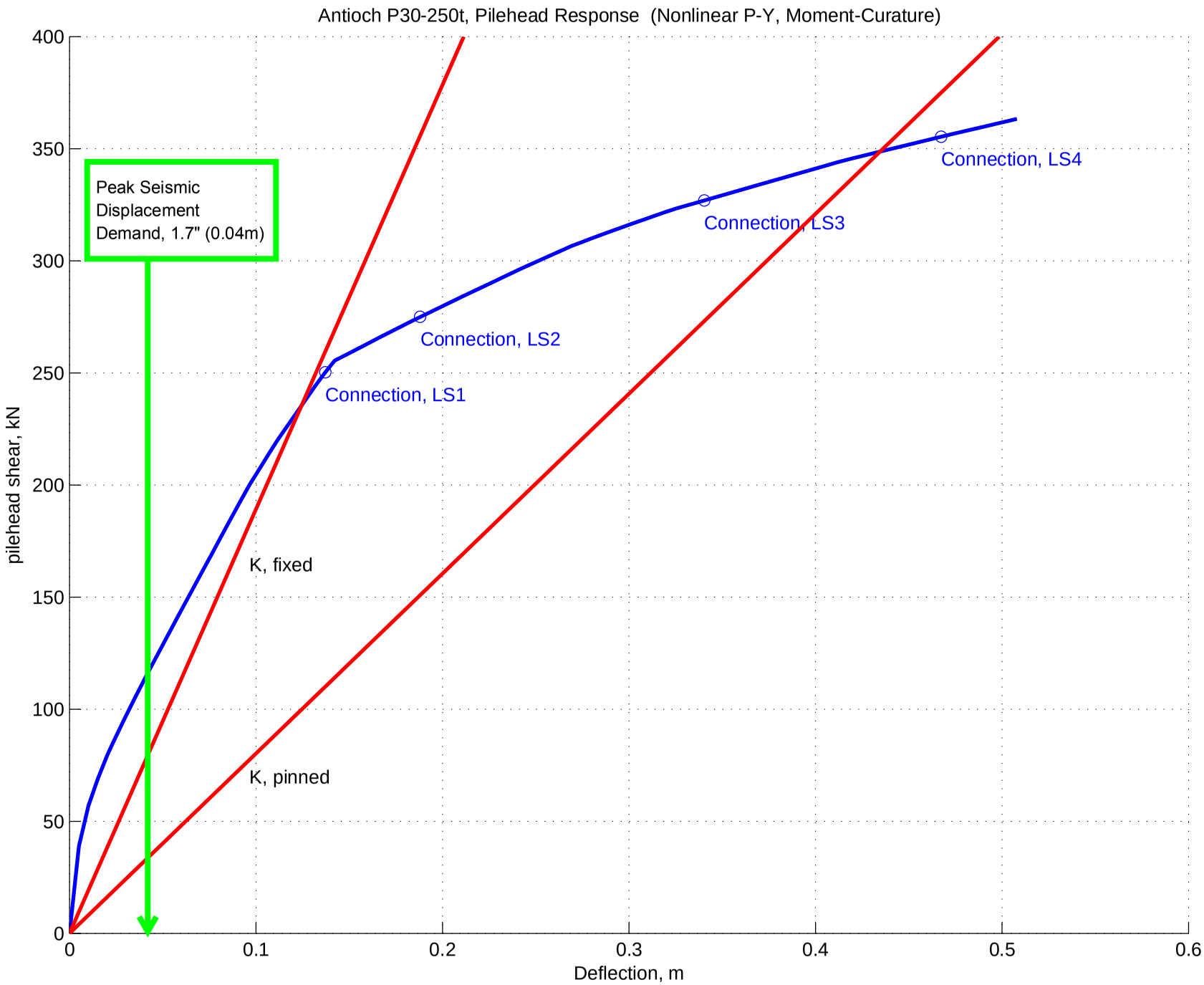
Single Pile Pushover Analysis

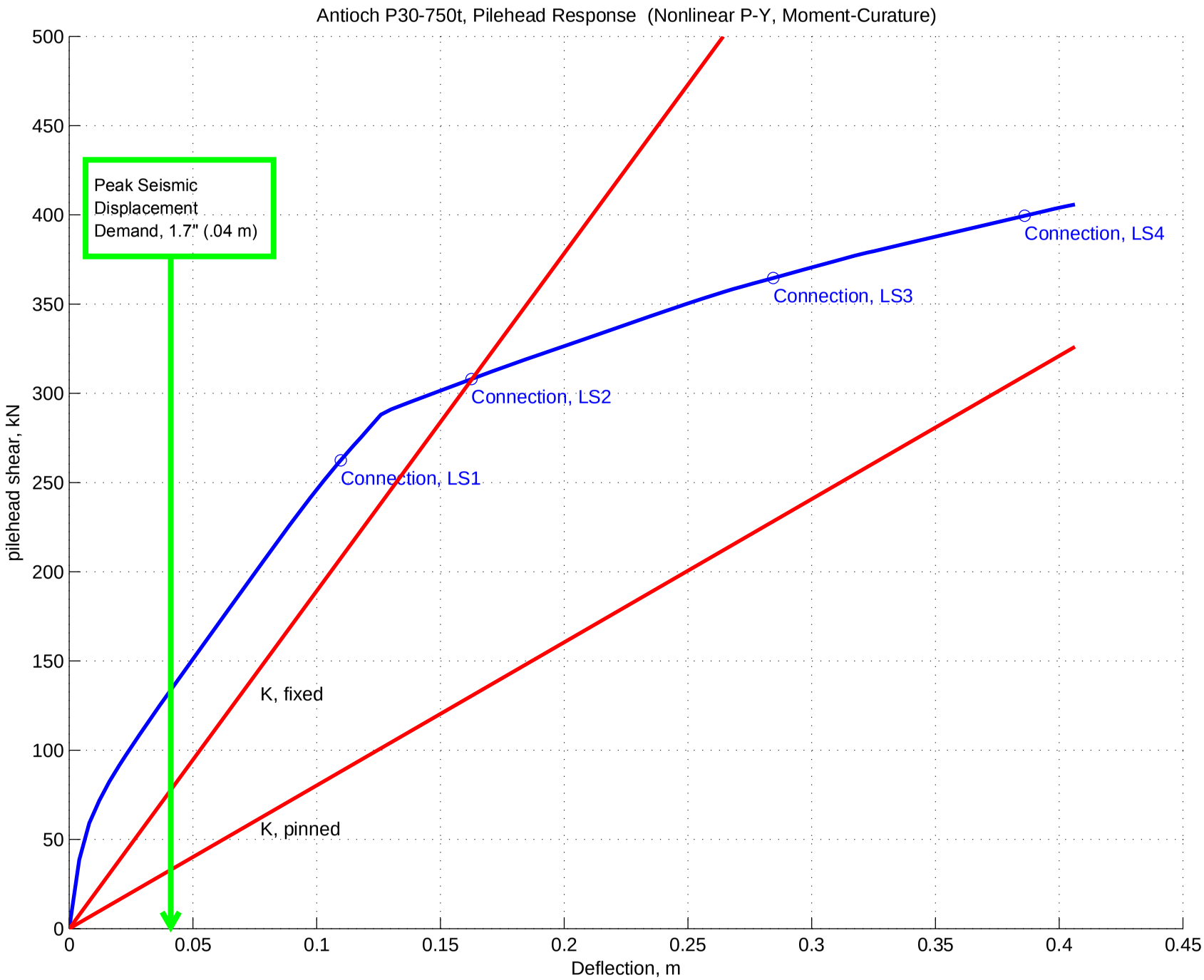

Antioch P11-250t, Pilehead Response (Nonlinear P-Y, Moment-Curature)
pilehead shear, kN
Deflection, m
300
250
200
150
100
50
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Peak Seismic
Displacement
Demand, 6.3" (.16m)
K, fixed
K, pinned
Connection, LS1
Connection, LS2
Connection, LS3
Connection, LS4
Section Bot., LS2
Section Bot., LS3

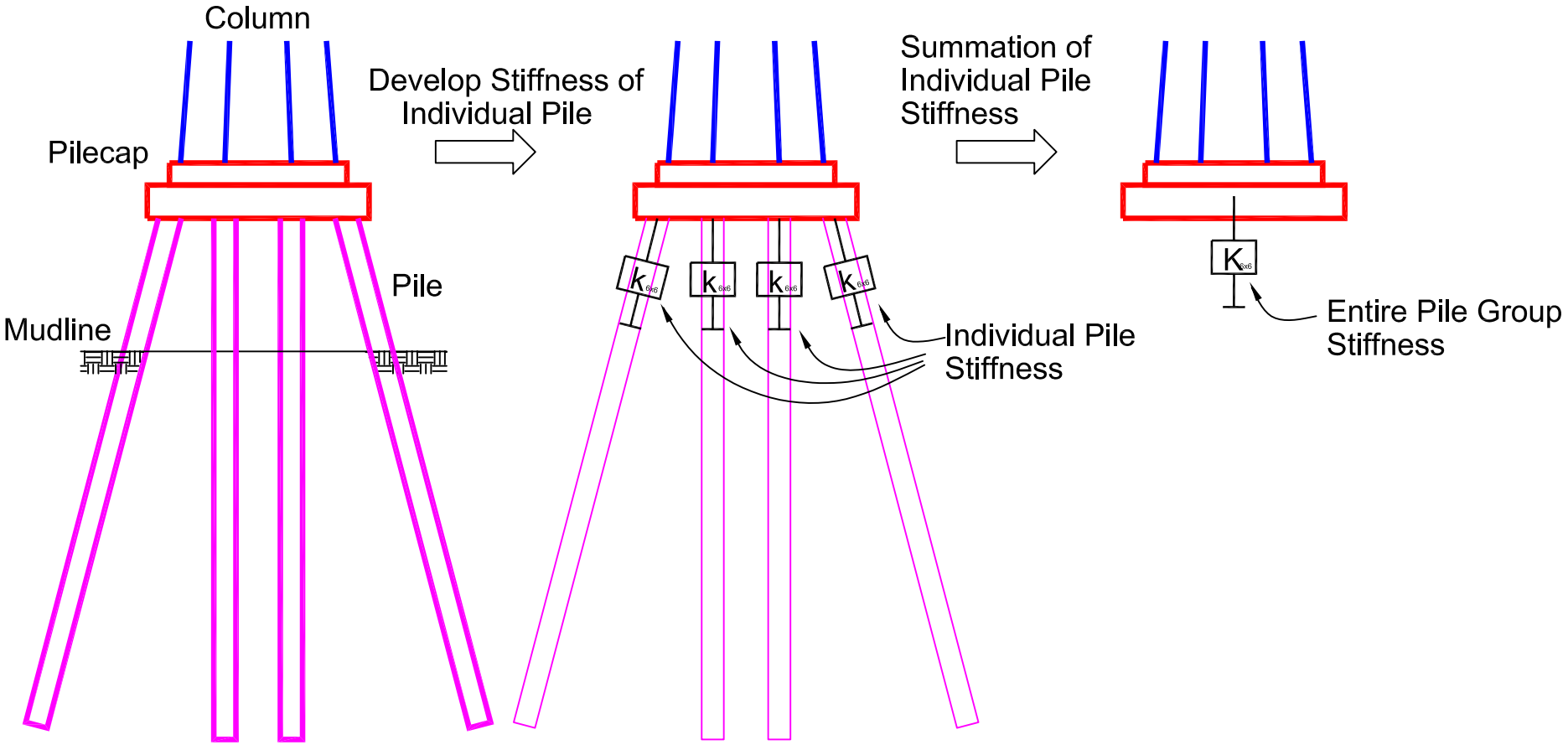

Antioch P11-750t, Pilehead Response (Nonlinear P-Y, Moment-Curature)
Peak Seismic
Displacement
Demand, 6.3" (.16m)
Section Bot., LS1
Section Bot., LS2
Section Bot., LS3
Connection, LS1
Connection, LS2
Connection, LS3
Connection, LS4
K, fixed
K, pinned
pilehead shear, kN
Deflection, m
0
50
100
150
200
250
300
350
400
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1


Antioch P19-500t, Pilehead Response (Nonlinear P-Y, Moment-Curature)
pilehead shear, kN
Deflection, m
Peak Seismic
Displacement
Demand, 4.1" (0.1m)
K, fixed
K, pinned
Section Top, LS1
Connection, LS2
Section Bot., LS1
Connection, LS1
Connection, LS3
Connection, LS4
0
100
200
300
400
500
600
700
800
900
1000
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6

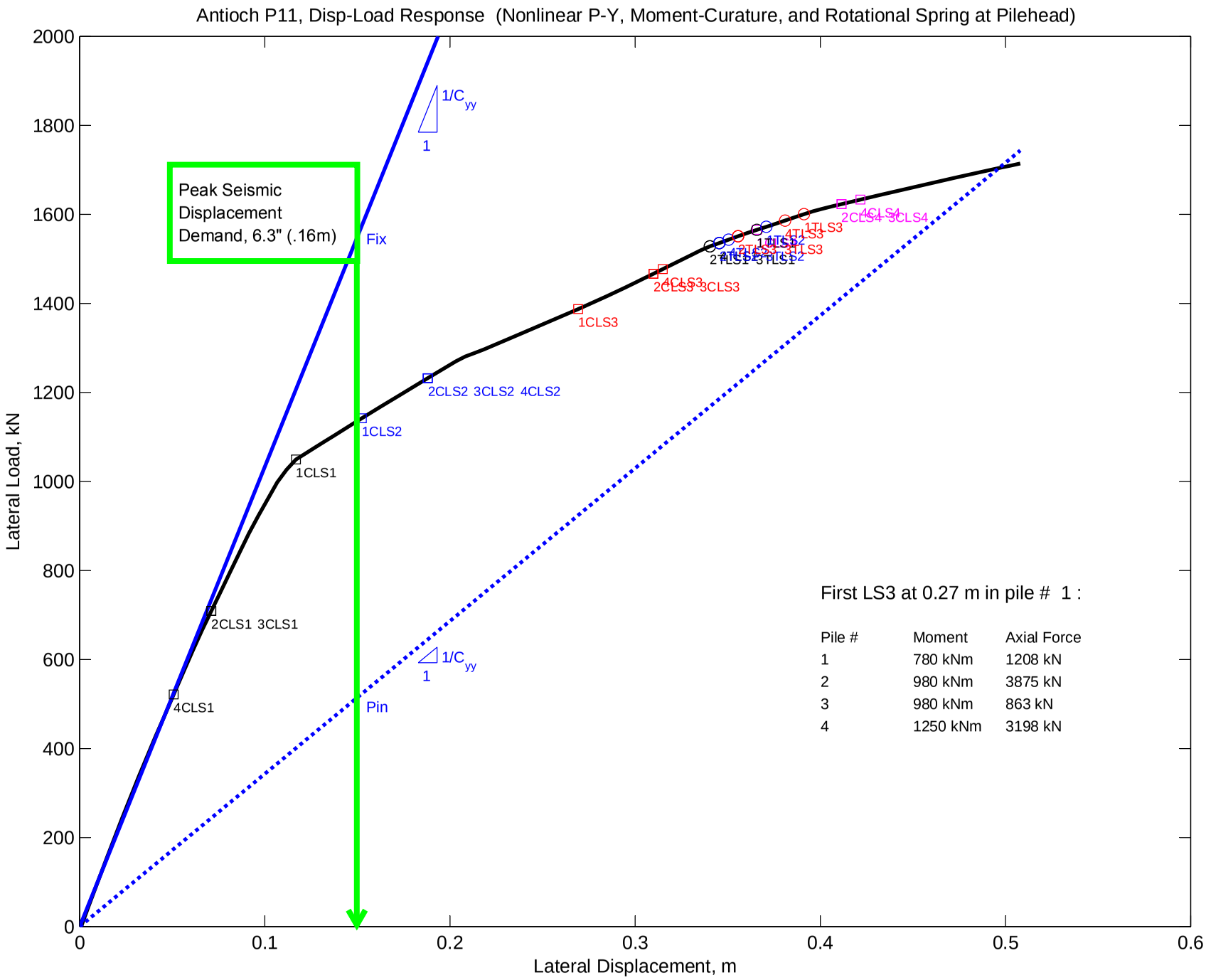

Antioch P19-1500t, Pilehead Response (Nonlinear P-Y, Moment-Curature)
pilehead shear, kN
Deflection, m
0
200
400
600
800
1000
1200
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
Peak Seismic
Displacement
Demand, 4.1" (0.1m)
Section Bot., LS1
Connection, LS1
Connection, LS2
Connection, LS3
Connection, LS4
K, fixed
K, pinned

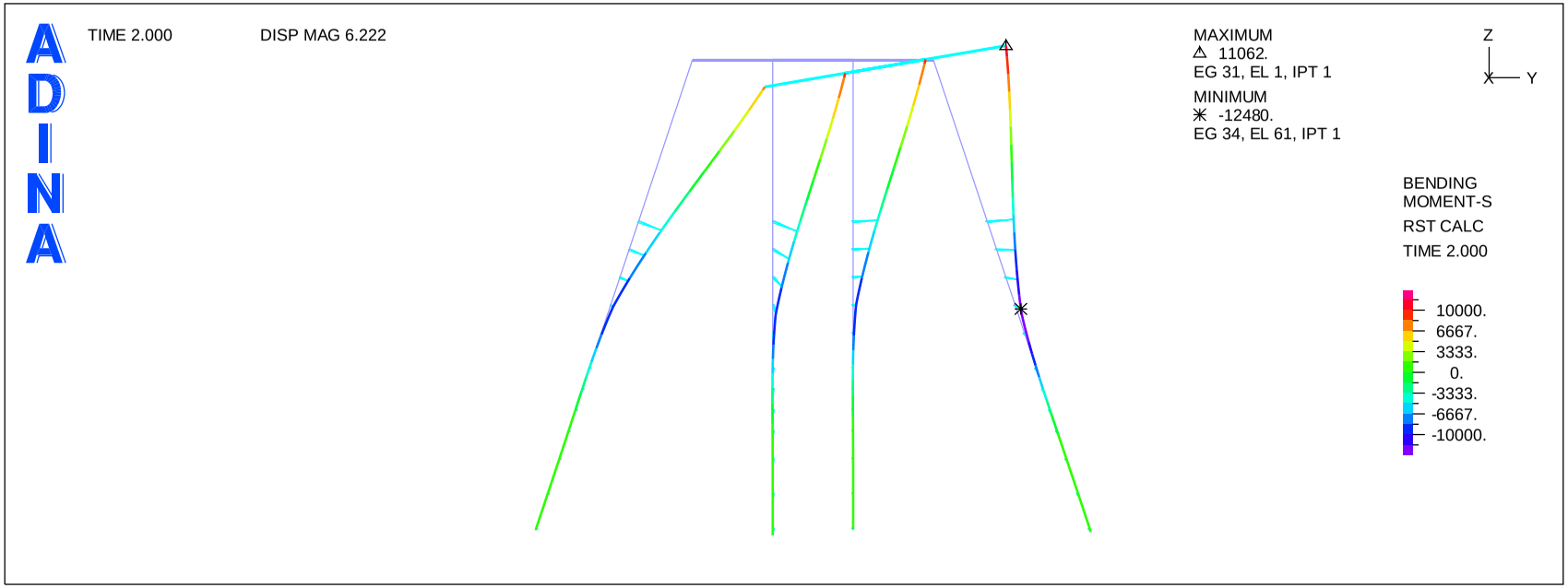

Antioch P30-250t, Pilehead Response (Nonlinear P-Y, Moment-Curature)
pilehead shear, kN
Deflection, m
0
50
100
150
200
250
300
350
400
0
0.1
0.2
0.3
0.4
0.5
0.6
Peak Seismic
Displacement
Demand, 1.7" (0.04m)
Connection, LS1
Connection, LS2
Connection, LS3
Connection, LS4
K, fixed
K, pinned

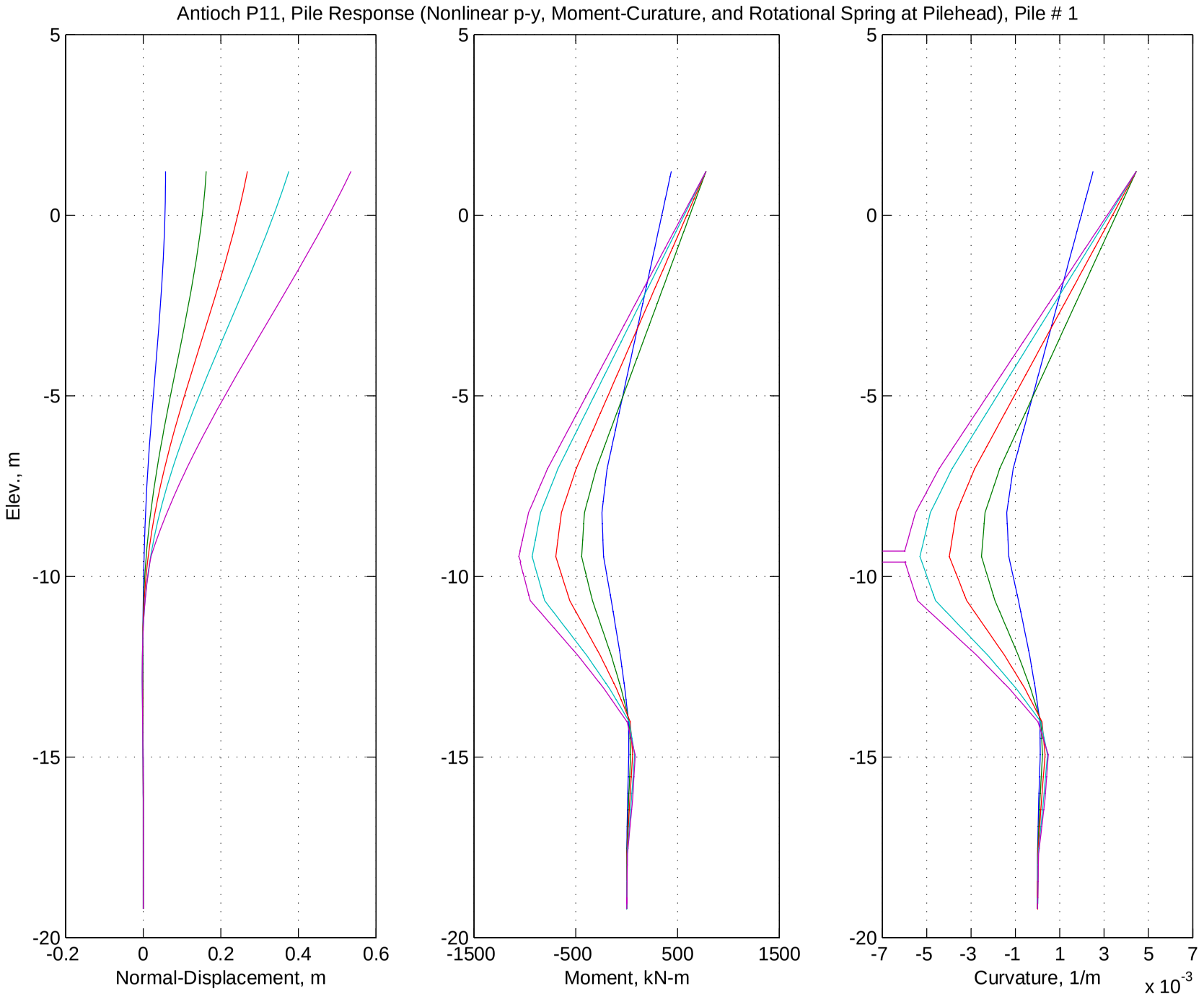

Antioch P30-750t, Pilehead Response (Nonlinear P-Y, Moment-Curature)
Peak Seismic
Displacement
Demand, 1.7" (.04 m)
Connection, LS1
Connection, LS2
Connection, LS3
Connection, LS4
K, fixed
K, pinned
pilehead shear, kN
Deflection, m
0
50
100
150
200
250
300
350
400
450
500
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45

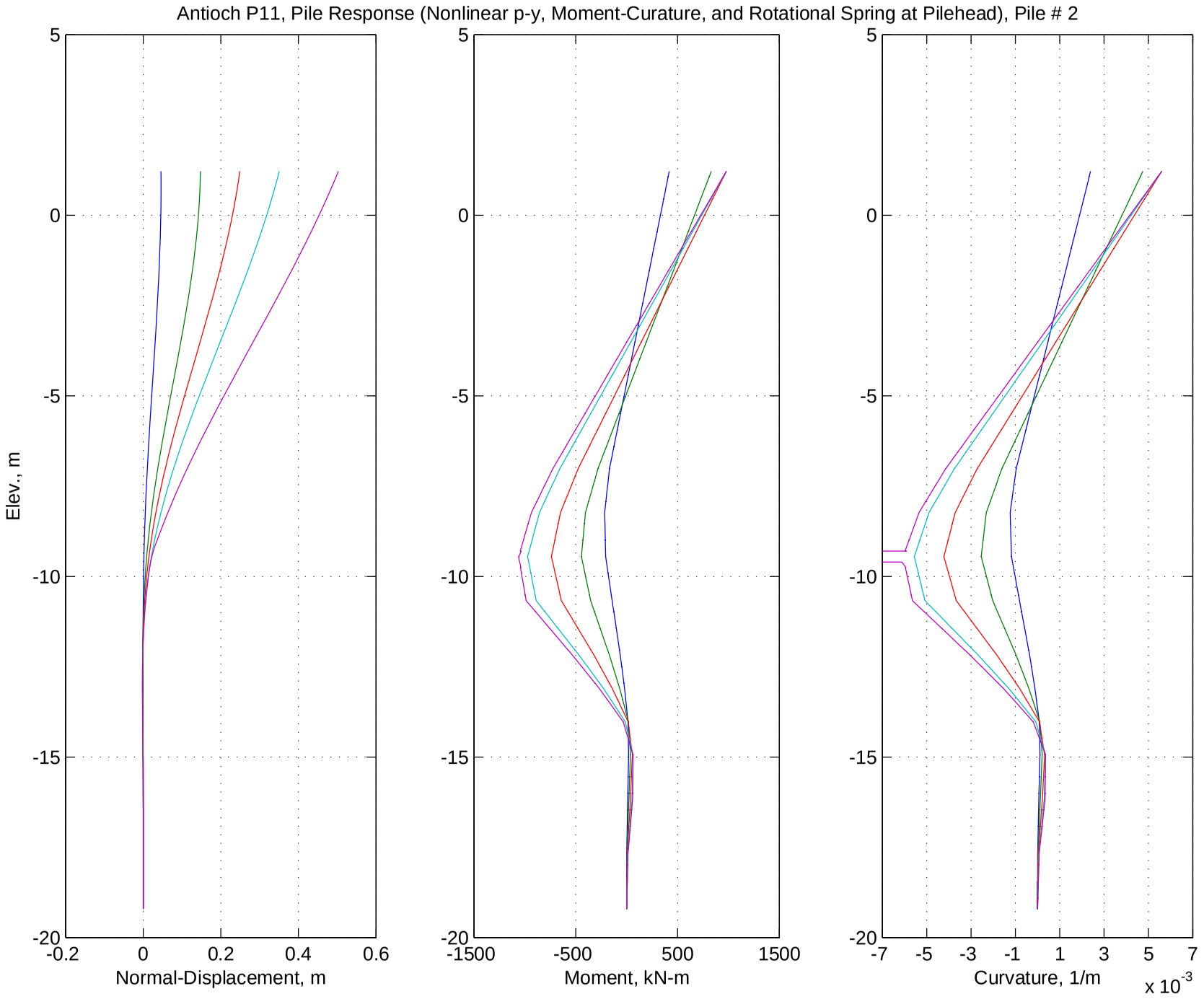

Column
Pilecap
Pile
Mudline
Develop Stiffness of
Individual Pile
Summation of
Individual Pile
Stiffness
Individual Pile
Stiffness
Entire Pile Group
Stiffness

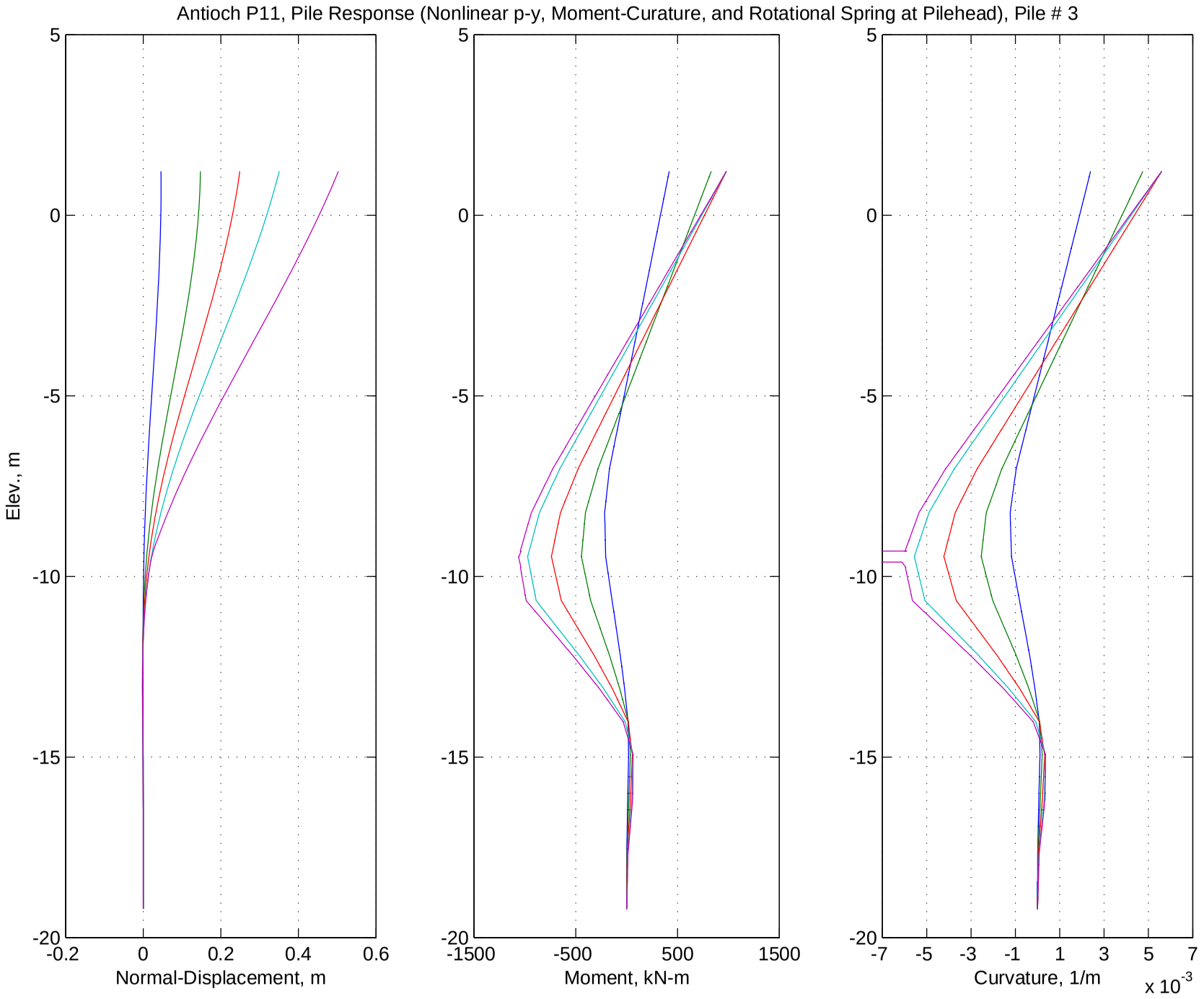
Pile Group Pushover Analysis

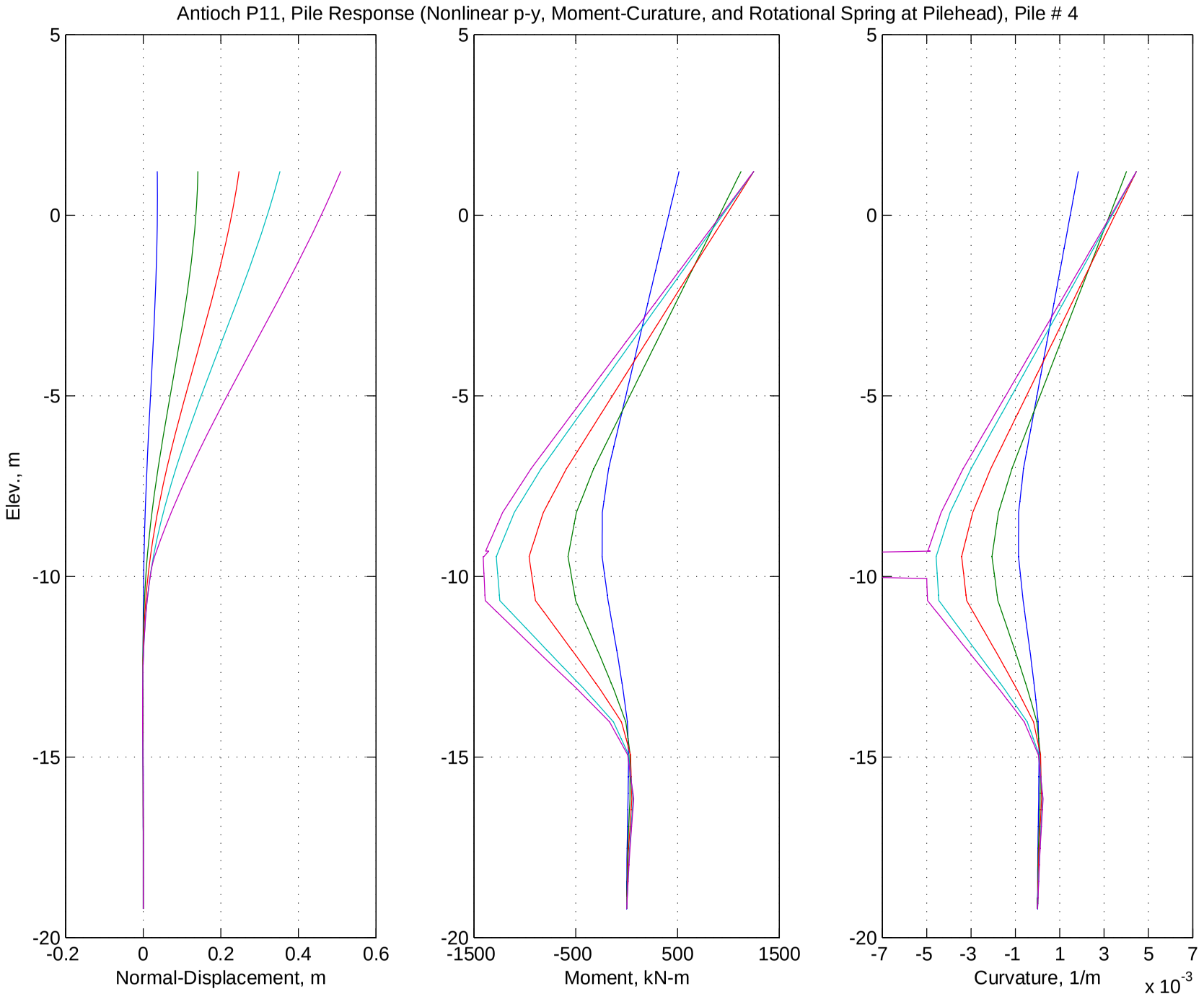

Antioch P11, Disp-Load Response (Nonlinear P-Y, Moment-Curature, and Rotational Spring at Pilehead)
Lateral Load, kN
Lateral Displacement, m
2000
1800
1600
1400
1200
1000
800
600
400
200
0
0
0.1
0.2
0.3
0.4
0.5
0.6
1/C yy
1
Peak Seismic
Displacement
Demand, 6.3" (.16m)
Fix
Pin
1/C yy
1
4CLS1
2CLS1 3CLS1
1CLS1
1CLS2
2CLS2 3CLS2 4CLS2
1CLS3
2CLS3 3CLS3
4CLS3
2CLS4 3CLS4
4CLS4
1TLS3
4TLS3
First LS3 at 0.27 m in pile # 1 :
Pile # Moment Axial Force
1 780 kNm 1208 kN
2 980 kNm 3875 kN
3 980 kNm 863 kN
4 1250 kNm 3198 kN

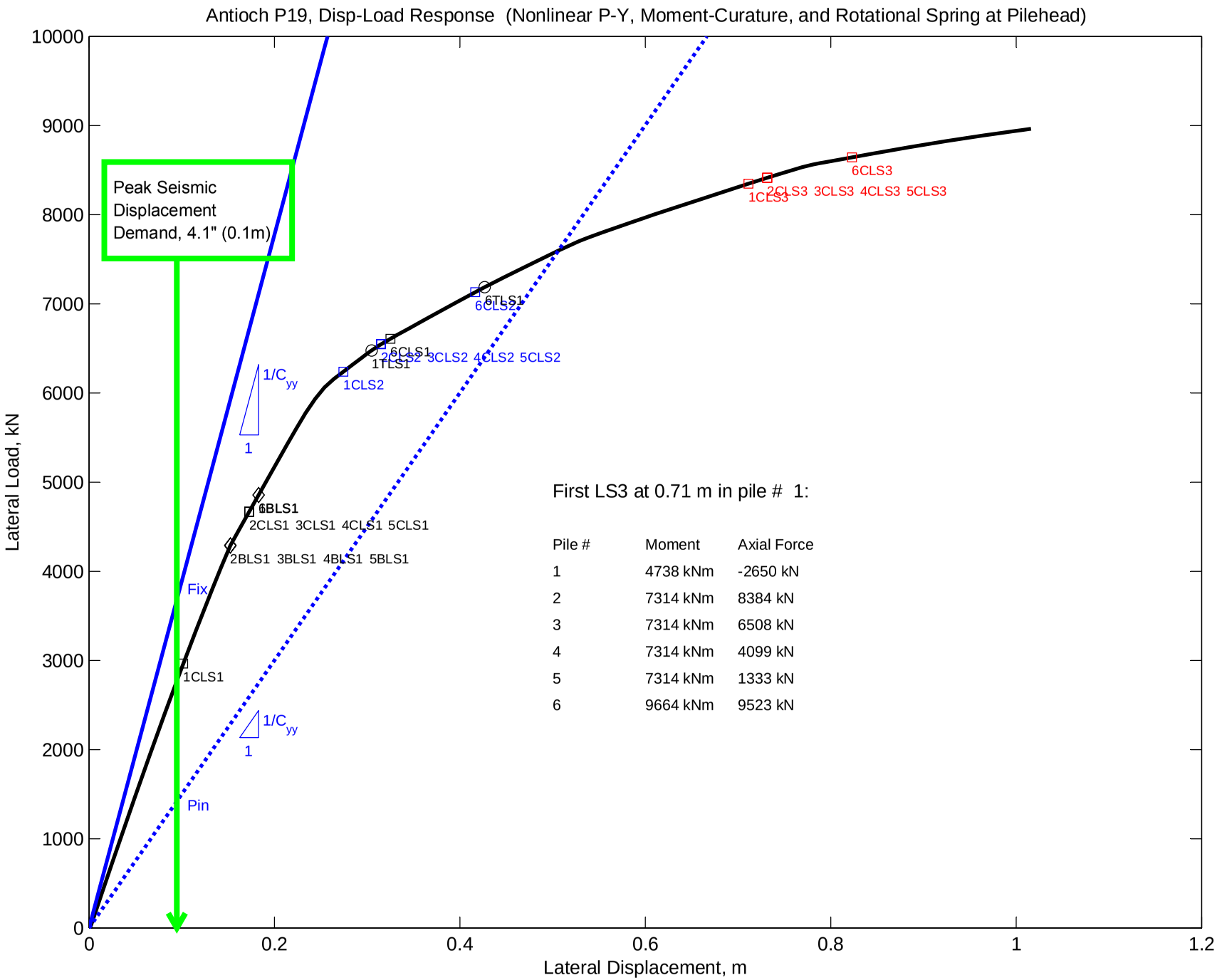

ADINA
TIME 2.000
DISP MAG 6.222
MAXIMUM
11062.
EG 31, EL 1, IPT 1
MINIMUM
-12480.
EG 34, EL 61, IPT 1
Z
Y
BENDING
MOMENT-S
RST CALC
TIME 2.000
10000.
6667.
3333.
0.
-3333.
-6667.
-10000.

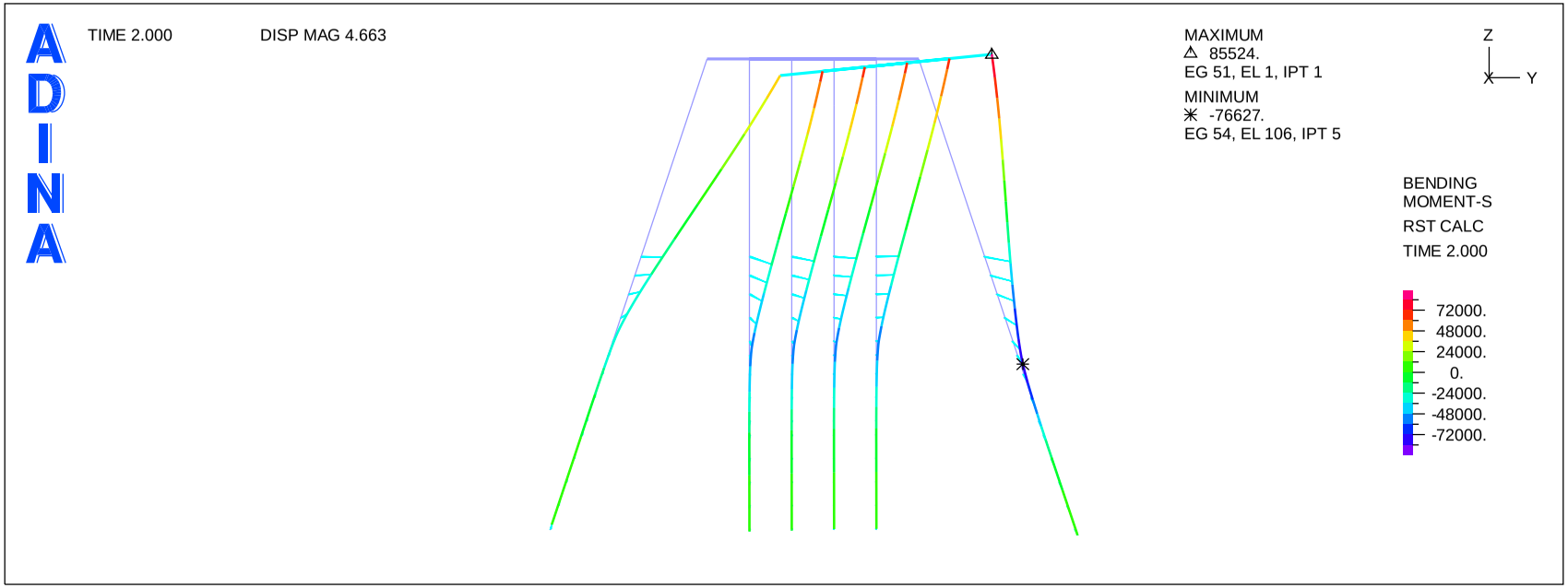

Antioch P11, Pile Response (Nonlinear p-y, Moment-Curature, and Rotational Spring at Pilehead), Pile # 1
Elev., m
5
0
-5
-10
-15
-20
-0.2
0
0.2
0.4
0.6
Normal-Displacement, m
-1500
-500
500
1500
Moment, kN-m
-7
-5
-3
-1
1
3
5
7
Curvature, 1/m
x 10-3

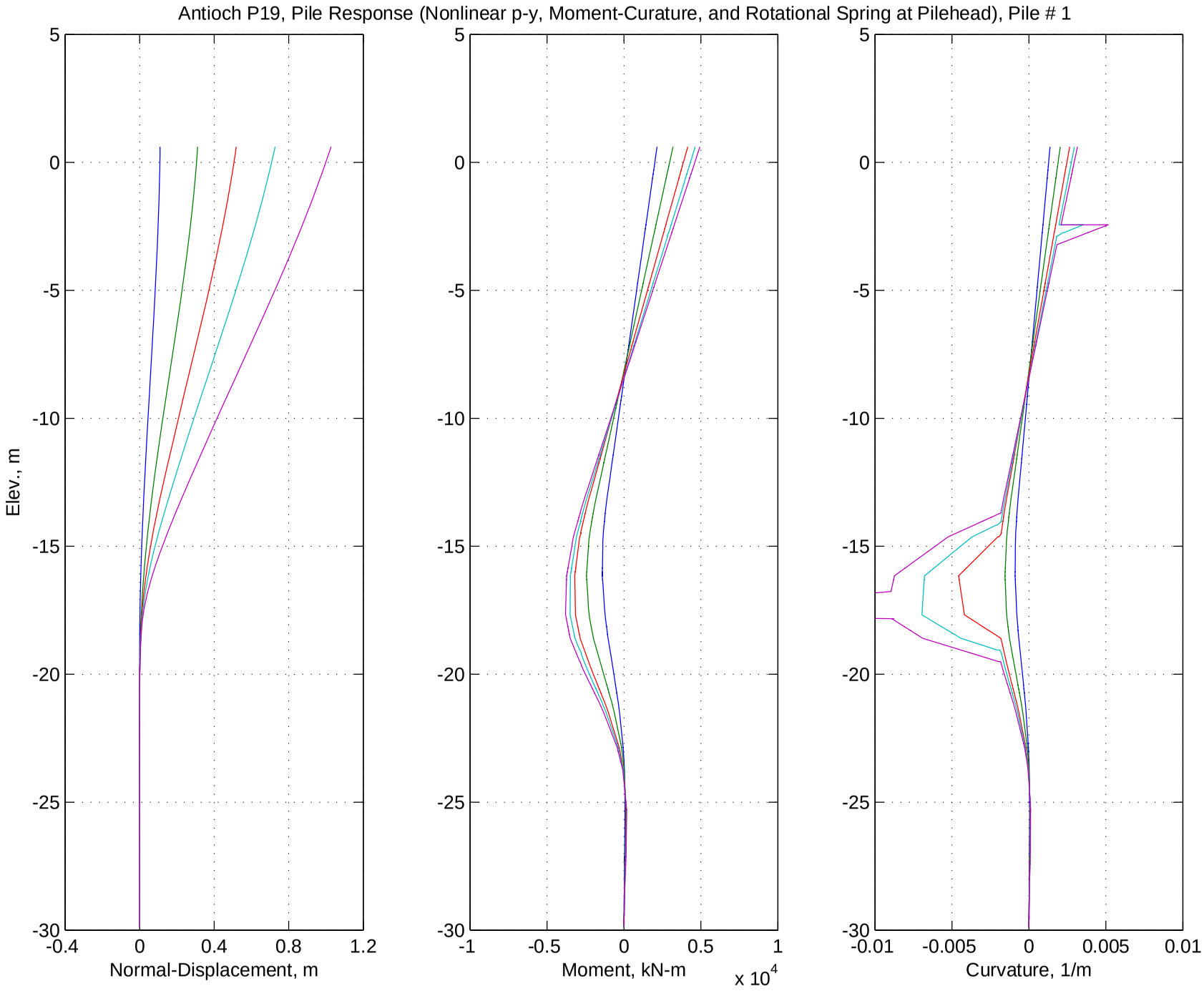

Antioch P11, Pile Response (Nonlinear p-y, Moment-Curature, and Rotational Spring at Pilehead), Pile # 2
Elev., m
5
0
-5
-10
-15
-20
-0.2
0
0.2
0.4
0.6
Normal-Displacement, m
-1500
-500
500
1500
Moment, kN-m
-7
-5
-3
-1
1
3
5
7
Curvature, 1/m
x 10-3

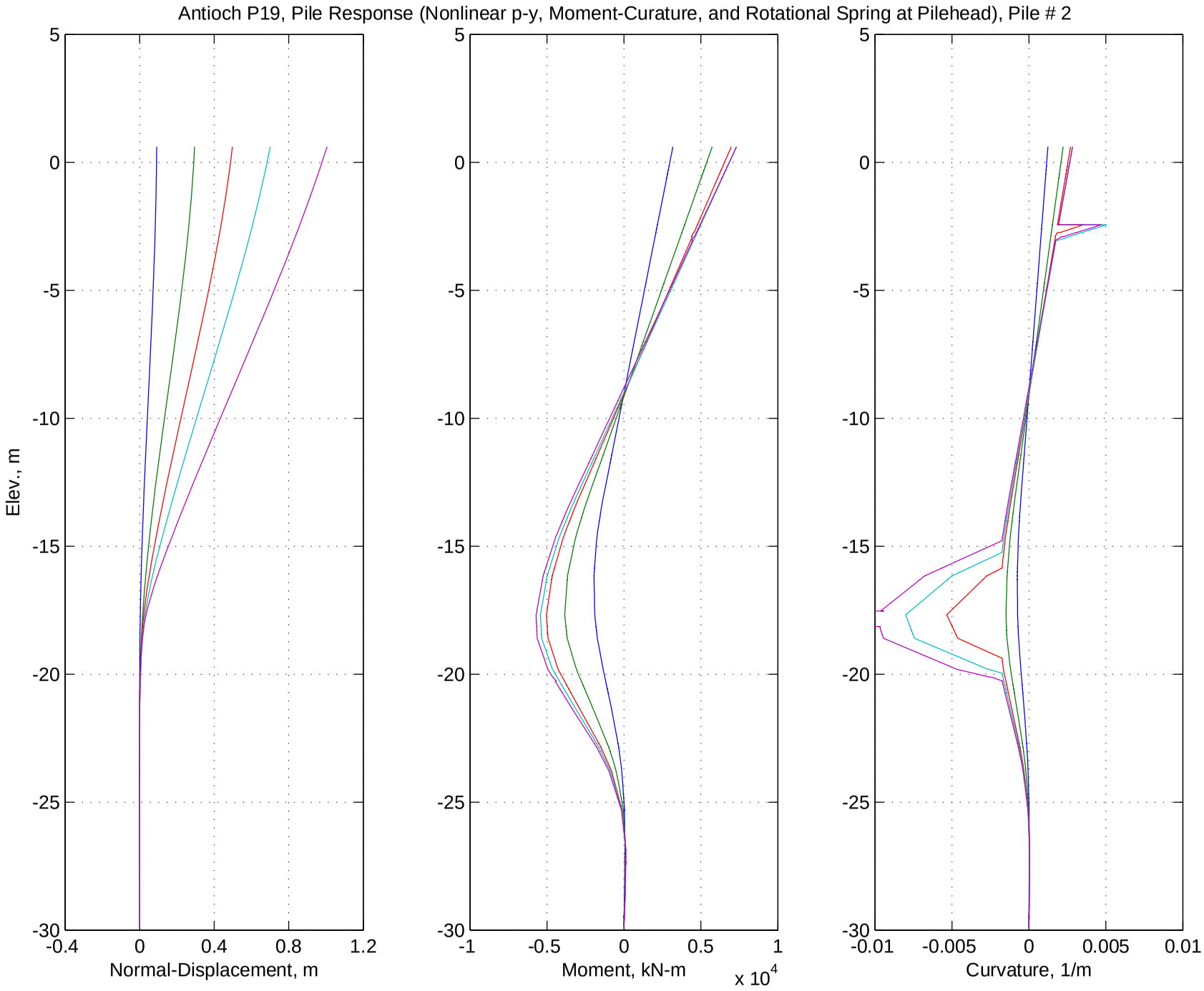

Antioch P11, Pile Response (Nonlinear p-y, Moment-Curature, and Rotational Spring at Pilehead), Pile # 3
Elev., m
5
0
-5
-10
-15
-20
-0.2
0
0.2
0.4
0.6
Normal-Displacement, m
-1500
-500
500
1500
Moment, kN-m
-7
-5
-3
-1
1
3
5
7
Curvature, 1/m
x 10-3

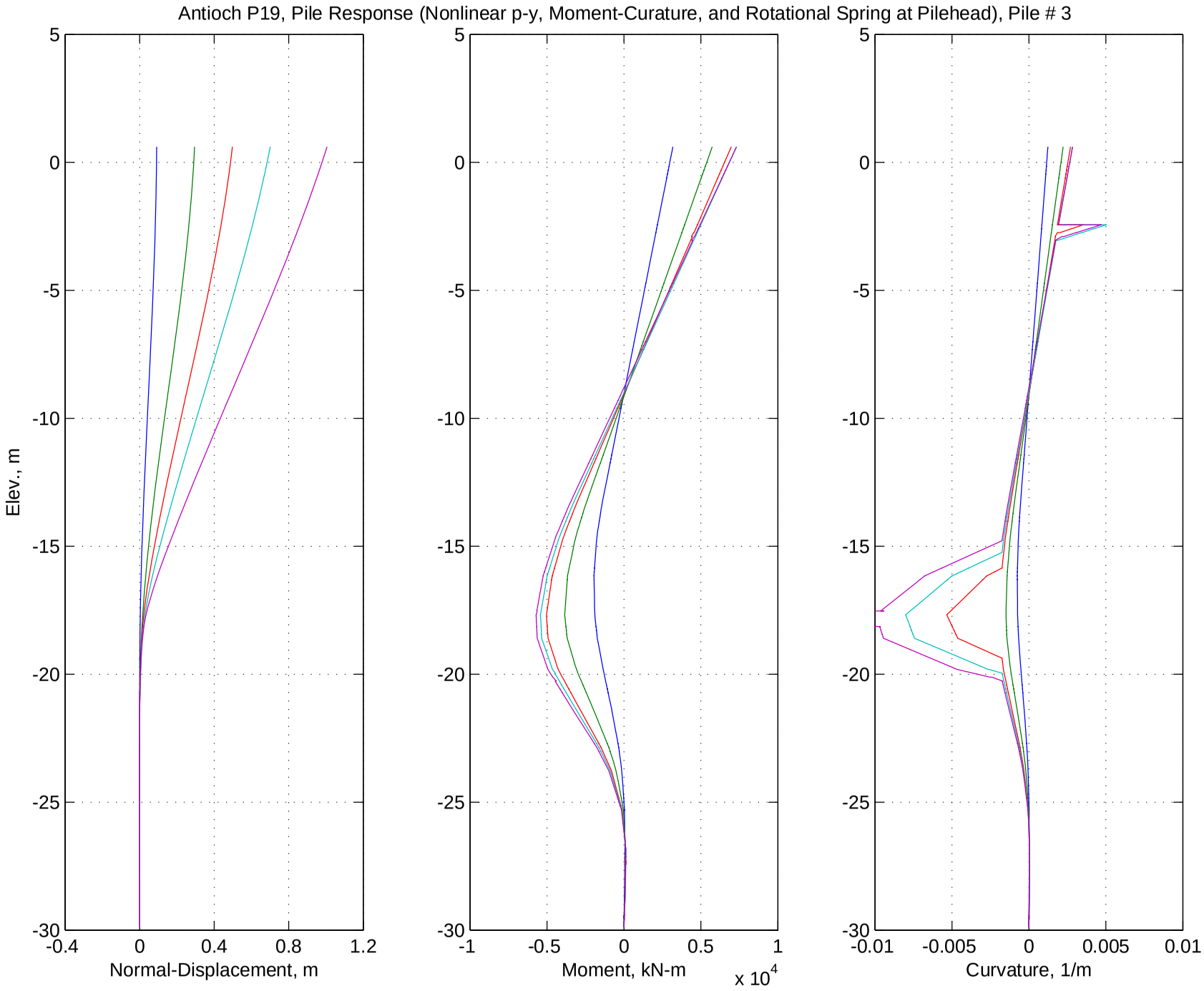

Antioch P11, Pile Response (Nonlinear p-y, Moment-Curature, and Rotational Spring at Pilehead), Pile # 4
Elev., m
5
0
-5
-10
-15
-20
-0.2
0
0.2
0.4
0.6
Normal-Displacement, m
-1500
-500
500
1500
Moment, kN-m
-7
-5
-3
-1
1
3
5
7
Curvature, 1/m
x 10-3

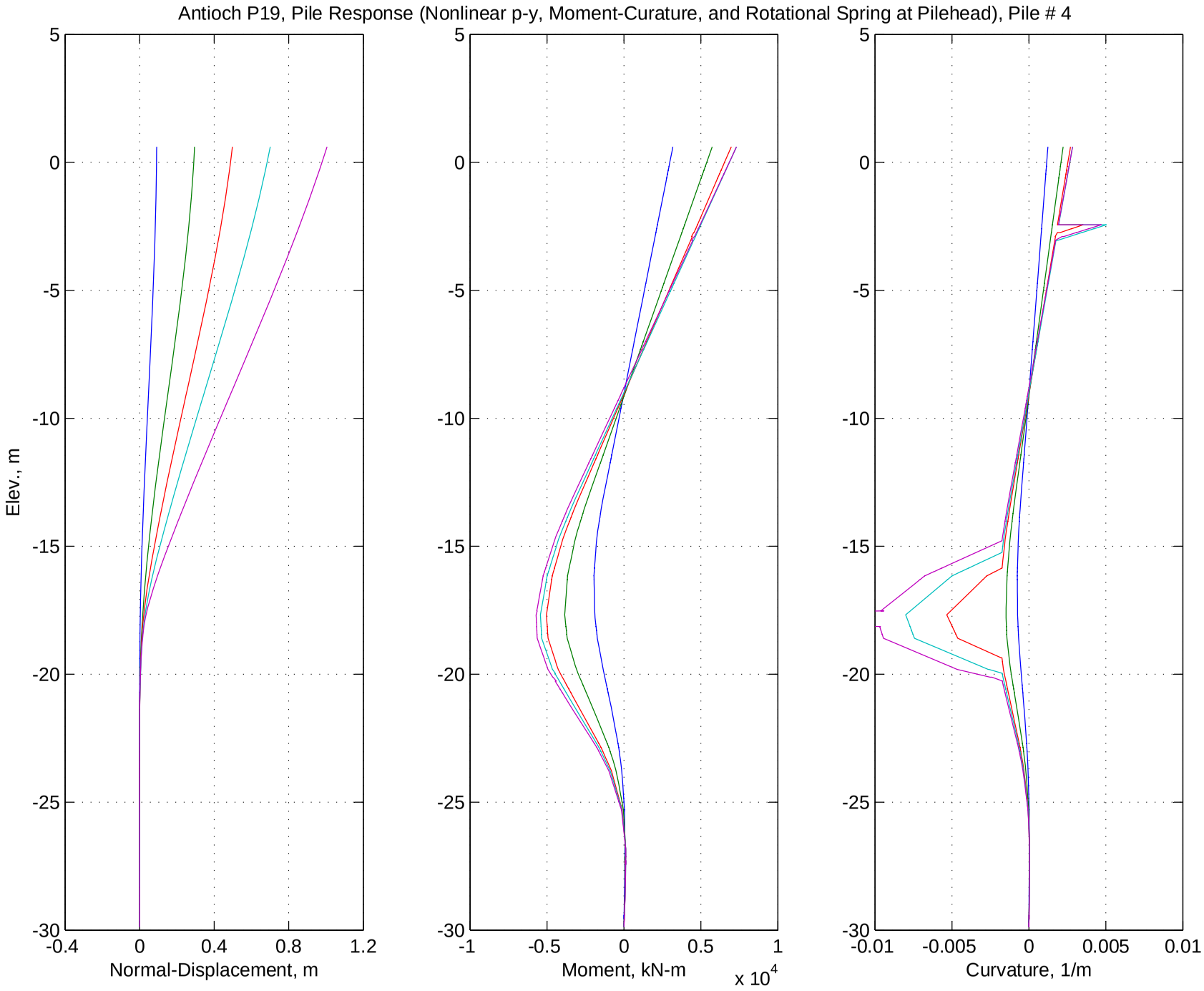

Antioch P19, Disp-Load Response (Nonlinear P-Y, Moment-Curature, and Rotational Spring at Pilehead)
Lateral Load, kN
Lateral Displacement, m
Peak Seismic Displacement Demand, 4.1" (0.1m)
1/C_yy
1
Fix
Pin
1CLS1
1CLS2
1TLS1
6TLS1
6CLS1
6CLS2
1CLS3
6CLS3
2CLS3 3CLS3 4CLS3 5CLS3
2CLS1 3CLS1 4CLS1 5CLS1
2BLS1 3BLS1 4BLS1 5BLS1
First LS3 at 0.71 m in pile # 1:
Pile # Moment Axial Force
1 4738 kNm -2650 kN
2 7314 kNm 8384 kN
3 7314 kNm 6508 kN
4 7314 kNm 4099 kN
5 7314 kNm 1333 kN
6 9664 kNm 9523 kN

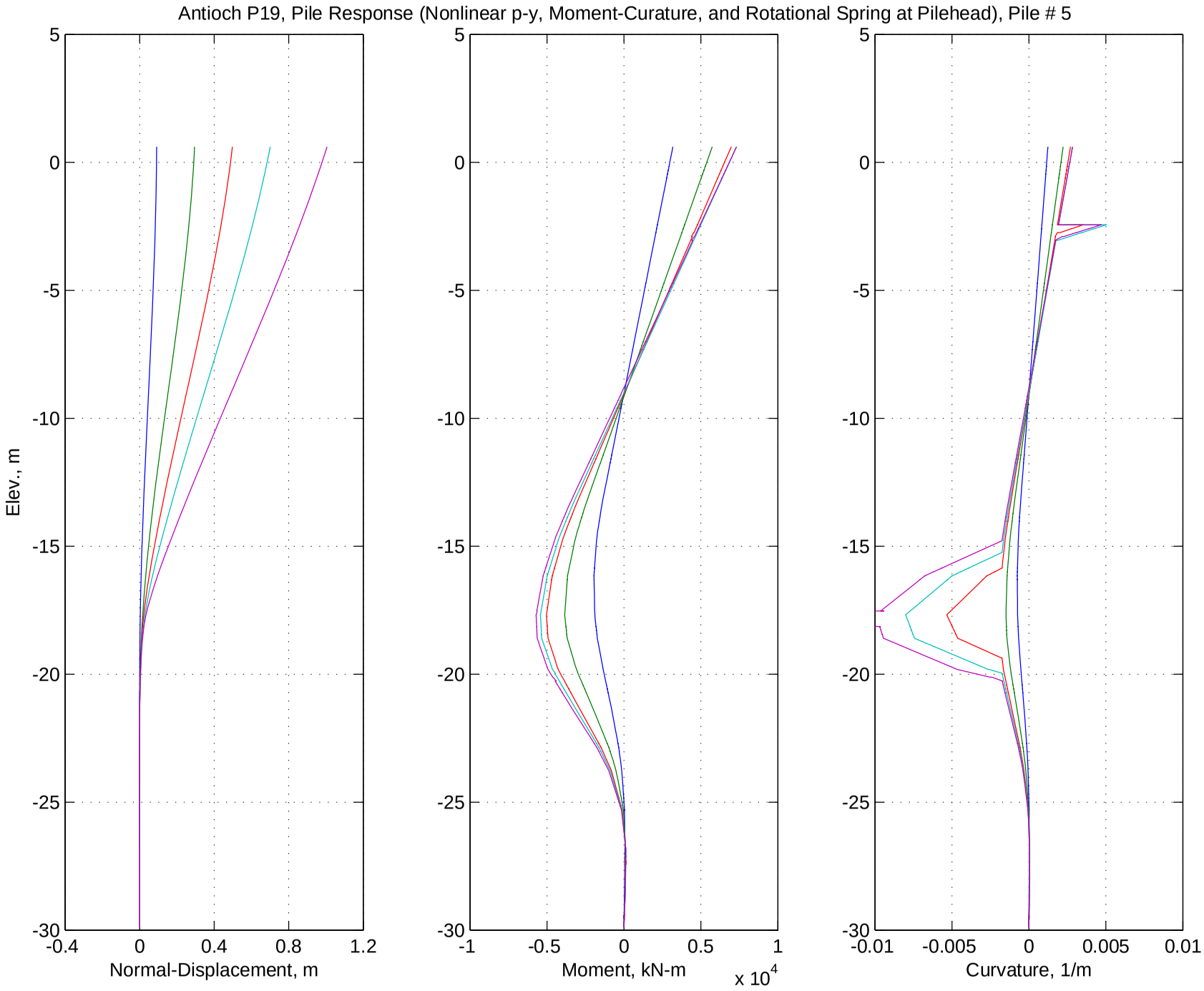

ADINA
TIME 2.000
DISP MAG 4.663
MAXIMUM
85524.
EG 51, EL 1, IPT 1
MINIMUM
-76627.
EG 54, EL 106, IPT 5
Z
Y
BENDING
MOMENT-S
RST CALC
TIME 2.000
72000.
48000.
24000.
0.
-24000.
-48000.
-72000.

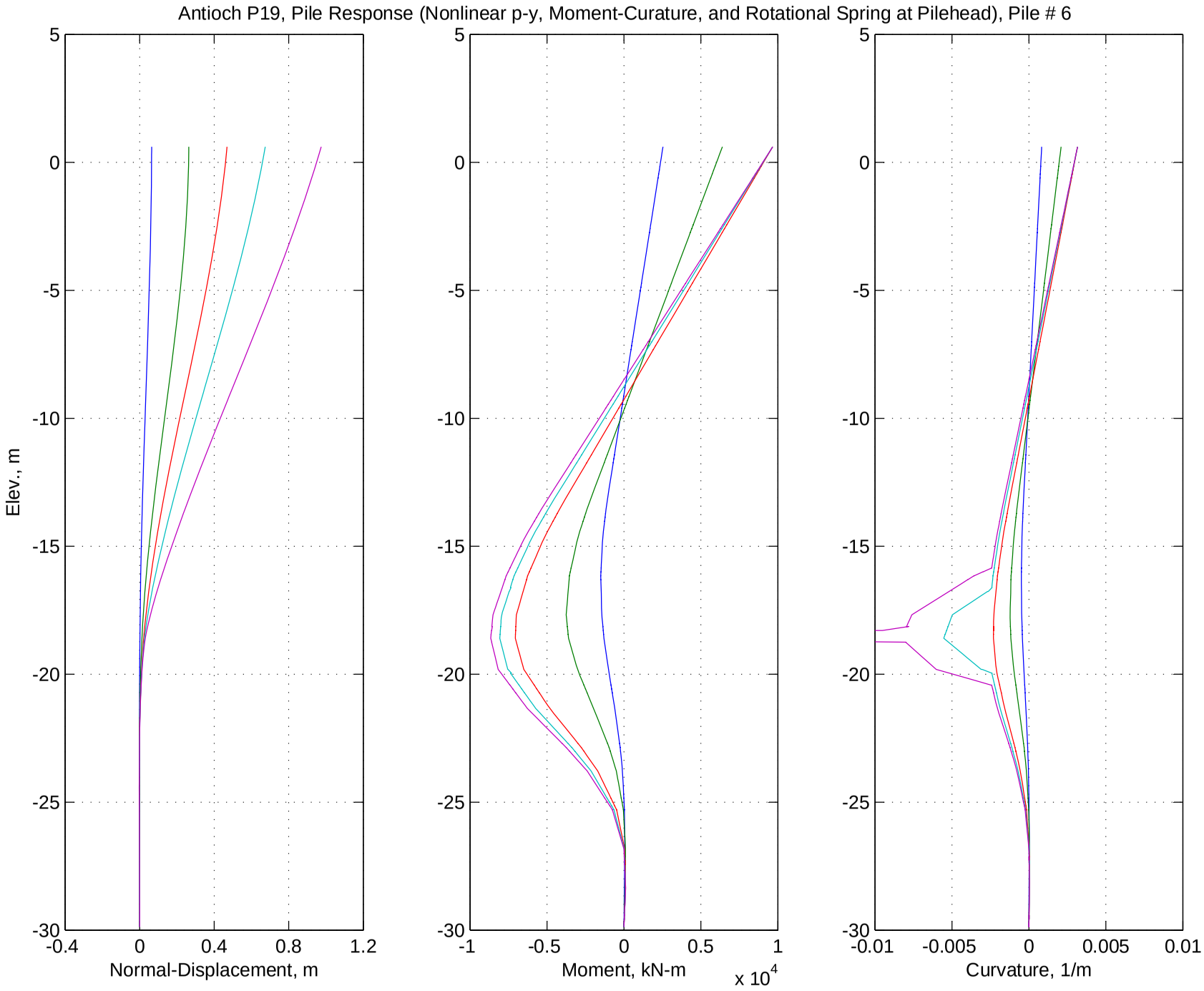

Antioch P19, Pile Response (Nonlinear p-y, Moment-Curature, and Rotational Spring at Pilehead), Pile # 1
Elev., m
5
0
-5
-10
-15
-20
-25
-30
-0.4
0
0.4
0.8
1.2
Normal-Displacement, m
-1
-0.5
0
0.5
1
Moment, kN-m
x 10^4
-0.01
-0.005
0
0.005
0.01
Curvature, 1/m

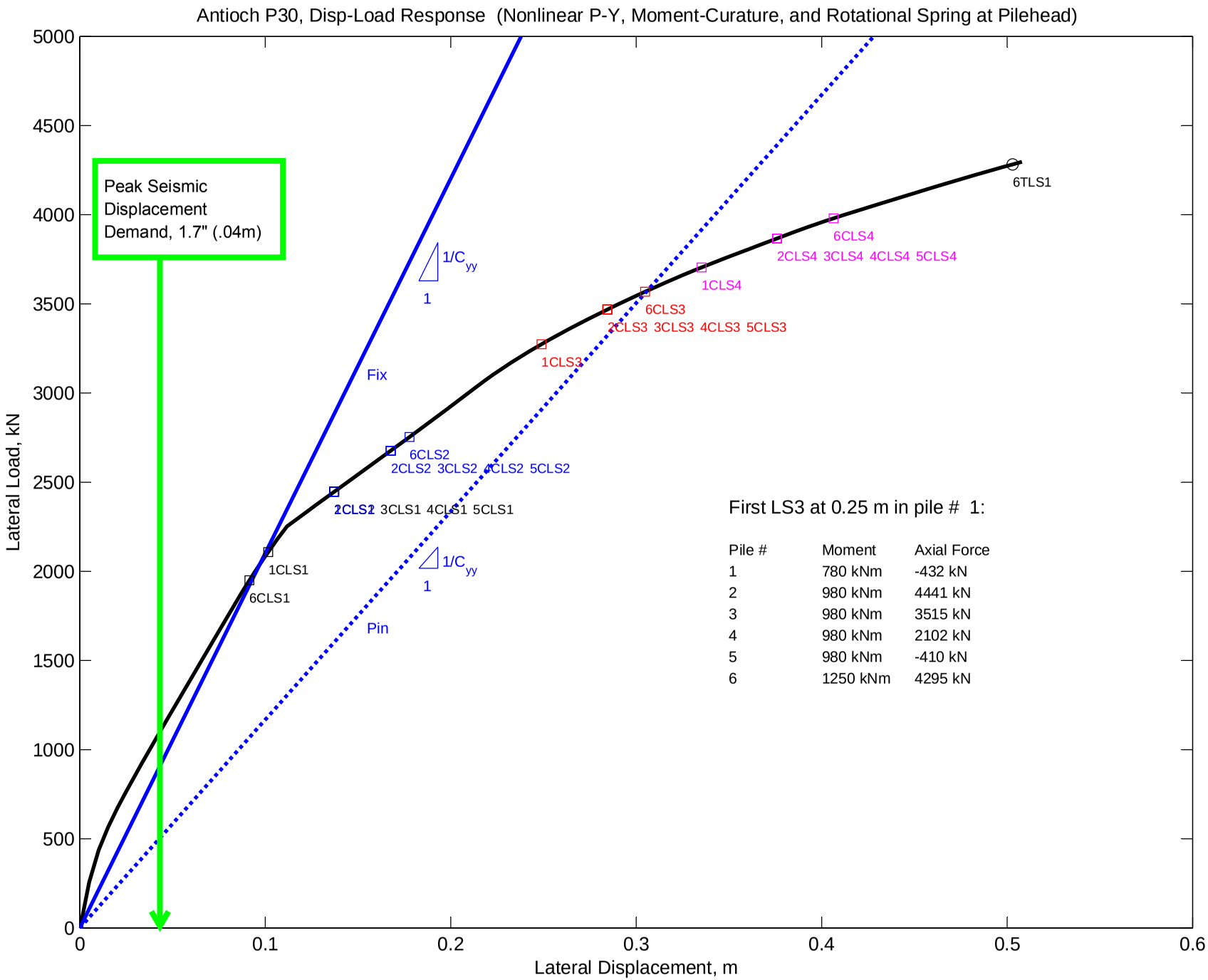

Antioch P19, Pile Response (Nonlinear p-y, Moment-Curature, and Rotational Spring at Pilehead), Pile # 2
Elev., m
5
0
-5
-10
-15
-20
-25
-30
-0.4
0
0.4
0.8
1.2
Normal-Displacement, m
-1
-0.5
0
0.5
1
Moment, kN-m
x 10^4
-0.01
-0.005
0
0.005
0.01
Curvature, 1/m

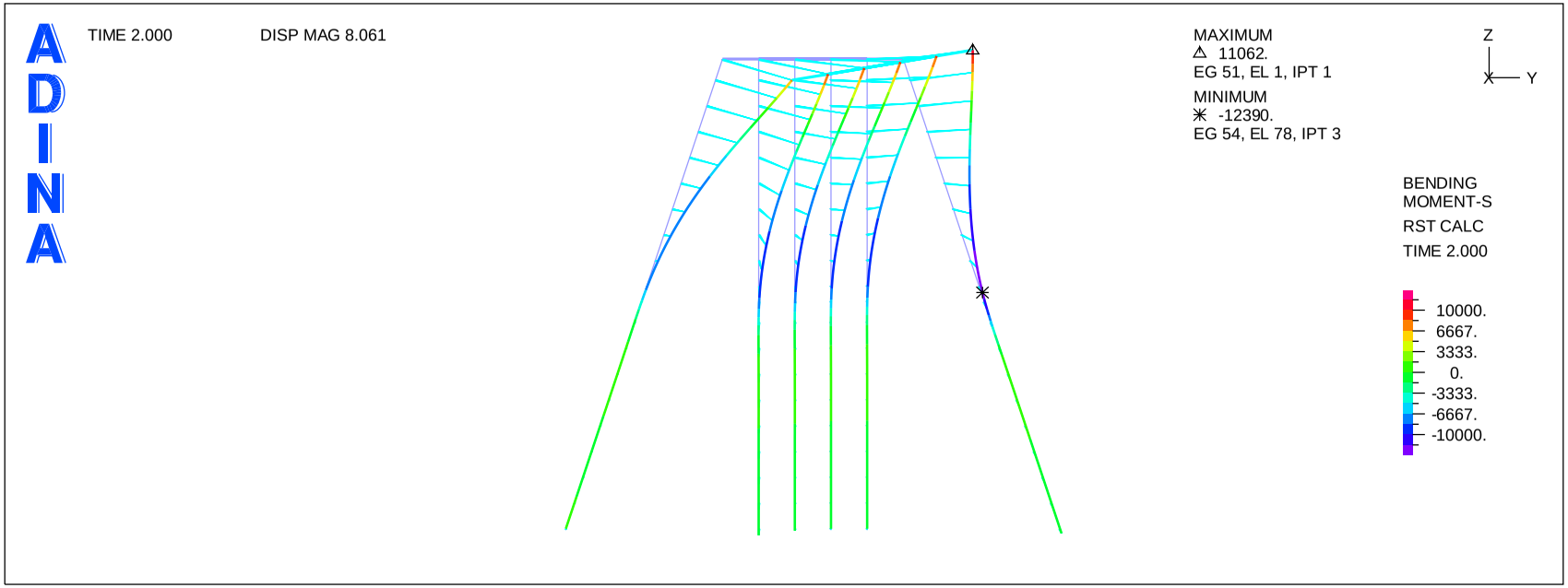

Antioch P19, Pile Response (Nonlinear p-y, Moment-Curature, and Rotational Spring at Pilehead), Pile # 3
Elev., m
5
0
-5
-10
-15
-20
-25
-30
-0.4
0
0.4
0.8
1.2
Normal-Displacement, m
-1
-0.5
0
0.5
1
Moment, kN-m
x 10^4
-0.01
-0.005
0
0.005
0.01
Curvature, 1/m

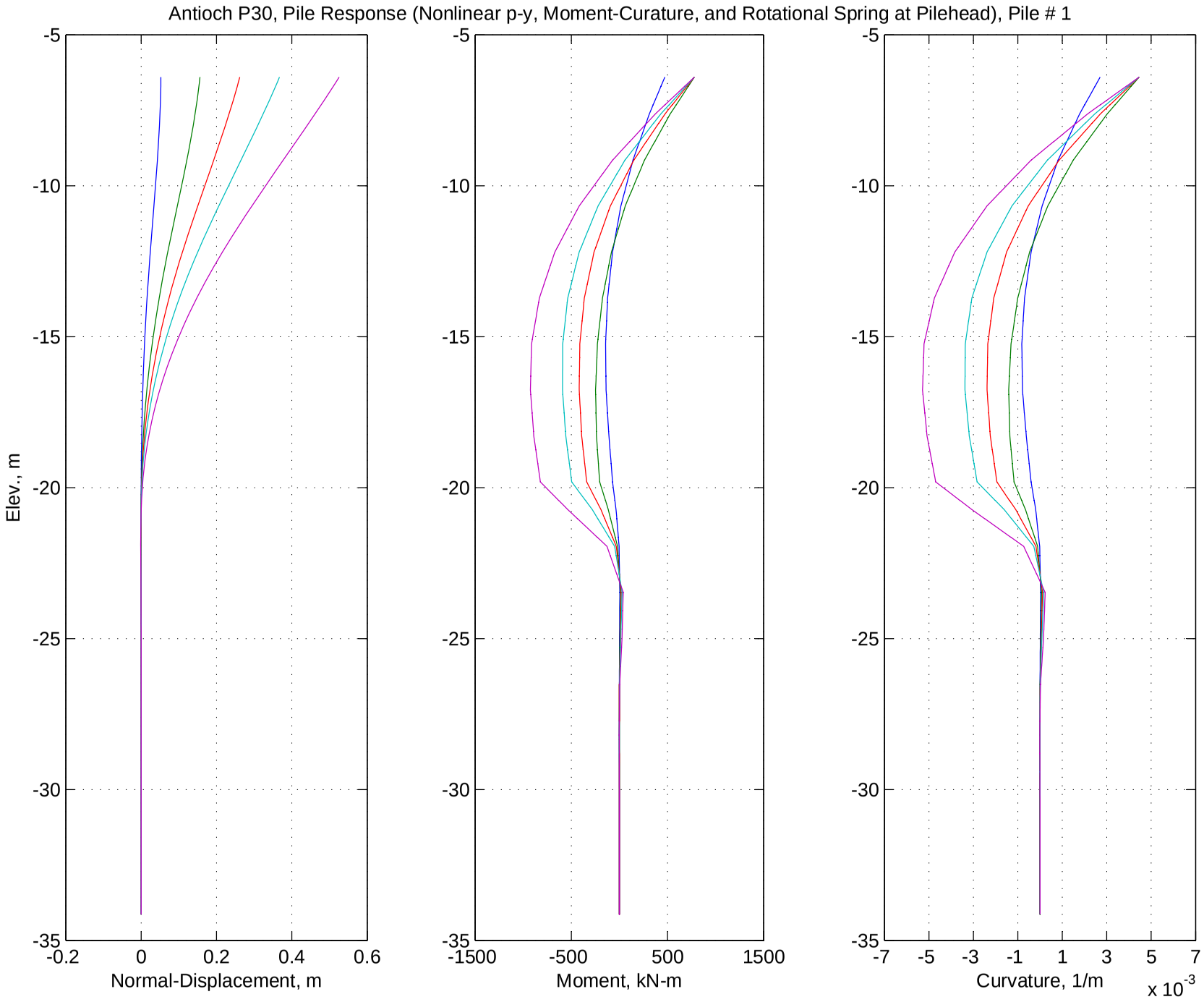

Antioch P19, Pile Response (Nonlinear p-y, Moment-Curature, and Rotational Spring at Pilehead), Pile # 4
Elev., m
5
0
-5
-10
-15
-20
-25
-30
-0.4
0
0.4
0.8
1.2
Normal-Displacement, m
-1
-0.5
0
0.5
1
Moment, kN-m
x 10^4
-0.01
-0.005
0
0.005
0.01
Curvature, 1/m

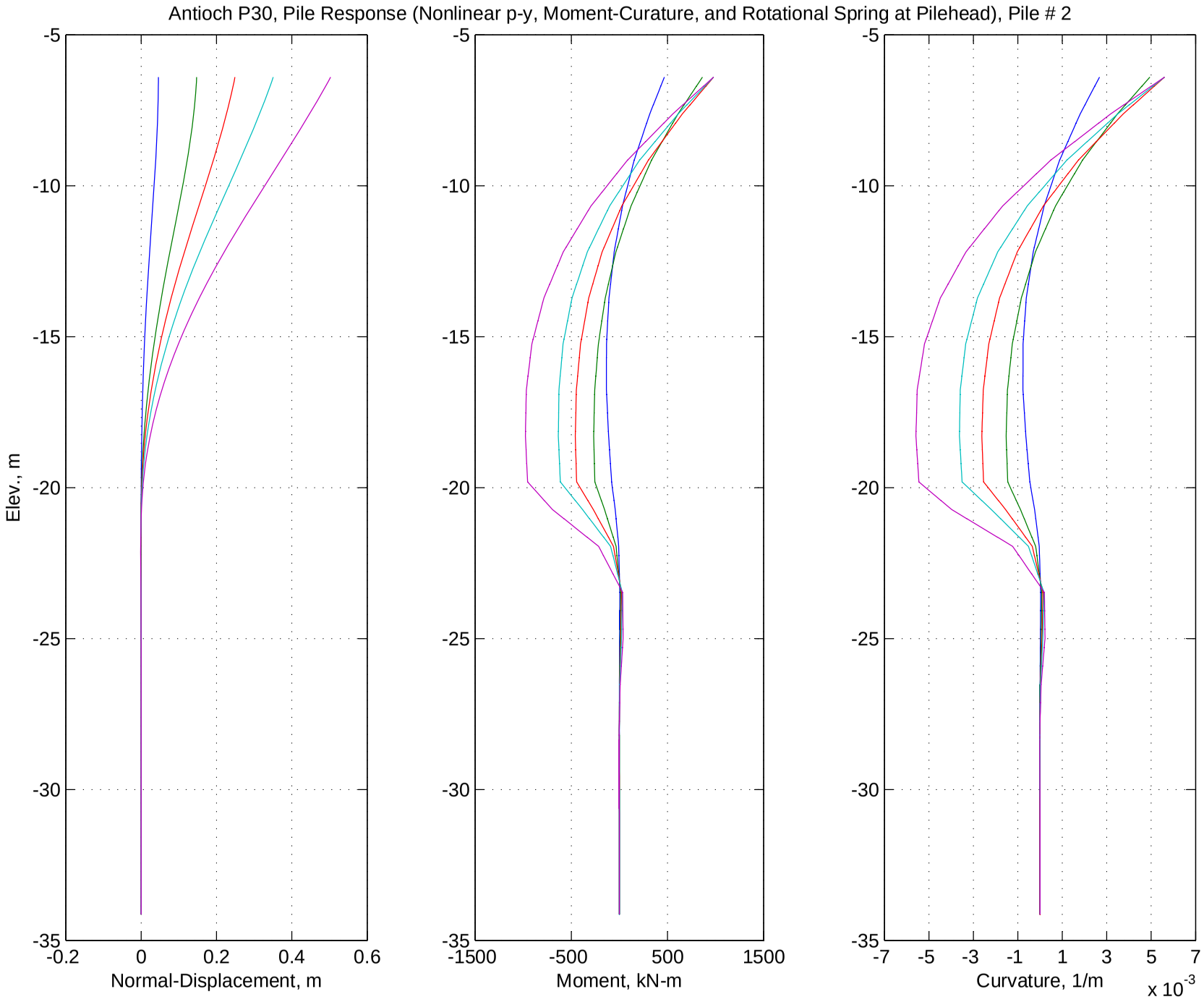

Antioch P19, Pile Response (Nonlinear p-y, Moment-Curature, and Rotational Spring at Pilehead), Pile # 5
Elev., m
Normal-Displacement, m
Moment, kN-m
x 10^4
Curvature, 1/m
5
0
-5
-10
-15
-20
-25
-30
-0.4
0
0.4
0.8
1.2
-1
-0.5
0.5
1
-0.01
-0.005
0.005
0.01

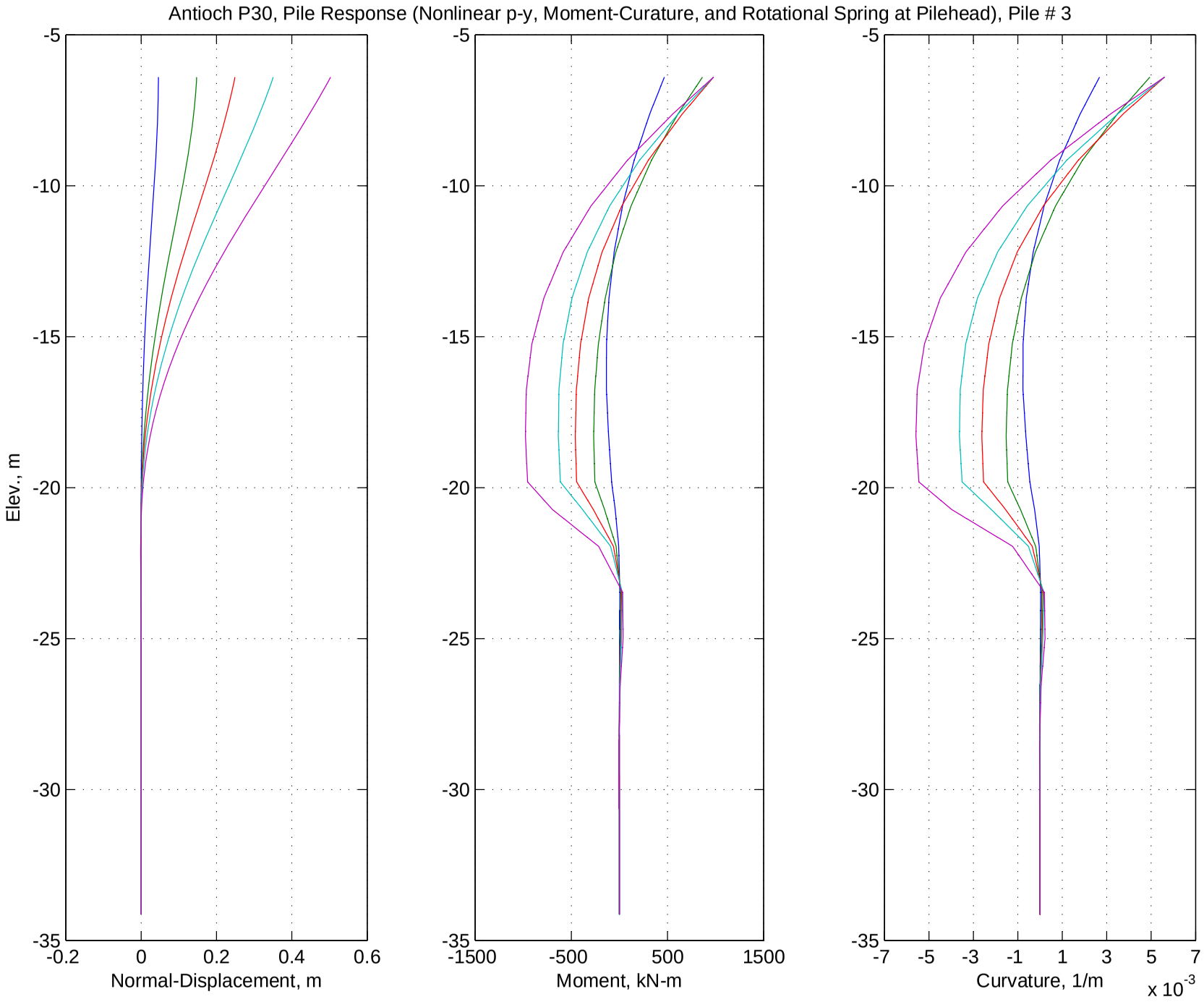

Antioch P19, Pile Response (Nonlinear p-y, Moment-Curature, and Rotational Spring at Pilehead), Pile # 6
Elev., m
5
0
-5
-10
-15
-20
-25
-30
-0.4
0
0.4
0.8
1.2
Normal-Displacement, m
-1
-0.5
0
0.5
1
Moment, kN-m
x 10^4
-0.01
-0.005
0
0.005
0.01
Curvature, 1/m

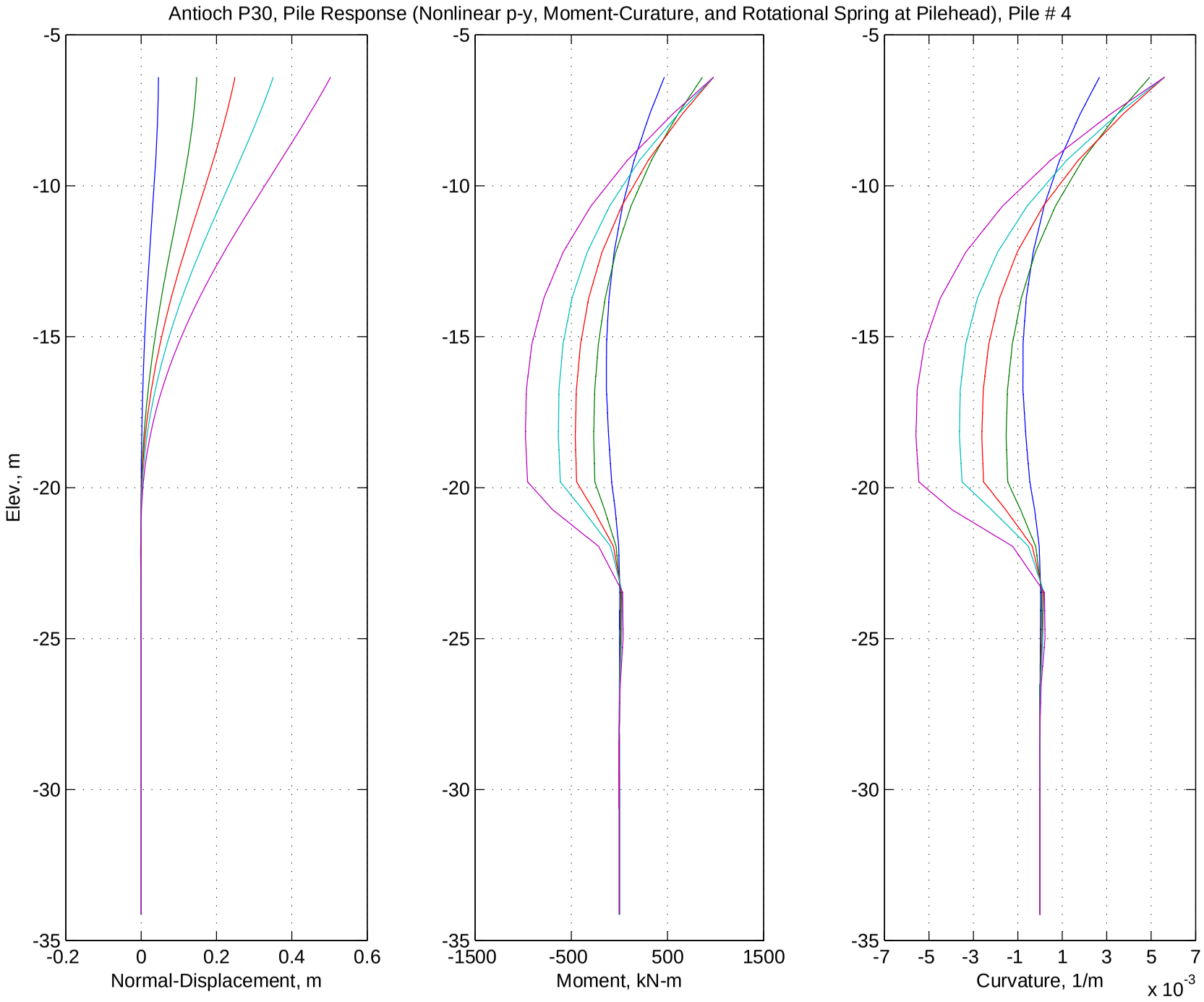

Antioch P30, Disp-Load Response (Nonlinear P-Y, Moment-Curature, and Rotational Spring at Pilehead)
Lateral Load, kN
Lateral Displacement, m
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
0.1
0.2
0.3
0.4
0.5
0.6
Peak Seismic Displacement Demand, 1.7" (.04m)
1/C_yy
1
Fix
Pin
1/C_yy
1
6TLS1
6CLS4
2CLS4 3CLS4 4CLS4 5CLS4
1CLS4
6CLS3
2CLS3 3CLS3 4CLS3 5CLS3
1CLS3
6CLS2
2CLS2 3CLS2 4CLS2 5CLS2
2CLS1 3CLS1 4CLS1 5CLS1
1CLS1
6CLS1
First LS3 at 0.25 m in pile # 1:
Pile # Moment Axial Force
1 780 kNm -432 kN
2 980 kNm 4441 kN
3 980 kNm 3515 kN
4 980 kNm 2102 kN
5 980 kNm -410 kN
6 1250 kNm 4295 kN

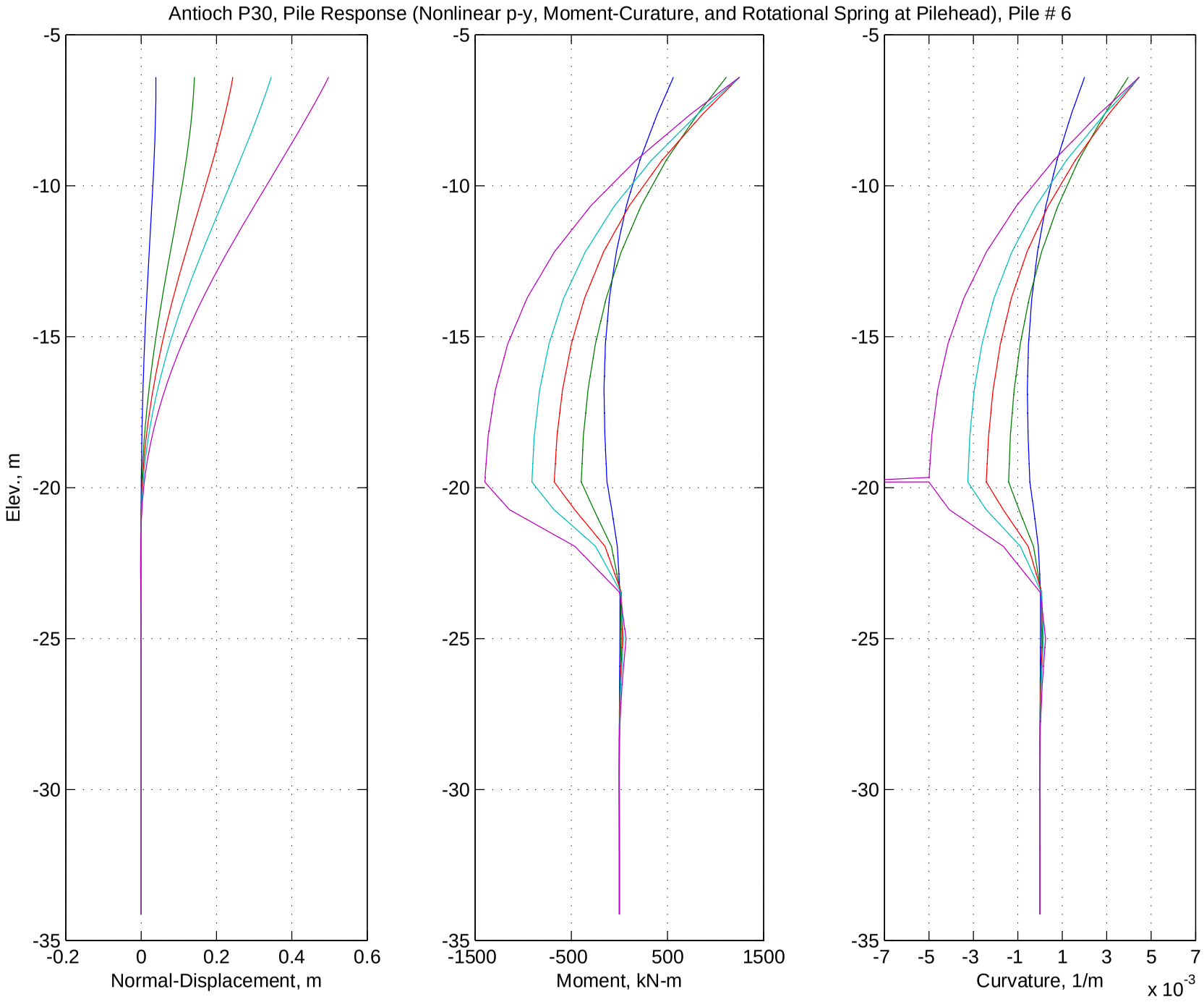

ADINA
TIME 2.000
DISP MAG 8.061
MAXIMUM
11062.
EG 51, EL 1, IPT 1
MINIMUM
-12390.
EG 54, EL 78, IPT 3
Z
Y
BENDING
MOMENT-S
RST CALC
TIME 2.000
10000.
6667.
3333.
0.
-3333.
-6667.
-10000.


Antioch P30, Pile Response (Nonlinear p-y, Moment-Curature, and Rotational Spring at Pilehead), Pile # 1
Elev., m
-5
-10
-15
-20
-25
-30
-35
-0.2
0
0.2
0.4
0.6
Normal-Displacement, m
-1500
-500
500
1500
Moment, kN-m
-7
-5
-3
-1
1
3
5
7
Curvature, 1/m
x 10-3


Antioch P30, Pile Response (Nonlinear p-y, Moment-Curature, and Rotational Spring at Pilehead), Pile # 2
Elev., m
-5
-10
-15
-20
-25
-30
-35
-0.2
0
0.2
0.4
0.6
Normal-Displacement, m
-1500
-500
500
1500
Moment, kN-m
-7
-5
-3
-1
1
3
5
7
Curvature, 1/m
x 10-3


Antioch P30, Pile Response (Nonlinear p-y, Moment-Curature, and Rotational Spring at Pilehead), Pile # 3
Elev., m
-5
-10
-15
-20
-25
-30
-35
-0.2
0
0.2
0.4
0.6
Normal-Displacement, m
-1500
-500
500
1500
Moment, kN-m
-7
-5
-3
-1
1
3
5
7
Curvature, 1/m
x 10-3


Antioch P30, Pile Response (Nonlinear p-y, Moment-Curature, and Rotational Spring at Pilehead), Pile # 4
Elev., m
-5
-10
-15
-20
-25
-30
-35
-0.2
0
0.2
0.4
0.6
Normal-Displacement, m
-1500
-500
500
1500
Moment, kN-m
-7
-5
-3
-1
1
3
5
7
Curvature, 1/m
x 10-3


Antioch P30, Pile Response (Nonlinear p-y, Moment-Curature, and Rotational Spring at Pilehead), Pile # 6
Elev., m
-5
-10
-15
-20
-25
-30
-35
-0.2
0
0.2
0.4
0.6
Normal-Displacement, m
-1500
-500
500
1500
Moment, kN-m
-7
-5
-3
-1
1
3
5
7
Curvature, 1/m
x 10-3

ANTIOCH BRIDGE PILE ANALYSES

PRELIMINARY REPORT (PIER 19)

Nigel Priestley

1. Introduction:

This preliminary report gives results of moment-curvature, moment-rotation, and displacement capacity of a typical 54 in (1.372m) diameter prestressed pile at Pier 19. Analyses were separately carried out for the pile/footing connection detail, and for the prestressed section below the dowel connection. The following data were applicable (or assumed for the analyses:

Connection:

Dowels: 12#14 grade 60 rebar: yield assumed: f_y = 455MPa (66ksi)
ultimate assumed : f_u = 683MPa (99ksi)
P.C.D. of dowels: 857mm (33.7in)
Concrete: f'_c = 1.3x6000psi i.e. f'_c = 53.8MPa (7.8ksi)
Cover to confinement: 76mm (3in)
Confinement: W20 spiral (12.7mm dia., pitch=2in)
: f_{yh} =420MPa (60ksi)
(note: This yield strength may be conservative, but has little influence)
Axial Loads: Three levels considered: 500tons, 1500tons, -250tons
(4450kN, 13344kN, -2225kN)

Prestressed Section:

Prestressing: 28x0.6in strands (Total area = 3922mm^2 =6.08in^2)
Cover to prestressing: 89mm (3.5in)
Initial stress: 1172MPa (170ksi)
Yield stress: 1500MPa (217.5ksi)
Ultimate stress 1863MPa (270ksi)
Confinement: W20 spiral – as for footing connection)
Axial Loadds: Three levels considered: 500tons, 1500tons, 25tons
(4450kN, 13344kN, 223kN)

Data for Deflection Calculations:

Pile free length to mudline: 12.8m (42ft)
Depth below mudline to max. moment 2.0m (6.6ft) (assumed)
Depth to effective fixity for elastic deflections: 3.0m (9.8ft) (assumed)
Plastic hinge length at footing connection:

$$L_P = 0.03 f_y d_{bd} = 0.03 \times 455 \times 44.5 = 607mm$$

Plastic hinge length in-ground (conservative estimate)

$$L_P = 1.5 D_P = 1.5x1.372 = 2.06m$$

Limit States Considered:

Yield: For footing connection, ε_s = 0.002275, or ε_c = 0.002 (whichever first)
Prestressed**:** ε_p = 0.0075 or ε_c = 0.002 (whichever first)

Serviceability: Footing Conn: ε_s = 0.015 or ε_c = 0.004 (whichever first)
Prestressed: (same as footing connection)

Damage Control: Footing Conn: ε_s = 0.07, or ε_c = 0.0147 (energy balance)
Prestressed: ε_p = 0.04 or ε_c = 0.008

Ultimate: Footing Connection: ε_s =0.07
Prestressed: Same as Damage control.

Notes on Above:

1. For the prestressed section, it is assumed that the hollow has been filled with concrete. It is not clear from the plans whether this is the case for the full length of the pile.

2. The depths to maximum moment and effective fixity for elastic displacements are "guesses" based on EMI values for Dumbarton Bridge. Small adjustments are to be expected.

3. The plastic hinge length for the in-ground hinge, at $1.5D_p$ is small compared with the normally assumed value of $2D_p$. However, the latter value is based on smaller diameter piles, and with higher shear force. I feel that the value of $1.5D_p$ is more appropriate.

4. The ultimate condition for the pile/footing connection is based on an "ultimate" dowel strain of 70% of a uniaxial value of 0.10, and hence takes account of reduction of ultimate strain as a consequence of cyclic response under EQ loading.

5. The damage control and ultimate conditions for the in-ground hinge are based on an extreme fibre compression strain of 0.008, based on theoretical and experimental results. At higher strains the cover deteriorates, and the plastic hinge length reduces rapidly. Although larger plastic rotations may occur, they should not be relied on.

6. The analysis program including prestressing is unstable for low or negative axial compression. As a consequence, the minimum axial compression for the prestressed section is 223kN, while the footing connection is analyzed for a tension force of 250 tons. Note, however, that the critical in-ground section will be subjected to higher compressive loading than the top of the pile, due to the pile weight (approx. 37.5kN/m, or about 500kN total)

2. Pile/Footing Connection Characteristics

2.1 Moment-Curvature Response:

Moment-curvature characteristics are based on analyses considering strain-hardening of the reinforcement and confinement of the core concrete, using the Mander et al model. Results of the analyses are plotted in Fig. 1, and listed in Table 1. In Fig.1 a bilinear approximation to the moment-curvature curves is included, and the various limit states are identified by solid circles.

It will be noted that at the upper limit of axial compression (1500tons) the analyses indicate a significant strength drop (about 5%) just before the damage-control limit state. This is a

consequence of cover spalling, but is unlikely to be realistic, as the confinement provided by the footing concrete above the critical section, and by the additional strength resulting from prestress immediately below the critical section has been found in experiments to inhibit the strength drop predicted by moment-curvature analysis. Despite this apparent strength drop, the ultimate curvature is larger for the section with high axial compression than for the same section with lower axial compression. This is because the critical case for the ultimate curvature is steel fracture, and with high axial compression, the distance from the neutral axis to the extreme dowel position is reduced as the axial compression increases.

2.2 Moment-Rotation Response:

The moment-rotation response of the pile/footing connection is shown in Fig.2 in quadri-linear and bilinear forms, with the quadrilinear curve defined by the four limit states. It will be seen than the plastic rotation capacity of the section is close to 0.05 for the critical case of maximum axial tension, and more than 0.05 for other cases. The rotation at the yield limit state (LS1) corresponds to elastic strain penetration of the dowel bars into the footing, and is typically about 0.0013. Rotational values at the four limit states are included in Table 1.

3. Prestressed Section Characteristics

3.1 Moment-Curvature Response:

Moment-curvature response of the prestressed section at three different axial load levels, together with bilinear approximations, are shown in Fig.3, with the limit states identified by solid circles. Note that only LS1, LS2 and LS3 are shown, since the ultimate limit state (LS4) is the same as the damage-control (LS3) limit state. Values for moment and curvature for the limit states are listed in Table 2.

It will be noted that the moment capacities of the prestressed section for a given limit state and axial load level are lower than for the dowel connection –typically by between 0% and 20%, though a maximum discrepancy of 24% exists for the ultimate limit state with an axial compression of 500 tons. This raises the possibility that plastic hinging could develop at the lower end of the dowels, some 3.04m below the pile/footing connection. However, if we conservatively assume that the point of contraflexure in the pile is 8m below the pile/footing connection, the maximum moment in the prestressed section, above the point of contraflexure will be approximately 63% of the peak moment at the pile/footing connection. Since this is lower than the minimum strength ratio of 76% it follows that hinging will never develop in the prestressed section above the point of contraflexure. Note also that the implication of the relative strength ratio is that some minor inelasticity may develop in the prestressed portion of the pile. This will be beneficial, in that it will increase the displacement capacity of the pile, without jeopardizing strength.

3.2 Moment-Rotation Response:

Key values of the rotational capacity of the in-ground hinge at the serviceability and ultimate limit states are also listed in Table 2. Note that there is no yield rotation, as strain penetration does not occur at the critical in-ground location. Since there are only two data points for each limit state, plots of rotational capacity are not provided.

4. Displacement Capacity

Approximate displacement capacities have been estimated based on the stiffness of the prestressed section at 75% of nominal capacity, and the rotational capacities of the top plastic hinge, as listed in Table 1. These values should be expected to contain errors up to about 10%. More accurate values can only be obtained based on pushover analyses using the moment-rotation characteristics defined in Table 1.

For the Antioch bridge, the critical assessment concern is the displacement capacity of the piles at the ultimate limit state. It will be seen from Table 3 that the displacement capacity for this limit state is not very sensitive to the axial load level, and a value of 0.85m could be considered to be conservative.

No attempt has been made to estimate the displacement capacity based on the rotation capacity of the in-ground hinge. There are too reasons for this. 1) The displacement at which the in-ground hinge yields cannot be estimated with any accuracy based on the simple modes used for this analysis. An inelastic pushover analysis would be required. 2) If the assessment criterion is “No collapse” it is hard to see how a failure of the in-ground hinge would lead to structural failure of the bridge. The in-ground hinge is confined by ground that has to be competent to cause a plastic hinge to form, and confinement of the pile by the soil will ensure that catastrophic failure doesn’t occur. Nevertheless, I recommend that displacement capacity based on rotation capacity of the in-ground hinge to assessed by a push-over analysis.

Nigel Priestley, April 29,2008

TABLE 1: PILE/FOOTING LIMIT-STATE DEFORMATIONS

LIMIT-STATE VALUES	P=4450kN	P=13344kN	P=-2225kN
First-Yield Moment (kNm)	5142	8443	2224
First-Yield Curvature (m^{-1})	0.00321	0.00371	0.00263
First-Yield Rotation (rad)	0.00125	0.00129	0.00136
Serviceability Moment (kNm)	6609	9663	3798
Serviceability Curvature (m^{-1})	0.0137	0.0990	0.01638
Serviceability Rotation (rad)	0.00706	0.00472	0.00860
Damage-Control Moment (kNm)	7313	9600	4650
Damage-Control Curvature (m^{-1})	0.04906	0.03147	0.0631
Damage-Control Rotation (rad)	0.0285	0.0178	0.0369
Ultimate Moment (kNm)	7313	9200	4750
Ultimate Curvature (m^{-1})	0.0862	0.1094	0.0791
Ultimate Rotation (rad)	0.0511	0.0651	0.0466
Bilinear Yield Moment (kNm)	6609	9600	3798
Bilinear Yield Curvature (m^{-1})	0.00413	0.00425	0.00449
Bilinear Ultimate Moment (kNm)	7313	9600	4750
Bilinear Ultimate Curvature (m^{-1})	0.0862	0.1094	0.0791

TABLE 2: PRESTRESSED SECTION LIMIT-STATE DEFORMATIONS

LIMIT-STATE VALUES	P=4450kN	P=13344kN	P=223kN
First-Yield Moment (kNm)	4514	7405	2849
First-Yield Curvature (m^{-1})	0.00175	0.00242	0.00182
First-Yield Rotation (rad)	0	0	0
Serviceability Moment (kNm)	5678	8597	3756
Serviceability Curvature (m^{-1})	0.00972	0.00802	0.00897
Serviceability Rotation (rad)	0.0155	0.0107	0.0136
Ultimate Moment (kNm) (also LS3)	5489	8217	3815
Ultimate Curvature (m^{-1}) (also LS3)	0.02489	0.0171	0.03343
Ultimate Rotation (rad) (also LS3)	0.0467	0.0294	0.0639
Bilinear Yield Moment (kNm)	5588	8400	3756
Bilinear Yield Curvature (m^{-1})	0.0022	0.0281	0.00239
Bilinear Ultimate Moment (kNm)	5588	8400	3815
Bilinear Ultimate Curvature (m^{-1})	0.02489	0.0171	0.03343

TABLE 3: DISPLACEMENT CAPACITIES BASED ON PILE/FOOTING ROTATION CAPACITY

LIMIT STATE VALUES	**P=4450kN**	**P=13344kN**	**P=-2225kN**
EI pile (kNm^2)	$2.5x10^6$	$4.05x10^6$	$1.2x10^6$
First yield displacement (m)	0.107	0.110	0.107
Serviceability Displacement (m)	0.201	0.180	0.286
Damage Control Displacement (m)	0.528	0.373	0.725
Ultimate Displacement (m)	0.863	1.073	0.868

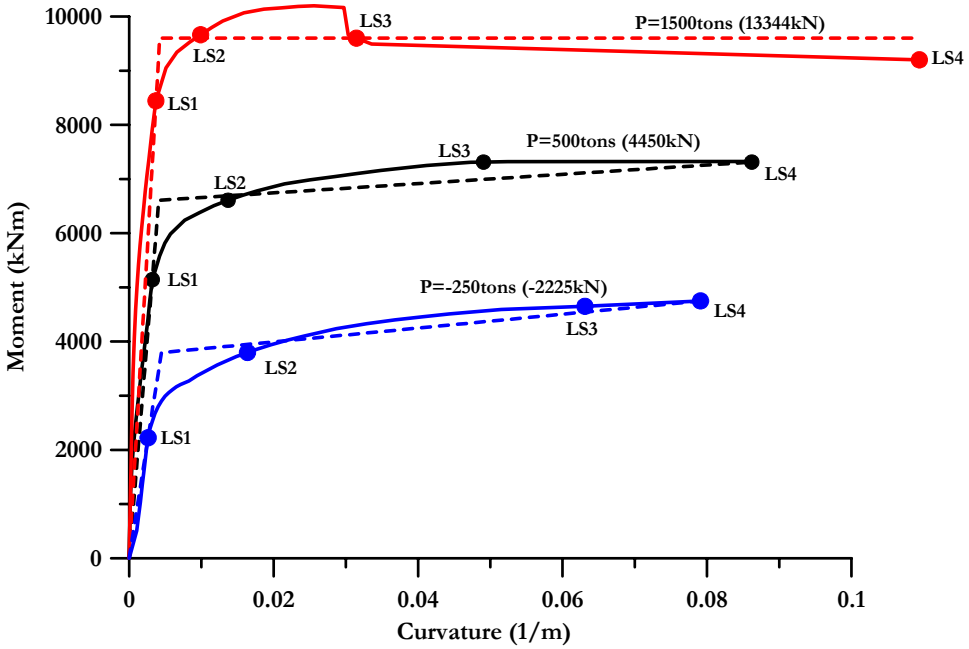


Fig.1 MOMENT-CURVATURE RESULTS FOR 54in PILE/FOOTING CONNECTION (LS1=Yield, LS2=Serviceability, LS3=Damage Control, LS4=Ultimate)

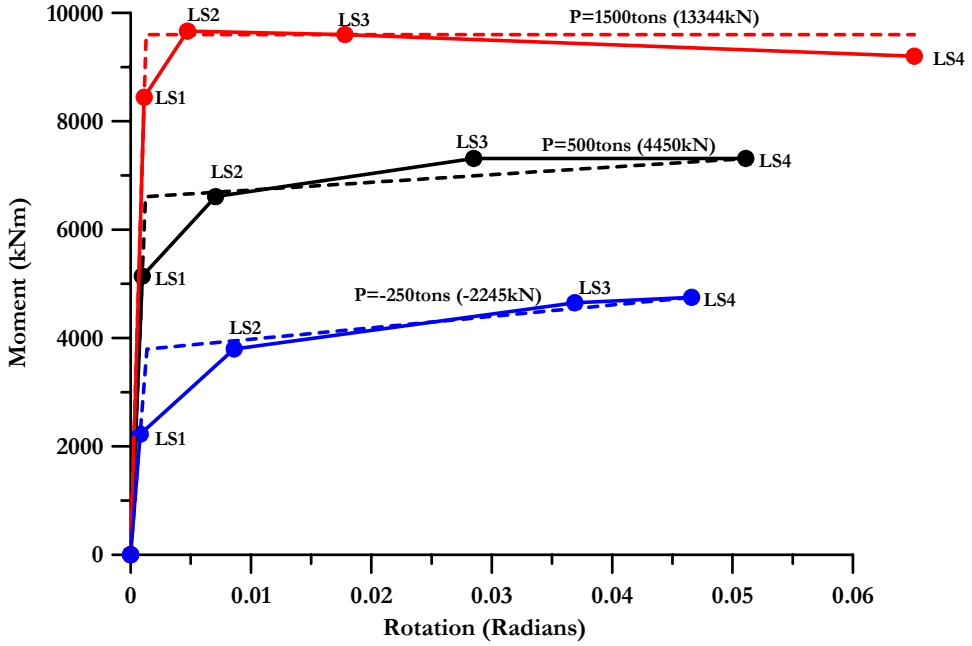


Fig.2 MOMENT-ROTATION RESULTS FOR 54in PILE-FOOTING CONNECTION LS1=Yield, LS2=Serviceability, LS3= Damage Control, LS4=Ultimate

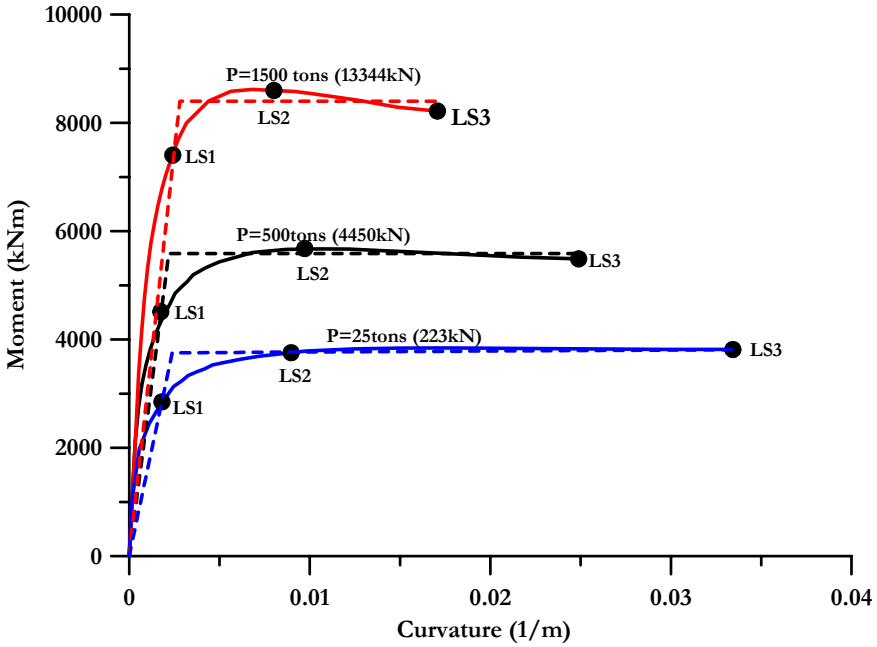


Fig.3 MOMENT-CURVATURE RESULTS FOR 54in PRESTRESSED PILE SECTION (LS1=Yield, LS2=Serviceability, LS3=Damage Control/Ultimate)

ANTIOCH BRIDGE PILE ANALYSIS

PRELIMINARY REPORT (PIER 30)

Nigel Priestley

1. Introduction:

This preliminary report gives results of moment-curvature and moment-rotation capacity of a typical square 24in. prestressed pile at Pier 30. Analyses were carried out separately for the pile/footing connection detail, and for the prestressed section below the dowel connection. The following data were applicable, (or assumed) for the analyses.

Connection:

Dowels: 6#11 Grade 60 bars. Assumed 1in. (25.4mm) clear between inside of 10.5in dia. void and inner spiral.

Cover to outer spiral = 3in (76mm)
Spiral W11 @ 76mm pitch
Material properties, as for Pier 19

Prestressed Section:

Prestressing: Number of strands is not given. 12x0.6in strands (Total area = 1680mm^2).
PCD of prestressing = 422mm
Initial stress = 1096MPa
Yield stress = 1500MPa
Ultimate stress = 1862MPa (270ksi)
Confinement W11 spiral @ 76mm.

Deflection Calculations:

Since the pile cap is embedded in the bay muds, simple deflection calculations based on an assumed depth to fixity were inappropriate. Hence this report only provides the appropriate moment-curvature and moment-rotation characteristics to be used in a push-over analysis. However, the following data were assumed for the plastic hinge lengths:

Plastic hinge length at footing connection:

$$L_P = 0.03 f_y d_{bd} = 0.03 \times 455 \times 34.9 = 466mm$$

Plastic hinge length in-ground (conservative estimate)

$$L_P = 2D_P = 2x0.61m = 1.22m$$

Limit States Considered:

Yield: For footing connection, ε_s = 0.002275, or ε_c = 0.002 (whichever first)
Prestressed**:** ε_p = 0.0075 or ε_c = 0.002 (whichever first)

Serviceability: Footing Conn: ε_s = 0.015 or ε_c = 0.004 (whichever first)
Prestressed: (same as footing connection)

Damage Control: Footing Conn: $\varepsilon_s = 0.07$, or $\varepsilon_c = 0.0147$ (energy balance)
Prestressed: $\varepsilon_p = 0.04$ or $\varepsilon_c = 0.008$

Ultimate: Footing Connection: $\varepsilon_s = 0.07$
Prestressed: Same as Damage control.

Notes:
1. The program used for moment-curvature analysis did not have the capability for analysis of rectangular prestressed piles with a circular inner core, or a circular disposition of dowels. Instead, two alternative approximations were used. The first used a rectangular section with a rectangular disposition of dowels and confinement. The second used an equivalent circular section with slightly increased diameter, but exact modelling of the prestressing or the dowel disposition. It was found that the strengths and limit state curvatures agreed to within about 5%. Since stability problems were found in the analyses with the circular section approximation, the equivalent square section with square reinforcement disposition was used to generate the following results.

2. Analyses were carried out for the nominal design load of 250 tons (2223kN), an upper limit of 750tons (6668kN) and, for the footing connection, a lower limit of 5.6tons (50kN). The program was unstable for lower axial loads for both the footing connection and the prestressed section. However, it was clear from the trends exhibited for the higher load levels that low compressive, or tensile axial forces would not create critical conditions.

3. Since the footing is embedded in the soft surficial bay muds, the plastic hinge length for the in-ground hinge is likely to be considerable. Based on experimental results at UCSD, a conservative estimate of $2D_P$ (1.22m) was assumed.

4. Experiments (UCSD) have shown that the presence of prestress at the top of the pile inhibits spalling of the cover concrete, particularly where the moment gradient is high, as will be the case with embedded footings. To represent this, the cover for the pile/footing connection was conservatively reduced to 36mm for the analyses. For the in-ground hinge, the soil confinement will also eliminate cover spalling until a peak surface strain of 0.008 (corresponding to LS3 and LS4). As a consequence, the effective cover was reduced to 20mm (the minimum value for which stable analytical results could be obtained) for the in-ground hinge calculations.

2. Pile/Footing Connection Characteristics

2.1 Moment-Curvature Response:

Results of the analyses are plotted in Fig.4 and listed in Table 4. A bilinear approximation to the moment-curvature curves is included and the various limit states are identified in Fig.4 by solid circles. It will be noted that the strength drop after the serviceability limit state is significant, as a consequence of spalling of the extensive cover. This is particularly apparent for the high axial load limit of 750tons.

It will be noted that the curvatures associated with a particular limit state decrease as the axial load increases.

2.2 Moment-Rotation Response:

The moment-rotation response of the pile/footing connection is shown in Fig.5 in quadri-linear and bilinear forms, with the quadrilinear curve defined by the four limit states. It will be seen than the plastic rotation capacity of the section is close to 0.03 for the critical case of maximum axial compression, and more than 0.04 for other cases. The rotation at the yield limit state (LS1) corresponds to elastic strain penetration of the dowel bars into the footing, and is typically about 0.002. Rotational values at the four limit states are included in Table 4.

3 Prestressed Section Characteristics

3.1 Moment-Curvature Response:

Moment-curvature response of the prestressed section at two different axial load levels, together with bilinear approximations, are shown in Fig.6, with the limit states identified by solid circles. Note that only LS1, LS2 and LS3 are shown, since the ultimate limit state (LS4) is the same as the damage-control (LS3) limit state. Values for moment and curvature for the limit states are listed in Table 5.

It will be noted that the prestressed section moment capacity, for a given limit state, exceeds the capacity of the dowel connection. There is thus no possibility of hinging developing in the piles immediately below the dowels.

3.2 Moment-Rotation Response:

Key values of the rotational capacity of the in-ground hinge at the serviceability and ultimate limit states are also listed in Table 5. Note that there is no yield rotation, as strain penetration does not occur at the critical in-ground location. Since there are only two data points for each limit state, plots of rotational capacity are not provided.

4. Elastic Stiffness of piles for Deflection Calculations

Pile Stiffness for the elastic component of deflection calculations should be based on moment-curvature response of the prestressed section at a moment of about 75% of nominal flexural strength. This resulted in the following elastic stiffness values:

Axial load = 2223 kN EI = 225,000kNm^2

Axial load = 6668 kN EI = 308,000kNm^2

TABLE 4: 24in PILE/FOOTING LIMIT-STATE DEFORMATIONS

LIMIT-STATE VALUES	P=2223kN	P=6668kN	P=50kN
First-Yield Moment (kNm)	937	1073	618
First-Yield Curvature (m^{-1})	0.0103	0.00623	0.00950
First-Yield Rotation (rad)	0.0024	0.00145	0.00221
Serviceability Moment (kNm)	1062	1350	790
Serviceability Curvature (m^{-1})	0.0221	0.0151	0.0296
Serviceability Rotation (rad)	0.0079	0.00557	0.0116
Damage-Control Moment (kNm)	980	1246	780
Damage-Control Curvature (m^{-1})	0.0589	0.0435	0.0775
Damage-Control Rotation (rad)	0.0250	0.0188	0.0339
Ultimate Moment (kNm)	900	1150	760
Ultimate Curvature (m^{-1})	0.0884	0.0653	0.1163
Ultimate Rotation (rad)	0.0388	0.0290	0.0520
Bilinear Yield Moment (kNm)	980	1250	780
Bilinear Yield Curvature (m^{-1})	0.0117	0.00784	0.0121
Bilinear Yield Rotation (rad)	0.00251	0.00169	0.00279
Bilinear Ultimate Moment (kNm)	980	1250	780
Bilinear Ultimate Curvature (m^{-1})	0.0884	0.0653	0.116
Bilinear Ultimate Rotation (rad)	0.0388	0.0290	0.0520

TABLE 5: 24in. PRESTRESSED SECTION LIMIT-STATE DEFORMATIONS

LIMIT-STATE VALUES	P=2223kN	P=6668kN
First-Yield Moment (kNm)	975	1452
First-Yield Curvature (m^{-1})	0.00720	0.00878
First-Yield Rotation (rad)	0	0
Serviceability Moment (kNm)	1067	1480
Serviceability Curvature (m^{-1})	0.0242	0.0126
Serviceability Rotation (rad)	0.0222	0.0093
Ultimate Moment (kNm) (also LS3)	1015	1351
Ultimate Curvature (m^{-1}) (also LS3)	0.0477	0.0265
Ultimate Rotation (rad) (also LS3)	0.0509	0.0262
Bilinear Yield Moment (kNm)	1050	1400
Bilinear Yield Curvature (m^{-1})	0.0060	0.0050
Bilinear Ultimate Moment (kNm)	1050	1400
Bilinear Ultimate Curvature (m^{-1})	0.0477	0.0265

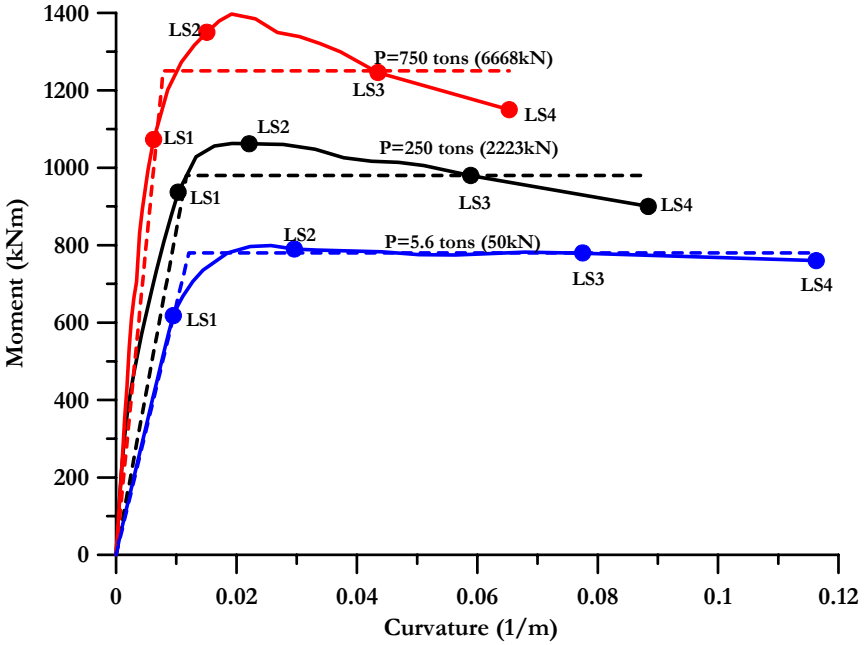


Fig.4 MOMENT-CURVATURE RESULTS FOR 24in PILE/FOOTING CONNECTION
(LS1 =Yield, LS2 = Serviceability, LS3 = Damage Control, LS4 = Ultimate)

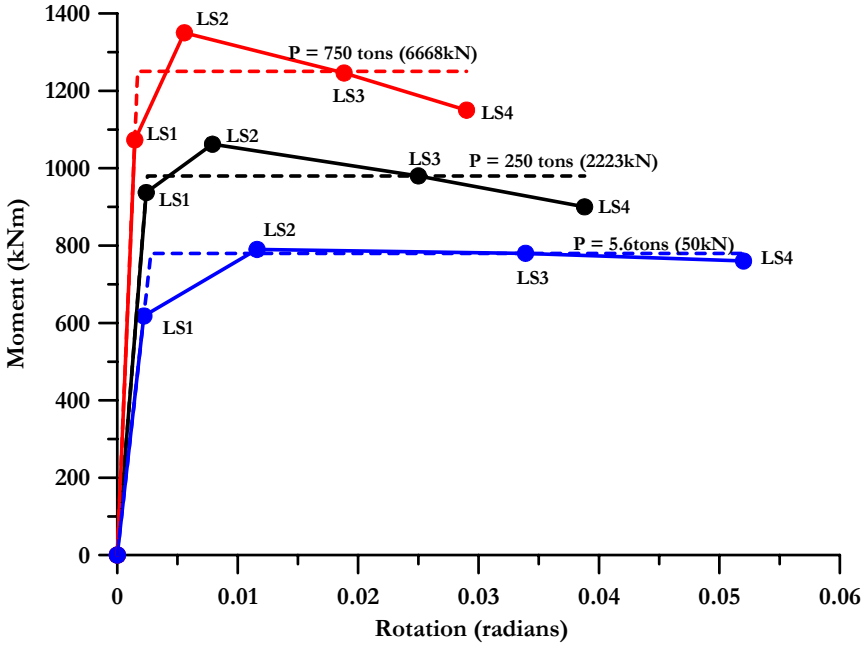


Fig.5 MOMENT-ROTATION RESULTS FOR 24IN PILE/FOOTING CONNECTION
(LS1 = Yield, LS2 = Serviceability, LS3 = Damage Control, LS4 = Ultimate)

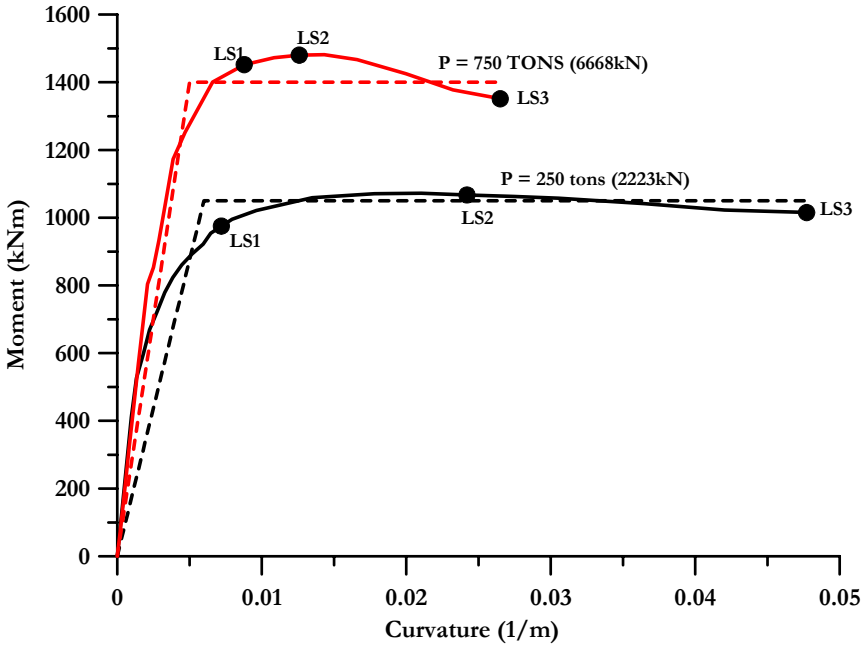


Fig.6 MOMENT-CURVATURE RESULTS FOR 24in PRESTRESSED PILE SECTION (LS1 = Yield, LS2 = Serviceability, LS3 = Damage Control/Ultimate)

GEOTECHNICAL SITE CHARACTERIZATIONREPORT ANTIOCH BRIDGE SEISMIC RETROFIT PROJECT

Task Order No. 2A

Prepared for:

Bay Area Toll Authority (BATA)
And
California Department of Transportation (Caltrans)

Submitted by:

EARTH MECHANICS, INC.

October 2, 2008

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1.0 INTRODUCTION

This Geotechnical Site Characterization Report presents the results of a geotechnical investigation and data analyses conducted by Earth Mechanics, Inc. (EMI) for the Antioch Toll Bridge Geotechnical Investigation project. This work was conducted under contract with the Bay Area Toll Authority (BATA), with the California Department of Transportation (Caltrans) providing technical oversight for the project. The project is located in the northeastern portion of the San Francisco Bay area, in the San Joaquin River Delta as indicated on the Site Location Map, Figure 1-1.

1.1 Purpose and Scope of Work

The overall geotechnical investigation program conducted by EMI consists of the following three major elements for the Antioch Toll Bridge:

Geotechnical Site Characterization: A number of soil borings (both marine and on-land), CPT soundings (marine and on-land), geophysical measurements, in-situ testing, laboratory testing, subsurface interpretation, and characterization of engineering properties of soils are performed. Faulting study was also conducted to clarify the existence of Antioch Fault and the possibility of surface fault rupturing. The operation of the field program, findings from the in-situ and laboratory testing, Logs-of-Test Borings (LOTBs), the interpreted subsurface conditions and the faulting study are documented in this report entitled "Geotechnical Site Characterization for Antioch Bridge Seismic Retrofit Project."

Ground Motion Study: The ground motion study includes probabilistic and deterministic seismic hazard analyses incorporating the 2007 Delta Risk Management Study by URS, development of reference rock motion criteria for the Safety Evaluation Earthquake (SEE), generation of spectrum compatible time histories for site response analyses, and kinematic soil-structure interaction analyses to develop ARS (Acceleration Response Spectrum) design curves and pier-specific kinematic time histories. The findings are documented in an EMI report is entitled "Ground Motion Study for Antioch Bridge Seismic Retrofit Project."

Foundation Analysis: Detailed analyses of the foundations are conducted. The analyses include characterizations of lateral soil supports (p-y curves), and axial soil supports (t-z and q-u curves) along the pile. Pile capacity evaluations are conducted by performing axial and lateral load-deformation analyses on a single pile. The pile groups are characterized by linearized 6x6 stiffness and mass matrices to be used in a global bridge model for seismic response evaluation. Liquefaction potential and associated settlement is also evaluated at susceptible locations. The results are provided in an EMI report entitled "Foundation Analysis for Antioch Bridge Seismic Retrofit Project."

The purpose of the geotechnical site investigation is to collect data in order for the characterization of geologic deposits and subsurface properties along the Antioch Toll Bridge alignment. The geotechnical site investigation services provided for this project include the following tasks:

- On-land and over-water field explorations including drilling and logging of soil borings, in-situ seismic wave velocity measurements, in-situ shear strength measurements, and an offshore geophysical survey.
- Laboratory testing to characterize materials properties for selected soil and rock samples.
- Interpretation subsurface information and preparation of this report presenting the geotechnical data obtained.

The geotechnical data collected and presented in this report were used in the determination of the performance of the bridge during a design earthquake and in the evaluation of seismic retrofit work needed for the bridge.

1.2 Project Description and Background

The project is located along the 1.6 mile-long Antioch Toll Bridge (officially known as the Senator John A. Nejedly Bridge). The bridge crosses the San Joaquin River and links Antioch, California (Contra Costa County) in the south with Sacramento County, California in the north via California State Highway 160 (Figure 1-1).

The original Antioch Bridge was privately owned and operated from its inception in 1926 to 1940, when it was purchased by the State of California. The older bridge was replaced in 1978 with the current structure; a portion of the former bridge still exists as a fishing pier southeast of the modern bridge in the town of Antioch. The southern abutment of the Antioch Toll Bridge is located in the northeastern corner of Antioch and the northern abutment extends 4,000 feet onto Sherman Island in Sacramento County. The high-level, steel plate girder structure is 1.6 miles long and 40 feet wide with a narrow shoulder in each direction for bicyclists, pedestrians, and emergency use. The bridge accomodates one lane of traffic in each direction. The navigational clearance of the modern bridge is 135 vertical feet and horizontal 400 feet.

The entire bridge is composed of Main Channel, South and North Approaches, and a slab structure in the north end (see Figure 1-2); all supported on pile foundations. The South Approach consists of Abutment 1 and Pier 2 through Pier 16, with Abutment 1 founded on 14-inch square concrete piles and Piers 2 to 16 on 24-inch square concrete piles. The Main Channel span contains Piers 17 to 21, each supported on 54-inch diameter concrete hollow piles with a pile cap cantilevered 27 to 52 ft above the mud-line. The North Approach consists of Piers 22 through 41, with Pier 22 through Pier 38 supported on 24-inch square concrete piles, Piers 39 and 40 on 30-inch diameter steel pipe piles in-filled with concrete, and Pier 41 founded on 14-inch square concrete piles.

The slab structure at the end of the North Approach is composed of 30 piers (Pier 42 through Pier 70 and Abutment 71), each supported on extensions of four 12-inch square concrete vertical piles with a slender cap-beam near the mud-line elevation.

While the Antioch Toll Bridge construction incorporated seismic resistant features as required by the post-1971 San Fernando earthquake codes, recent significant changes in seismic design practice prompted Caltrans to initiate vulnerability studies in 2004 (Caltrans, 2005). The studies were unable to conclusively determine the performance of the bridge during a maximum credible earthquake. The vulnerability studies recommended

that a comprehensive geotechnical study be conducted to determine whether seismic retrofit work is needed for the bridge.

In addition to this investigation, other current major projects in the region include a wide-ranging study recently begun by the California Department of Water Resources on the engineering integrity of levees in the Sacramento-San Joaquin Delta.

- A Department of Water Resources report entitled "Seismic Hazards in Sacramento-San Joaquin Delta", October 1980 (DWR, 1980)
- A report for CALFED Bay – Delta Program, "Seismic Vulnerability of the Sacramento – San Joaquin Delta Levees, April, 2000 (CALFED, 2000)
- A URS Corporation memo report entitled "Delta Risk Management Study (DRMS) Phase 1, Topical Area: Draft Seismology", conducted for the Department of Water Resources dated February 1, 2007 (URS, 2007)

1.3 Datum

Coordinates and elevations were determined through field surveying using a Thales ProMark3 differential global positioning system (DGPS) with GNSS processing software accurate to approximately 8 horizontal feet and 2-3 vertical feet. Locations are reported in feet using the California Coordinate System of 1983 (CCS83), California Zones 2 & 3 (Sacramento County and Contra Costa County, respectively) and are referenced to the (horizontal) North American Datum of 1983 (NAD83). Elevations are reported in feet and are referenced to the (vertical) National Geodetic Vertical Datum of 1929 (NGVD29). NGVD 29 was used rather than the North American Vertical Datum of 1988 (NAVD88) to maintain contiguity with existing as-built plans. Elevations for the over-water survey sites were initially referenced to river/tide-stage data from the California Department of Water Resources, San Joaquin River at the Antioch gauging station which uses NAVD88 as a vertical datum. The elevations were subsequently adjusted to the NGVD29 datum using a correction value established for the ANH (B95020) station in October 2006.

1.4 Report Organization

This report summarizes results of the geotechnical investigation in the following sections:

- Section 1.0 provides an introduction to the subject;
- Section 2.0 describes the site exploration program;
- Section 3.0 summarizes the laboratory testing program;
- Section 4.0 provides geology and subsurface conditions;
- Section 5.0 presents engineering properties of soil and design parameters; and
- Section 6.0 provides the references.

These text sections are followed by:

- Figures consisting of maps, soil profiles and data plots,
- Appendix A: Logs of Previous Explorations,

- Appendix B: Logs of Test Borings (LOTB),
- Appendix C: Suspension Logging Results,
- Appendix D: Cone Penetration Test Results,
- Appendix E: Geophysical Survey and Bathymetry Data,
- Appendix F: Laboratory Tests and Data,
- Appendix G: Site Exploration Photos,
- Appendix H: Review of Potential Seismic Sources, and
- Appendix I: Review of Antioch Fault

1.5 Previous Reports

The following existing reports document previous studies of interest to this project:

- "Antioch Toll Bridge: Seismic Vulnerability Study" prepared by Caltrans-DES/OEE, 2005.
- "Log of Test Borings, San Joaquin River Bridge, Drawings 98 to 106" By Caltrans, 1975.

2.0 FIELD INVESTIGATIONS

2.1 Review of Existing Data

We reviewed a variety of references related the geotechnical, geologic, and seismic conditions near the Antioch Toll Bridge and the southern San Francisco Bay. Selected references are listed at the end of this report in Section 6.0. Along the bridge alignment, explorations prior to the current project consist of soil borings and penetration tests performed by Caltrans in 1964, 1967, 1970, and 1974 for the San Joaquin River Bridge (the Antioch Toll Bridge) project.

A total of 37 soil borings and 15 penetration test borings were drilled during these periods. The deepest borings penetrated to elevation -220 feet. Findings from these drilling activities from different years were summarized on nine sheets of boring logs in 1975 during design of the San Joaquin River Bridge. Logs of these borings are presented in Appendix A.

In 2006, Caltrans drilled a deep borehole between Bents 3 and 4 of the Antioch Toll Bridge for installation of a downhole seismic array. The boring was approximately 350 feet deep and was logged for compression and shear wave velocities prior to installation of the seismic array. On Sherman Island side, DWP made measurements of shear wave and compression wave velocities in a 150 feet deep borehole in 1994. These shear wave velocity measurements were reviewed and the data are included on the idealized soil profile.

2.2 Present Field Investigation

2.2.1 General

During the period of November 6, 2006 to April 20, 2007, Earth Mechanics Inc. (EMI) conducted a geotechnical investigation along existing piers and abutment structures of the Antioch Toll Bridge. The field investigation was carried out both on-land and over-water, and consisted of ten soil borings, six downhole seismic suspension loggings, and 38 cone penetrometer tests (CPT). Whenever possible, on-land sites were located directly under the bridge structure on both the north (Sherman Island) and south (Antioch) sides of the bridge. Where access under the bridge was not possible, sites were located ~ 20’ adjacent to the structure. Over-water sites were located west of the pier supports in the San Joaquin River. Boreholes and CPT soundings ranged in depth from approximately 69 to 261 ft and have designations consistent with hole assignment criteria detailed in the Caltrans soil logging manual (Caltrans, 2007). These are based on borehole type (e.g., CPT) and relative position (e.g., 06-03). Summaries of the soil and CPT borings are presented in Table 2-1. Soil and CPT boring locations are shown in Figure 2-1. A geologic cross section is presented in Figure 2-2.

Of the ten soil borings, eight were positioned on-land (06-01 and 06-02, and 06-05 through 06-10) and the remaining two were positioned over-water (06-03 and 06-04). Over-water drilling was conducted from 1/30/2007 to 2/2/2007. On-land drilling was conducted from 11/6/2006 through 11/18/2006 at five locations of the six locations; the final on-land borehole (06-05) was inaccessible due to wet conditions and was drilled April 12, 2007. On-land drilling required two ~10 hour day shifts per site; over-water drilling was conducted around-

the-clock and lasted ~29 to 34 hours per location depending on site conditions and borehole depth. Logs of test borings (LOTBs) are presented in Appendix B.

In addition to drilling and sampling, downhole seismic suspension logging was performed at six borehole locations (06-02, 06-03, 06-04, 06-05, 06-07, and 06-08). Results of the suspension logging are presented in Appendix C.

25 on-land and 13 additional over-water sites were selected for CPT testing. On-land CPT were performed as seismic soundings; the remaining tests were performed as conventional soundings. CPT durations ranged from ~1 to 4 hours depending on site location and conditions. Most CPT were conducted from 11/13/06 to 11/22/06; three (06-CPT-19, 06-CPT-35 and 06-CPT-36) were delayed until 4/20/2007 due to soft ground conditions. Results of the CPT borings are presented in Appendix D.

Table 2-1. Summary of Soil Borings and CPTs

	Boring	Coordinates (CCS83; CA-Zone 2 and 3, NAD83)		Dates Drilled		Total Depth (ft)
		Northing	Easting	Start Date	End Date	
On-land soil borings	06-01	2195074.61	6201159.23	11/6/06	11/7/06	121.5
	06-02	2196002.65	6201136.19	11/14/06	11/15/06	200.5
	06-05	2200250.22	6201188.25	4/12/07	4/13/07	101.5
	06-06	2201249.40	6201199.57	11/8/06	11/9/06	121.5
	06-07	2202447.25	6201216.19	11/20/06	11/21/06	260.5
	06-08	2203762.66	6201259.24	11/17/06	11/18/06	121.5
	06-09	2204182.20	6201181.09	11/8/06	11/9/06	121.5
	06-10	2204562.70	6201185.83	11/6/06	11/7/06	121.5
Over-water Soil Borings	06-03	2197414.69	6201067.72	1/30/07	1/31/07	-10.8
	06-04	2198565.36	6201079.97	2/1/07	2/2/07	-22.3
On-land CPT Borings	06-CPT-01	2195275.71	6201093.60	11/14/06	11/14/06	93.50
	06-CPT-02	2195453.17	6201084.80	11/13/06	11/13/06	88.75
	06-CPT-03	2195608.14	6201086.45	11/14/06	11/14/06	83.50
	06-CPT-04	2195849.98	6201086.76	11/14/06	11/14/06	77.59
	06-CPT-18	2200003.30	6201244.05	11/17/06	11/17/06	100.23
	06-CPT-19	2200475.40	6201189.46	04/20/07	04/20/07	59.6
	06-CPT-20	2200651.27	6201193.95	11/21/06	11/21/06	100.06
	06-CPT-21	2200845.74	6201195.47	11/21/06	11/21/06	100.23
	06-CPT-22	2201044.52	6201199.95	11/21/06	11/21/06	100.06
	06-CPT-23	2201448.06	6201202.04	11/20/06	11/20/06	100.23
	06-CPT-24	2201665.03	6201204.06	11/20/06	11/20/06	100.06
	06-CPT-25	2201837.09	6201208.10	11/16/06	11/16/06	100.23
	06-CPT-26	2202061.78	6201210.56	11/15/06	11/15/06	101.05
	06-CPT-27	2202277.81	6201211.19	11/15/06	11/15/06	100.23
	06-CPT-28	2202662.82	6201213.64	11/15/06	11/15/06	100.23
	06-CPT-29	2202854.83	6201214.16	11/16/06	11/16/06	100.23
	06-CPT-30	2203055.75	6201216.11	11/16/06	11/16/06	100.23
	06-CPT-31	2203162.61	6201214.86	11/20/06	11/20/06	88.09
	06-CPT-32	2203351.53	6201269.12	11/17/06	11/17/06	100.23
	06-CPT-33	2203637.08	6201285.57	11/22/06	11/22/06	100.23

Table 2-1 (continued). Summary of Soil Borings and CPTs

	Boring	Coordinates (CCS83; CA-Zone 3, NAD83)		Dates Drilled		Total Depth (ft)
		Northing	Easting	Start Date	End Date	
On-Land CPT borings	06-CPT-34	2203950.48	6201189.53	11/13/06	11/13/06	100.06
	06-CPT-35	2204418.70	6201197.87	11/13/06	11/13/06	100.23
	06-CPT-36	2204975.60	6201205.14	04/20/07	04/20/07	62
	06-CPT-37	2205388.55	6201213.02	04/20/07	04/20/07	60
Over-water CPT borings	06-CPT-05	2196246.50	6201038.83	2/5/07	2/5/07	-7.0
	06-CPT-06	2196478.81	6201056.74	2/3/07	2/3/07	-11.4
	06-CPT-07	2196624.27	6201077.50	2/10/07	2/10/07	-10.8
	06-CPT-08	2196824.26	6201085.70	2/9/07	2/9/07	-10.0
	06-CPT-09	2197024.05	6201084.71	2/9/07	2/9/07	-10.9
	06-CPT-10	2197224.23	6201090.78	2/8/07	2/8/07	-13.9
	06-CPT-11	2197624.08	6201067.48	2/8/07	2/8/07	-20.4
	06-CPT-12	2197824.22	6201092.67	2/7/07	2/7/07	-21.2
	06-CPT-13	2198024.28	6201095.98	2/6/07	2/6/07	-23.1
	06-CPT-14	2198234.26	6201087.28	2/5/07	2/5/07	-19.8
	06-CPT-15	2198840.80	6201120.82	2/12/07	2/12/07	-34.3
	06-CPT-16	2199327.93	6201051.78	2/11/07	2/11/07	-44.6
	06-CPT-17	2199655.20	6201044.38	2/11/07	2/11/07	-12.3

2.2.2 Drilling and Soil Sampling Operations

General Drilling and Sampling Procedures.

All soil borings were drilled by Gregg Drilling, located in Martinez, CA and East Palo Alto, CA using mud-rotary-wash drilling methods. Soils were generally sampled at ~5 ft intervals for ~100 ft; below the uppermost ~100 ft, sample intervals were altered to every ~10 ft. Sampling alternated between Standard Penetration Test (SPT) and California Modified (MC) samplers. Shelby tube (ST) and Pitcher tube (PT) samplers were used at on-land sites at depths where soils were expected to be predominantly fine-grained. The precise depth interval for sampling with Shelby/Pitcher tubes was determined in the field when drilling conditions (i.e., blow counts or degree of resistance encountered) suggested soils were the appropriate density/consistency for lab tests. SPT sampling was conducted to analyze grain size distributions and moisture content; California Modified, Shelby and Pitcher tube sampling were conducted for consolidation tests and shear tests that require that require soil samples that are relatively undisturbed.

Standard Penetration Tests (SPT) and California Modified (MC) samplers were driven using a 140-lb hammer free falling from a height of 30 inches. The number of blows required to advance the sampler 18 inches was recorded to determine penetration resistance. Blow counts were recorded for each 6" interval; counts from the last 12" were used to calculate consistency and density values. Where the count exceeded 50 blows in the first 6", the blow count was recorded as '0' or, 'refusal' and hammer driving for that depth increment was terminated. Where the count exceeded 50 blows in the second or third 6" interval, driving for that depth increment was terminated and blow counts were recorded as the number of blows driven below the first 6", per number of inches penetrated before meeting resistance (i.e., > 50 blows per <12").

SPT split-tube samplers, 18" in length, with inner and outer diameters of 1.4" and 2.0" respectively, were used in the drilling. SPT samples were placed in plastic sampling bags and tightly sealed with twist ties and electric tape. MC split-spoon samplers, 18" in length, with inner and outer diameters of 2.5" and 3.0" respectively, were lined with one-inch brass rings. Generally, the lowest 6 rings (6" of sample) that were relatively undisturbed by the drilling and extraction processes were encased in 6" plastic-lined sampling tubes, capped, and sealed with electrical tape. Shelby and Pitcher tubes were pushed with a continuous motion using the drill rig's hydraulic system. After the push was completed, the drill rod string was rotated to shear off the sample at the cutting edge. The sample tubes were then capped, sealed with electric tape, and kept in an upright position. All samples were logged in the field and moved to storage in a refrigerated trailer.

On-land Drilling and Sampling Procedures

On-land drilling procedures involved the use of a truck-mounted Failing 1500 drill rig equipped with a 3.87" diameter tri-cone drill bit operated by Gregg Drilling out of their East Palo Alto, CA office. In addition to alternating SPT and MC sampling, hand–augured bulk samples were collected from the first four ft of each borehole. Soil sampling was conducted with alternating SPT, MC and Shelby/Pitcher tube samplers varying depths between ~100' and ~250' at each of the eight on-land sites (06-01, 06-02, and 06-05 through 06-10).

Over-water Drilling and Sampling Procedures

Over-water drilling was conducted using Gregg Drilling's *Quin Delta*, equipped with a Mobile B-80/22 mud-rotary drill rig, mounted ~ 30 ft from the bow. The 110' long ship was navigated into position next to the pier structures so boreholes could be drilled as closely as possible to the pier footings. The ship's design, with a shallow (3 ft) draft and long (80 ft) spuds, allowed for stable anchoring in the fluctuating channel conditions of the San Joaquin River delta.

An on-board, real-time DGPS system was used for navigation and calculating tide elevations. At each site, prior to drilling, initial water depth (depth to mudline) was measured using a weighted tape. Water depths ranged from 0 to 50+ feet depending on channel bathymetry and tidal fluctuations (up to 8 ft). Elevations were referenced to river/tide-stage data from the Antioch gauging station, and depths were monitored and readjusted for river stage/tidal fluctuations in order to maintain consistent sampling intervals and to conduct tests at target elevations. Depth corrections in the field were based on charts provided by the NOAA's Electronic Navigational Charts database.

Soil Logging

Soil logging was conducted in accordance with procedures defined in Caltrans Soil and Rock Logging Classification Manual (Caltrans, 2006). Caltrans has recently released an updated version of this manual; however, it was not available at the time of the field investigation. Logs include borehole location, time and date of drilling, sample depths, blow counts, percent recovery, in-situ test depths, and soil classification with soil descriptions. Soil samples were classified using the Unified Soil Classification System (USCS); bedrock was not encountered in any of the boreholes. Field-based estimates of soil properties (i.e., color, soil moisture, grain size, etc.) were used for initial soil description and classification; classifications were subsequently modified based on quantitative values from laboratory tests.

SPT Energy Calibration

SPT energy calibrations were conducted to correct for the energy loss transferred to the drilling rod with each hammer blow. To conduct SPT energy calibrations, instrumented sections are attached to rods that measure strain and elevation with each hammer blow. SPT energy calibrations were conducted with Gregg Drilling's Pile Driving Analyzer® (PDA). The N values calculated by the PDA were adjusted to the normalized (60% energy ration) standard for energy transferred to the rods. All equipment and analyses conform to ASTM D6066.

Borehole Abandonment and Waste Disposal

At the completion of drilling, boreholes were backfilled with grout, and soil and drilling-mud waste was placed into labeled 55-gallon steel drums that were removed from site by Waste Management, Kettleman City, CA. The contents of the drums were tested for Title 22 metals (EPA 6010B/7471A), volatile organics/BTEX (EPA 5030B/8260B), and total recoverable petroleum hydrocarbons (EPA 418.1). Based on the testing, the contents were classified as non-hazardous and suitable for disposal at approved waste repositories.

2.2.3 Logs of Test Borings

Ten Logs of Test Borings are provided in Appendix B. The soil logs generally follow the Caltrans' standard format and give borehole locations and depths, condensed descriptions of boring operations, blowcounts, descriptions and classifications of soils, and annotated references to soil laboratory tests.

2.2.4 Down-hole Seismic Suspension Logging

Down-hole seismic suspension logging (P-S logging) was conducted to supplement stratigraphic information and establish shear wave velocity profiles of the subsurface.

P-S logging was performed at six locations, both on-land and over-water, by GEOVision of Corona, CA between the dates of 11/16/2006 and 2/2/07 using the OYO Model 170 Suspension Logging system. Detailed descriptions of the instrumentation, procedures results and analysis of the seismic suspension logging are presented in Appendix D.

2.2.5 Cone Penetration Tests

Cone penetration tests (CPT) were performed over-water and on-land, respectively, at 38 locations. Detailed results of CPT borings are presented in Appendix D.

CPT Procedures

Over-water CPT were carried out aboard the Gregg Drilling's *Quin Delta* drill ship from 02/03/07 and 02/12/07. Soundings were conducted using a 20-ton capacity cone with an equal end area friction sleeve of 225 cm^2, a tip area of 15 cm^2 (60° apex), and a tip end area ratio of 0.85. Appendix D provides data for corrected tip stress (q_t), sleeve friction (f_s,), friction ratios (R_f), correlations to normalized SPT blow counts (SPT N/60), pore water pressure (u_2) and model soil behavior type (SBT). All measurements of q_c, f_s, and u_2 were taken at 5 cm intervals and values were plotted as a function of depth, providing a virtually continuous, real-time log of soils properties.

Seismic CPT Procedures

On-land seismic CPTs were carried out by Gregg Drilling from 11/13/06 to 4/20/07. Seismic CPT were conducted every five feet using the same cone, sleeve, tip, etc. as described above. The geophone offset distance was 0.66 feet and the source offset distance was 1.67 feet. Corrections for offset distances between the seismic beam and both geophone sets were applied in velocity calculations. To check waveform consistency and maintain desired signal resolution with depth, a minimum of two waves were recorded for each test and the input sensitivity was increased with depth. Shear wave data were sampled at a frequency of 20 kHz and compression wave data were sampled at 50 kHz. Wave form plots and data for shear wave velocity calculations are presented in Appendix D.

2.2.6 Offshore Geophysical Survey

An offshore geophysical program for the Antioch and Dumbarton Bridges was conducted by Golder Associates Inc. in December of 2006. The program consisted of multibeam bathymetry, sidescan sonar and subbottom/seismic reflection profiling. The report by Golder Associates, presented as Appendix E, provides information on testing equipment and procedures, analyses, and information on surficial data from the Bay floor, including a bathymetry map. The Microstation contour files and raw data for the bathymetry map is presented on a CD included with this report. This data has been electronically submitted to Caltrans. The bathymetry data on the CD includes: the "original" points gathered in the MLLW vertical control system; the original points "translated" into the NGVD29 vertical control system; and files showing both the NGVD29 elevation and the MLLW elevations.

3.0 LABORATORY TESTING PROGRAM

Laboratory tests were conducted between the dates of 3/20/2007 and 7/2/2007 by Earth Mechanics, Inc., Fountain Valley, CA, by Petra Geotechnical, Inc, Orange County and by Cooper Testing Laboratory in Palo Alto, CA. Tests were conducted on soil samples that were considered representative of subsurface conditions in general accordance with applicable American Society for Testing and Materials (ASTM) standards. The Shelby/Pitcher tube samples were x-rayed by Testing Engineers, Inc. of San Leandro, CA to identify possible voids, sedimentary discontinuities, coarse-grained intervals, etc.

Soils were classified in general accordance with ASTM D2488, which is based on the Unified Soil Classification System. Tests conducted for this project included moisture content, unit weight, grain size distribution, No. 200 sieve wash, Atterberg limits, unconsolidated-undrained triaxial compression tests, unconfined compression tests, direct shear, organic content, and corrosivity.

3.1 Descriptions of Laboratory Tests

3.1.1 Moisture-Unit Weight Tests (ASTM D-2216 & D-2937)

The in-situ moisture content in percent of dry weight and total unit weight were determined on selected drive samples taken in the field exploration. The information is useful for soil classification and the state of in-situ compaction and water content. Test results, in terms of moisture content in percent and unit weight in pound per cubic foot are given on the boring logs.

3.1.2 Grain Size Analyses (ASTM D-422) and Wash on #200 (D-1140)

Sieve and hydrometer tests as well as wash on #200 sieve were performed on representative samples of the various soils to assist in the soils classification. Liquefaction analysis and scour evaluation also rely on the grain size data. Particle sizes finer than No. 200 are determined using hydrometer tests. Results of these analyses are presented on gradation curves describing relative percentages of different particle sizes.

3.1.3 Atterberg Limits (ASTM D-4318)

Atterberg Limits Tests were performed to evaluate their plasticity and aid in their classification. The Atterberg Limits include Plastic Limit (PL), Liquid Limit (LL), and Plastic Index (PI). PL is defined as moisture content at the point of transition from semisolid to plastic state: and LL from plastic to liquid state. PI is difference between Plastic Limit and Liquid Limit which is a main parameter in distinguishing clayey soils from sandy soils.

3.1.4 Direct Shear (ASTM D-3080)

Direct shear tests were run on selected drive samples using a constant strain-rate shear machine. Samples were placed in the shear machine, a normal load applied and the samples soaked prior to shear. The samples were sheared to the end of the shear box

using an appropriate shearing rate. The test was repeated on two other samples using different normal loads. The ultimate shearing resistance for each sample was determined and a plot prepared indicating the strength parameters, the angle of internal friction (Phi) and the cohesion (C).

3.1.5 Consolidated-Undrained Triaxial (ASTM D-2850)

Consolidated-Undrained Triaxial tests were run on clayey soil samples to determine the compressive strength of the soils. Samples with a length to diameter ratio of 2 were loaded in a triaxial cell with appropriate confining pressure. However, the sample wrapped in rubber membrane is not allowed to consolidate; i.e., drainage is closed. The compressive load and axial deformation were recorded.

3.1.6 Consolidation (ASTM D-2435)

Consolidation tests were performed on drive samples to determine the moisture sensitivity and compressibility of the typical soils. This test involved loading samples into a consolidometer, which contained porous stones both top and bottom. Vertical loads were applied and the resulting deflections were recorded at various times. Normal loads were applied at a constant load-increment ratio, successive loads being generally twice the preceding load. Moisture infiltration was allowed during the tests to determine whether the samples would swell or collapse. Coefficient of consolidation, compression index, and swell index can be obtained from the consolidation testing.

3.1.7 Soil Corrosivity (CA Tests 417/422/532/643)

Resistivity, pH, soluble sulfate and chloride concentrations were determined for two bulk soil samples to evaluate the corrosion potential of common construction materials in contact with site soils. The resistivity is measured in ohm-cm, and sulfate and chloride contents in parts per million (ppm). According to Caltrans Corrosion Guidelines (Caltrans, 2003), a site is considered to be corrosive if the pH is less than 5.5, the chloride content is higher than 500 ppm or soluble sulfate content is more than 2,000 ppm.

3.1.8 Organic Test (ASTM D-2974)

The percent of organic matter in the soil is determined. It involves determination of ash content of an organic soil sample by igniting the oven-dried soil sample. The substance remaining after ignition is the ash, and the ash content is expressed as a percentage of the mass of the oven-dried sample. Organic matter is determined by subtracting percent aimed content from one hundred.

3.2 Laboratory Tests Results

A summary of types and distribution of laboratory tests performed are presented in Table 3-1. Detailed test results are presented in Appendix G and on the Logs of Test Borings (Appendix B).

Graphical summaries of N-value, unit weight, water content and index properties, undrained shear strength, and shear wave velocity taken from suspension logging and

seismic CPT are presented in Section 5.

Discussions of engineering properties, including N-value, unit weight, water content and index properties, undrained shear strength, and shear wave velocity taken from suspension logging and seismic CPT are presented in Section 5.0.

Table 3-1. Summary of Laboratory Tests

Boring#	Grain size distribution		Plasticity of cohesive soils	Compression	Organic material	Shear strength		Soil corrosivity
	ASTM D-1140	ASTM D422-63/CT 203	ASTM D 4318-84/CT 204	ASTM D 2435/CT 219	ASTM D 2974	ASTM D-2850	ASTM 3080-90	ASTM G 57-78/CT 643; ASTM G 51-77/CT 643; CT 417; CT 422
	W	SA	AL	CN	OC	UU	DS	CA
06-01	S-2 (+19) S-5 (+4) D-8 (-11) S-11 (-26)	D-4 (+9) S-7 (-6) D-10 (-21) S-15 (-46) D-22 (-91)					D-4 (+9) D-12 (-31) D-20 (-71)	S-1 (+24)
06-02	D-2 (-1) S-7 (-26) S-11 (-46) S-13 (-56)	S-1 (+4) S-5 (-16) S-9 (-36)			**S-3 (15')	D-12 (-51) D-24 (-125)	D-2 (-1) D-8 (-31)	S-3 (-6)
06-03							*D-3 (-44)	
06-04							*D-10 (-94)	
06-05					D-3 (-27)			
06-06	D-14 (-75) S-19 (-100)	D-16 (-85) D-18 (-95)	S-9 (-60)	D-3 (-30) D-22 (-115)	**S-2 (-25)	D-6 (-45) D-20 (-95)	D-16 (-85)	D-1 (-20) S-7 (-50)
06-07	D-12 (60') S-13 (64')	S-11 (54') S-15 (74')		D-19 (94')	**S-6 (29')		D-14 (69') D-16 (79')	S-1 (4') D-5 (24')
06-08	S-16 (71')	S-14 (60.5') S-18 (81') S-20 (91')	D-8 (36')	D-5 (21') D-22 (100')	**S-8 (36')	D-10 (46') D-24 (120')	D-15 (66')	S-2 (6') S-8 (26')
06-09	S-4 (-31) S-6 (-41) S-10 (-61) S-14 (-81) S-16 (-91)	D-3 (-26) S-8 (-51) S-12 (-71) D-15 (-86)	S-20 (-111)			D-13 (-76) D-21 (-121)	D-5 (-36) D-11 (-66)	D-1 (-16)
06-10	S-1 (-16) S-4 (-31) S-8 (-51) S-12 (-71)	D-3 (-26) S-6 (-41) S-10 (-61) S-14 (-81) S-16 (-88)	S-21 (-114)	D-23 (-132)	**S-2 (-21)	D-20 (-109)	D-11 (-66)	S-2 (-21)

Notes:
1) W: % < 200 Sieve ; SA: Particle Size Analysis; AL: Atterberg Limits: CN: One Dimensional Consolidation of Soil; UU: Unconsolidated Undrained Triaxial Test; DS: Direct Shear Test; CA: Measurement of Soil Corrosivity
2) ASTM = American Society for Testing and Materials; CT = California Test Methods
3) * Indicates tests performed by Cooper Laboratory, Davis, CA; ** indicates tests performed by Petra Geotechnical, Inc., Orange County, CA; all other tests performed by Earth Mechanics, Inc., Fountain Valley, CA
4) 'S'-SPT sample; 'D'-California Modified sample (elevation)

4.0 GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology and Geomorphology

The Antioch Toll Bridge spans the San Joaquin River along the eastern margin of the California Coast Range, a geomorphic province characterized by parallel to subparallel, elongated, northwest-southeast trending ranges and valleys formed as a result of ongoing motion along the Pacific-North American plate boundary. The San Joaquin River flows north from its headwaters in the southern Sierra Nevada range and cuts back to the west where it joins the Sacramento River ~ 4 miles west of the Antioch Bridge. At their confluence, the San Joaquin/Sacramento Rivers cut through the Coast Ranges into the northern San Francisco Bay and continue on to the Pacific Ocean. The uplifted Coast Ranges west of the San Joaquin/Sacramento River confluence has created a unique topographic condition resulting in the formation of an inverted delta. An inverted delta forms as the river drops sediment in a low-lying inland valley, thus creating the fan-shaped distributaries' delta; by contrast, a conventional delta forms as sediment is dropped into the ocean or another large body of water.

Once the sediment load is reduced, the rivers retain a single-channel form as they pass through the eastern Coast Ranges to the San Francisco Bay. The surficial deposits in the San Joaquin River near Antioch are highly influenced by changes in sea level that control local base level and the present inland deltaic sedimentation. Sherman Island and other delta-formed islands to the north and east are covered with up to 40' of peaty deposits, reflecting the modern conditions of sea level high. The underlying coarse sand and gravel in the channel reflect periods of lower sea level/lower base level that initiated earlier channel carving providing an outlet to the Bay.

The bedrock in the Antioch Bridge vicinity includes folded and faulted late Jurassic to Tertiary-aged rocks of the Great Valley Group (east) and the Franciscan Complex (west). Rock types are highly variable and include greywacke sandstone, chert, shale, and volcanic and metamorphic rocks. The bedrock is overlain by channelized sands and gravels eroded from underlying bedrock and higher terrain to both the east and west and fine-grained deltaic sediments at the channel base and margins.

4.2 Regional Tectonics and Seismicity

Figure 4-1 shows major faults in the Bay area. The geology of the San Francisco Bay region is controlled by the northwest trending, right-lateral San Andreas fault system that comprises several major and minor fault strands with generally similar trends, deformation styles, and seismic histories. The fault system accommodates ~1.5 inches/year of relative dextral shear within the broad boundary (60-120 miles) between the Pacific and North American plates. The sub-parallel San Andreas and Hayward fault zones strike ~N35°W to N37°W and cut through the crust at variably high angles. The San Andreas fault on the San Francisco Peninsula is a relatively young strand that has undergone ~15 miles of right-lateral offset in the past 3.3-1.3 Ma (Parsons, et. al., 2002). The Hayward fault system, including the Hayward, Calaveras, Rodgers Creek, and Healdsburg faults, has undergone ~65 miles of cumulative offset in the past 12 Ma

(Graymer, 2003).

Appendix H presents a detailed discussion of the project tectonics and seismicity by Dr. Douglas Hamilton.

Appendix I is a review of the current understanding of the nature of the Antioch fault. Based on the review, it is concluded that the possibility of surface rupture along the alignment of the Antioch Bridge resulting from tectonic faulting is extremely remote. With respect to the Antioch fault, which is included in the 1996 version of the Caltrans' Seismic Hazard Map, the California Geological Survey (then known as the California Division of Mines and Geology, CDMG) has already removed the Antioch fault from Alquist-Priolo Special Studies Zone. Upon further research, the team concluded that the Antioch fault is not considered active. Consistent with this position, the Antioch fault was not considered as a seismic source in either the 2000 Calfed Bay-Delta Program or the 2007 URS reports. Furthermore, Caltrans has removed the Antioch fault from the most recent version of the updated seismic hazard map.

4.3 Stratigraphy of the San Joaquin River, Antioch Bridge Section

Soil borings and CPT conducted for this report extend to depths of ~210 ft below ground surface. The following units have been identified and interpreted based on current and previous borehole data, and geophysical information. Within the limits of the bridge alignment, the subsurface conditions underlying the site are rather uniform and flat-lying in the region north of the main channel, with considerable variation in the area beneath the South Approach span. A cross section based on CPT data and the soil samples recovered from the borings is presented in Figure 2-2.

4.3.1 Artificial Fill

Approximately 30 feet of artificial fill was encountered at the top of the southernmost on-land boring on the south side of the bridge (06-01). Fill generally consisted of loose, fine- to very fine-grained, well-graded sand with varying clay and silt content.

4.3.2 Silty Sand, Clay, and Peat

Loose silty sand and sand with peat were encountered in the southern channel area from depths of approximately +5' to -50' mean sea level (msl). Sandy peat deposits are very soft to soft and highly organic. The sandy peat grades to loose silty sand that coarsens toward the center of the channel laterally and fines downward to soft clay and peat. Sands range from fine-grained to medium-grained with trace fine gravels of varying rock types.

Very soft to firm clay and peat deposits appear laterally continuous from depths of approximately +5' to -60' mean sea level (msl). The clayey peat deposits thicken and become more firm from south to north. Clayey peats are organic rich and highly plastic.

4.3.3 Medium Dense Sand

Laterally continuous, medium dense sand was encountered at approximately mean sea

level of –60-ft. The unit varies irregularly in thickness from <10 feet to ~40 feet with the thickness increasing toward the center of the channel. In the southern channel, the sand is interbedded with and overlies stiff clay. The sand is poorly-graded and coarsens downward, grading from fine sand to coarse-grained sand with trace fine gravel. Upper fine-grained units are faintly laminated with occasional thin (¼") clay lenses. Finer sand grains are predominantly clear quartz and micas; subangular to subrounded coarser sands and gravels are comprised of hard, black and gray rock fragments with occasional coarse milky quartz grains. Wood fragments are rare.

4.3.4 Stiff Clay

A discontinuous lens of interbedded firm to stiff, plastic clay and medium dense, clayey sand extends laterally from the southern abutment structure to the vicinity of Piers 17 and 18. The lens is relatively thin (~ > 10 to 20 feet) and is encountered at depths of approximately -30 to ~ -40-ft msl. The stiff clay is truncated or pinches out near the northern channel margin.

4.3.5 Sand and Gravel

Laterally continuous, dense to very dense interbedded sands, gravelly sands and sandy gravels are located between the depths of -20' and -100' msl. The lower contact with the hard, silty clay below (Montezuma Formation?) is abrupt. Apparent thickness varies from 15' to 80' generally thinning and decreasing in gravel content to the north. Beds tend to be thin where observed in place in the sampler. Subangular to subrounded sands and gravelly sands are poorly-graded to well-graded and generally medium- to coarse-grained with little to no fines. Coarse sand and gravels (up to ~ 3 inches) are generally poorly-graded, subrounded to well-rounded, and compositionally diverse. Rock types include dark, hard sandstone, siltstone, volcanic and metamorphic rocks, quartz and chert.

4.3.6 Hard Clay (Montezuma Formation)

Hard to stiff, yellowish brown to olive gray silty clay found continuously between approximately –100-ft to –120-ft msl. The unit may be greater in thickness than 100 feet, but data is limited below –160-ft msl. Silt content, fine sand content and plasticity are variable, but generally the unit appears homogenous. The silty clay has faint mottling texture and soil carbonate, which occurs both disseminated in the fine-grained material and as small (< ¼") nodules and filaments. The silty clay is likely from the Pleistocene-aged Montezuma Formation that outcrops to the north in the Montezuma Hills.

5.0 ENGINEERING PROPERTIES OF SOILS

The materials and sediments underlying the bridge, which belong to the late Pleistocene to Holocene deposition, is a typical of the San Joaquin/Sacramento River Delta geology. Figure 2-2 presents the idealized subsurface soil profile developed along the bridge. Within the limits of the bridge alignment, the subsurface conditions underlying the site are rather uniform and flat-lying in the region north of the main channel, with considerable variation in the area beneath the South Approach span. According to the current investigation results and previous work, the in-situ lithological units can be interpreted and grouped into the following principal strata:

- Compacted Sand Fill – Approximately 25 feet of medium dense, fine-grained, well-graded sand present at the top of the south side of the bridge;
- Loose Silty Sand and Peat – Loose silty sand and sand with peat existing in the southern channel area from elevation +10 to -60 ft;
- Medium Dense Sand – Laterally continuous, medium dense, poorly-graded sand present about at the elevation -80 ft in the main channel and -20 ft in the south approach and the north end of slab bridge span, with thickness varying from 10 to 60 feet ;
- Very soft to Firm Clay and Peat – Laterally continuous soft clay and peat present north of the main channel from elevation +10 to -60 ft;
- Stiff Clay – Discontinuous thin lenses of interbedded firm to stiff, plastic clay and medium dense, clayey sand extending laterally from the southern abutment structure to the vicinity of Piers 17 and 18 from elevation -30 to -50 ft;
- Dense to Very Dense Sand – Laterally continuous, dense to very dense interbedded sands, gravelly sands and sandy gravels present from elevation -20 to -110 ft;
- Hard Clay, Silty Clay and Clayey Silt – Hard to stiff, yellowish brown to olive gray silty clay (Montezuma Formation) found continuously below the elevation of -100 to -120 ft with thickness greater than 100 feet;
- Dense to Very Dense Sand – Isolated lenses of dense to very dense sand were occasionally encountered at elevation -200 ft.

Figures 5-1 to 5-6 show graphical summaries of N-value, unit weight, water content and index properties, undrained shear strength, and shear wave velocity taken from suspension logging and seismic CPT tests. Distinct marker colors are used in these figures in order to differentiate test results for the eight strata discussed above. Based on Figures 5-1 to 5-6, the engineering properties of the soil strata is evaluated and discussed in the following sub sections.

5.1 Blowcounts

The subsurface profiles include SPT blowcounts measured in the field and SPT-equivalent blowcounts correlated from the modified California Drive sampler blowcounts. Figure 5-1 shows the variation of these blowcounts measured in all borings with elevation.

The blowcounts in the compacted sand Fill of the south approach is in the range of 16 to 22 blows per foot, with an average of 18. The average blowcounts in the loose suilty sand and peat stratum varies from about 1 to 9 blows per foot, with an average blowcount of 5. The laterally continuous medium dense sand layer has an average blowcount of 15 above elevation -60 ft, and about 20 below that elevation. The average blowcount for very soft clay and peat layer is 2 to 3 blows per foot. For stiff clay layer the average blowcount is about 12. The average blowcount for dense to very dense sand layer above elevation -60 ft is 30 blows per feet. Below the elevation of -60ft the average blowcount varies in a wide range, with an average of more than 45. The average blowcount for hard clay and silty clay stratum is about 30 between elevations -100 and -220 feet, and about 50 below -220 feet. The average blowcount for dense to very dense sand lenses at elevation -200 ft is larger than 50.

5.2 Unit Weight

Figure 5-2 summarizes the dry and total (wet) unit weights determined from ring-lined California Drive samples plotted with elevations where the samples were retrieved. Other than very soft clay and dense to very dense sand samples, generally site soil layers have total unit weights in the range of 115 to 125 pcf. There is considerable scattering in measured unit weights for the soft clay samples. The average unit weight for the dense to very dense sand layer ranges from 125 to 135 pcf.

5.3 Water Content

Moisture (water) contents of soil specimens were determined from both SPT and ring-lined California Drive samples. The water content, Liquid Limit (LL), and Plastic Limit (PL) measured in all borings are summarized in Figure 5-3. The water contents for the very soft clay and peat layer are very high, some approaching Liquid Limit; this suggests that these very soft clays may behave like fluid. The dense to very dense sand stratum has the lowest water content; between 10 and 25%. The water contents for majority of other soils range from 20 to 35%. In general, the measured water contents and Plastic Indices (PI=LL-PL) are consistent with the soil types and ages of the formations.

5.4 Undrained Shear Strength

Figure 5-4 summarizes undrained shear strengths determined from all CPT measurements for this project. For the very soft clay and peat layer underlying the project alignment, the undrained shear strengths range from 200 psf at elevation -20 ft to 500 psf at elevation -70 ft. Significant scattering of undrained shear strength data (1,000 psf to more than 3,000 psf) can be observed in stiff clay samples. Most of the piles supporting the Antioch Bridge tip into the dense to very dense sand layer, or the hard clay, silty clay and clayey silt layer underneath that layer. The undrained shear strength of the later layer ranges from 2500 psf to 5000 psf, with significant scattering.

5.5 Shear Wave Velocity

Seismic shear wave velocities in the soils were logged using the suspension logging

method in some of the borings drilled for the project. The data was supplemented by the suspension logging data collected by others in the area. These shear wave velocities are graphically presented on the idealized soil profiles and are summarized in Figure 5-5 compiling all the data from the suspension logging. Shear wave velocities obtained from seismic CPT cones are provided in Figure 5-6. The comparison of shear wave velocity data between the suspension logging and seismic CPT is favorable.

Shear wave velocities show consistent increase in depth between elevations +0 ft and -110 ft (top of the hard clay, silty clay and clayey silt layer). They range from 400 to 800 ft/sec in medium dense sand layer, from 100 to 500 ft/sec in very soft clay and peat layer, from 300 to 600 ft/sec in stiff clay layer, and from 650to 1000 ft/sec in dense to very dense sand layer. They show moderate increase below elevation -110 ft in the hard clay, silty clay and clayey silt layer; they increase from 900 ft/sec at elevation -110 ft to 1200 ft/sec at elevation -240 ft.

5.6 Recommended Pile Design Parameters

Using the field and laboratory test data from the present investigation and the prior studies by others, a set of geotechnical design parameters were adopted for seismic evaluations. A summary of the design soil parameters developed along the bridge are presented in Table 5-1. These design soil properties were utilized during foundation analysis and ground motion studies.

Table 5-1: Geotechnical Design Parameters along the Bridge

Soil Profile I: South Approach: Abutment P01 (Sta. 134+00)

Soil Layer	Top Elevation (ft)	γ (pcf)	c (psf)	ε_{50}	ϕ (°)	k (pci)	V_s (fps)
Fill (Sand)	+20	115	-	-	32	70[1]	350~450
Medium Sand	+5	120	-	-	33	90[1]/60[2]	450~800
Dense Sand	-35	125	-	-	36	90[2]	800~1000
Hard Clay	-103	125	4000	0.005	-	-	1000~1200

Note: [1] above GWT; [2] below GWT.

Soil Profile II: South Approach: Pier P02 ~ Pier P07 (Sta. 135+00 ~ 146+00)

Soil Layer	Top Elevation (ft)	γ (pcf)	c (psf)	ε_{50}	ϕ (°)	k (pci)	V_s (fps)
Loose Sand[3]	+8 ~ +10	115	-	-	30	45[1]	300~400
Medium Sand[4]	+2	120	-	-	32	70[1]/50[2]	400~500
Soft Clay	-10 ~ +2	115	600	0.015	-	-	300~400
Medium Sand[5]	-26 ~ -12	120	-	-	33	60[2]	400~700
Dense Sand[6]	-48 ~ -34	125~128	-	-	36~38	90~115[2]	700~1000
Hard Clay	-103 ~ -102	125	4000	0.005	-	-	1000~1200

Note: [1] above GWT; [2] below GWT; [3] disappears near Pier 07; [4] only apperas near Pier 02;
[5] a soft clay sub-layer 3'~5' thick appears between Pier 02 and Pier 05 ;
[6] a firm clay sub-layer 4'~14' thick appears between Pier 05 and Pier 07 (See below for their properties).

Soil Profile III: South Approach: Pier P08 ~ Pier P16 (Sta. 147+00 ~ 164+00)

Soil Layer	Top Elevation (ft)	γ (pcf)	c (psf)	ε_{50}	ϕ (°)	k (pci)	V_s (fps)
Loose Sand	-27 ~ -16	115	-	-	30	33	300~450
Medium Sand	-37 ~ -18	120	-	-	33	60	450~700
Firm Clay	-48 ~ -28	120	1000	0.01	-	-	500~600
Dense Sand	-54 ~ -43	128	-	-	38	115	600~1000
Hard Clay	-120 ~ -98	125	4000	0.005	-	-	1000~1200

Soil Profile IV: South Approach: Pier P08 ~ Pier P16 (Sta. 147+00 ~ 164+00)

Soil Layer	Top Elevation (ft)	γ (pcf)	c (psf)	ε_{50}	ϕ (°)	k (pci)	V_s (fps)
Loose Sand	-40 ~ -34	115	-	-	30	33	300~400
Medium Sand	-60 ~ -37	120	-	-	34	70	400~700
Dense Sand	-86 ~ -72	128	-	-	38	115	600~1000
Hard Clay	-117 ~ -107	125	4000	0.005	-	-	1000~1200

Soil Profile V: Main Channel Pier P20 ~ North Approach Pier 40 (Sta. 175+00 ~ 219+00)

Soil Layer	Top Elevation (ft)	γ (pcf)	c (psf)	ε_{50}	ϕ (°)	k (pci)	V_s (fps)
Soft Clay	-46 ~ -9	110	300	0.02	-	-	250~450
Medium Sand	-79 ~ -63	120	-	-	34	70	500~700
Dense Sand[1]	-101 ~ -78	125~128	-	-	36~38	90~115	700~1000
Hard Clay	-115 ~ -98	125	4000	0.005	-	-	900~1200

Note: [1] does not appear between Pier 27 and Pier 31.

6.0 REFERENCES

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7.0 FIGURES

8.0 APPENDIX A, LOGS OF PREVIOUS EXPLORATIONS

9.0 APPENDIX B, LOGS OF TEST BORINGS

10.0 APPENDIX C, SUSPENSION LOGGING RESULTS

11.0 APPENDIX D, CONE PENETRATION TEST RESULTS

12.0 APPENDIX E, GEOPHYSICAL SURVEY AND BATHYMETRY MAP

13.0 APPENDIX F, LABORATORY TEST RESULTS

14.0 APPENDIX G, SITE EXPLORATION PHOTOS

15.0 APPENDIX H, SEISMICITY REPORT

16.0 APPENDIX I, ANTIOCH FAULT REVIEW

FED. ROAD DIST. NO.	STATE	F.A. PROJECT No.	SHEET No.	TOTAL SHEETS
7	CALIF.			

DIST.	COUNTY	ROUTE	POST MILES	SHEET No.	TOTAL SHEETS
04	CC,Sac	84	17.1/R 18.4/R	191	199

Robert C. Reynolds - # 165

DATE APPROVED December 22, 1975

TO ANTIOCH

TO SACRAMENTO

"E Const."

"E Const." 134+69.30 POT
"H" 19+48+00.00 POT

"H" LINE

B-1 B-2 B-3 B-4 B-5 B-6 B-7

BM #740

About 300' S of S abut Antioch Br along Bridgehead Ave; 103.3' NW of NW cor boat shop; 5' W of water line of yacht basin a std CHC disc in conc

Elev. 5.558

PLAN
1"=20'

Approximate ground line along "E Const."

B-3 (134+95)

Gray-brown sandy clayey silt.
GWE 11-5-66 Ft. 2.3
Stiff yellow, gray-brown clayey silt.
Very stiff gray-tan clayey silt.
Soft yellow-tan iron stained silty clay.
Very stiff yellow-brown clayey silt.
Compact yellow, gray-brown fine sand.
Compact brown fine sandy micaceous silt.
Compact gray-brown to grey fine sand.
Dense to compact grey clean fine sand.
1-5-66

B-2 (134+10)

Very stiff brown silty clay.
Very stiff light brown clay.
Compact brown fine sand.
Dense brown medium sand.
Dense to very dense grey medium sand.
Dense gray fine to medium sand.
7-21-66
300/66 1-6-66

B-7 (134+32)

Compact brown medium sand.
GWE 11-5-66 Ft. 3.4
Very stiff yellow-brown clayey silt.
Stiff yellow, gray-brown clayey silt.
Stiff gray-brown silty clay.
Slightly compact light brown sandy silt.
Compact gray silty sand.
Compact interbedded fine silty micaceous sand & sandy silt.
Very dense gray fine micaceous sand.
Dense gray fine to medium sand.
Compact gray fine to coarse sand - poorly sorted.
1-4-66

B-4 (134+51)

Gray-brown gravelly silt.
Slightly compact brown sandy silt.
GWE 11-5-66 Ft. 2.8
Fine sandy silt - occasional gravel.
Very stiff yellow-brown clayey silt.
Stiff yellow, gray-brown clayey silt.
Stiff gray-brown silty clay.
Slightly compact light brown sandy silt.
Compact gray silty sand.
Compact interbedded fine silty micaceous sand & sandy silt.
Very dense gray fine micaceous sand.
Dense gray fine to medium sand.
Compact gray fine to coarse sand - poorly sorted.
1-4-66

B-1 (134+70)

Dense gray fine to medium sand.
7-21-66
300/66 1-6-66

B-6 (134+80)

Compact gray fine to coarse sand - poorly sorted.
7-15-66

B-5 (136+35)

Soft mottled brown & gray sandy clay.
Stiff tan silty clay.
Very stiff tan silty clay.
Very stiff gray clay.
Very stiff mottled brown & gray clay.
Soft gray clay with interbedded least fine sand.
Dense gray medium sand.
Dense gray fine sand with some silt.
Very dense gray medium sand.
7-20-66

PROFILE
1"=10'

Structural Steel Alternative

LEGEND OF BORING OPERATIONS

Penetrometer
2½" Core Penetrometer
Standard Sampling (Cont.)
Rotary Sampling (Cont.)
Jet Sample
Auger Sample
Test Pit

LEGEND OF EARTH MATERIALS

Gravel
Sand
Silt
Clay
Silty Clay or Clayey Silt
Sandy Silt or Silty Sand
Fill Material
Bedrock
Sedimentary Rock
Metamorphic Rock

CLASSIFICATION OF MATERIAL ENCOUNTERED IN BORINGS

NOTE: Classification of earth material as shown on this sheet is based upon field inspection and is not to be construed to imply mechanical analysis.

BRIDGE DEPARTMENT
ENGINEERING GEOLOGY SECTION

191

STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION

SAN JOAQUIN RIVER BRIDGE
("H" LINE UNDERCROSSING)

LOG OF TEST BORINGS 1 of 9

BRIDGE NO.	POST MILE	DRAWING NO.	SHEET	OF
28-09			98	106

157811
10204

PREL. ENGINEERING EA. 04-157804

AS BUILT PLANS
Contract No. 04-157804
Date Completed
Document No. 82773

I HEREBY CERTIFY THAT THIS IS A TRUE AND ACCURATE COPY OF THE ABOVE DOCUMENT TAKEN UNDER MY DIRECTION AND CONTROL ON THIS DATE IN SACRAMENTO, CALIFORNIA PURSUANT TO AUTHORIZATION BY THE DIRECTOR OF TRANSPORTATION.

DATE 3-12 SIGNATURE Joseph M Cota TITLE SUPERVISOR OF DRAFTING SERVICES

BM "USGS J 376"
In top of E. concrete curb at S. end of Br. 35' E of ℄ Hwy 4, N. of S. end of Br.
Elev. 10 ± MSL

Addendum #165
December 22, 1975

AS BUILT
CORRECTIONS BY E. BLEG
[illegible] CH. LS 7801
May 9, 1979
EP 24 Sep 1979

PLAN
1"=50'

℄ Const.

B-1 B-2 B-3 B-4 B-5 B-6 B-7 B-8 B-9

Approximate ground line along ℄ Const.

Loose mottled brown & gray SANDY CLAY.
Stiff tan SILTY CLAY.
Very stiff tan SILTY CLAY.
Very stiff gray CLAY.
Very stiff mottled brown & gray CLAY.
Soft gray CLAY interbedded with loose Fine SAND.
Dense gray medium SAND.
Dense gray Fine SAND with a little SILT.
Very dense gray medium SAND.
Compact brown medium SAND.
Very stiff brown SILTY CLAY.
Very stiff light brown CLAY.
Compact brown Fine SAND.
Dense brown medium SAND.
Dense to very dense gray medium SAND.
Dense gray Fine to medium SAND.
Loose gray Fine to medium SAND.
Very soft black Fine SANDY CLAY with 15% VEGETATION
Very loose gray SILTY Fine SAND.
Slightly compact gray Fine to medium SAND.
Very stiff gray CLAY with SAND lenses.
Very dense gray medium SAND.
Very soft PEAT.
Very loose gray CLAYEY medium SAND with a little WOOD.
Stiff gray CLAY with a little Fine SAND.
Compact gray Fine SAND with a little SILT.
Compact gray medium SAND.
Compact black clean medium SAND with CLAY lenses.
Stiff brown SANDY CLAY.
Stiff brown medium SANDY CLAY with CLAY lenses.
Very dense gray medium SAND.

PROFILE
7-14-64 Horiz. 1"=40'
Vert. 1"=10'

Structural Steel Alternative

LEGEND OF BORING OPERATIONS
Penetrometer
24" Core Penetrometer
Sampler Boring (Arc)
Rotary Boring (Rot)
Auger Boring (Aug)
Jet Boring
Core Boring
Test Pit
1-Soil Tank
Ref. Bridge Foundation Report
Ref. Bridge Foundation Report

LEGEND OF EARTH MATERIALS
Gravel
Silty Clay or Clayey Silt
Sand
Silt
Clay
Fill Material
Igneous Rock
Sedimentary Rock
Metamorphic Rock

CLASSIFICATION OF MATERIAL BASED ON STANDARD GRADE SIZE LIMITS

NOTE: Classification of earth material as shown on this sheet is based upon field inspection and is not to be construed to imply mechanical analysis.

FIELD STUDY	L. W. Shawley	7-64
DRAWN	R. C. Erickson	8-17-64
CHECKED	L. M. Hannay	8-18-64
Approved	W. F. Hagen	Oct 15-64

BRIDGE DEPARTMENT
ENGINEERING GEOLOGY SECTION

192

STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION

SAN JOAQUIN RIVER BRIDGE
("A" STREET TO BRIDGE)

LOG OF TEST BORINGS 2 of 2

38100-4 NO.	POST MILE	DRAWING NO.	SHEET	OF
	28-09		99	106

157801
10204

Disregard prints bearing earlier numbers.

PRELIM. DRAWING NO. PR-280P-28

AS BUILT PLANS
Contract No. 04-157804
Date Completed

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DATE 3-12 SIGNATURE Joseph M. Cota TITLE SUPERVISOR OF DRAFTING SERVICES

DIST.	COUNTY	ROUTE	POST MILES—TOTAL PROJECT	SHEET NO.	TOTAL SHEETS
06	Cc Sac	84	11.1/11.8, 20/29	193	199

Robert W. Reynolds #165
REGISTERED PROFESSIONAL ENGINEER
December 22, 1975

BM "USGS 1376" Elev. 10.02.
In top of east concrete curb at south end of bridge, 9.5' east of ℄.

"℄ Const."

PLAN
Scale: 1" = 40'

AS BUILT
CORRECTIONS BY E. Biles
CONTRACT NO. 04-157804
DATE May 4, 1979
KU 24 Sep 1979

LEGEND OF BORING OPERATIONS

LEGEND OF EARTH MATERIALS

CLASSIFICATION OF NATURAL SOILS ON STANDARD GRAIN SIZE CHART

NOTE: Classification of earth material as shown on this sheet is based upon field inspection and is not to be construed to imply mechanical analysis.

Structural Steel Alternative

STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION
SAN JOAQUIN RIVER BRIDGE
LOG OF TEST BORINGS 3 of 9

BRIDGE DEPARTMENT
ENGINEERING GEOLOGY SECTION

193

AS BUILT PLANS
Contract No. 04-157804
Date Completed
Document No.

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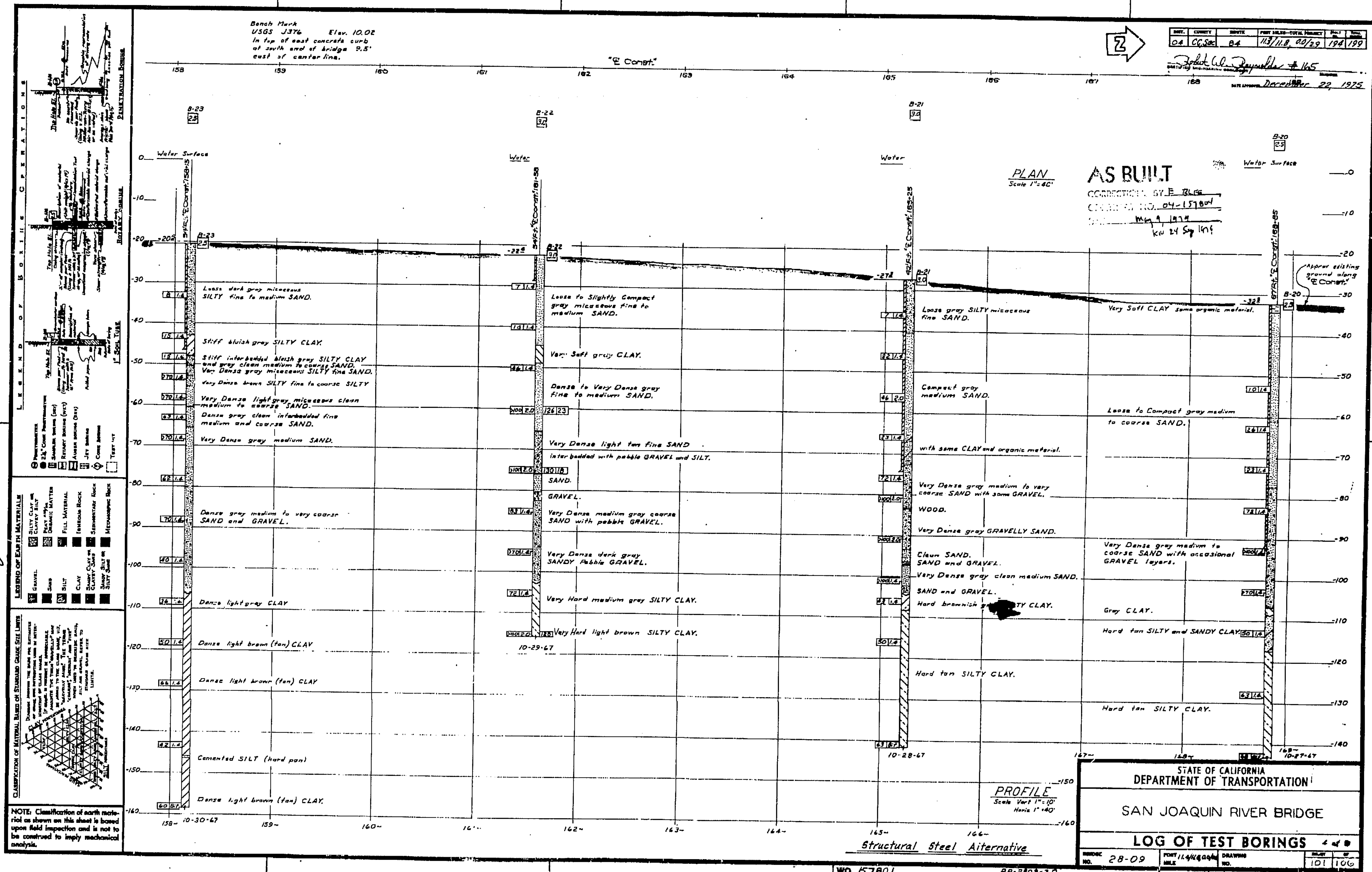
DATE 3-12 SIGNATURE Joseph M Cota TITLE SUPERVISOR OF DRAFTING SERVICES



194

AS BUILT PLANS

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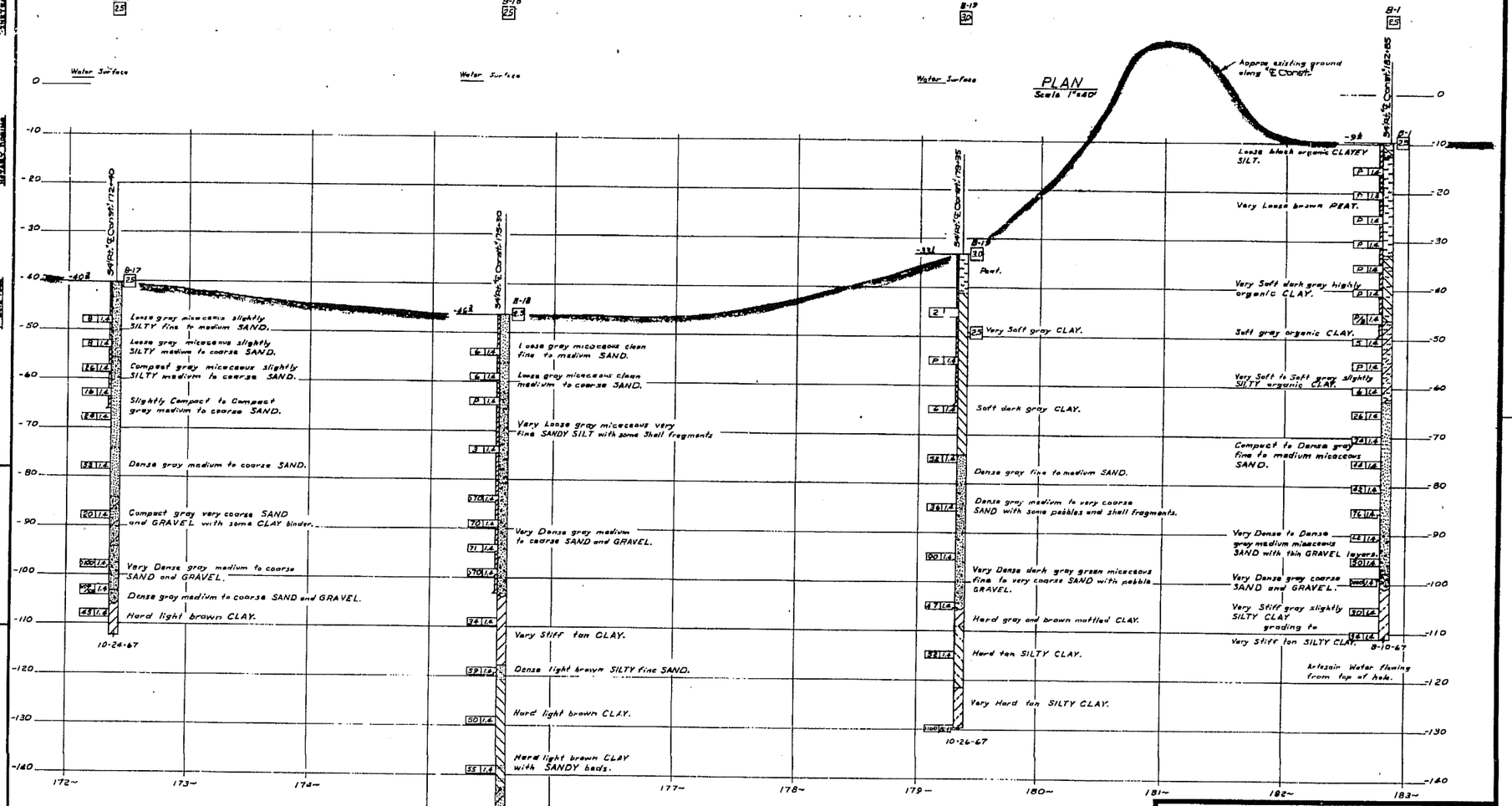
Bench Mark
See Sheet No. 2

DIST.	COUNTY	ROUTE	POST MILES—TOTAL PROJECT	SHEET NO.	TOTAL SHEETS
06	FRE. SJ.	99	113/118, 00/28	195	199

Robert W. Sprague #165
December 22, 1975



LEGEND OF BORING OPERATIONS

Penetrometer: 2½" Cone Penetrometer; Standard Sampler (Split); Barrel Sampler (Split); Auger Borings (Open); Jet Borings; Core Barrel; Test Pit

LEGEND OF EARTH MATERIALS

Gravel; Sand; Silt; Clay; Clay Gravel; Clay Sand; Sandy Silt; Silty Silt; Fill Material; Igneous Rock; Sedimentary Rock; Metamorphic Rock

CLASSIFICATION OF MATERIAL BASED ON STANDARD GRAIN SIZE LIMITS

Divisions between the major soil separates of gravel and sand are arbitrarily set at the No. 10 sieve. Divisions between the terms "coarse," "medium," and "fine" are arbitrarily set at the No. 4 and No. 40 sieves. Divisions between the terms "gravelly," "sandy," "silty," and "clayey" are arbitrarily set at 15%, 15%, 15%, and 15% respectively. The terms "trace" and "with" refer to the minor constituents. Silt and clay grain size limits.

NOTE: Classification of earth material as shown on this sheet is based upon field inspection and is not to be construed to imply mechanical analysis.

FIELD STUDY	N.R. Unger	11-67
DRAWN	N.R. Curtis	11-7-67
CHECKED	Wm. F. Hurst	11-24-67

Approved Recommended for [illegible]

BRIDGE DEPARTMENT
ENGINEERING GEOLOGY SECTION

195

STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION

SAN JOAQUIN RIVER BRIDGE

LOG OF TEST BORINGS 5 of 9

BRIDGE NO.	POST MILE	DRAWING NO.	SHEET NO.	OF
28-09	11.4/11.8 00/06		102	106

WO 157801
CU 10204

PR-2809-2E
Disregard prints bearing earlier revision dates

Revision Dates: 1/19/73; 1/19/73

AS BUILT PLANS
Contract No. 04-157804
Date Completed
Payment No. (Item 9777

I HEREBY CERTIFY THAT THIS IS A TRUE AND ACCURATE COPY OF THE ABOVE DOCUMENT TAKEN UNDER MY DIRECTION AND CONTROL ON THIS DATE IN SACRAMENTO, CALIFORNIA PURSUANT TO AUTHORIZATION BY THE DIRECTOR OF TRANSPORTATION.

DATE 3-12 SIGNATURE Joseph M Cota TITLE SUPERVISOR OF DRAFTING SERVICES

DIST.	COUNTY	ROUTE	POST MILES—TOTAL PROJECT	SHEET NO.	TOTAL SHEETS
04	CC, Sac	84	11.8/11.8, 00/29	196	199

Joseph L. Gagnepain No. 165

DATE APPROVED December 22, 1972

Bench Mark
See Sheet No. 2

"E" Const.

PLAN
Scale: 1"=50'

PROFILE
Scale: Vert. 1"=10'
Horiz. 1"=40'

Approx. ground line along E Const.

B-2 GWS -10± 10-24-67

B-3

B-4 -14.8

B-5 GWS -27.5 10-18-67

Sta Rel "E Const" 188+25

Sta Rel "E Const" 189+70

Sta Rel "E Const" 189+90

Sta Rel "E Const" 196+30

Very Loose brown Mud.

Very Soft gray organic CLAY.

Very Soft gray organic CLAY.

Soft gray organic SILTY CLAY.

Slightly Compact gray SILTY fine SAND grading to

Stiff gray SANDY CLAY.

Very Stiff gray mottled tan and gray SAND with abundant lenses

Very Dense gray medium micaceous SAND.

Very Stiff tan SILTY CLAY.

Hard tan CLAYEY SILT.

Hard to Very Hard tan SILTY CLAY.

Compact to Dense gray fine micaceous SAND.

Hard gray and brown mottled CLAYEY SILT.

360/08 10-24-67

10-19-67

10-12-67

10-18-67

Structural Steel Alternative

AS BUILT
CORRECTIONS BY E. BLEE
CONTRACT NO. 04-157804
DATE May 4, 1976
KH 4/4 Sac (17)

STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION

SAN JOAQUIN RIVER BRIDGE

LOG OF TEST BORINGS 6 of 9

BRIDGE NO. 28-09 POST MILE 00/06 SHEET NO. 105 OF SHEETS 106

WO 1578 DE
CU 10204

FR-8809-EF

LEGEND OF BORING OPERATIONS

Penetrometer
2½" Core Penetrometer
Standard penetration (blows)
Recovery standard (wet)
Standard recovery (dry)
Jet washing
Core sample
Test pit

Penetration Borings
Standard Borings
1" Shell Tube

LEGEND OF EARTH MATERIALS

Gravel
Sand
Silt
Clay
Silty Clay or Clayey Silt
Silty, Clay or Clayey Sand
Peat
Organic Matter
Fill Material
Igneous Rock
Sedimentary Rock
Metamorphic Rock

CLASSIFICATION OF MATERIAL BASED ON STANDARD GRADE SIZE LIMITS

Distinct contacts between materials are shown as solid lines, gradual changes as dashed lines. Where the nature of the change is not known, the contact is shown as a solid line. The lines designating the limits between different materials on the logs represent the approximate boundaries only. The transition may be gradual.

NOTE: Classification of earth material as shown on this sheet is based upon field inspection and is not to be construed to imply environmental analysis.

FIELD SURVEY by R. Dixon 11-67
by R. Dixon 11-67
by J. Hebr 10-67

Signed Recommended R. Z. Hyer

BRIDGE DEPARTMENT
ENGINEERING GEOLOGY SECTION

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AS BUILT PLANS
Contract No. 04-157804
Date Completed
Document No. 4000 9277

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DATE 3-12 SIGNATURE Joseph M Cota TITLE SUPERVISOR OF MICROFILM SERVICES

DIST.	COUNTY	ROUTE	POST MILES—TOTAL PROJECT	SHEET NO.	TOTAL SHEETS
04	CC.Sac	84	11.8/11.8 20/29	197	199

Robert W. Reynolds # 165
CONSTRUCTION ENGINEER / PROJECT MANAGER
DATE APPROVED December 22 1975

B-13A 204 B-15A 206 "Const. ℄" B-17A 207 208 B-16A 209 210 B-11A 211 212 213 B-12A 214 215

B.M. Pt #3
Sta. C16+52.04
Elev. 6.16

AS BUILT
CONSTRUCTED BY E. BLEE
04-157804
May 9, 1977
K.P. W. Sept 1979

PLAN
Scale: 1" = 50'

PROFILE
Scale: Horz. 1" = 50'
Vert. 1" = 10'

On Line "Const ℄" 202+99 — Sta. "Const. ℄" 205+02 — On Const. ℄ 207+20 — On Const. ℄ 209+12 — On Line "Const ℄" 211+17 — On Line "Const ℄" 214+17

B-13A -13.8 — Very loose dark brown PEAT. — Very soft brown PEAT & gray CLAY — Very soft gray CLAY with scattered black PEAT. — Very soft gray SILTY CLAY. — Slightly compact gray MICACEOUS slightly SILTY fine SAND. — Dense gray MICACEOUS clean medium SAND. — Dense gray coarse SAND with scattered PEBBLE GRAVEL. — Very dense gray coarse SAND & PEBBLE GRAVEL. — Dense tan cemented CLAYEY SILT. — 11-25-70

B-15A -15.2 — Slightly compact brown SILT & PEAT. — Very soft dark gray PEAT & CLAYS. — Loose light gray SILT. — Very soft gray CLAY & PEAT. — Very soft gray CLAY. — Loose gray fine MICACEOUS SAND. — Slightly compact gray inter-bedded SILT & fine SILTY SAND. — Slightly compact gray fine SAND. — Compact to dense gray fine to medium SAND. — Dense gray medium to coarse SAND with GRAVEL seams. — Dense gray green SILT. — Dense gray brown MICACEOUS SILT. — 7-23-74

B-17A -16.2 — Very soft gray CLAY. — Very soft gray SANDY CLAY. — Very soft green gray CLAY. — Compact gray fine to medium clean SAND. — Compact gray fine to medium SAND with some MICA. — Dense gray fine to medium SAND with a few PEBBLES. — Compact to dense gray medium SAND. — Dense gray medium SAND with some GRAVEL. — Dense gray MICACEOUS SILT. — Dense light brown CLAYEY SILT with a little LIME. — 7-23-74

B-16A -15.5 — Very soft PEAT & gray CLAY. — 7-23-74

B-11A -14.1 — Approximate ground line along Const. ℄ — GWS EL -17.2 11-24-70 — Very loose dark brown PEAT. — Very soft black PEAT & gray CLAY. — Very soft gray SILTY CLAY with occasional PEAT. — Very soft gray SILTY CLAY. — Dense gray clean medium SAND. — Compact gray clean medium to coarse SAND with occasional PEBBLE GRAVEL. — Dense gray clean coarse SAND with PEBBLE GRAVEL. — Compact brown & gray mottled CLAYEY SILT. — Dense tan cemented CLAYEY SILT. — 11-24-70

B-12A — 300/0.2' — 11-24-70

-10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -110 -120 -130

205 210 215

LEGEND OF BORING OPERATIONS

Penetrometer: 2½" Cone Penetrometer; Rotary boring (cw); Auger boring (cw); Jet borings; Core borings; Test pit

LEGEND OF EARTH MATERIALS

Gravel; Sand; Silt; Clay; Sandy Clay or Clayey Sand; Silty Clay or Clayey Silt; Peat, Muck, Organic Matter; Fill Material; Igneous Rock; Sedimentary Rock; Metamorphic Rock

CLASSIFICATION OF MATERIAL BASED ON STANDARD GRADE SIZE LIMITS

NOTE: Classification of earth material as shown on this sheet is based upon field inspection and is not to be construed to imply mechanical analysis.

FIELD STUDY — by C. Hoover 11-70
DRAWN — by S. Schroeder 6-72
CHECKED — by R. Wong 6-72
Approved Recommended for Approval — C.F. Hoover

BRIDGE DEPARTMENT
ENGINEERING GEOLOGY SECTION

197

STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION

SAN JOAQUIN RIVER BRIDGE

LOG OF TEST BORINGS 7 of 9

BRIDGE NO.	POST MILE	DRAWING NO.	SHEET	OF
28-0.9			104	106

Structural Steel Alternative

Revised by: R. Wong 8-7-74
Added borings 15A, 19A, & 17A

WO 157801
CU 10209

Elongated pitch bearing number revision dates → 8/74 11/75

AS BUILT PLANS
Contract No. 04-157804
Date Completed
Document No. 4000 9277

I HEREBY CERTIFY THAT THIS IS A TRUE AND ACCURATE COPY OF THE ABOVE DOCUMENT TAKEN UNDER MY DIRECTION AND CONTROL ON THIS DATE IN SACRAMENTO, CALIFORNIA PURSUANT TO AUTHORIZATION BY THE DIRECTOR OF TRANSPORTATION.

DATE 3-12 — Delineator Joseph M. Pinta — TITLE SUPERVISOR OF DRAFTING SERVICES

DIST.	COUNTY	ROUTE	POST MILES—TOTAL PROJECT	SHEET NO.	TOTAL SHEETS
04	CC, Sac	84	11.3/11.8, 0.0/2.9	198	199

Robert L. Reynolds #165

DATE APPROVED December 22, 1975.

AS BUILT

CORRECTIONS BY E. BLDG.

CONSTR. REV. 604-657 604

May 9, 1979

K.D. 24 Sep 1979

Plan
Scale: 1"=50'

B-10A B-9A B-8A B-7A B-6A B-5A B-4A B-3A B-2A B-1A "E Const."

STOCKTON

MAYBERRY

BM 70-Sac-84-5"
Stat. CHD disc
Elev. 7.45

E Const. 217+17 | E Const. 218+65 | E Const. 220+45 | E Const. 222+24 | E Const. 223+05 | E Const. 223+61 | E Const. 224+39 | E Const. 225+07 | E Const. 226+09 | E Const. 228+11

Approx. ground line using E Const.

B-10A: Barge. Water. Very soft PEAT. Very soft blue gray CLAY with some ORGANIC material. Very soft brown PEAT to CLAYEY PEAT. Very soft PEAT & gray SILTY CLAY. Green gray CLAY with some ORGANIC material. Blue gray SILTY CLAY with very little ORGANIC material. Loose gray SILT. Compact gray fine SAND with some MICA. Compact gray fine to medium SAND. Dense gray fine SAND. Dense to very dense gray medium SAND with GRAVEL. Stiff to very stiff brown CLAY.

B-9A: Barge. Water. Very soft gray SILTY CLAY with ORGANIC material. Very soft gray PEAT & SILTY CLAY. Very soft blue gray CLAY with some PEAT. Very soft blue gray CLAY with some LIME (at top) ROOTS! Very soft gray to blue gray SILTY CLAY. Very loose gray SILT to CLAYEY SILT. Compact gray fine SAND. Compact gray fine SAND with SHELL fragments. Dense gray fine to medium SAND with a few PEBBLES. Very dense gray SAND with GRAVEL. STRIATIONS ENCOUNTERED with cloth. Compact gray medium SAND & PEBBLES. Compact gray medium SAND & small GRAVEL. Dense tan SAND to CLAYEY SILT.

B-8A: Loose gray SILT-Lenses. Very soft gray CLAY. Very soft gray MICACEOUS CLAYEY SILT. Very soft gray MICACEOUS CLAYEY SILT with some ORGANIC partings. Very soft gray CLAY. Very soft light gray PEAT. Very soft, green gray CLAY with a few ROOTS. Loose gray green slightly CLAYEY fine SAND grading to slightly CLAYEY SILT. Compact gray fine to medium SAND. Dense gray coarse SAND. Dense gray coarse SAND with traces of fine GRAVEL. Dense gray coarse SAND with some GRAVEL. Compact gray tan slightly CLAYEY SILT. Dense tan CLAYEY SILT.

B-7A: Very soft PEAT with gray CLAY. Very soft gray CLAY with ORGANIC material. Very loose gray SILT. Very loose gray fine very SILTY SAND. Slightly compact blue gray fine SILTY SAND. Slightly compact & compact gray fine SAND. Very soft gray SILTY ORGANIC CLAY with PEAT. Very soft gray SILTY CLAY with PEAT. Very loose gray SILTY SAND with ORGANIC material. Slightly compact gray fine SAND. Compact gray fine SAND. Compact gray fine to medium SAND with some MICA. Slightly compact gray fine to medium SAND with some MICA. Compact gray fine to medium SAND with some MICA. Very stiff gray SILTY ORGANIC CLAY with PEAT. Slightly compact dark gray fine SAND with thin SILT seams. Dense gray fine SAND. Compact gray SILTY fine SAND with some MICA. Compact gray fine SAND. Dense gray medium to coarse SAND with some GRAVEL. Dense gray coarse SAND & small GRAVEL. Dense tan to gray green SAND & SILT. Very stiff tan CLAY.

B-6A: Very soft gray MICACEOUS CLAYEY SILT. Very soft light gray PEAT. Very soft, gray CLAY with PEAT. Very loose gray SILTY SAND with ORGANIC material. Slightly compact gray fine SAND. Compact gray fine SAND. Compact gray fine to medium SAND with some MICA. Compact gray fine to medium SAND with some MICA. Compact to dense fine to medium SAND. Dense gray medium SAND with a few PEBBLES. Dense gray fine SAND with thin brown SILT interbeds containing ORGANIC material. Very stiff tan & gray mottled CLAYEY SILT.

B-5A: Very loose brown SILT. Very soft brown CLAYEY PEAT. Very soft gray CLAY with PEAT. Very loose gray SILTY SAND with ORGANIC material. Slightly compact gray fine SAND. Compact gray fine SAND. Compact gray fine to medium SAND with some MICA. Compact gray fine to medium SAND with some MICA. Compact to dense fine to medium SAND. Dense gray medium SAND with a few PEBBLES. Dense gray fine SAND with thin brown SILT interbeds containing ORGANIC material. Very stiff tan & gray mottled CLAYEY SILT.

B-4A: Very soft gray CLAY with PEAT. Very soft gray PEAT. Very soft brown PEAT. Loose gray fine SAND. Slightly compact & compact gray fine & medium SAND. Slightly compact, compact & dense gray fine to medium MICACEOUS SAND. Slightly compact gray fine to medium MICACEOUS SAND with some SILT. Compact to slightly compact gray fine to medium SAND with some MICA. Compact gray medium SAND with scattered GRAVEL. Dense gray medium SAND with a few PEBBLES. Dense gray medium SAND with GRAVEL. Dense gray medium SAND with thin SILT interbeds containing ORGANIC material. Dense gray medium to coarse SAND with some GRAVEL. Very stiff gray & brown SILTY CLAY. Hard brown SANDY CLAY.

B-3A: Stiffly compact gray SILT & scattered PEAT. Loose dark gray brown SILT with ROOTS & FIBRES. Very soft brown PEAT. Very soft gray PEAT with CLAY seams. Stiff gray CLAY with FIBRES. Loose gray fine SAND. Slightly compact & compact gray fine & medium SAND. Slightly compact, compact & dense gray fine to medium MICACEOUS SAND. Dense coarse MICACEOUS SAND with GRAVEL. Compact gray coarse SAND & GRAVEL. Dense gray medium to coarse SAND & GRAVEL. Dense gray coarse SAND with trace of fine GRAVEL. Dense gray coarse SAND. Compact tan gray slightly CLAYEY SILT. Dense tan SILT with interbedding SAND layers.

7-9-70 | 7-8-70 | 7-2-70 | 6-30-70 | 6-29-70 | 6-29-70 | 6-29-70 | 6-25-70 | 6-25-70 | 7-2-70

300 200 100 300 200 100 300 200 100

217 218 219 220 221 222 223 224 225 226 227 228

-10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -110 -120 -130

Profile
Scale: Hor. 1"=40'
Ver. 1"=10'

Structural Steel Alternative

LEGEND OF BORING OPERATIONS

Penetration: 2½" Core Penetration; Standard Sampler (2in); Rotary Sample (3in); Auger Sample (4½); Key Sample; Core Sample; Test Pit

LEGEND OF EARTH MATERIALS

Gravel; Sand; Silt; Clay; Silty Clay or Clayey Silt; Peat or Organic Matter; Fill Material; Igneous Rock; Sedimentary Rock; Metamorphic Rock; Sandy Clay or Clayey Sand; Sandy Silt or Silty Sand

CLASSIFICATION OF MATERIAL BASED ON STANDARD CAVE SIEC LIMITS

NOTE: Classification of earth material as shown on this sheet is based upon field inspection and is not to be construed to imply mechanical analysis.

FIELD SURVEY	M.A. Hoover	7-70
DRAWN	M.A. Hoover	8-25-70
CHECKED	W.A. Hoppe	9-25-70

Approved & recommended by: A.Z. Klymer

BRIDGE DEPARTMENT
ENGINEERING GEOLOGY SECTION

198

STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION

SAN JOAQUIN RIVER BRIDGE

LOG OF TEST BORINGS Sheet 8 of 9

BRIDGE NO.	POST MILE	DRAWING NO.	SHEET	OF
28-09			105	106

REVISION DATES (PRELIMINARY STAGE ONLY)

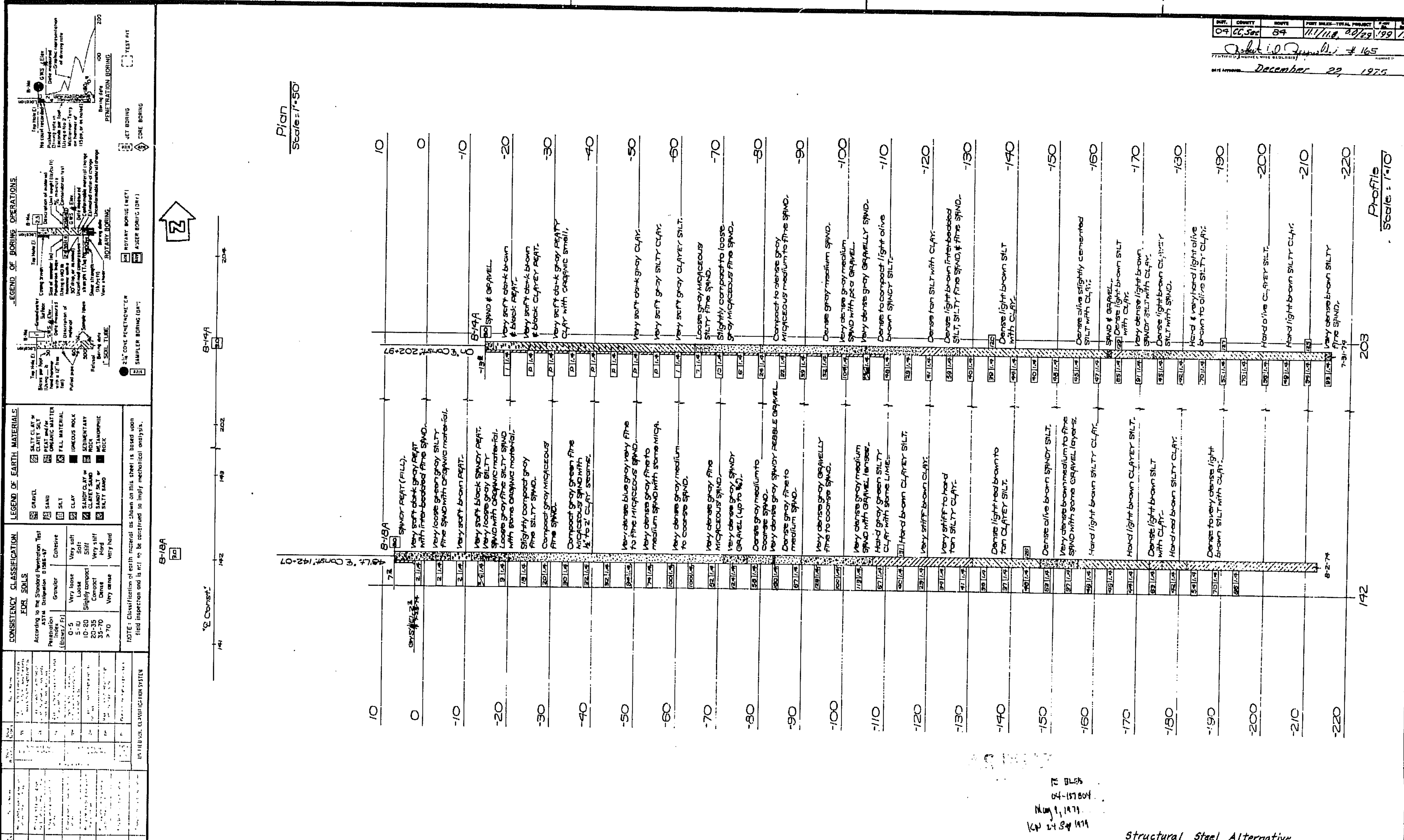
WO 157801
CU 10204 FR 2809-2

Disregard prints bearing earlier revision dates

AS BUILT PLANS
Contract No. 04-157804
Date Completed
Document No. from 9277

I HEREBY CERTIFY THAT THIS IS A TRUE AND ACCURATE COPY OF THE ABOVE DOCUMENT TAKEN UNDER MY DIRECTION AND CONTROL ON THIS DATE IN SACRAMENTO, CALIFORNIA PURSUANT TO AUTHORIZATION BY THE DIRECTOR OF TRANSPORTATION.

DATE 3-12 SIGNATURE Joseph M. Cota TITLE SUPERVISOR OF DRAWING SERVICES



Structural Steel Alternative

ENGINEERING GEOLOGY SECTION

FIELD STUDY	R. Hager	8-74
DN/WN	R. Wong	8-12-74
CHECKED	M. [illegible]	5/74

State of CALIFORNIA DEPARTMENT OF TRANSPORTATION

BRIDGE DEPARTMENT DESIGN SECTION 15

BRIDGE NO. 28-09

SAN JOAQUIN RIVER BRIDGE

LOG OF TEST BORINGS

9 of 9

CU 10204
WO 157801

04 | CC, Sac | 84 | 11.1/11.8 | 199 | 199

December 22, 1975

199

AS BUILT PLANS
Contract No. 04-157804
Date Completed
Document No. 4000 9277

I HEREBY CERTIFY THAT THIS IS A TRUE AND ACCURATE COPY OF THE ABOVE DOCUMENT TAKEN UNDER MY DIRECTION AND CONTROL ON THIS DATE IN SACRAMENTO, CALIFORNIA PURSUANT TO AUTHORIZATION BY THE DIRECTOR OF TRANSPORTATION.

DIST	COUNTY	ROUTE	POST MILES TOTAL PROJECT	SHEET NO.	TOTAL SHEETS
04	CC Sac	160			

Jody A. Castle 3/20/09
PROFESSIONAL GEOLOGIST DATE

PROFESSIONAL GEOLOGIST J. CASTLE No. PG 8162 Exp. 12-31-10 STATE OF CALIFORNIA

PLANS APPROVAL DATE

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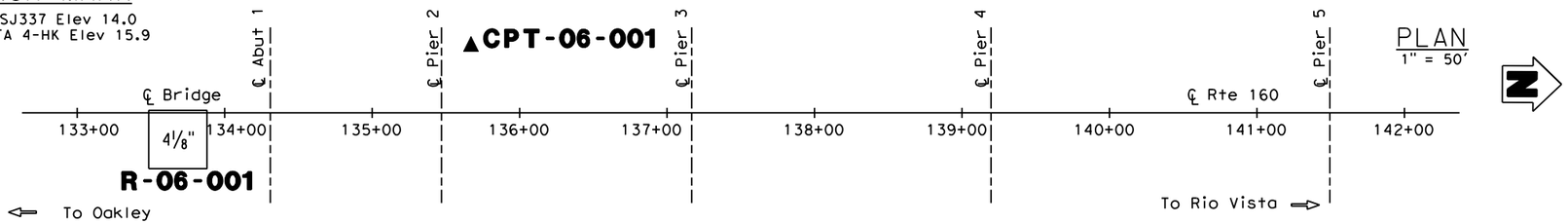
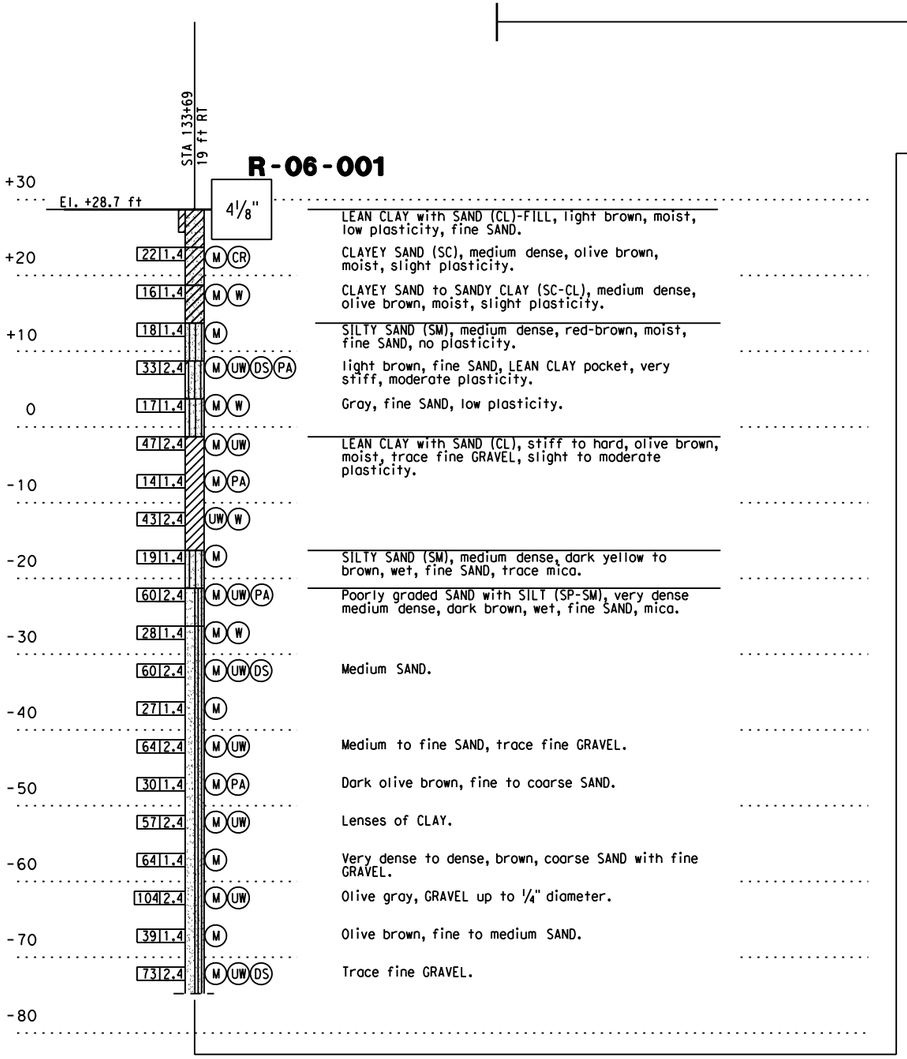
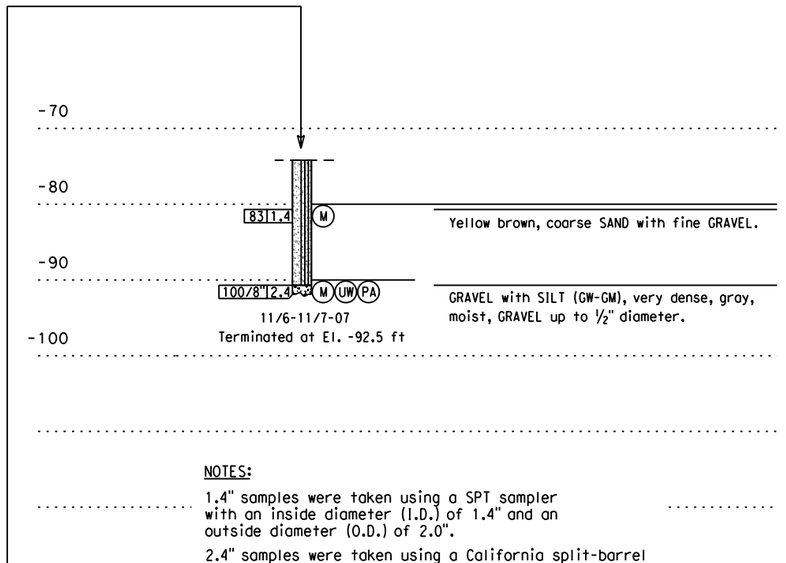
Geotechnical and Earthquake Engineering
7750 Pardee Lane, Suite 120
Oakland, California 94621

BENCH MARK

BM 29 SJ337 Elev 14.0
BM 29 STA 4-HK Elev 15.9







NOTES:

1.4" samples were taken using a SPT sampler with an inside diameter (I.D.) of 1.4" and an outside diameter (O.D.) of 2.0".

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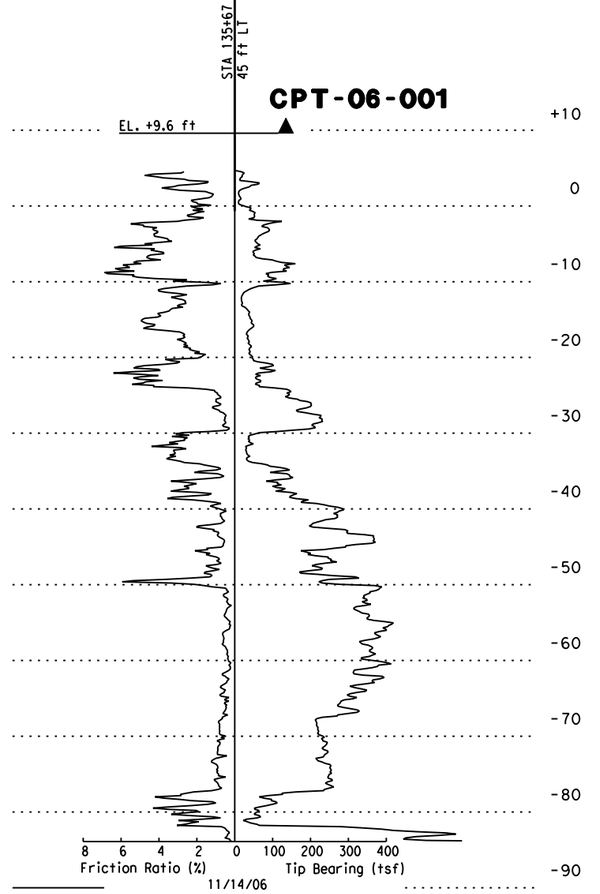
An automatic trip hammer system consisting of a hammer weight of 140 lbs falling a distance of 30" was used to advance both samplers.

PROFILE
VERTICAL 1" = 10'
HORIZONTAL 1" = 50'



Stationing Along ℄ Bridge

133+00 134+00 135+00 136+00 137+00 138+00 139+00 140+00 141+00 142+00 143+00 144+00 145+00

ENGINEERING SERVICES		GEOTECHNICAL SERVICES		STATE OF CALIFORNIA DEPARTMENT OF TRANSPORTATION		BRIDGE NO.	ANTIOCH BRIDGE
FUNCTIONAL SUPERVISOR SABA MOHAN	DRAWN BY: M. KAPUSKAR, K. THANT	FIELD INVESTIGATION BY: J. CASTLE			H. LAW PROJECT ENGINEER	28-0009	
NAME	CHECKED BY: E. BROWN, J. CASTLE					POST MILE 0.82	LOG OF TEST BORING NO. 1
OSF GEOTECHNICAL LOG OF TEST BORINGS SHEET	ORIGINAL SCALE IN INCHES FOR REDUCED PLANS 0 1 2 3			CU EA	DISREGARD PRINTS BEARING EARLIER REVISION DATES →	REVISION DATES (PRELIMINARY STAGE ONLY) 7/6/07 3/20/09	SHEET OF

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DIST	COUNTY	ROUTE	POST MILES TOTAL PROJECT	SHEET NO.	TOTAL SHEETS
04	CC Sac	160			

Jody A. Castle 3/20/09
PROFESSIONAL GEOLOGIST DATE

PLANS APPROVAL DATE

PROFESSIONAL GEOLOGIST
J. CASTLE
No. PG 8162
Exp. 12-31-10
STATE OF CALIFORNIA

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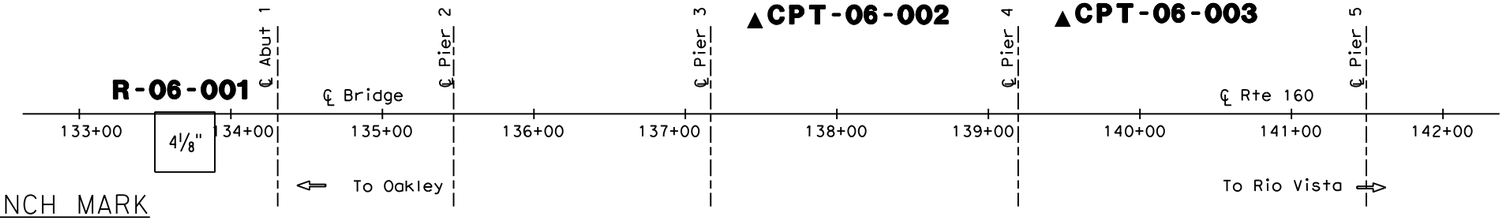

BENCH MARK

BM 29 SJ337 Elev 14.0
BM 29 STA 4-HK Elev 15.9

PLAN
1" = 50'

NOTES,

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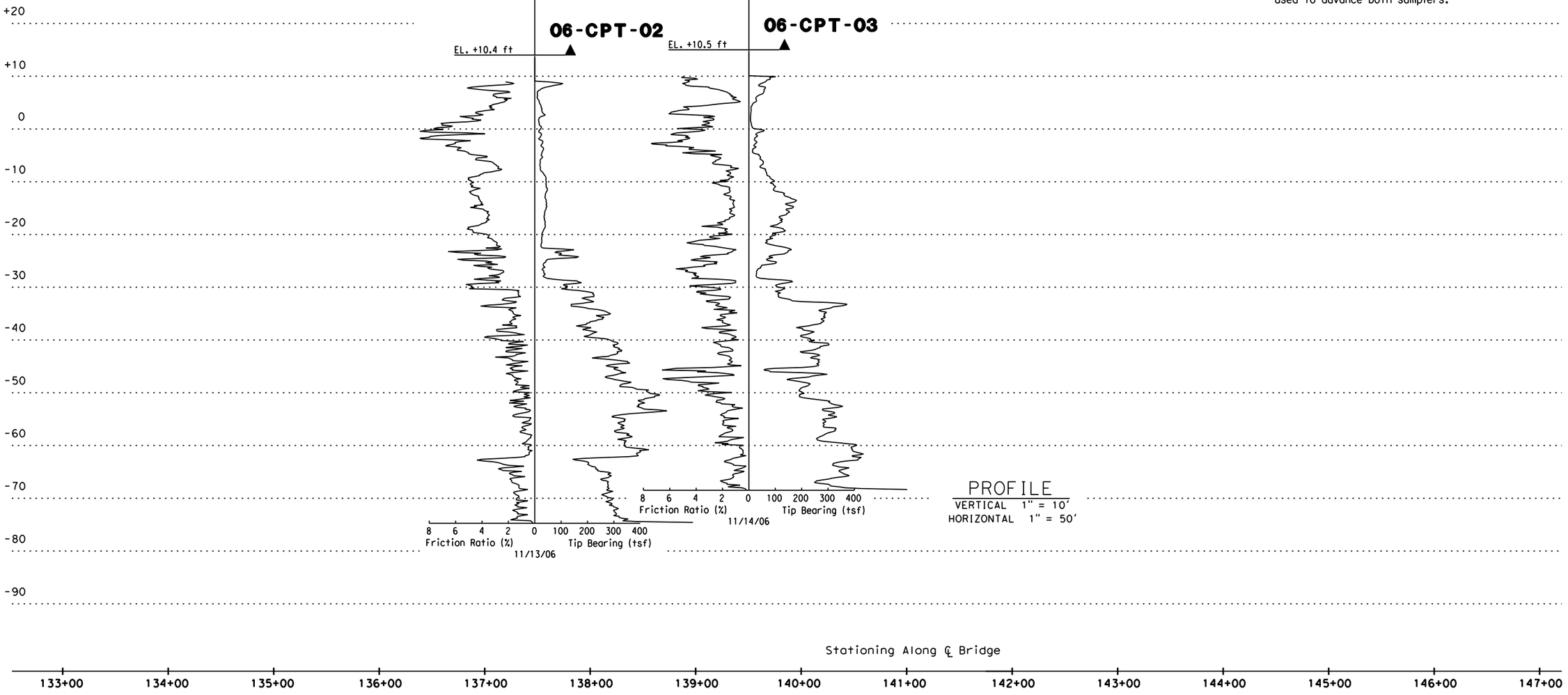
An automatic trip hammer system consisting of a hammer weight of 140 lbs falling a distance of 30" was used to advance both samplers.



PROFILE
VERTICAL 1" = 10'
HORIZONTAL 1" = 50'

ENGINEERING SERVICES		GEOTECHNICAL SERVICES	STATE OF CALIFORNIA DEPARTMENT OF TRANSPORTATION		BRIDGE NO.	ANTIOCH BRIDGE
FUNCTIONAL SUPERVISOR SABA MOHAN	DRAWN BY: M. KAPUSKAR, K. THANT	FIELD INVESTIGATION BY: J. CASTLE		H. LAW PROJECT ENGINEER	28-0009	
NAME	CHECKED BY: E. BROWN, J. CASTLE				POST MILE 0.82	LOG OF TEST BORING NO. 2
OSF GEOTECHNICAL LOG OF TEST BORINGS SHEET	ORIGINAL SCALE IN INCHES FOR REDUCED PLANS 0 1 2 3			CU EA	DISREGARD PRINTS BEARING EARLIER REVISION DATES →	REVISION DATES (PRELIMINARY STAGE ONLY) 7/6/07 3/20/09 SHEET OF

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DIST	COUNTY	ROUTE	POST MILES TOTAL PROJECT	SHEET NO.	TOTAL SHEETS
04	CC Sac	160			

Jody A. Castle 3/20/09
PROFESSIONAL GEOLOGIST DATE

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J. CASTLE
No. PG 8162
Exp. 12-31-10
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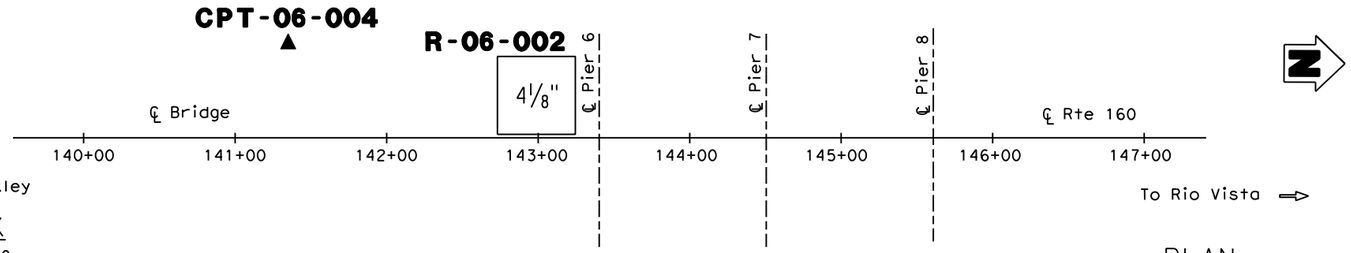
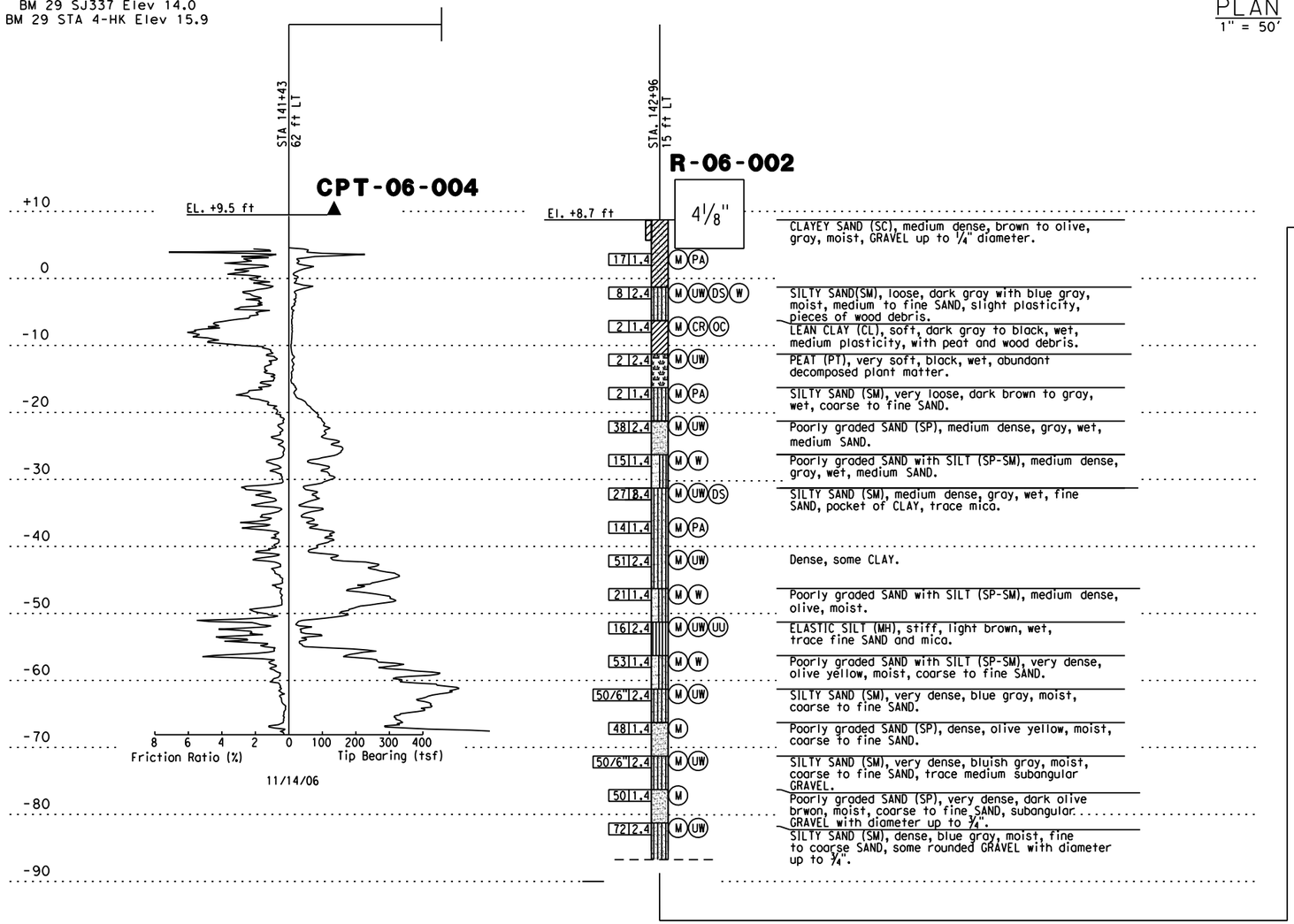


PLAN
1" = 50'

BENCH MARK

BM 29 SJ337 Elev 14.0
BM 29 STA 4-HK Elev 15.9



PROFILE
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HORIZONTAL 1" = 50'

NOTES:

1.4" samples were taken using a SPT sampler with an inside diameter (I.D.) of 1.4" and an outside diameter (O.D.) of 2.0".

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An automatic trip hammer system consisting of a hammer weight of 140 lbs falling a distance of 30" was used to advance both samplers.

ENGINEERING SERVICES		GEOTECHNICAL SERVICES	STATE OF CALIFORNIA DEPARTMENT OF TRANSPORTATION		BRIDGE NO.	ANTIOCH BRIDGE
FUNCTIONAL SUPERVISOR SABA MOHAN	DRAWN BY: M. KAPUSKAR, K. THANT	FIELD INVESTIGATION BY: J. CASTLE		H. LAW PROJECT ENGINEER	28-0009	
NAME	CHECKED BY: E. BROWN, J. CASTLE				POST MILE 0.82	LOG OF TEST BORING NO. 3
OSF GEOTECHNICAL LOG OF TEST BORINGS SHEET		ORIGINAL SCALE IN INCHES FOR REDUCED PLANS P 1 2 3		CU EA	DISREGARD PRINTS BEARING EARLIER REVISION DATES →	REVISION DATES (PRELIMINARY STAGE ONLY) 7/6/07 3/20/09 — SHEET OF

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DIST	COUNTY	ROUTE	POST MILES TOTAL PROJECT	SHEET NO.	TOTAL SHEETS
04	CC Sac	160			

Jody A. Castle 3/20/09
PROFESSIONAL GEOLOGIST DATE

PROFESSIONAL GEOLOGIST
J. CASTLE
No. PG 8162
Exp. 12-31-10
STATE OF CALIFORNIA

PLANS APPROVAL DATE

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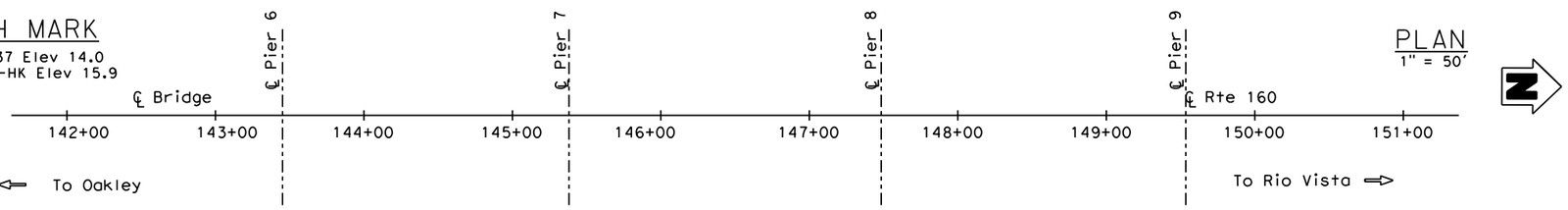
Oakland, California 94621

▲CPT-06-005

▲CPT-06-006

BENCH MARK
BM 29 SJ337 Elev 14.0
BM 29 STA 4-HK Elev 15.9

PLAN
1" = 50'



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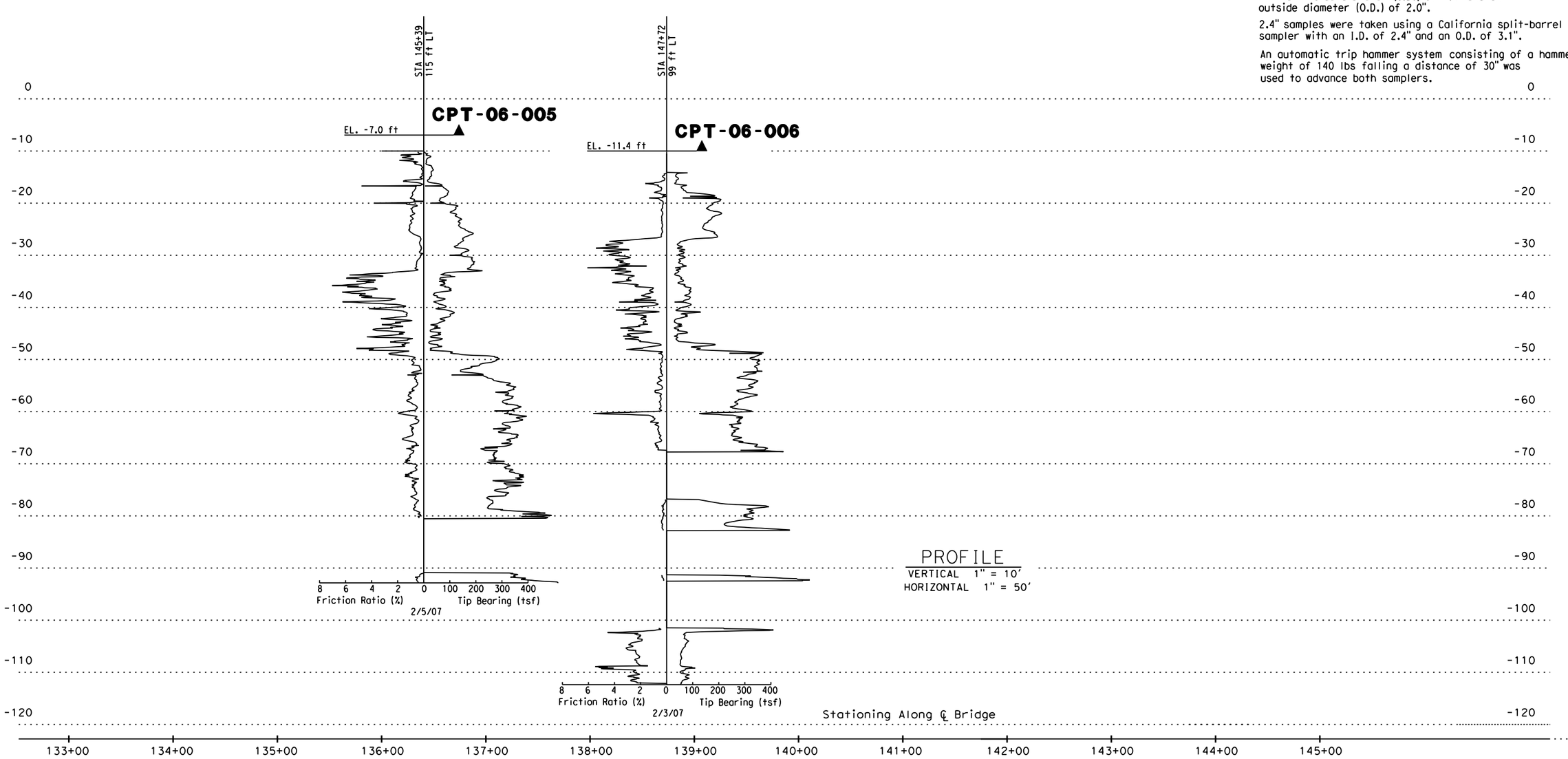

ENGINEERING SERVICES		GEOTECHNICAL SERVICES		STATE OF CALIFORNIA DEPARTMENT OF TRANSPORTATION		BRIDGE NO.	ANTIOCH BRIDGE
FUNCTIONAL SUPERVISOR SABA MOHAN	DRAWN BY: M. KAPUSKAR, K. THANT	FIELD INVESTIGATION BY: J. CASTLE			H. LAW PROJECT ENGINEER	28-0009	
NAME	CHECKED BY: E. BROWN, J. CASTLE					POST MILE 0.82	LOG OF TEST BORING NO. 4
OSF GEOTECHNICAL LOG OF TEST BORINGS SHEET		ORIGINAL SCALE IN INCHES FOR REDUCED PLANS P 1 2 3			CU EA	DISREGARD PRINTS BEARING EARLIER REVISION DATES →	REVISION DATES (PRELIMINARY STAGE ONLY) 7/6/07 3/20/09 SHEET OF

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DIST	COUNTY	ROUTE	POST MILES TOTAL PROJECT	SHEET NO.	TOTAL SHEETS
04	CC SAC	160			

Jody A. Castle 3/20/09
PROFESSIONAL GEOLOGIST DATE

J. CASTLE No. PG 8162 Exp. 12-31-10
PROFESSIONAL GEOLOGIST STATE OF CALIFORNIA

PLANS APPROVAL DATE

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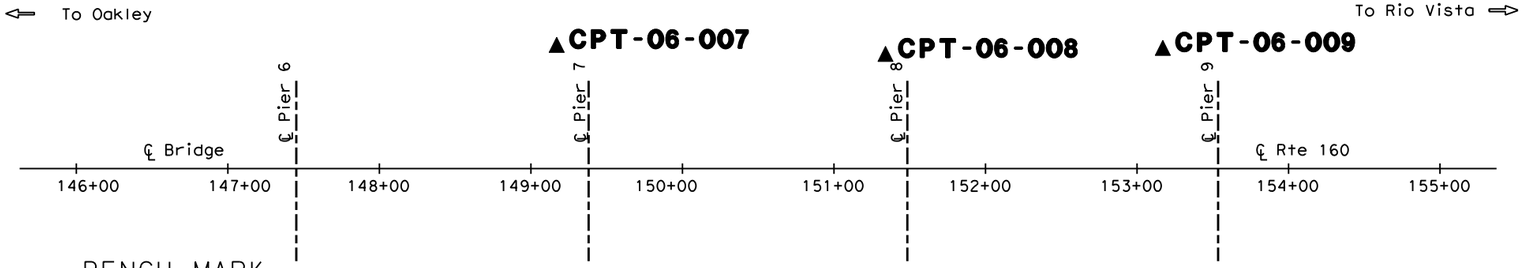
Geotechnical and Earthquake Engineering
7750 Pardee Lane, Suite 120
Oakland, California 94621

⇐ To Oakley

To Rio Vista ⇒



PLAN
1" = 50'

BENCH MARK

BM 29 SJ337 Elev 14.0
BM 29 STA 4-HK Elev 15.9

NOTES:

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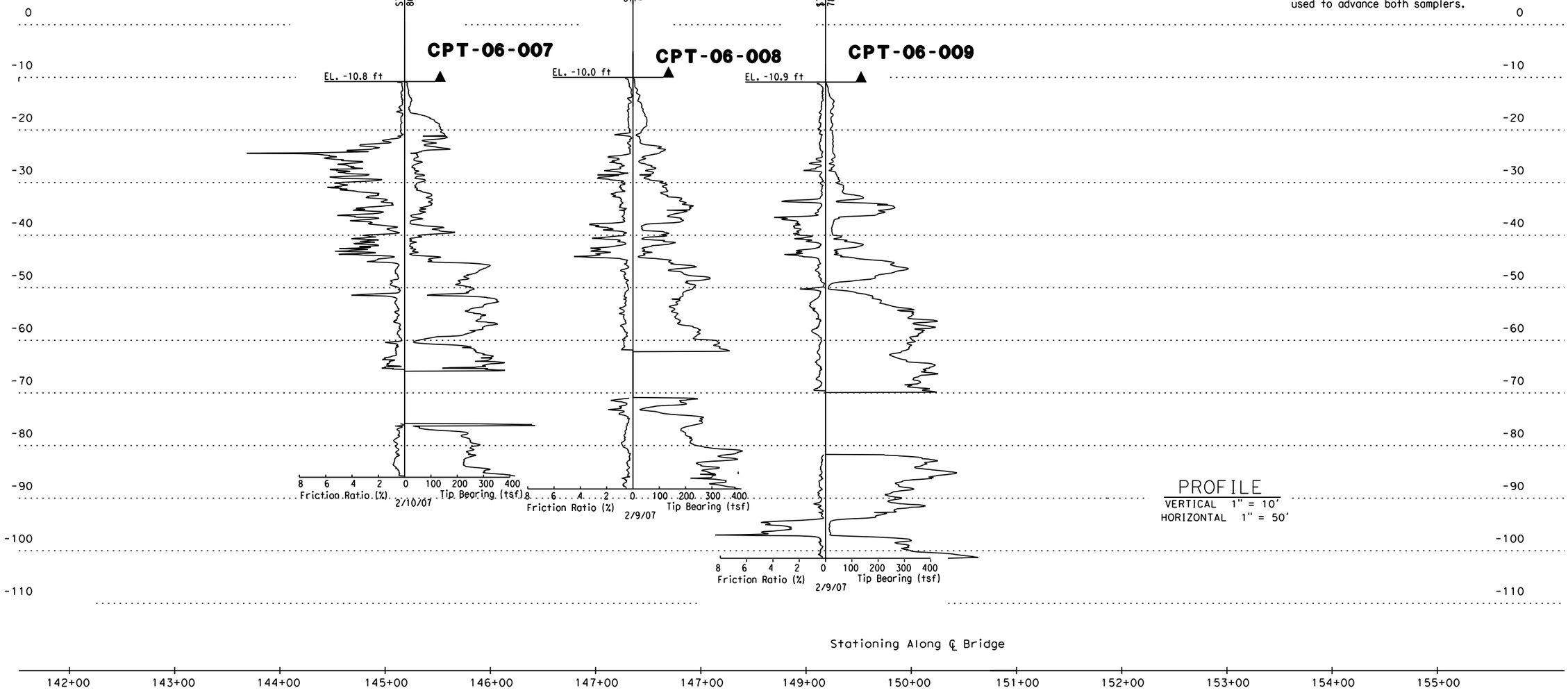

ENGINEERING SERVICES		GEOTECHNICAL SERVICES		STATE OF CALIFORNIA DEPARTMENT OF TRANSPORTATION		BRIDGE NO.	ANTIOCH BRIDGE
FUNCTIONAL SUPERVISOR SABA MOHAN NAME	DRAWN BY: M. KAPUSKAR, K. THANT	FIELD INVESTIGATION BY: J. CASTLE			H. LAW PROJECT ENGINEER	28-0009	
	CHECKED BY: E. BROWN, J. CASTLE					POST MILE 0.82	LOG OF TEST BORING NO. 5
OSF GEOTECHNICAL LOG OF TEST BORINGS SHEET		ORIGINAL SCALE IN INCHES FOR REDUCED PLANS P 1 2 3		CU EA	DISREGARD PRINTS BEARING EARLIER REVISION DATES →	REVISION DATES (PRELIMINARY STAGE ONLY) 7/6/07 3/20/09	SHEET OF

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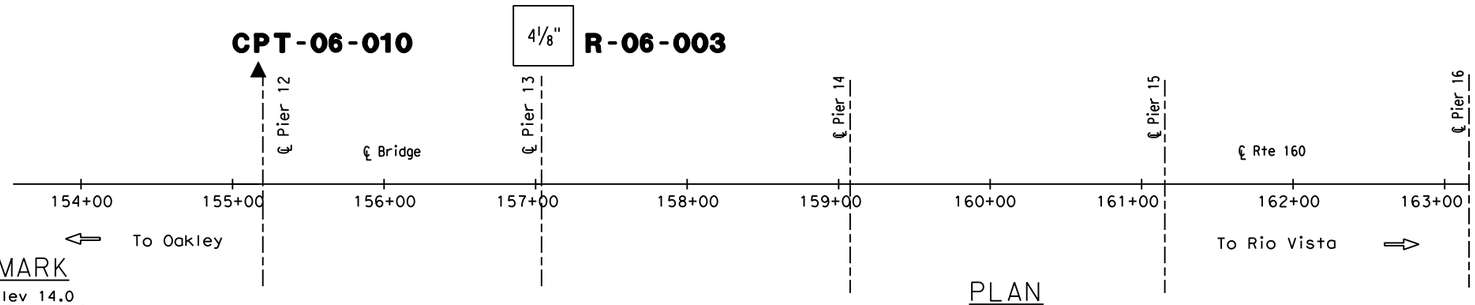

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DIST	COUNTY	ROUTE	POST MILES TOTAL PROJECT	SHEET NO.	TOTAL SHEETS
04	CC SAC	160			

Jody A. Castle 3/20/09
PROFESSIONAL GEOLOGIST DATE

PROFESSIONAL GEOLOGIST
J. CASTLE
No. PG 8162
Exp. 12-31-10
STATE OF CALIFORNIA

PLANS APPROVAL DATE

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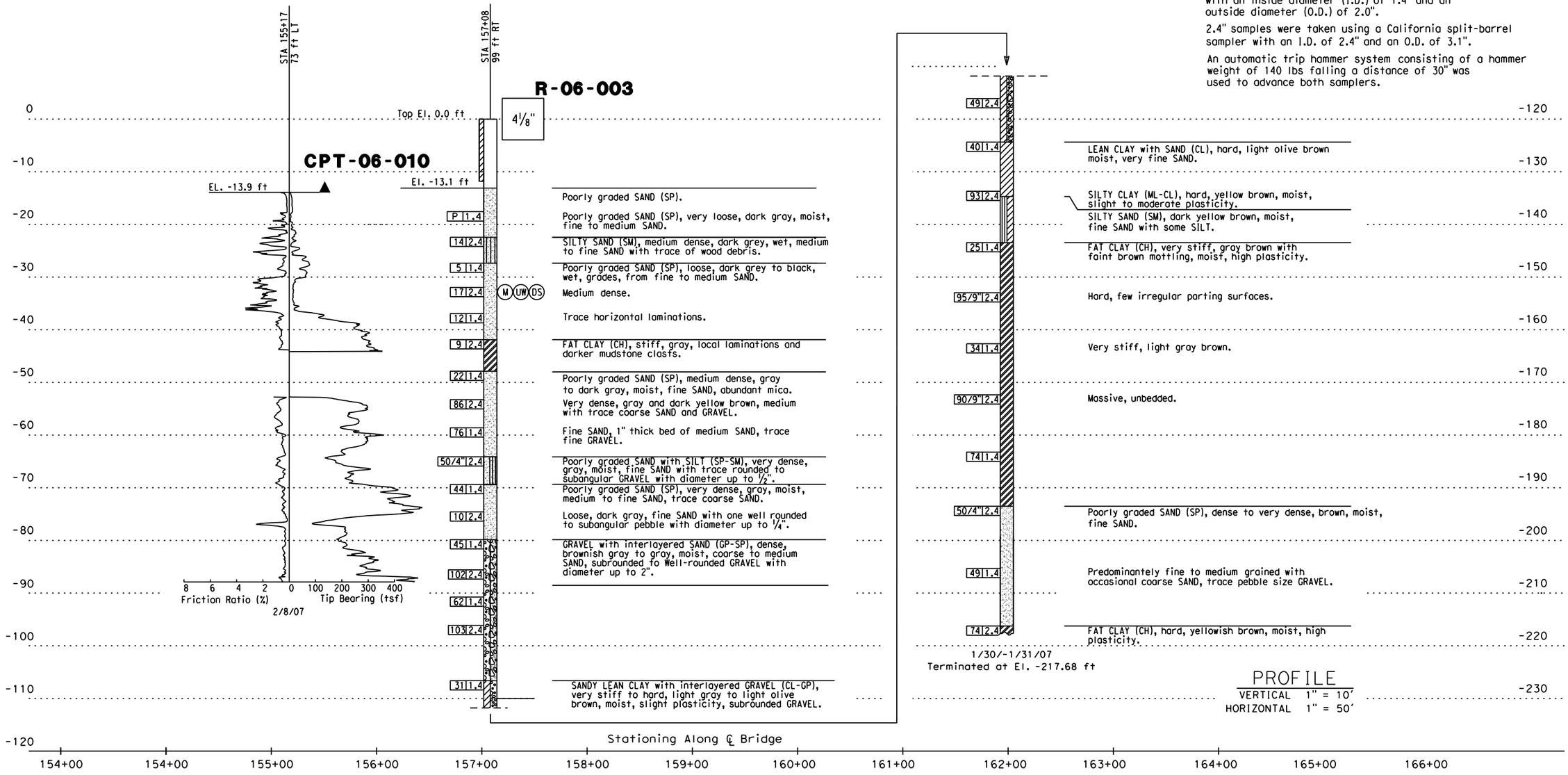
BENCH MARK

BM 29 SJ337 Elev 14.0
BM 29 STA 4-HK Elev 15.9

PLAN
1" = 50'



PROFILE
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ENGINEERING SERVICES		GEOTECHNICAL SERVICES	STATE OF CALIFORNIA DEPARTMENT OF TRANSPORTATION		BRIDGE NO.	ANTIOCH BRIDGE
FUNCTIONAL SUPERVISOR SABA MOHAN	DRAWN BY: M. KAPUSKAR, K. THANT	FIELD INVESTIGATION BY: B. SCHELL, C. DOMROSE M. THAN, K. THANT		H. LAW PROJECT ENGINEER	28-0009	
NAME	CHECKED BY: E. BROWN, J. CASTLE				POST MILE 0.82	LOG OF TEST BORING NO.6
OSF GEOTECHNICAL LOG OF TEST BORINGS SHEET	ORIGINAL SCALE IN INCHES FOR REDUCED PLANS 0 1 2 3			CU EA	DISREGARD PRINTS BEARING EARLIER REVISION DATES →	REVISION DATES (PRELIMINARY STAGE ONLY) 1 6/07 3/20/09 SHEET OF

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USERNAME => $USER DATE PLOTTED => $DATE TIME PLOTTED => $TIME

DIST	COUNTY	ROUTE	POST MILES TOTAL PROJECT	SHEET NO.	TOTAL SHEETS
04	CC Sac	160			

Jody A. Castle 3/20/09
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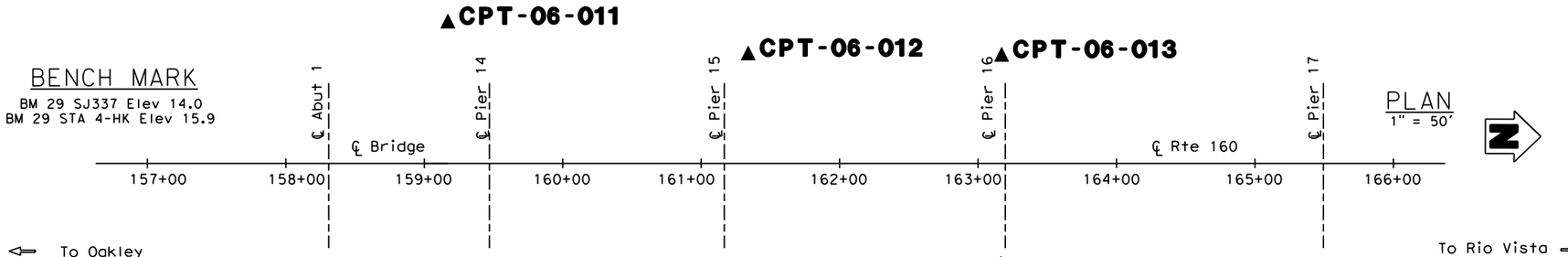
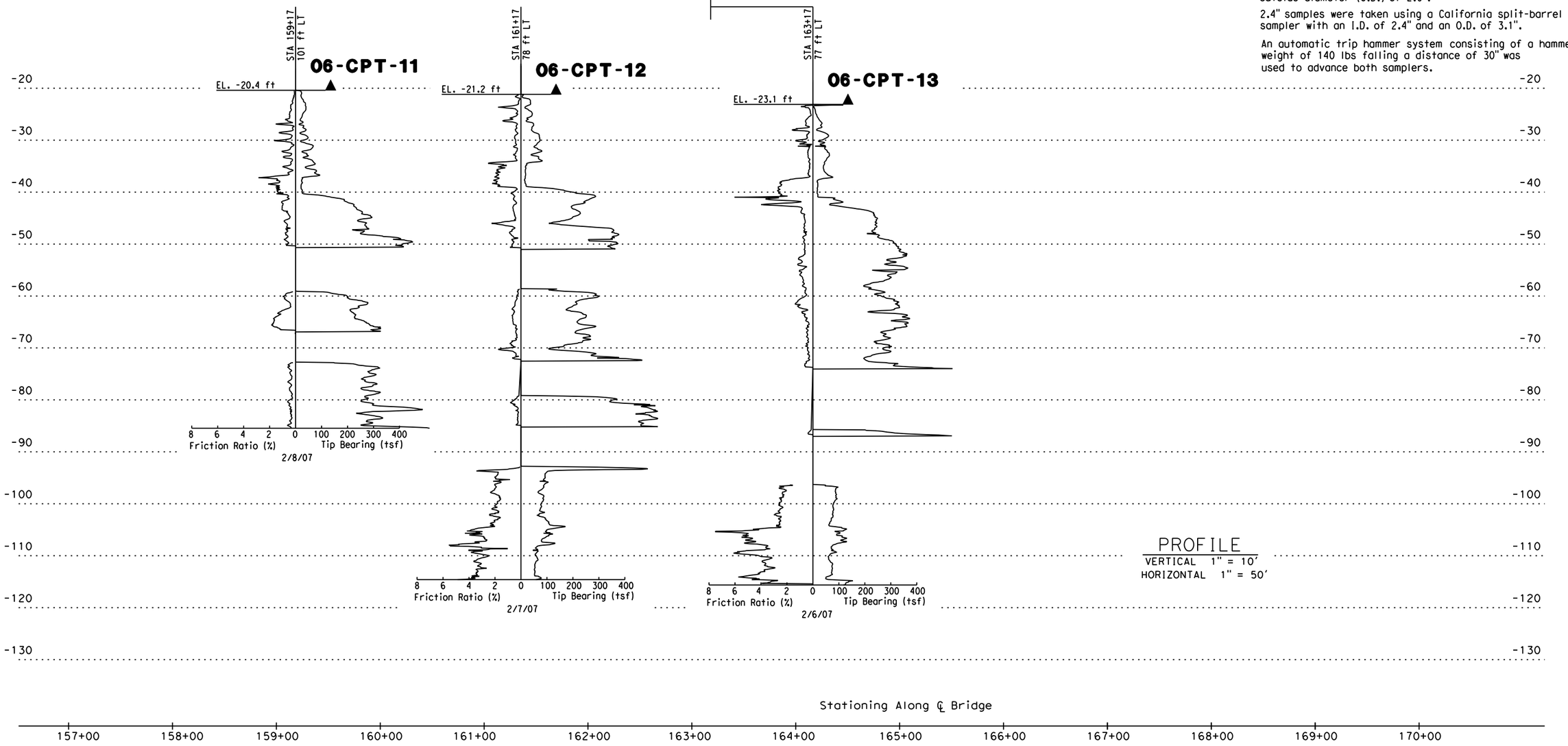


NOTES:

1.4" samples were taken using a SPT sampler with an inside diameter (I.D.) of 1.4" and an outside diameter (O.D.) of 2.0".

2.4" samples were taken using a California split-barrel sampler with an I.D. of 2.4" and an O.D. of 3.1".

An automatic trip hammer system consisting of a hammer weight of 140 lbs falling a distance of 30" was used to advance both samplers.



ENGINEERING SERVICES		GEOTECHNICAL SERVICES		STATE OF CALIFORNIA DEPARTMENT OF TRANSPORTATION		BRIDGE NO.	ANTIOCH BRIDGE
FUNCTIONAL SUPERVISOR SABA MOHAN	DRAWN BY: M. KAPUSKAR, K. THANT	FIELD INVESTIGATION BY: J. CASTLE			H. LAW PROJECT ENGINEER	28-0009	
NAME	CHECKED BY: E. BROWN, J. CASTLE					POST MILE 0.82	LOG OF TEST BORING NO. 7
OSF GEOTECHNICAL LOG OF TEST BORINGS SHEET		ORIGINAL SCALE IN INCHES FOR REDUCED PLANS	P 1 2 3	CU EA	FILE => $REQUEST	DISREGARD PRINTS BEARING EARLIER REVISION DATES →	REVISION DATES (PRELIMINARY STAGE ONLY) 7/6/07 3/20/09 SHEET OF

USERNAME => $USER DATE PLOTTED => $DATE TIME PLOTTED => $TIME

DIST	COUNTY	ROUTE	POST MILES TOTAL PROJECT	SHEET NO.	TOTAL SHEETS
04	CC Sac	160			

Jody A. Castle 3/20/09
PROFESSIONAL GEOLOGIST DATE

PROFESSIONAL GEOLOGIST J. CASTLE No. PG 8162 Exp. 12-31-10 STATE OF CALIFORNIA

PLANS APPROVAL DATE

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Earth Mechanics, Inc.
Geotechnical and Earthquake Engineering
7750 Pardee Lane, Suite 120
Oakland, California 94621

CPT-06-014 **R-06-004** 4 1/8"

⇐ To Oakley

℄ Pier 18 | ℄ Pier 18 | ℄ Pier 19 | To Rio Vista ⇒ | ℄ Bridge | ℄ Rte 160

164+00 165+00 166+00 167+00 168+00 169+00 170+00 171+00 172+00 173+00 174+00 175+00

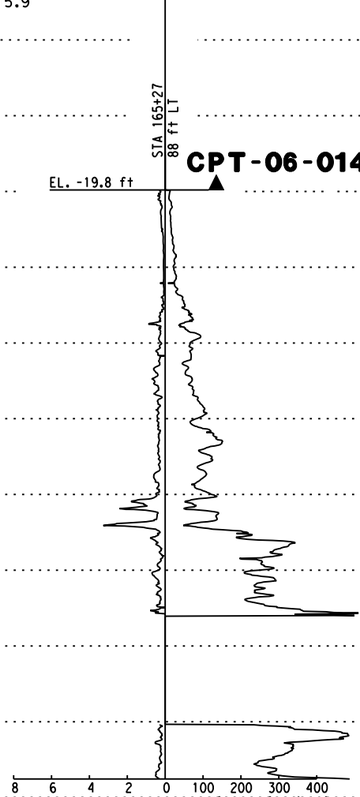
N

BENCH MARK

BM 29 SJ337 Elev 14.0
BM 29 STA 4-HK Elev 15.9

STA 165+27 88 ft LT — **CPT-06-014** — EL. -19.8 ft

STA 168+58 99 ft LT — **R-06-004** 4 1/8" — El. 0.0 ft — Mudline El. -22.30 ft



2/5/07

1	1.4		SILTY SAND (SM).
10	2.4		SILTY SAND (SM), very loose, dark brown, wet.
3	1.4		Well-graded SAND (SW), loose, dark gray brown to brown, wet, well graded from fine SAND to GRAVEL, subrounded to subangular GRAVEL.
11	2.4		Poorly graded SAND (SP), loose, dark gray, wet, fine to coarse SAND, mica flakes.
10	1.4		
33	2.4		Medium dense, predominantly fine with trace coarse SAND.
15	1.4		
45	2.4		
14	1.4		
29	2.4	M UW DS	Grades to coarse near tip of sample.
76	1.4		Well-graded SAND with interlayered GRAVEL (SW-GP), very dense, dark gray, moist, well graded to poorly graded SAND, well rounded to subrounded fine GRAVEL
93	2.4		
81	1.4		
18	2.4		GRAVEL with SAND (GW), loose, gray to dark gray, wet, well graded, subrounded to rounded GRAVEL.
35	1.4		Poorly graded SAND (SP), medium dense, gray, wet, fine to coarse SAND.
54	2.4		SANDY FAT CLAY (CH), hard, moist, brown to pale brown and brown gray, moderate to high plasticity.
36	1.4		
98	2.4		Abundant carbonate.
39	1.4		SILTY CLAY (CL), hard, yellowish brown to brown, moist, moderate plasticity, some cemented SAND and carbonate nodules.

PROFILE

VERTICAL 1" = 10'
HORIZONTAL 1" = 50'

PLAN

1" = 50'

75	2.4		
43	1.4	M UW	FAT CLAY (CH), very stiff to hard, yellow brown, moist, high plasticity.
81	2.4		Grades to SILTY CLAY (CL) near tip of sample
30	1.4		Moderate to high plasticity.
90	2.4		CLAYEY SAND (SC), very dense, dark yellowish brown,moist; very fine SAND, low plasticity, no bedding.
33	1.4		FAT CLAY (CH), hard, gray to brown, moist, high plasticity, trace carbonate.
88/11"	2.4		SILTY CLAY (CL), hard, gray brown, moist, trace fine SAND, slight to moderate plasticity, carbonate cemented material.
93/11"	1.4		Poorly graded SAND (SP), very dense, dark gray, wet, predominately medium to fine SAND, well rounded to subrounded GRAVEL.
82/10"	2.4		SILTY SAND (SM), very dense, dark brown to brown, moist, fine SAND, grades to SANDY SILT (ML).
50/6"	1.4		Poorly graded SAND with GRAVEL (SP), very dense, dark gray to gray brown, moist, coarse to fine SAND, rounded to subrounded pebble sized GRAVEL.
50/4"	2.4		SANDY SILT with CLAY, (ML), hard, brown, moist, friable, very fine to fine SAND, no bedding.

2/1-2/2/07

Terminated at El. -223.1 ft

-10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -110 -120 -130

-130 -140 -150 -160 -170 -180 -190 -200 -210 -220 -230 -240 -250

NOTES:

1.4" samples were taken using a SPT sampler with an inside diameter (I.D.) of 1.4" and an outside diameter (O.D.) of 2.0".

2.4" samples were taken using a California split-barrel sampler with an I.D. of 2.4" and an O.D. of 3.1".

An automatic trip hammer system consisting of a hammer weight of 140 lbs falling a distance of 30" was used to advance both samplers.

Stationing Along ℄ Bridge

164+00 165+00 166+00 167+00 168+00 169+00 170+00 171+00 172+00 173+00 174+00 175+00 176+00 177+00

ENGINEERING SERVICES		GEOTECHNICAL SERVICES			
FUNCTIONAL SUPERVISOR SABA MOHAN NAME	DRAWN BY: M. KAPUSKAR, K. THANT	FIELD INVESTIGATION BY: B. SCHELL, C. DOMROSE M. THAN, K. THANT	STATE OF CALIFORNIA DEPARTMENT OF TRANSPORTATION	H. LAW PROJECT ENGINEER	BRIDGE NO. 28-0009
	CHECKED BY: E. BROWN, J. CASTLE				POST MILE 0.82

ANTIOCH BRIDGE

LOG OF TEST BORING NO. 8

OSF GEOTECHNICAL LOG OF TEST BORINGS SHEET

ORIGINAL SCALE IN INCHES FOR REDUCED PLANS P 1 2 3

CU EA

DISREGARD PRINTS BEARING EARLIER REVISION DATES →

REVISION DATES (PRELIMINARY STAGE ONLY) 7/6/07 3/20/09 SHEET OF

FILE => $REQUEST

DATE PLOTTED => $DATE TIME PLOTTED => $TIME USERNAME => $USER

DIST	COUNTY	ROUTE	POST MILES TOTAL PROJECT	SHEET NO.	TOTAL SHEETS
04	CC Sac	160			

Jody A. Castle 3/20/09
PROFESSIONAL GEOLOGIST DATE

PROFESSIONAL GEOLOGIST
J. CASTLE
No. PG 8162
Exp. 12-31-10
STATE OF CALIFORNIA

PLANS APPROVAL DATE

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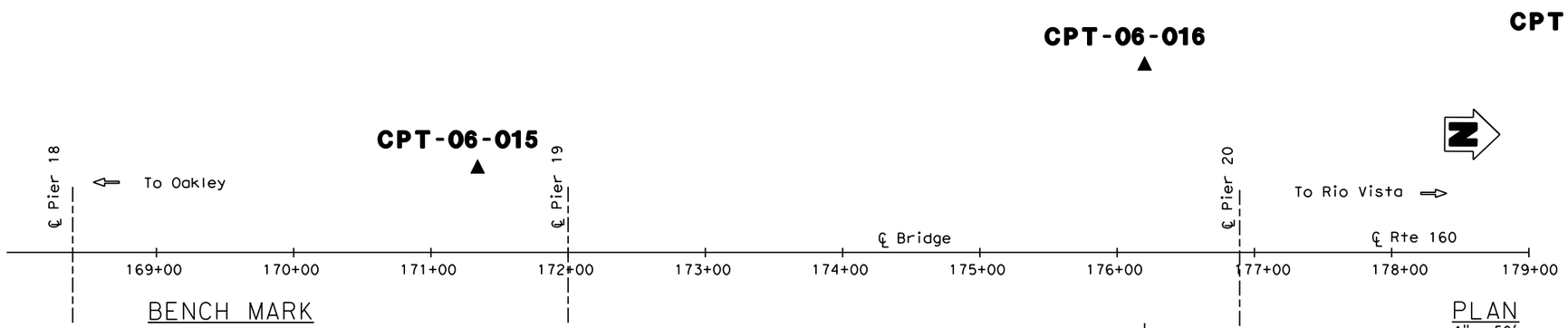
Oakland, California 94621



BENCH MARK
BM 29 SJ337 Elev 14.0
BM 29 STA 4-HK Elev 15.9

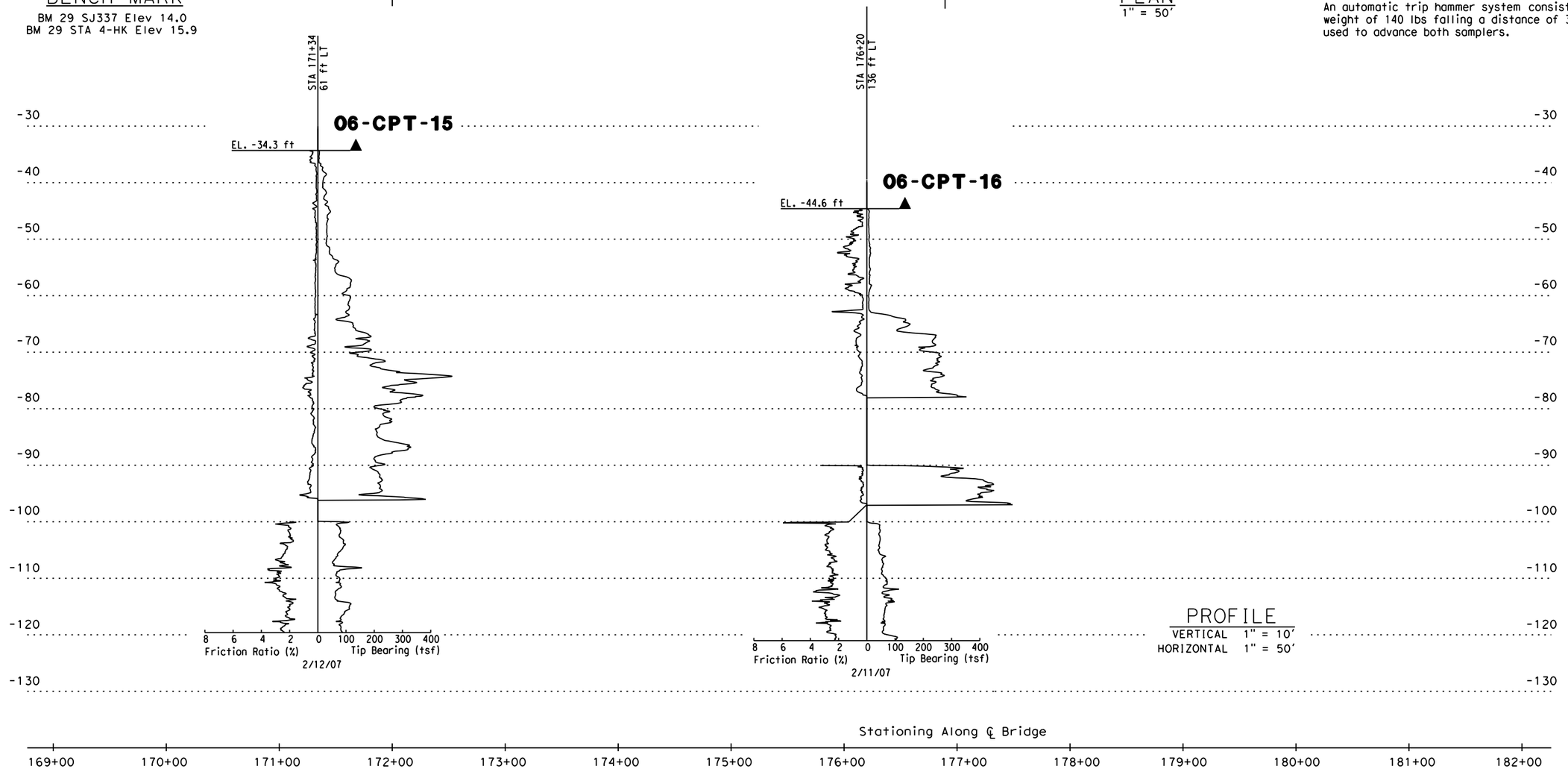
PLAN
1" = 50'

NOTES:

1.4" samples were taken using a SPT sampler with an inside diameter (I.D.) of 1.4" and an outside diameter (O.D.) of 2.0".

2.4" samples were taken using a California split-barrel sampler with an I.D. of 2.4" and an O.D. of 3.1".

An automatic trip hammer system consisting of a hammer weight of 140 lbs falling a distance of 30" was used to advance both samplers.



ENGINEERING SERVICES		GEOTECHNICAL SERVICES		STATE OF CALIFORNIA DEPARTMENT OF TRANSPORTATION		BRIDGE NO.	ANTIOCH BRIDGE
FUNCTIONAL SUPERVISOR SABA MOHAN	DRAWN BY: M. KAPUSKAR, K. THANT	FIELD INVESTIGATION BY: J. CASTLE			H. LAW PROJECT ENGINEER	28-0009	
NAME	CHECKED BY: E. BROWN, J. CASTLE					POST MILE 0.82	LOG OF TEST BORING NO. 9

OSF GEOTECHNICAL LOG OF TEST BORINGS SHEET

ORIGINAL SCALE IN INCHES FOR REDUCED PLANS 0 1 2 3

CU
EA

FILE => $REQUEST

DISREGARD PRINTS BEARING EARLIER REVISION DATES →

REVISION DATES (PRELIMINARY STAGE ONLY): 7/6/07, 3/20/09

SHEET OF

USERNAME => $USER DATE PLOTTED => $DATE TIME PLOTTED => $TIME

DIST	COUNTY	ROUTE	POST MILES TOTAL PROJECT	SHEET NO.	TOTAL SHEETS
04	CC Sac	160			

Jody A. Castle 3/20/09
PROFESSIONAL GEOLOGIST DATE

PROFESSIONAL GEOLOGIST * J. CASTLE No. PG 8162 Exp. 12-31-10 * STATE OF CALIFORNIA *

PLANS APPROVAL DATE

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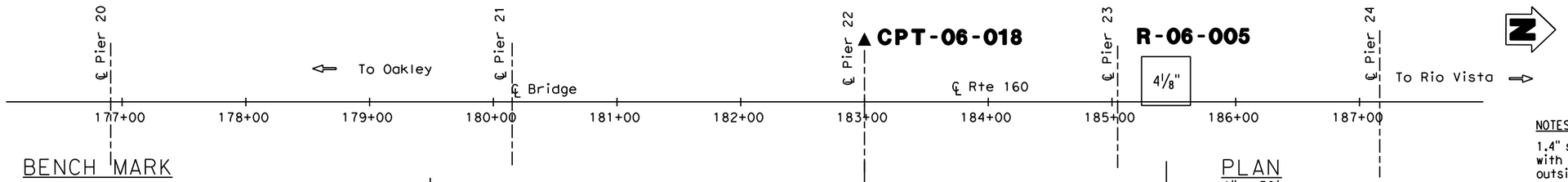
Geotechnical and Earthquake Engineering
7750 Pardee Lane, Suite 120
Oakland, California 94621

▲ CPT-06-017



BENCH MARK

BM 29 SJ337 Elev 14.0
BM 29 STA 4-HK Elev 15.9

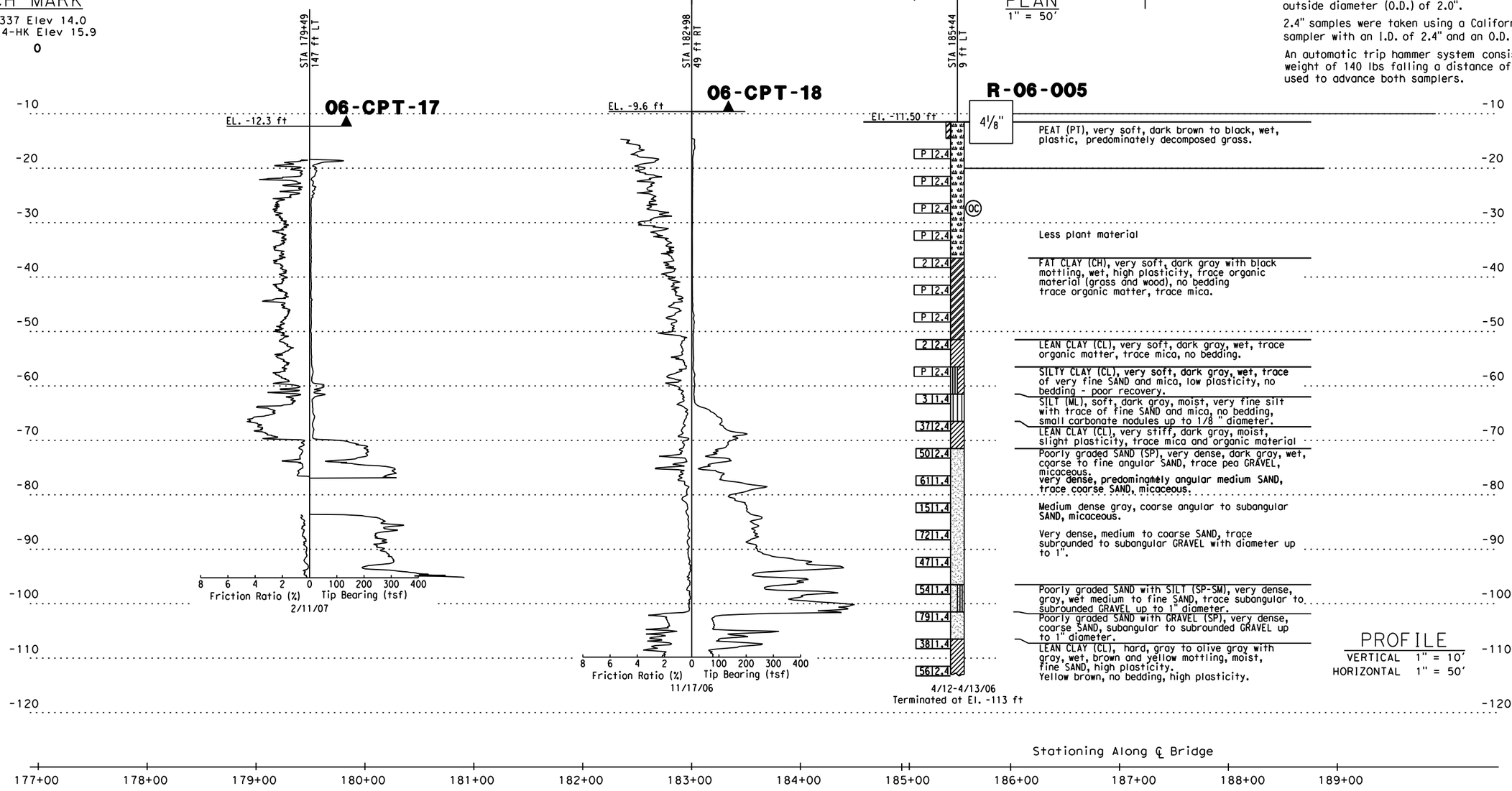
PLAN
1" = 50'

NOTES:

1.4" samples were taken using a SPT sampler with an inside diameter (I.D.) of 1.4" and an outside diameter (O.D.) of 2.0".

2.4" samples were taken using a California split-barrel sampler with an I.D. of 2.4" and an O.D. of 3.1".

An automatic trip hammer system consisting of a hammer weight of 140 lbs falling a distance of 30" was used to advance both samplers.



PROFILE
VERTICAL 1" = 10'
HORIZONTAL 1" = 50'

Stationing Along ℄ Bridge

177+00 178+00 179+00 180+00 181+00 182+00 183+00 184+00 185+00 186+00 187+00 188+00 189+00

ENGINEERING SERVICES		GEOTECHNICAL SERVICES		STATE OF CALIFORNIA DEPARTMENT OF TRANSPORTATION		BRIDGE NO.	ANTIOCH BRIDGE
FUNCTIONAL SUPERVISOR SABA MOHAN	DRAWN BY: M. KAPUSKAR, K. THANT	FIELD INVESTIGATION BY: J. CASTLE			H. LAW PROJECT ENGINEER	28-0009	
NAME	CHECKED BY: E. BROWN, J. CASTLE					POST MILE 0.82	LOG OF TEST BORING NO. 10
OSF GEOTECHNICAL LOG OF TEST BORINGS SHEET	ORIGINAL SCALE IN INCHES FOR REDUCED PLANS P 1 2 3			CU EA		DISREGARD PRINTS BEARING EARLIER REVISION DATES →	REVISION DATES (PRELIMINARY STAGE ONLY) 7/6/07 3/20/09 SHEET OF

FILE => $REQUEST

USERNAME => $USER DATE PLOTTED => $DATE TIME PLOTTED => $TIME

DIST	COUNTY	ROUTE	POST MILES TOTAL PROJECT	SHEET NO.	TOTAL SHEETS
04	CC Sac	160			

Jody A. Castle 3/20/09
PROFESSIONAL GEOLOGIST DATE

PROFESSIONAL GEOLOGIST
J. CASTLE
No. PG 8162
Exp. 12-31-10
STATE OF CALIFORNIA

PLANS APPROVAL DATE

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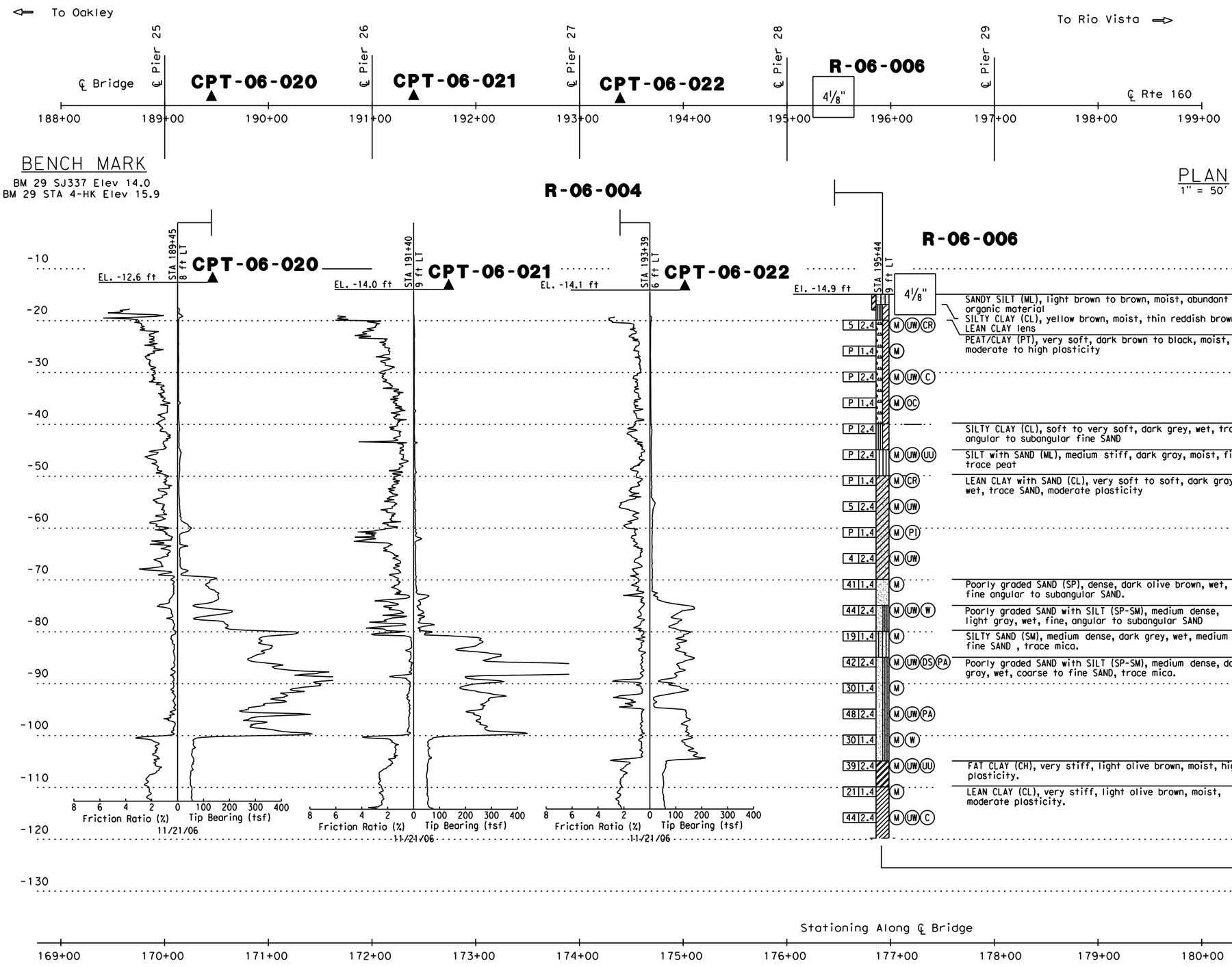
Geotechnical and Earthquake Engineering
7750 Pardee Lane, Suite 120
Oakland, California 94621



NOTES:

1.4" samples were taken using a SPT sampler with an inside diameter (I.D.) of 1.4" and an outside diameter (O.D.) of 2.0".

2.4" samples were taken using a California split-barrel sampler with an I.D. of 2.4" and an O.D. of 3.1".

An automatic trip hammer system consisting of a hammer weight of 140 lbs falling a distance of 30" was used to advance both samplers.

ENGINEERING SERVICES		GEOTECHNICAL SERVICES	STATE OF CALIFORNIA DEPARTMENT OF TRANSPORTATION		BRIDGE NO.	ANTIOCH BRIDGE
FUNCTIONAL SUPERVISOR SABA MOHAN	DRAWN BY: M. KAPUSKAR, K. THANT	FIELD INVESTIGATION BY: J. CASTLE		H. LAW PROJECT ENGINEER	28-0009	
NAME	CHECKED BY: E. BROWN, J. CASTLE				POST MILE 0.82	LOG OF TEST BORING NO. 11
OSF GEOTECHNICAL LOG OF TEST BORINGS SHEET	ORIGINAL SCALE IN INCHES FOR REDUCED PLANS P 1 2 3			CU EA	DISREGARD PRINTS BEARING EARLIER REVISION DATES →	REVISION DATES (PRELIMINARY STAGE ONLY) 7/6/07 3/20/09 SHEET OF

FILE => $REQUEST

DATE PLOTTED => $DATE TIME PLOTTED => $TIME USERNAME => $USER

DIST	COUNTY	ROUTE	POST MILES TOTAL PROJECT	SHEET NO.	TOTAL SHEETS
04	CC SAC	160			

Jody A. Castle 3/20/09
PROFESSIONAL GEOLOGIST DATE

PROFESSIONAL GEOLOGIST J. CASTLE No. PG 8162 Exp. 12-31-10 STATE OF CALIFORNIA

PLANS APPROVAL DATE

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Geotechnical and Earthquake Engineering
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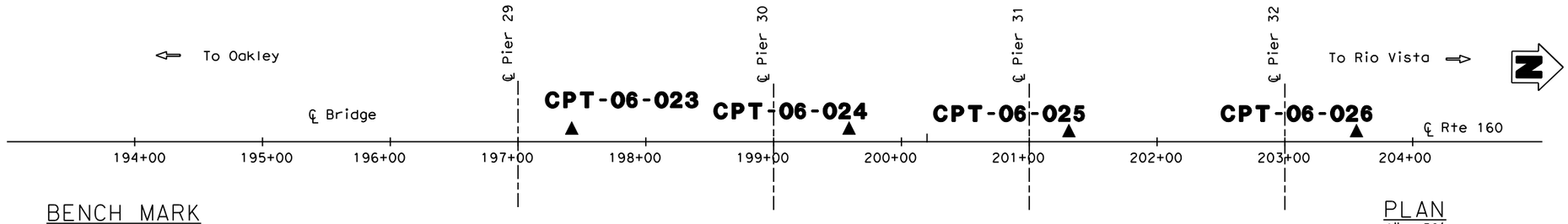
Oakland, California 94621



PLAN
1" = 50'

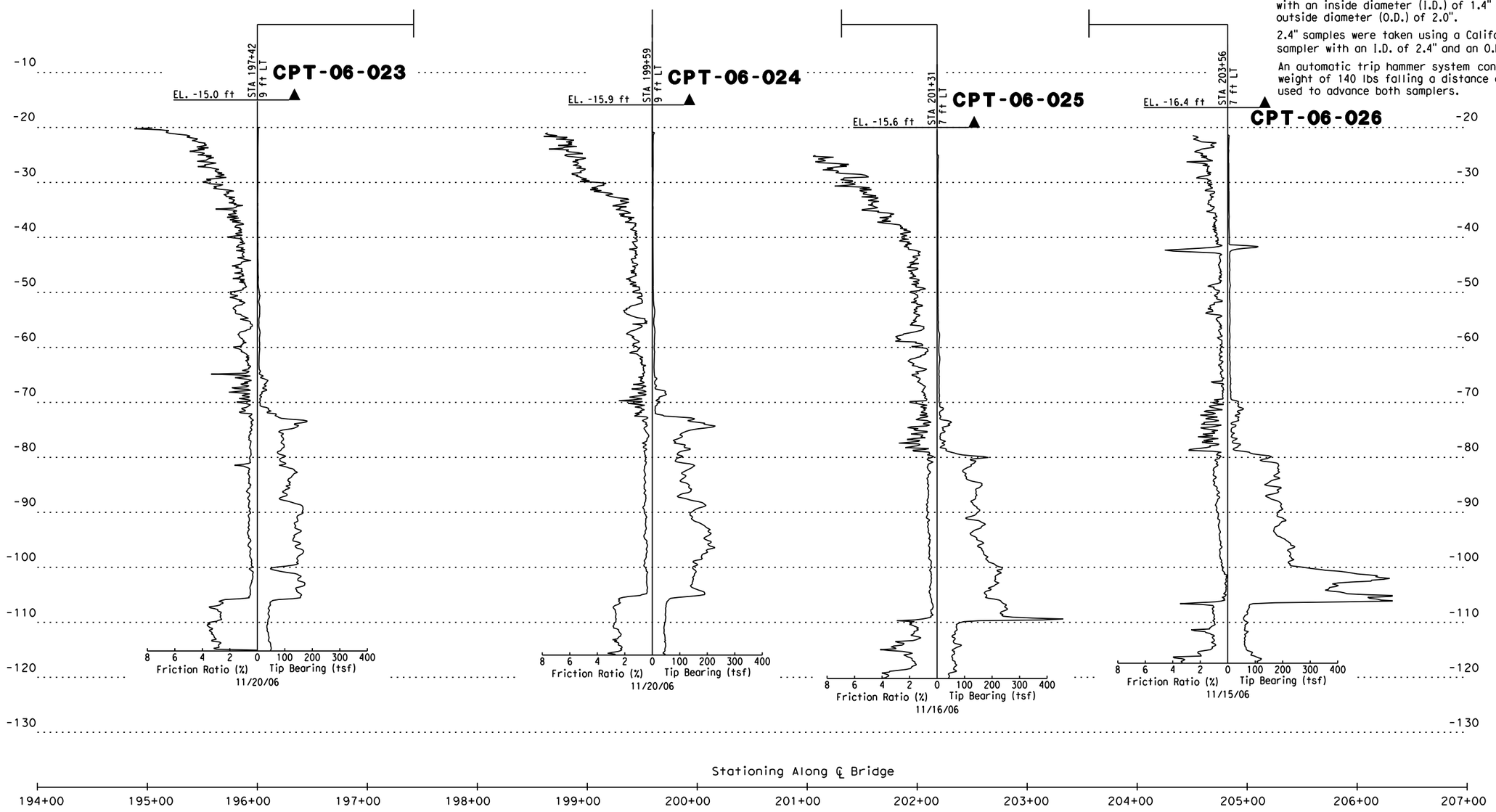
BENCH MARK
BM 29 SJ337 Elev 14.0

NOTES:

1.4" samples were taken using a SPT sampler with an inside diameter (I.D.) of 1.4" and an outside diameter (O.D.) of 2.0".

2.4" samples were taken using a California split-barrel sampler with an I.D. of 2.4" and an O.D. of 3.1".

An automatic trip hammer system consisting of a hammer weight of 140 lbs falling a distance of 30" was used to advance both samplers.



ENGINEERING SERVICES		GEOTECHNICAL SERVICES	STATE OF CALIFORNIA DEPARTMENT OF TRANSPORTATION		BRIDGE NO.	ANTIOCH BRIDGE
FUNCTIONAL SUPERVISOR SABA MOHAN NAME	DRAWN BY: M. KAPUSKAR, K. THANT	FIELD INVESTIGATION BY: J. CASTLE		H. LAW PROJECT ENGINEER	28-0009	
	CHECKED BY: E. BROWN, J. CASTLE				POST MILE 0.82	LOG OF TEST BORING NO. 12

OSF GEOTECHNICAL LOG OF TEST BORINGS SHEET

ORIGINAL SCALE IN INCHES FOR REDUCED PLANS P 1 2 3

CU
EA

DISREGARD PRINTS BEARING EARLIER REVISION DATES →

REVISION DATES (PRELIMINARY STAGE ONLY): 7/6/07 3/20/09 | SHEET | OF

FILE => $REQUEST

USERNAME => $USER DATE PLOTTED => $DATE TIME PLOTTED => $TIME

DIST	COUNTY	ROUTE	POST MILES TOTAL PROJECT	SHEET NO.	TOTAL SHEETS
04	CC Sac	160			

Jody A. Castle 3/20/09
PROFESSIONAL GEOLOGIST DATE

PLANS APPROVAL DATE

J. CASTLE No. PG 8162 Exp. 12-31-10 PROFESSIONAL GEOLOGIST STATE OF CALIFORNIA

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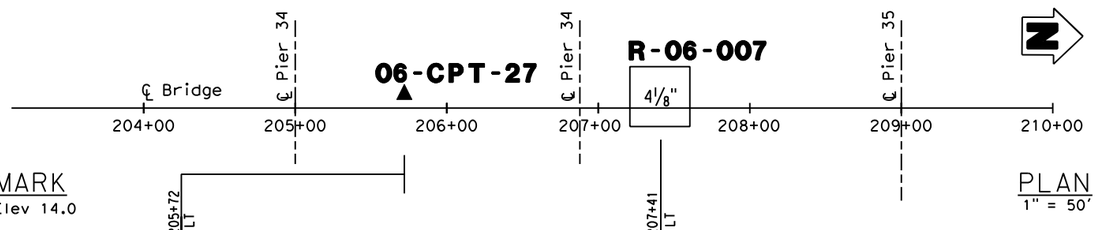


PLAN
1" = 50'

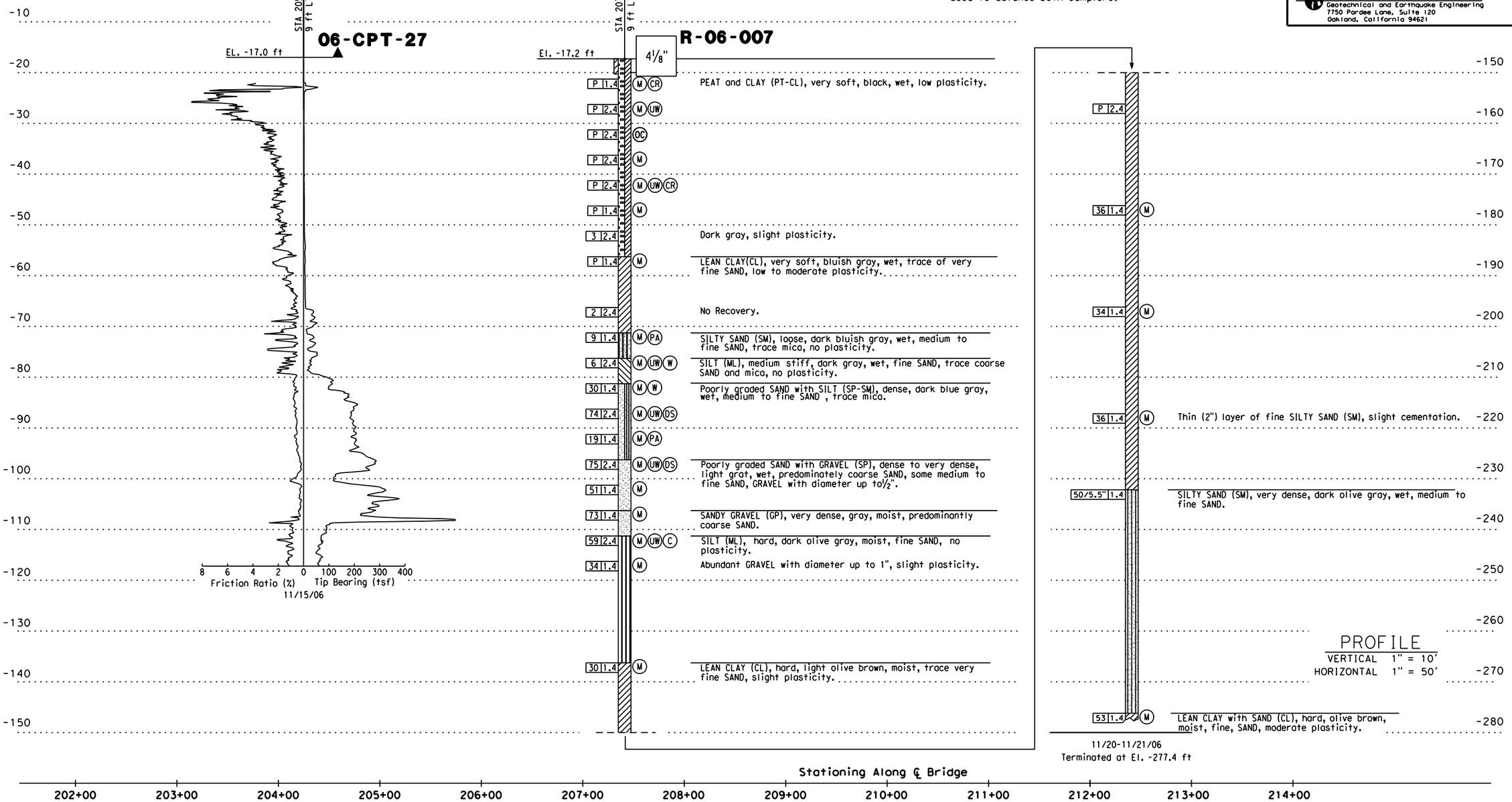
NOTES:

1.4" samples were taken using a SPT sampler with an inside diameter (I.D.) of 1.4" and an outside diameter (O.D.) of 2.0".

2.4" samples were taken using a California split-barrel sampler with an I.D. of 2.4" and an O.D. of 3.1".

An automatic trip hammer system consisting of a hammer weight of 140 lbs falling a distance of 30" was used to advance both samplers.

BENCH MARK
BM 29 SJ337 Elev 14.0



PROFILE
VERTICAL 1" = 10'
HORIZONTAL 1" = 50'

ENGINEERING SERVICES		GEOTECHNICAL SERVICES		STATE OF CALIFORNIA DEPARTMENT OF TRANSPORTATION		BRIDGE NO.	ANTIOCH BRIDGE
FUNCTIONAL SUPERVISOR SABA MOHAN	DRAWN BY: M. KAPUSKAR, K. THANT	FIELD INVESTIGATION BY: J. CASTLE, G. GUNARANJAN		H. LAW PROJECT ENGINEER		28-0009	LOG OF TEST BORING NO. 13
NAME	CHECKED BY: E. BROWN, J. CASTLE					POST MILE 0.82	

OSF GEOTECHNICAL LOG OF TEST BORINGS SHEET

ORIGINAL SCALE IN INCHES FOR REDUCED PLANS 0 1 2 3

CU EA

DISREGARD PRINTS BEARING EARLIER REVISION DATES →

REVISION DATES (PRELIMINARY STAGE ONLY): 7/6/07 3/20/09 | SHEET | OF

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DATE PLOTTED => $DATE TIME PLOTTED => $TIME USERNAME => $USER

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DIST	COUNTY	ROUTE	POST MILES TOTAL PROJECT	SHEET NO.	TOTAL SHEETS
04	CC Sac	160			

Jody A. Castle 3/20/09
PROFESSIONAL GEOLOGIST DATE

PROFESSIONAL GEOLOGIST
J. CASTLE
No. PG 8162
Exp. 12-31-10
STATE OF CALIFORNIA

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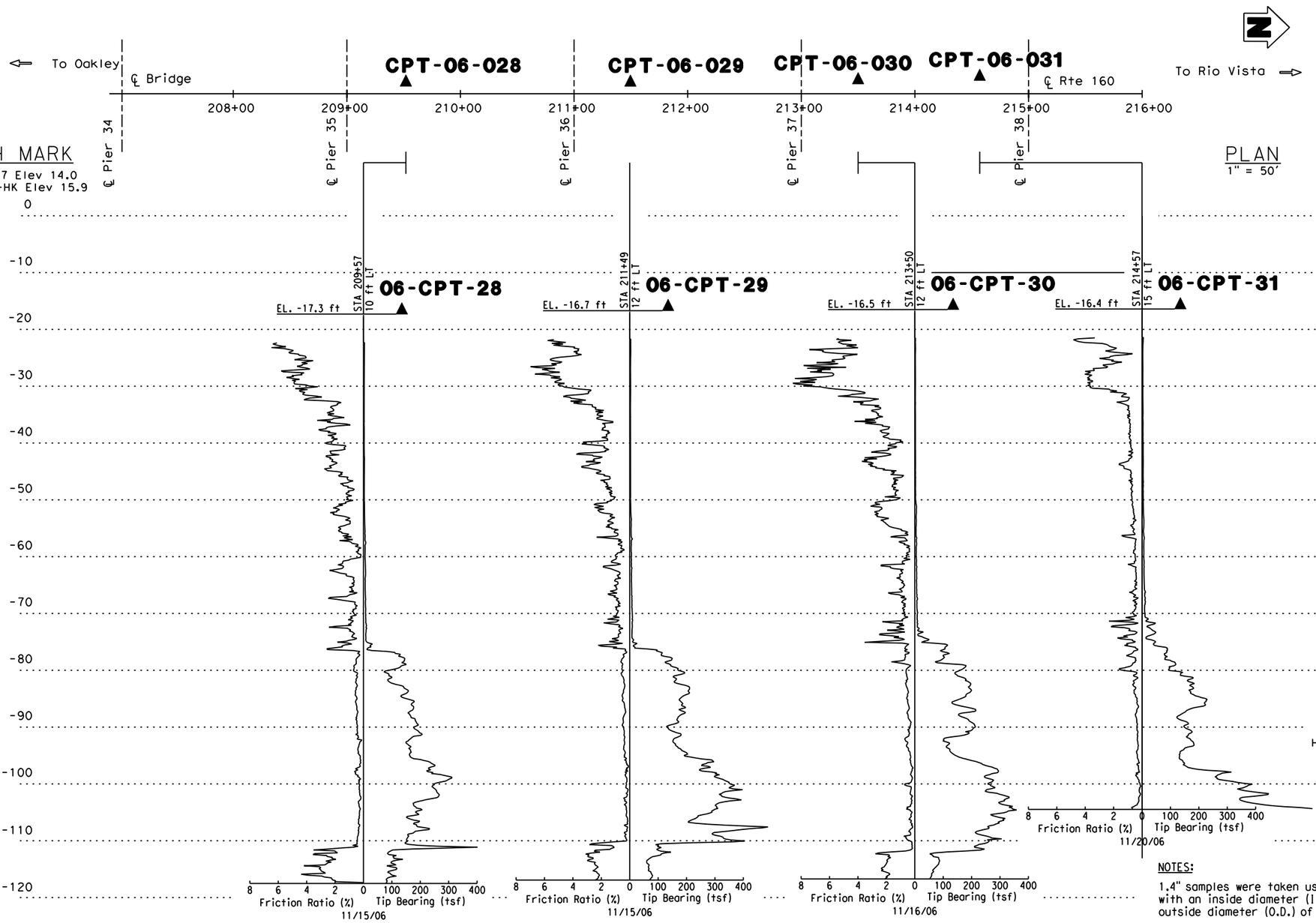

NOTES:

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ENGINEERING SERVICES		GEOTECHNICAL SERVICES		STATE OF CALIFORNIA DEPARTMENT OF TRANSPORTATION		BRIDGE NO.	ANTIOCH BRIDGE
FUNCTIONAL SUPERVISOR SABA MOHAN	DRAWN BY: M. KAPUSKAR, K. THANT	FIELD INVESTIGATION BY: J. CASTLE		H. LAW PROJECT ENGINEER		28-0009	
NAME	CHECKED BY: J. CASTLE					POST MILE 0.82	LOG OF TEST BORING NO. 14
OSF GEOTECHNICAL LOG OF TEST BORINGS SHEET	ORIGINAL SCALE IN INCHES FOR REDUCED PLANS 0 1 2 3			CU EA		DISREGARD PRINTS BEARING EARLIER REVISION DATES →	REVISION DATES (PRELIMINARY STAGE ONLY) 7/6/07 3/20/09 SHEET OF

FILE => $REQUEST

USERNAME => $USER DATE PLOTTED => $DATE TIME PLOTTED => $TIME

DIST	COUNTY	ROUTE	POST MILES TOTAL PROJECT	SHEET NO.	TOTAL SHEETS
04	CC Sac	160			

Jody A. Castle 3/20/09
PROFESSIONAL GEOLOGIST DATE

PROFESSIONAL GEOLOGIST J. CASTLE No. PG 8162 Exp. 12-31-10 STATE OF CALIFORNIA

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Geotechnical and Earthquake Engineering
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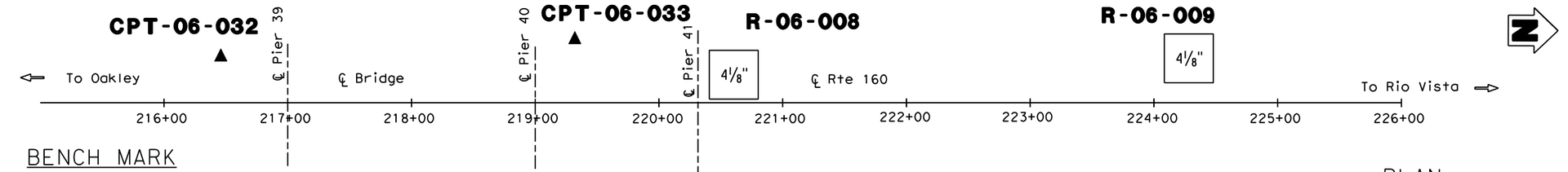
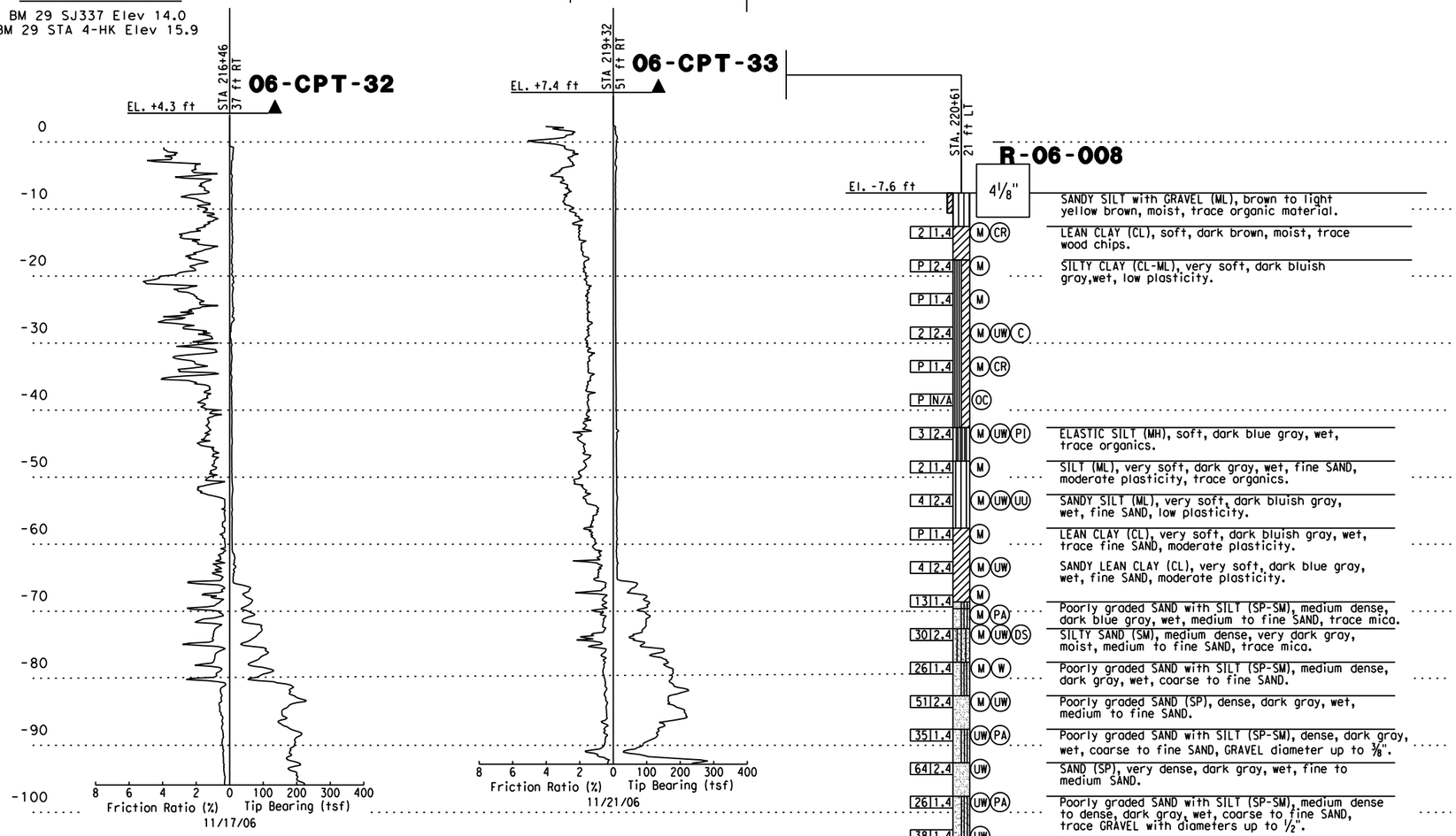
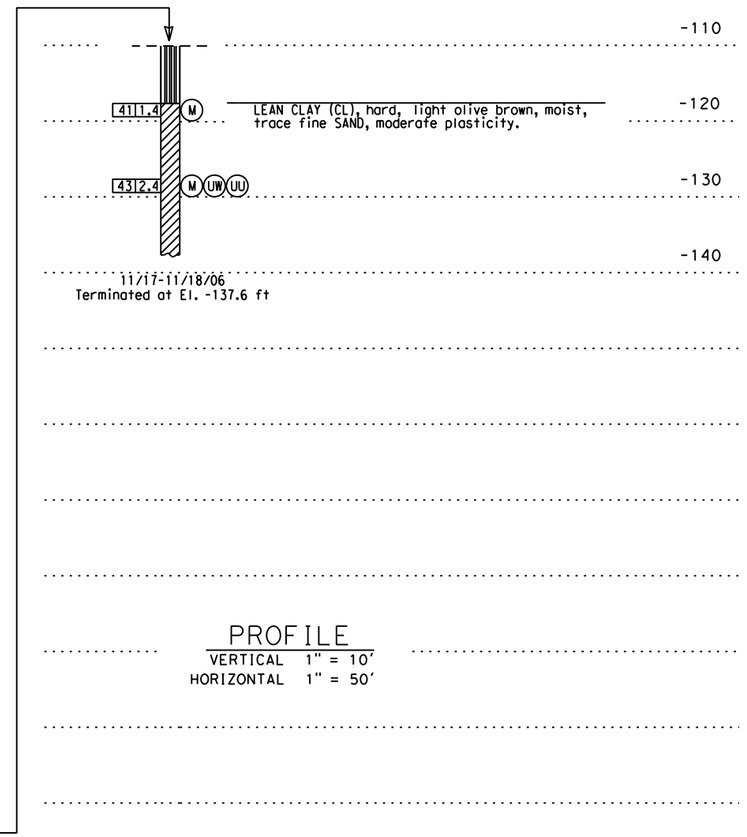


BENCH MARK

BM 29 SJ337 Elev 14.0
BM 29 STA 4-HK Elev 15.9



PLAN
1" = 50'



PROFILE
VERTICAL 1" = 10'
HORIZONTAL 1" = 50'

NOTES:

1.4" samples were taken using a SPT sampler with an inside diameter (I.D.) of 1.4" and an outside diameter (O.D.) of 2.0".

2.4" samples were taken using a California split-barrel sampler with an I.D. of 2.4" and an O.D. of 3.1".

An automatic trip hammer system consisting of a hammer weight of 140 lbs falling a distance of 30" was used to advance both samplers.

Stationing Along ℄ Bridge

215+00 216+00 217+00 218+00 219+00 220+00 221+00 222+00 223+00 224+00 225+00 226+00 227+00 228+00 229+00 230+00

ENGINEERING SERVICES		GEOTECHNICAL SERVICES		STATE OF CALIFORNIA DEPARTMENT OF TRANSPORTATION		BRIDGE NO.	ANTIOCH BRIDGE
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	CHECKED BY: J. CASTLE					POST MILE 0.82	LOG OF TEST BORING NO. 15
OSF GEOTECHNICAL LOG OF TEST BORINGS SHEET		ORIGINAL SCALE IN INCHES FOR REDUCED PLANS	P 1 2 3	CU EA	DISREGARD PRINTS BEARING EARLIER REVISION DATES →	REVISION DATES (PRELIMINARY STAGE ONLY) 1 6/07 3/20/09	SHEET OF

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04	CC Sac	160			

Jody A. Castle 3/20/09
PROFESSIONAL GEOLOGIST DATE

PROFESSIONAL GEOLOGIST
J. CASTLE
No. PG 8162
Exp. 12-31-10
STATE OF CALIFORNIA

PLANS APPROVAL DATE

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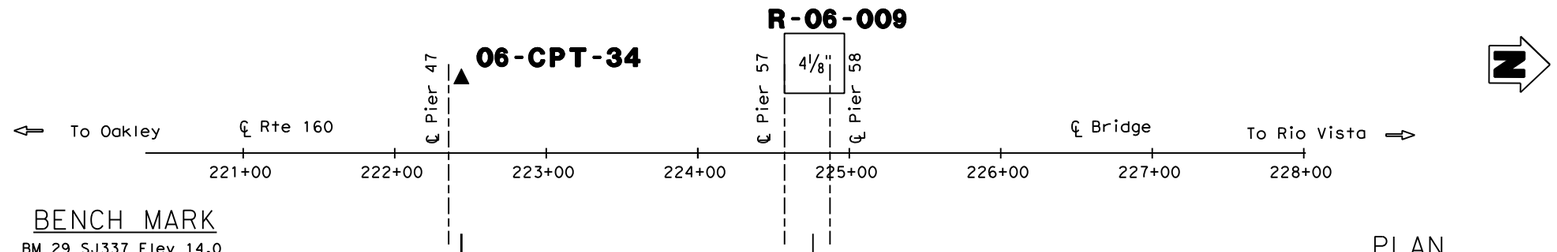
Earth Mechanics, Inc.
Geotechnical and Earthquake Engineering
7750 Pardee Lane, Suite 120
Oakland, California 94621



BENCH MARK
BM 29 SJ337 Elev 14.0
BM 29 STA 4-HK Elev 15.9

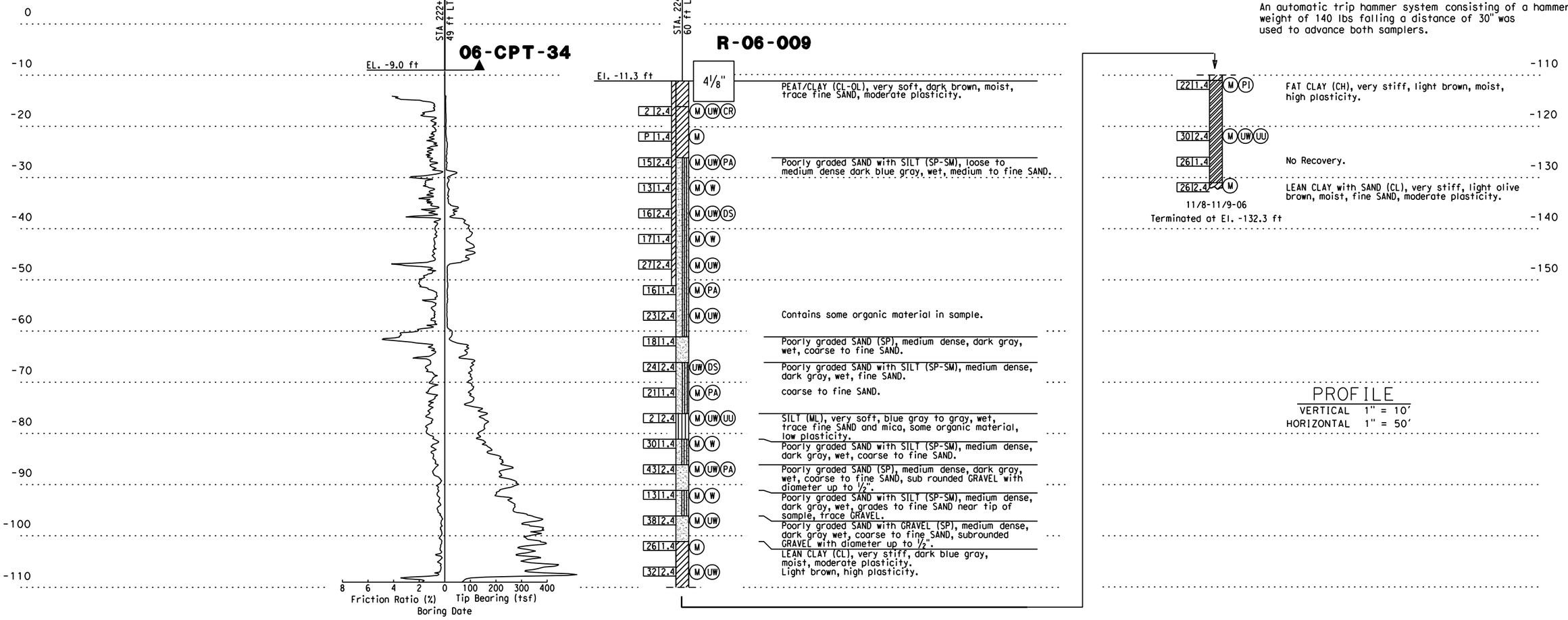
PLAN
1" = 50'

NOTES:

1.4" samples were taken using a SPT sampler with an inside diameter (I.D.) of 1.4" and an outside diameter (O.D.) of 2.0".

2.4" samples were taken using a California split-barrel sampler with an I.D. of 2.4" and an O.D. of 3.1".

An automatic trip hammer system consisting of a hammer weight of 140 lbs falling a distance of 30" was used to advance both samplers.



2 | 2.4	M UW CR	PEAT/CLAY (CL-OL), very soft, dark brown, moist, trace fine SAND, moderate plasticity.
P | 1.4	M	
15 | 2.4	M UW PA	Poorly graded SAND with SILT (SP-SM), loose to medium dense dark blue gray, wet, medium to fine SAND.
13 | 1.4	M W	
16 | 2.4	M UW DS	
17 | 1.4	M W	
27 | 2.4	M UW	
16 | 1.4	M PA	
23 | 2.4	M UW	Contains some organic material in sample.
18 | 1.4		Poorly graded SAND (SP), medium dense, dark gray, wet, coarse to fine SAND.
24 | 2.4	UW DS	Poorly graded SAND with SILT (SP-SM), medium dense, dark gray, wet, fine SAND.
21 | 1.4	M PA	coarse to fine SAND.
2 | 2.4	M UW UU	SILT (ML), very soft, blue gray to gray, wet, trace fine SAND and mica, some organic material, low plasticity.
30 | 1.4	M W	Poorly graded SAND with SILT (SP-SM), medium dense, dark gray, wet, coarse to fine SAND.
43 | 2.4	M UW PA	Poorly graded SAND (SP), medium dense, dark gray, wet, coarse to fine SAND, sub rounded GRAVEL with diameter up to ½".
13 | 1.4	M W	Poorly graded SAND with SILT (SP-SM), medium dense, dark gray, wet, grades to fine SAND near tip of sample, trace GRAVEL.
38 | 2.4	M UW	Poorly graded SAND with GRAVEL (SP), medium dense, dark gray wet, coarse to fine SAND, subrounded GRAVEL with diameter up to ½".
26 | 1.4	M	LEAN CLAY (CL), very stiff, dark blue gray, moist, moderate plasticity.
32 | 2.4	M UW	Light brown, high plasticity.
22 | 1.4	M PI	FAT CLAY (CH), very stiff, light brown, moist, high plasticity.
30 | 2.4	M UW UU	
26 | 1.4		No Recovery.
26 | 2.4	M	LEAN CLAY with SAND (CL), very stiff, light olive brown, moist, fine SAND, moderate plasticity.

PROFILE
VERTICAL 1" = 10'
HORIZONTAL 1" = 50'

Stationing Along ℄ Bridge
219+00 220+00 221+00 222+00 223+00 224+00 225+00 226+00 227+00 228+00 229+00 230+00 231+00 232+00 233+00

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NAME	CHECKED BY: J. CASTLE					POST MILE 0.82	LOG OF TEST BORING NO. 16
OSF GEOTECHNICAL LOG OF TEST BORINGS SHEET	ORIGINAL SCALE IN INCHES FOR REDUCED PLANS 0 1 2 3			CU EA		DISREGARD PRINTS BEARING EARLIER REVISION DATES →	REVISION DATES (PRELIMINARY STAGE ONLY) 7/6/07 3/20/09 SHEET OF

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DIST	COUNTY	ROUTE	POST MILES TOTAL PROJECT	SHEET NO.	TOTAL SHEETS
04	CC Sac	160			

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No. PG 8162
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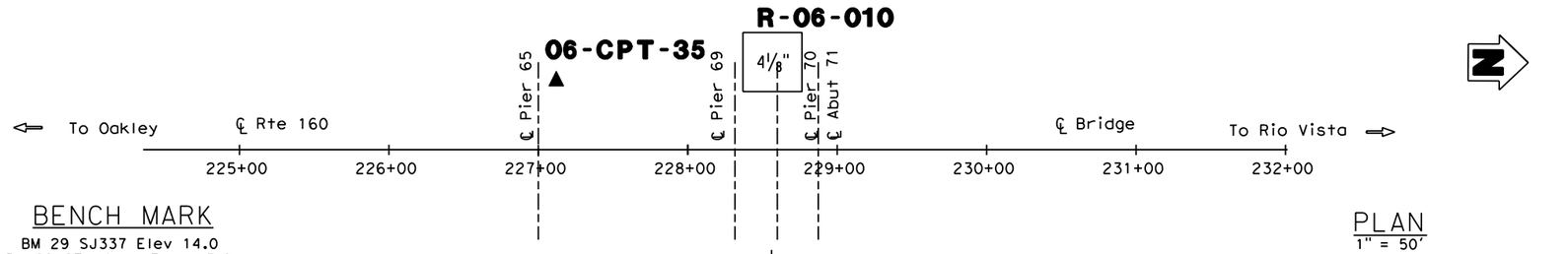

PLAN
1" = 50'

BENCH MARK
BM 29 SJ337 Elev 14.0
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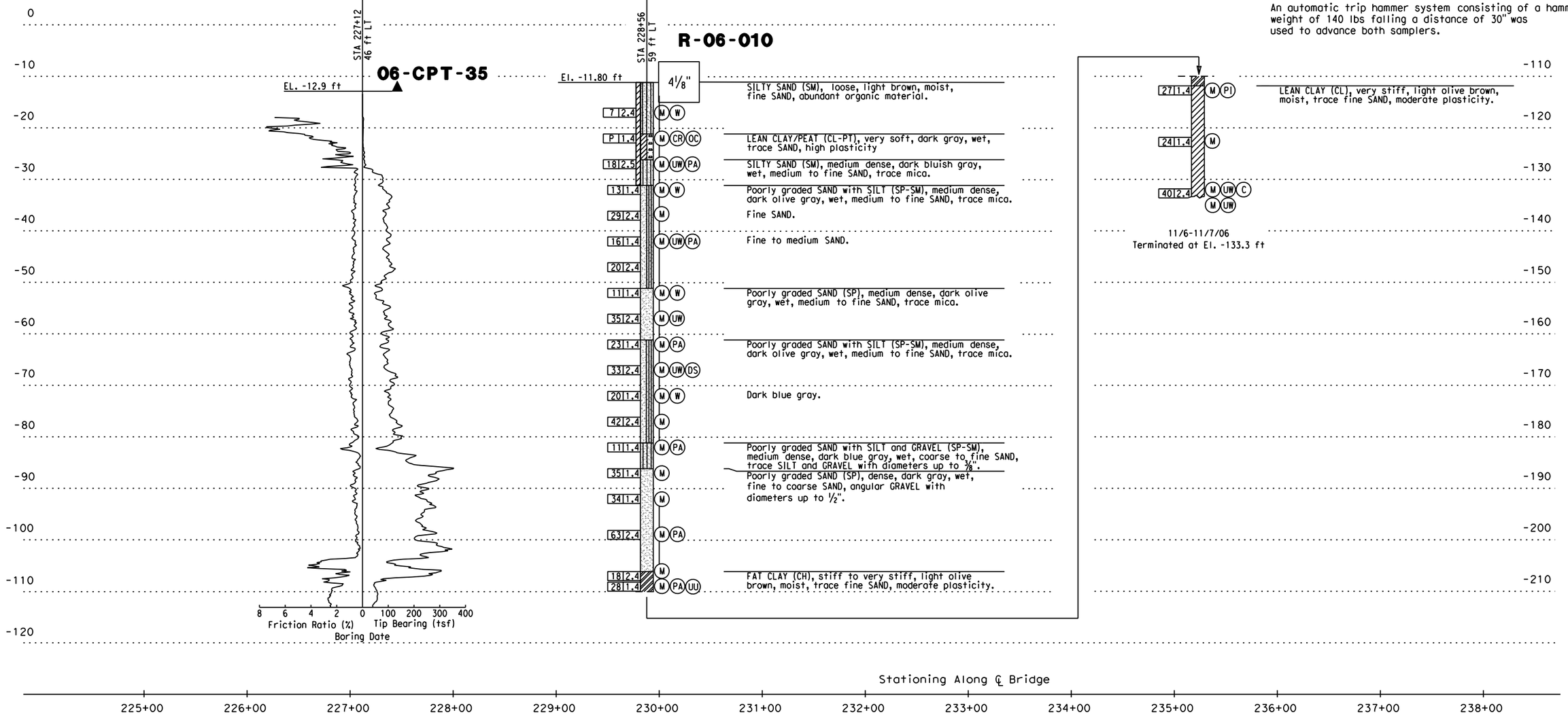
An automatic trip hammer system consisting of a hammer weight of 140 lbs falling a distance of 30" was used to advance both samplers.



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FUNCTIONAL SUPERVISOR SABA MOHAN	DRAWN BY: M. KAPUSKAR, K. THANT	FIELD INVESTIGATION BY: J. CASTLE			H. LAW PROJECT ENGINEER	28-0009	
NAME	CHECKED BY: J. CASTLE					POST MILE 0.82	LOG OF TEST BORING NO. 17
OSF GEOTECHNICAL LOG OF TEST BORINGS SHEET	ORIGINAL SCALE IN INCHES FOR REDUCED PLANS 0 1 2 3			CU EA	FILE => $REQUEST	DISREGARD PRINTS BEARING EARLIER REVISION DATES →	REVISION DATES (PRELIMINARY STAGE ONLY) 1 2 3/20/09 SHEET OF

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GEOVision
geophysical services

ANTIOCH BRIDGE INVESTIGATION

BORINGS 06-02, 06-03, 06-04,

06-07 AND 06-08,

SUSPENSION P & S VELOCITIES

May 8, 2007
Report 6554-02 Rev 02

ANTIOCH BRIDGE INVESTIGATION

BORINGS 06-02, 06-03, 06-04,

06-07 AND 06-08,

SUSPENSION P & S VELOCITIES

Prepared for

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17660 Newhope Street, Suite E
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Project #06-155

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1151 Pomona Road, Unit P
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Project 6554

May 8, 2007
Report 6554-02 Rev 02

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INTRODUCTION

OYO suspension velocity measurements were performed in three land and two marine borings beneath the Antioch Bridge, as a component of the Investigation of the bridge. Suspension logging data acquisition was performed between November 16, 2006 and February 2, 2007 by Rob Steller of GEOVision. The work was performed under subcontract with Earth Mechanics, Inc. (EMI), with Jody Castle as the point of contact for EMI.

This report describes the field measurements, data analysis, and results of this work.

SCOPE OF WORK

This report presents the results of suspension velocity measurements collected between November 16, 2006 and February 2, 2007, in the uncased borings designated 06-02 through 06-08, as detailed below. The purpose of these studies was to supplement stratigraphic information obtained during EMI's soil sampling program and to acquire shear wave velocities and compressional wave velocities as a function of depth, which, in turn, can be used to characterize soil condition and calculate site response.

BORING DESIGNATION	LOCATION	DATE LOGGED	APPROX ELEV. (NGVD) (FEET)	COORDINATES (NAD83)	
				EASTING (FT)	NORTHING (FT)
06-02	LAND	11/16/06	+8.7	6,201,136.2	2,196,002.6
06-03	MARINE	2/1/07	-10.8	6,201,067.7	2,197,414.7
06-04	MARINE	2/2/07	-22.3	6,201,080.0	2,198,565.4
06-07	LAND	11/21/06	-17.2	6,201,216.2	2,202,447.3
06-08	LAND	11/18/06	-7.6	6,201,259.2	2,203,762.7

(Survey data provided by EMI 4/26/07 cjd)

Table 1. Boring locations and logging dates

The OYO Model 170 Suspension Logging Recorder and Suspension Logging Probe were used to obtain in-situ horizontal shear and compressional wave velocity measurements at 1.64 ft intervals. The acquired data was analyzed and a profile of velocity versus depth was produced for both compressional and horizontally polarized shear waves.

A detailed reference for the velocity measurement techniques used in this study is:

> Guidelines for Determining Design Basis Ground Motions, Report TR-102293, Electric Power Research Institute, Palo Alto, California, November 1993, Sections 7 and 8.

SUSPENSION INSTRUMENTATION

Suspension soil velocity measurements were performed using the Model 170 Suspension Logging system, manufactured by OYO Corporation. This system directly determines the average velocity of a 3.28 ft high segment of the soil column surrounding the boring of interest by measuring the elapsed time between arrivals of a wave propagating upward through the soil column. The receivers that detect the wave, and the source that generates the wave, are moved as a unit in the boring producing relatively constant amplitude signals at all depths.

The suspension system probe consists of a combined reversible polarity solenoid horizontal shear-wave source (S_H) and compressional-wave source (P), joined to two biaxial receivers by a flexible isolation cylinder, as shown in Figure 1. The separation of the two receivers is 3.28 ft, allowing average wave velocity in the region between the receivers to be determined by inversion of the wave travel time between the two receivers. The total length of the probe as used in this survey is 19 ft, with the center point of the receiver pair 12.1 ft above the bottom end of the probe. The probe receives control signals from, and sends the amplified receiver signals to, instrumentation on the surface via an armored 7 conductor cable. The cable is wound onto the drum of a winch and is used to support the probe. Cable travel is measured to provide probe depth data.

The entire probe is suspended by the cable and centered in the boring by nylon "whiskers", therefore, source motion is not coupled directly to the boring walls; rather, the source motion creates a horizontally propagating impulsive pressure wave in the fluid filling the boring and surrounding the source. This pressure wave is converted to P and S_H-waves in the surrounding soil and rock as it impinges upon the boring wall. These waves propagate through the soil and rock surrounding the boring, in turn causing a pressure wave to be generated in the fluid surrounding the receivers as the soil waves pass their location. Separation of the P and S_H-waves at the receivers is performed using the following steps:

1. Orientation of the horizontal receivers is maintained parallel to the axis of the source, maximizing the amplitude of the recorded S_H -wave signals.
2. At each depth, S_H-wave signals are recorded with the source actuated in opposite directions, producing S_H-wave signals of opposite polarity, providing a characteristic S_H-wave signature distinct from the P-wave signal.
3. The 7.0 ft separation of source and receiver 1 permits the P-wave signal to pass and damp significantly before the slower S_H-wave signal arrives at the receiver. In faster soils or rock, the isolation cylinder is extended to allow greater separation of the P- and S_H-wave signals.
4. In saturated soils, the received P-wave signal is typically of much higher frequency than the received S_H-wave signal, permitting additional separation of the two signals by low pass filtering.
5. Direct arrival of the original pressure pulse in the fluid is not detected at the receivers because the wavelength of the pressure pulse in fluid is significantly greater than the dimension of the fluid annulus surrounding the probe (foot versus inch scale), preventing significant energy transmission through the fluid medium.

In operation, a distinct, repeatable pattern of impulses is generated at each depth as follows:

1. The source is fired in one direction producing dominantly horizontal shear with some vertical compression, and the signals from the horizontal receivers situated parallel to the axis of motion of the source are recorded.
2. The source is fired again in the opposite direction and the horizontal receiver signals are recorded.
3. The source is fired again and the vertical receiver signals are recorded. The repeated source pattern facilitates the picking of the P and S_H-wave arrivals; reversal of the source changes the polarity of the S_H-wave pattern but not the P-wave pattern.

The data from each receiver during each source activation is recorded as a different channel on the recording system. The Model 170 has six channels (two simultaneous recording channels), each with a 12 bit 1024 sample record. The recorded data is displayed on a CRT display and on paper tape output as six channels with a common time scale. Data is stored on 3.5 inch floppy diskettes for further processing. Up to 8 sampling sequences can be summed to improve the signal to noise ratio of the signals.

Review of the displayed data on the CRT or paper tape allows the operator to set the gains, filters, delay time, pulse length (energy), sample rate, and summing number to optimize the quality of the data before recording. Verification of the calibration of the Model 170 digital recorder is performed every twelve months using a NIST traceable frequency source and counter, as outlined in Appendix B.

SUSPENSION MEASUREMENT PROCEDURES

The borings were logged uncased, filled with bentonite or polymer based drilling fluid. The boring probe was positioned with the mid-point of the receiver spacing at grade or deck level, and the mechanical and electronic depth counters were set to zero. The probe was lowered to the bottom of the boring, stopping at 1.64 ft intervals to collect data, as summarized below.

At each measurement depth the measurement sequence of two opposite horizontal records and one vertical record was performed, and the gains were adjusted as required. The data from each depth was printed on paper tape, checked, and recorded on diskette before moving to the next depth.

Upon completion of the measurements, the probe zero depth indication at grade or deck level was verified prior to removal from the boring.

BORING NUMBER	RUN NUMBER	DEPTH RANGE (FEET)	DEPTH AS DRILLED (FEET)	LOST TO SLOUGH/COLLAPSE (FEET)	SAMPLE INTERVAL (FEET)	DATE LOGGED
06-02	1	1.6 – 187.0	200	0.9	1.64	11/16/06
06-03	1	41.0 – 70.5		0	1.64	2/1/07
06-03	2	67.3 – 221.5	235	1.4	1.64	2/1/07
06-04	1	114.8 – 231.3	250	6.6	1.64	2/2/07
06-04	2	83.7 – 129.6		0	1.64	2/2/07
06-04	3	52.5 – 82.0		2.1	1.64	2/2/07
06-07	1	23.0 – 247.7	260.5	0.7	1.64	11/21/06
06-08	1	3.3 – 114.8	130	3.1	1.64	11/18/06

Table 2. Logging dates and depth ranges

SUSPENSION DATA ANALYSIS

The recorded digital waveforms were analyzed to locate the first minima on the vertical axis records, indicating the arrival of P-wave energy. The difference in travel time between receiver 1 and receiver 2 (R1-R2) arrivals was used to calculate the P-wave velocity for that 3.28 ft segment of the soil column. When observable, P-wave arrivals on the horizontal axis records were used to verify the velocities determined from the vertical axis data.

The P-wave velocity calculated from the travel time over the 7.0 ft interval from source to receiver 1 (S-R1) was calculated and plotted for quality assurance of the velocity derived from the travel time between receivers. In this analysis, the depth values as recorded were increased by 5.15 ft to correspond to the mid-point of the 7.0 ft S-R1 interval, as illustrated in Figure 1. Travel times were obtained by picking the first break of the P-wave signal at receiver 1 and subtracting 3.85 milliseconds, the calculated and experimentally verified delay from source trigger pulse (beginning of record) to source impact. This delay corresponds to the duration of acceleration of the solenoid before impact.

The recorded digital records were studied to establish the presence of clear S_H-wave pulses, as indicated by the presence of opposite polarity pulses on each pair of horizontal records. Ideally, the S_H-wave signals from the 'normal' and 'reverse' source pulses are very nearly inverted images of each other. Digital FFT - IFFT lowpass filtering was used to remove the higher frequency P-wave signal from the S_H-wave signal. Different filter cutoffs were used to separate P- and S_H-waves at different depths, ranging from 500 Hz in the slowest zones to 4000 Hz in the regions of highest velocity. At each depth, the filter frequency was selected to be at least twice the fundamental frequency of the S_H-wave signal being filtered.

Generally, the first maxima was picked for the 'normal' signals and the first minima for the 'reverse' signals, although other points on the waveform were used if the first pulse was distorted. The absolute arrival time of the 'normal' and 'reverse' signals may vary by +/- 0.2 milliseconds, due to differences in the actuation time of the solenoid source caused by constant mechanical bias in the source or by boring inclination. This variation does not affect the R1-R2 velocity determinations, as the differential time is measured between arrivals of waves created by the same source actuation. The final velocity value is the average of the values obtained from the 'normal' and 'reverse' source actuations.

As with the P-wave data, S_H-wave velocity calculated from the travel time over the 7.0 ft interval from source to receiver 1 was calculated and plotted for verification of the velocity derived from the travel time between receivers. In this analysis, the depth values were increased by 5.15 ft to correspond to the mid-point of the 7.0 ft S-R1 interval. Travel times were obtained by picking the first break of the S_H-wave signal at the near receiver and subtracting 3.85 milliseconds, the calculated and experimentally verified delay from the beginning of the record at the source trigger pulse to source impact.

Figure 2 shows an example of R1 - R2 measurements on a sample filtered suspension record. In Figure 2, the time difference over the 3.28 ft interval of 1.88 milliseconds for the horizontal signals is equivalent to an S_H-wave velocity of 1745 ft/sec. Whenever possible, time differences were determined from several phase points on the S_H-waveform records to verify the data obtained from the first arrival of the S_H-wave pulse. Figure 3 displays the same record before filtering of the S_H-waveform record with an 1400 Hz FFT - IFFT digital lowpass filter, illustrating the presence of higher frequency P-wave energy at the beginning of the record, and distortion of the lower frequency S_H-wave by residual P-wave signal.

SUSPENSION RESULTS

Suspension R1-R2 P- and S_H-wave velocities are plotted in Figures 4 through 8. The suspension velocity data shown in these figures are presented in Tables 3 through 7. P- and S_H-wave velocity data from R1-R2 analysis and quality assurance analysis of S-R1 data are plotted together in Figures A1 through A5 to aid in visual comparison. It must be noted that R1-R2 data is an average velocity over a 3.28 ft segment of the soil column; S-R1 data is an average over 7.0 ft, creating a significant smoothing relative to the R1-R2 plots. S-R1 data are presented in Tables A1 through A5. Good correspondence between the shapes of the P- and S_H-wave velocity curves is observed for both all these data sets. The velocities derived from S-R1 and R1-R2 data are in excellent agreement, providing verification of the higher resolution R1-R2 data.

Calibration procedures and records for the suspension measurement system are presented in Appendix B.

SUMMARY

Discussion of Suspension Results

Both P- and S_H-wave velocities were measured using the OYO Suspension Method in two uncased land borings and five uncased marine borings to depths up to 247.7 ft beneath the Antioch Bridge. All borings were located in adjacent to a heavily traveled highway bridge, but no significant signal contamination from ambient vibration was observed.

Quality Assurance

These velocity measurements were performed using industry-standard or better methods for both measurements and analyses. All work was performed under GEOVision quality assurance procedures, which include:

- Use of NIST-traceable calibrations, where applicable, for field and laboratory instrumentation
- Use of standard field data logs
- Use of independent verification of data by comparison of receiver-to-receiver and source-to-receiver velocities
- Independent review of calculations and results by a registered professional engineer, geologist, or geophysicist.

Data Reliability

P- and S_H-wave velocity measurement using the Suspension Method gives average velocities over a 3.28 ft interval of depth. This high resolution results in the scatter of values shown in the graphs. Individual measurements are very reliable with estimated precision of +/- 5%. Standardized field procedures and quality assurance checks add to the reliability of these data.

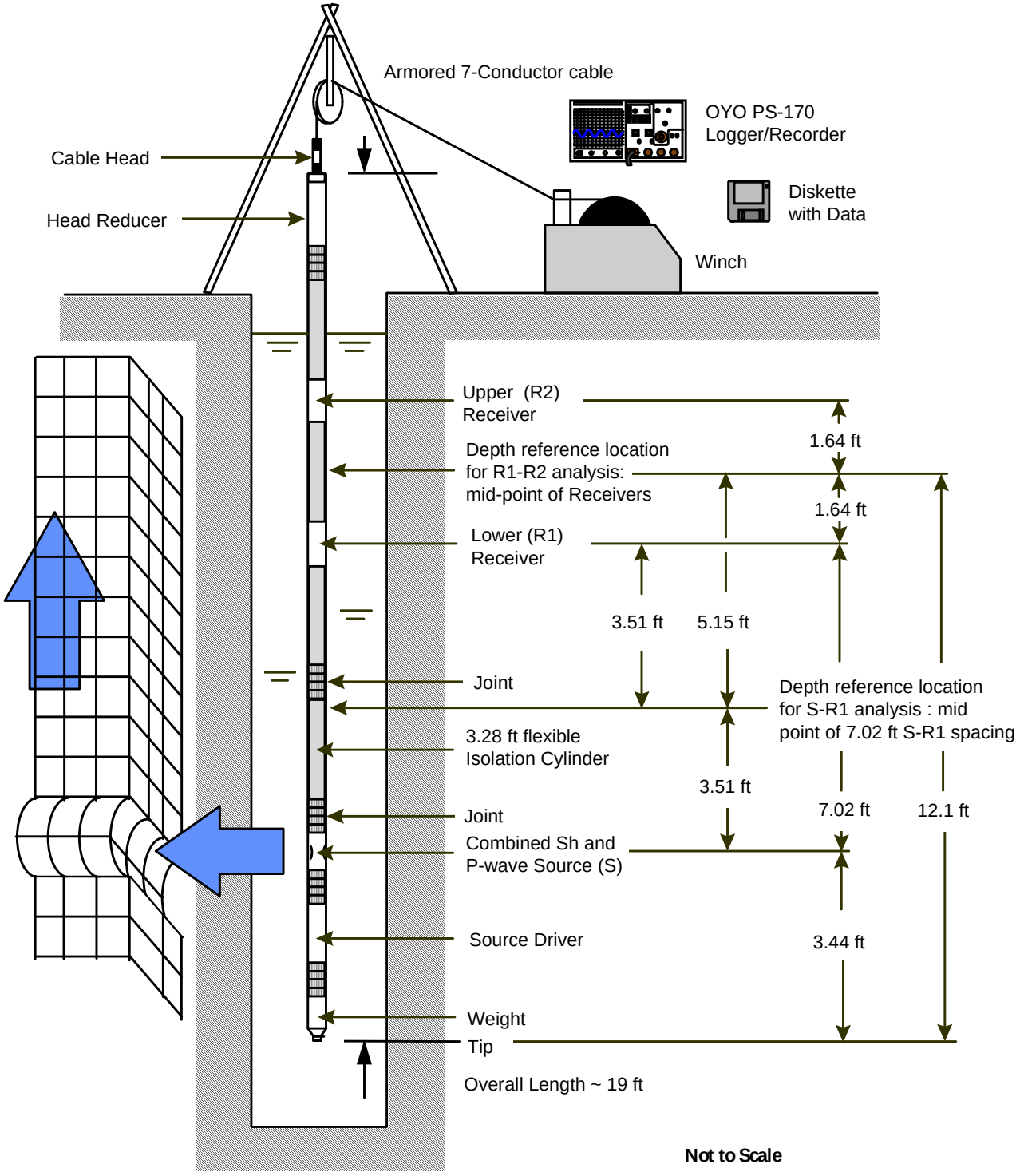


Figure 1. Concept illustration of P-S logging system

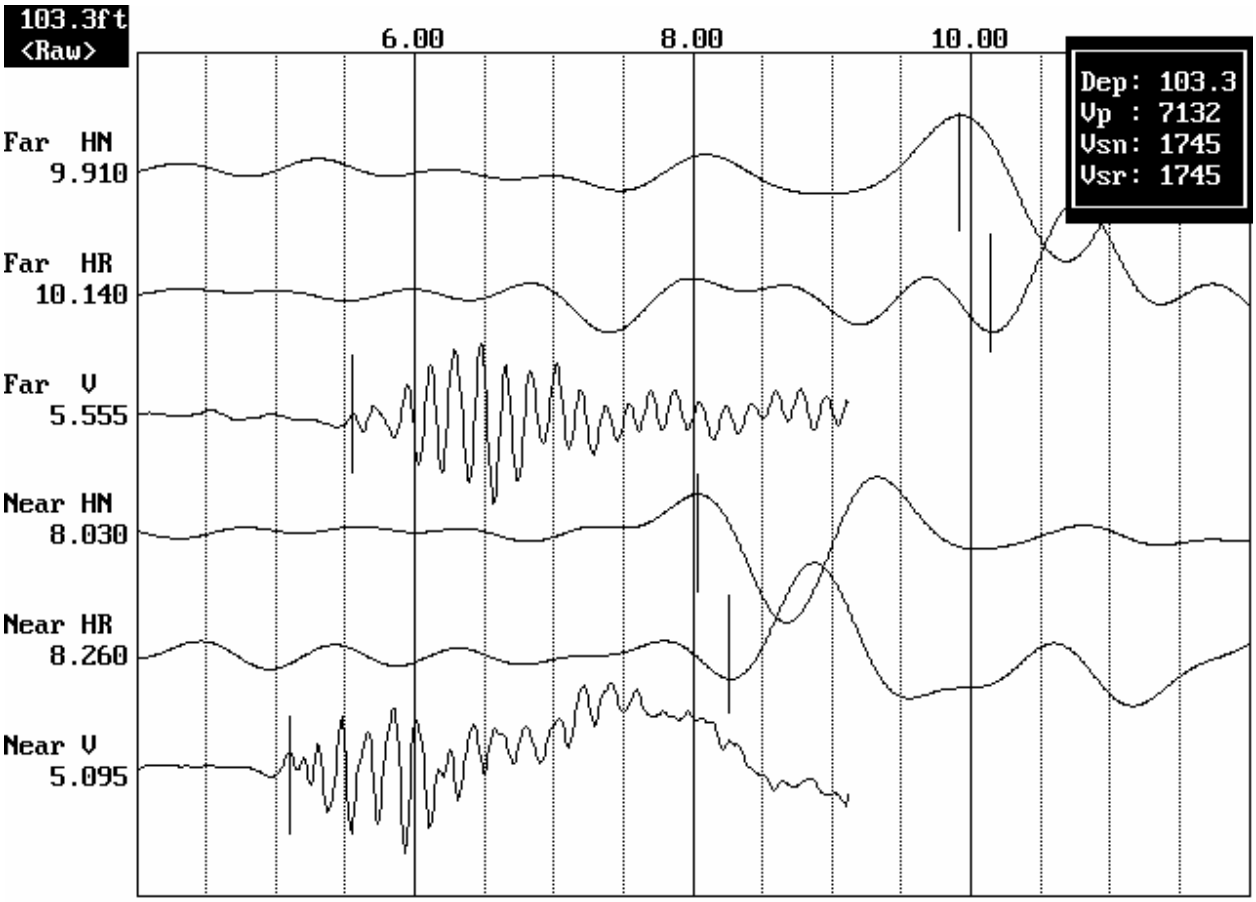


Figure 2. Example of filtered (1400 Hz lowpass) record

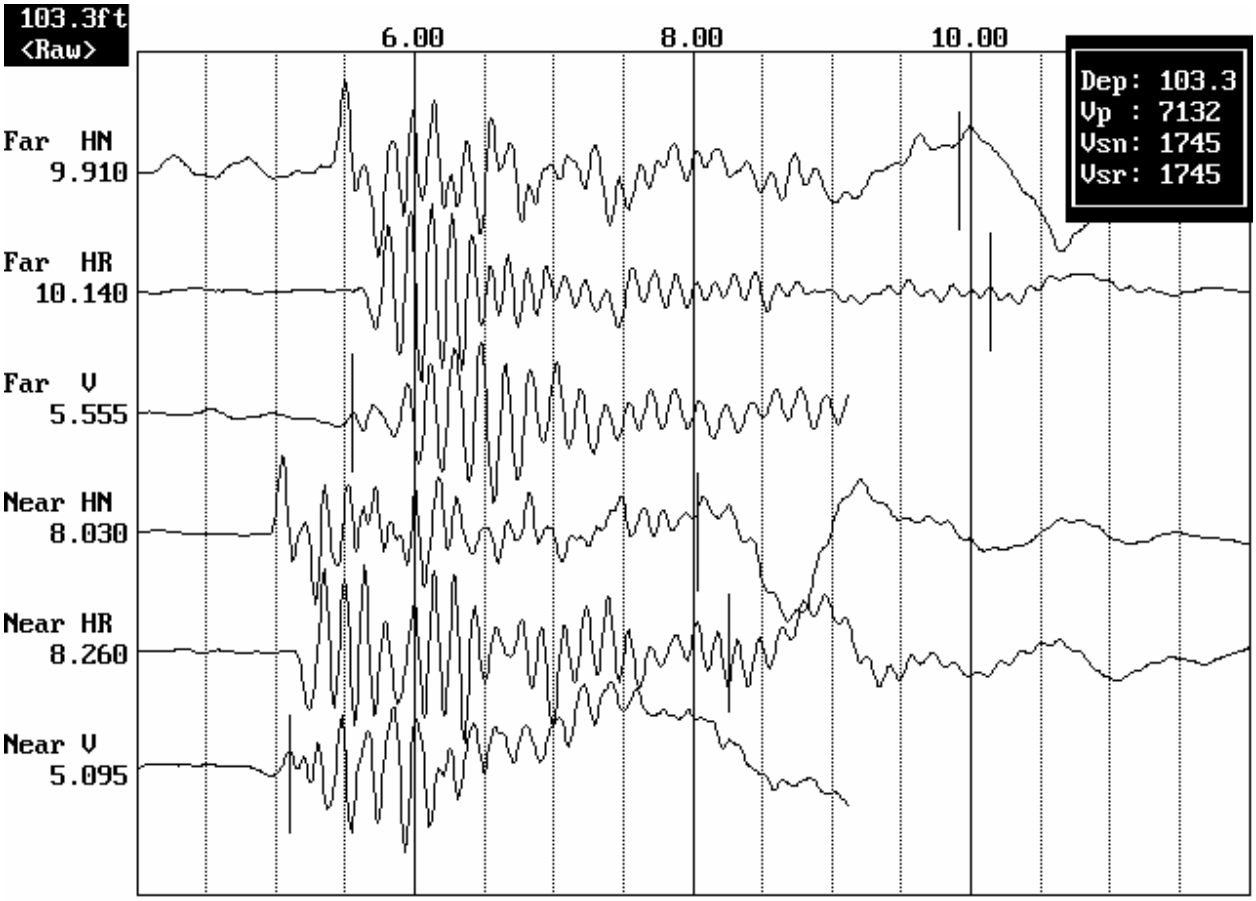


Figure 3. Example of unfiltered record

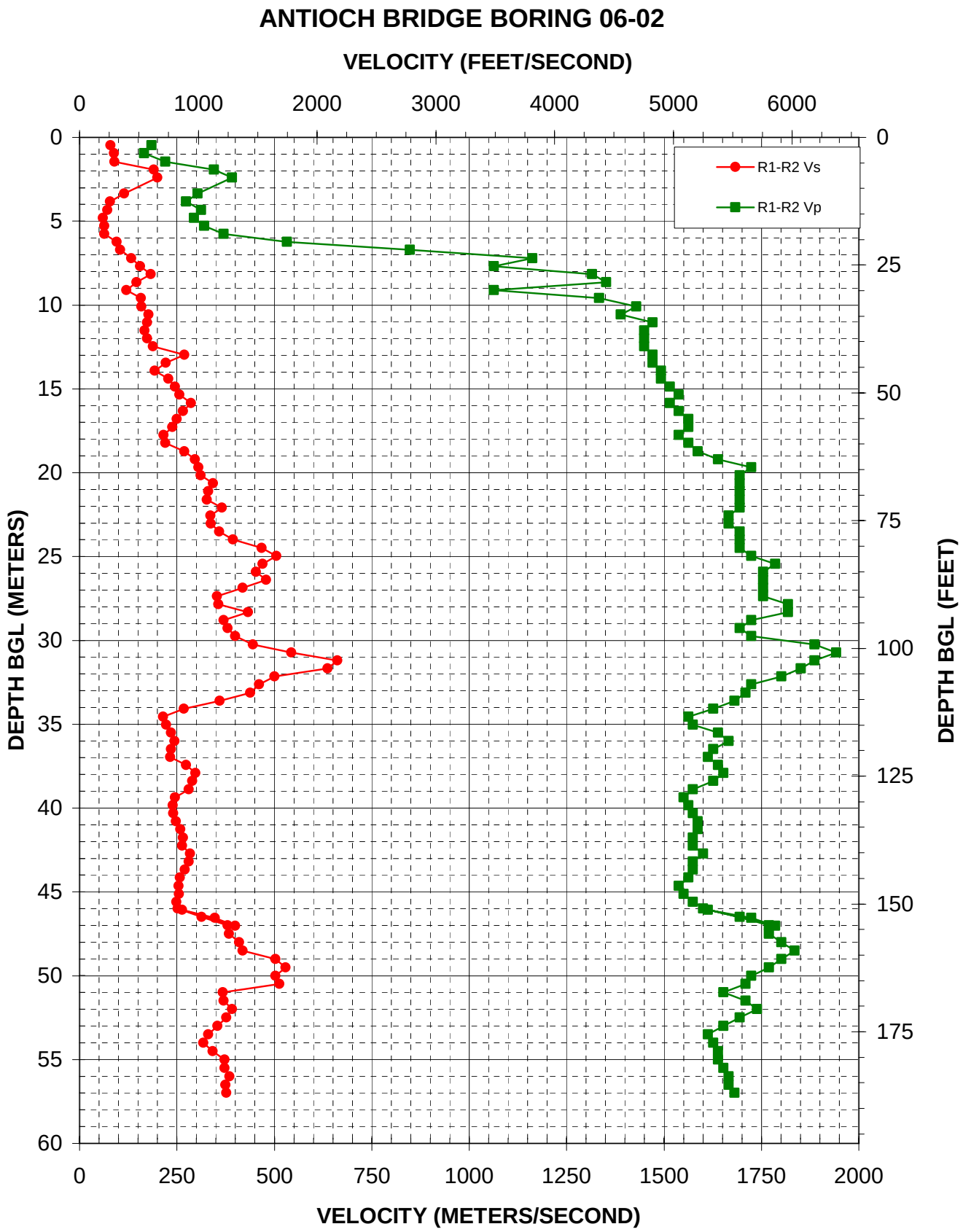


Figure 4. Boring 06-02, Suspension P- and S_H-wave velocities

Depth		Pick Times						Velocity			
(m)	(feet)	Far-Hn (millisec)	Far-Hr (millisec)	Far-V (millisec)	Near-Hn (millisec)	Near-Hr (millisec)	Near-V (millisec)	$V\text{-}S_H$ (m/sec)	V-P (m/sec)	$V\text{-}S_H$ (ft/sec)	V-P (ft/sec)
0.5	1.6	40.55	42.10	15.16	28.75	28.75	9.76	80	185	261	608
1.0	3.3	39.85	35.40	15.36	28.42	24.15	9.34	88	166	289	545
1.5	4.9	39.60	39.60	15.30	28.60	28.40	10.75	90	220	296	721
2.0	6.6	30.10	30.70	14.25	25.10	25.20	11.35	190	345	625	1131
2.5	8.2	33.20	33.50	13.55	28.20	28.50	11.00	200	392	656	1287
3.5	11.5	44.70	44.90	14.05	35.90	36.20	10.75	114	303	375	994
4.0	13.1	51.60	51.30	14.05	39.20	38.20	10.40	78	274	257	899
4.5	14.8	62.50	62.50	13.00	48.40	48.70	9.80	72	313	235	1025
5.0	16.4	59.80	61.30	12.06	43.30	44.80	8.66	61	294	199	965
5.5	18.0	50.00	53.10	10.68	34.30	37.40	7.56	64	321	209	1052
6.0	19.7	41.20	42.10	9.46	25.70	26.30	6.76	64	370	210	1215
6.5	21.3	40.40	40.60	8.44	29.20	30.80	6.56	95	532	312	1745
7.0	23.0	33.80	37.20	7.32	23.80	28.00	6.14	104	847	342	2780
7.5	24.6	30.15	29.65	6.76	22.70	22.10	5.90	133	1163	437	3815
8.0	26.2	28.05	27.85	6.78	21.70	21.30	5.84	155	1064	509	3490
8.5	27.9	26.30	26.15	6.70	20.80	20.70	5.94	183	1316	599	4317
9.0	29.5	26.05	25.70	6.68	18.65	19.40	5.94	146	1351	479	4434
9.5	31.2	26.35	26.35	6.54	18.05	17.95	5.60	120	1064	393	3490
10.0	32.8	23.65	23.65	6.56	17.45	17.15	5.81	157	1333	517	4374
10.5	34.4	22.50	22.50	6.45	16.45	15.95	5.75	159	1429	521	4687
11.0	36.1	21.70	21.20	6.45	15.85	15.75	5.73	177	1389	581	4557
11.5	37.7	20.95	20.85	6.35	15.20	15.10	5.67	174	1471	571	4825
12.0	39.4	20.60	20.60	6.35	14.65	14.55	5.66	167	1449	547	4755
12.5	41.0	19.25	19.15	6.41	13.55	13.30	5.72	173	1449	568	4755
13.0	42.7	18.80	18.65	6.32	13.45	13.40	5.63	189	1449	619	4755
13.5	44.3	17.25	17.25	6.28	13.55	13.50	5.60	268	1471	881	4825
14.0	45.9	17.18	17.00	6.20	12.64	12.50	5.52	221	1471	726	4825
14.5	47.6	17.26	17.12	6.21	12.08	11.96	5.54	193	1493	635	4897
15.0	49.2	16.62	16.44	6.17	12.22	12.06	5.50	228	1493	747	4897
15.5	50.9	16.24	16.16	6.19	12.22	12.04	5.53	246	1515	806	4971
16.0	52.5	16.60	16.40	6.19	12.70	12.52	5.54	257	1538	843	5047
16.5	54.1	17.00	16.86	6.19	13.52	13.36	5.53	287	1515	940	4971
17.0	55.8	17.14	17.02	6.17	13.34	13.28	5.52	265	1538	870	5047
17.5	57.4	17.26	17.14	6.19	13.26	13.12	5.55	249	1563	818	5126
18.0	59.1	17.08	17.02	6.14	12.86	12.86	5.50	239	1563	783	5126
18.5	60.7	16.68	16.52	6.11	12.04	11.88	5.46	216	1538	707	5047
19.0	62.3	16.06	15.92	6.09	11.48	11.40	5.45	220	1562	721	5126
19.5	64.0	15.10	14.98	6.05	11.38	11.26	5.42	269	1587	882	5208
20.0	65.6	14.46	14.30	6.03	11.08	10.92	5.42	296	1639	971	5378
20.5	67.3	14.26	14.10	6.00	10.98	10.82	5.42	305	1724	1000	5657
21.0	68.9	14.02	13.86	6.00	10.80	10.66	5.41	312	1695	1022	5561
21.5	70.5	13.70	13.56	5.99	10.78	10.64	5.40	342	1695	1124	5561
22.0	72.2	13.50	13.34	6.01	10.48	10.30	5.42	330	1695	1083	5561
22.5	73.8	13.20	13.06	6.01	10.14	10.00	5.42	327	1695	1072	5561
23.0	75.5	12.56	12.38	6.00	9.82	9.64	5.41	365	1695	1197	5561
23.5	77.1	12.32	12.14	5.98	9.36	9.14	5.38	336	1667	1101	5468
24.0	78.7	12.16	12.04	5.98	9.22	9.04	5.38	337	1667	1105	5468
24.5	80.4	11.76	11.62	5.96	8.98	8.82	5.37	358	1695	1176	5561
25.0	82.0	11.62	11.50	5.96	9.10	8.94	5.37	394	1695	1292	5561
25.5	83.7	11.56	11.42	5.95	9.42	9.28	5.36	467	1695	1533	5561

Table 3. Boring 06-02, Suspension R1-R2 depth, pick times, and velocities

Depth		Pick Times						Velocity			
(m)	(feet)	Far-Hn (millisec)	Far-Hr (millisec)	Far-V (millisec)	Near-Hn (millisec)	Near-Hr (millisec)	Near-V (millisec)	$V\text{-}S_H$ (m/sec)	V-P (m/sec)	$V\text{-}S_H$ (ft/sec)	V-P (ft/sec)
26.0	85.3	12.08	11.92	5.95	10.10	9.94	5.37	505	1724	1657	5657
26.5	86.9	11.74	11.54	5.93	9.58	9.44	5.37	469	1786	1540	5859
27.0	88.6	12.06	11.92	5.92	9.84	9.72	5.35	452	1754	1485	5756
27.5	90.2	12.20	12.06	5.91	10.06	10.02	5.34	478	1754	1570	5756
28.0	91.9	12.34	12.16	5.93	9.94	9.78	5.36	418	1754	1373	5756
28.5	93.5	12.58	12.40	5.95	9.74	9.58	5.38	353	1754	1159	5756
29.0	95.1	12.44	12.28	5.94	9.62	9.48	5.39	356	1818	1168	5965
29.5	96.8	11.42	11.24	5.91	9.08	8.96	5.36	433	1818	1420	5965
30.0	98.4	11.68	11.54	5.92	9.00	8.82	5.34	370	1724	1215	5657
30.5	100.1	11.60	11.42	5.92	8.96	8.80	5.33	380	1695	1247	5561
31.0	101.7	12.04	11.84	5.89	9.48	9.40	5.31	400	1724	1312	5657
31.5	103.3	11.38	11.30	5.89	9.16	9.02	5.36	444	1887	1458	6190
32.0	105.0	11.84	11.72	5.88	10.00	9.88	5.37	543	1942	1783	6371
32.5	106.6	11.20	11.32	5.92	9.66	9.84	5.39	662	1887	2173	6190
33.0	108.3	12.88	12.80	5.95	11.34	11.20	5.41	637	1852	2090	6076
33.5	109.9	13.42	13.34	6.01	11.44	11.32	5.46	500	1802	1640	5911
34.0	111.5	14.66	14.60	6.04	12.50	12.42	5.46	461	1724	1512	5657
34.5	113.2	15.28	15.18	6.09	13.02	12.88	5.50	439	1709	1439	5608
35.0	114.8	16.14	15.94	6.08	13.32	13.20	5.48	360	1681	1180	5514
35.5	116.5	16.52	16.48	6.08	12.80	12.74	5.47	268	1626	880	5335
36.0	118.1	17.42	17.32	6.10	12.76	12.64	5.46	214	1563	703	5126
36.5	119.8	16.78	16.64	6.10	12.26	12.18	5.47	223	1575	731	5167
37.0	121.4	16.32	16.12	6.09	12.02	11.90	5.48	235	1639	770	5378
37.5	123.0	16.00	15.88	6.09	11.90	11.78	5.49	244	1667	800	5468
38.0	124.7	15.66	15.58	6.09	11.42	11.32	5.47	235	1626	772	5335
38.5	126.3	16.10	16.02	6.10	11.82	11.72	5.48	233	1613	765	5292
39.0	128.0	15.82	15.74	6.10	12.16	12.08	5.49	273	1639	896	5378
39.5	129.6	15.76	15.62	6.10	12.40	12.26	5.50	298	1653	976	5423
40.0	131.2	15.94	15.80	6.10	12.48	12.36	5.49	290	1626	951	5335
40.5	132.9	16.14	16.00	6.11	12.58	12.44	5.48	281	1575	922	5167
41.0	134.5	16.12	15.96	6.12	12.04	11.90	5.48	246	1550	806	5087
41.5	136.2	16.16	15.92	6.11	11.94	11.78	5.47	239	1562	785	5126
42.0	137.8	15.90	15.74	6.11	11.74	11.58	5.48	240	1575	789	5167
42.5	139.4	15.48	15.32	6.24	11.44	11.28	5.61	248	1587	812	5208
43.0	141.1	15.44	15.28	6.22	11.58	11.40	5.59	258	1587	848	5208
43.5	142.7	15.48	15.38	6.13	11.74	11.58	5.49	265	1575	870	5167
44.0	144.4	15.58	15.44	6.13	11.82	11.62	5.50	264	1575	866	5167
44.5	146.0	15.66	15.52	6.14	12.12	12.00	5.51	283	1600	929	5249
45.0	147.6	15.94	15.74	6.14	12.34	12.20	5.51	280	1575	919	5167
45.5	149.3	16.02	15.86	6.16	12.30	12.18	5.52	270	1575	887	5167
46.0	150.9	15.68	15.54	6.13	11.80	11.66	5.49	258	1562	846	5126
46.5	152.6	14.98	14.88	6.11	11.08	10.92	5.46	254	1538	835	5047
47.0	154.2	14.40	14.26	6.12	10.46	10.36	5.47	255	1550	837	5087
47.5	155.8	13.70	13.56	6.04	9.68	9.54	5.40	249	1575	816	5167
48.0	157.5	12.96	12.80	6.05	9.16	9.02	5.43	264	1613	866	5292
48.5	159.1	12.06	11.94	5.99	9.20	9.04	5.41	347	1724	1139	5657
49.0	160.8	11.40	11.26	5.96	8.90	8.76	5.40	400	1786	1312	5859
46.0	150.9	13.34	13.14	5.96	9.38	9.18	5.34	253	1600	828	5249
46.5	152.6	12.52	12.32	6.02	9.32	9.14	5.43	313	1695	1028	5561

Table 3, continued. Boring 06-02, Suspension R1-R2 depth, pick times, and velocities

Depth		Pick Times						Velocity			
(m)	(feet)	Far-Hn (millisec)	Far-Hr (millisec)	Far-V (millisec)	Near-Hn (millisec)	Near-Hr (millisec)	Near-V (millisec)	$V\text{-}S_H$ (m/sec)	V-P (m/sec)	$V\text{-}S_H$ (ft/sec)	V-P (ft/sec)
47.0	154.2	11.78	11.62	5.97	9.14	9.00	5.40	380	1770	1247	5807
47.5	155.8	11.60	11.40	5.99	9.00	8.78	5.42	383	1770	1257	5807
48.0	157.5	11.48	11.18	5.99	9.02	8.76	5.43	410	1802	1345	5911
48.5	159.1	11.50	11.22	5.99	9.08	8.86	5.45	418	1835	1373	6020
49.0	160.8	11.06	10.92	5.99	9.10	8.90	5.44	503	1802	1649	5911
49.5	162.4	11.10	10.92	6.00	9.22	9.02	5.43	529	1770	1736	5807
50.0	164.0	11.48	11.30	6.01	9.48	9.32	5.43	503	1724	1649	5657
50.5	165.7	11.68	11.50	6.03	9.72	9.56	5.44	513	1709	1682	5608
51.0	167.3	12.46	12.16	6.17	9.70	9.48	5.56	368	1653	1206	5423
51.5	169.0	12.66	12.54	6.09	10.00	9.80	5.50	370	1709	1215	5608
52.0	170.6	12.86	12.68	6.06	10.32	10.12	5.49	392	1739	1287	5706
52.5	172.2	13.04	12.86	6.14	10.40	10.20	5.55	377	1695	1238	5561
53.0	173.9	13.16	12.98	6.17	10.34	10.16	5.57	355	1653	1163	5423
53.5	175.5	13.12	12.98	6.13	10.10	9.94	5.51	330	1613	1083	5292
54.0	177.2	13.10	12.98	6.11	9.96	9.82	5.50	317	1626	1042	5335
54.5	178.8	12.82	12.70	6.10	9.90	9.76	5.49	341	1639	1120	5378
55.0	180.4	12.48	12.46	6.11	9.80	9.76	5.50	372	1639	1220	5378
55.5	182.1	12.48	12.34	6.10	9.80	9.64	5.50	372	1653	1220	5423
56.0	183.7	12.36	12.22	6.09	9.76	9.62	5.49	385	1667	1262	5468
56.5	185.4	12.34	12.20	6.09	9.68	9.52	5.49	375	1667	1229	5468
57.0	187.0	12.20	12.08	6.07	9.56	9.42	5.48	377	1681	1238	5514

Table 3, continued. Boring 06-02, Suspension R1-R2 depth, pick times, and velocities

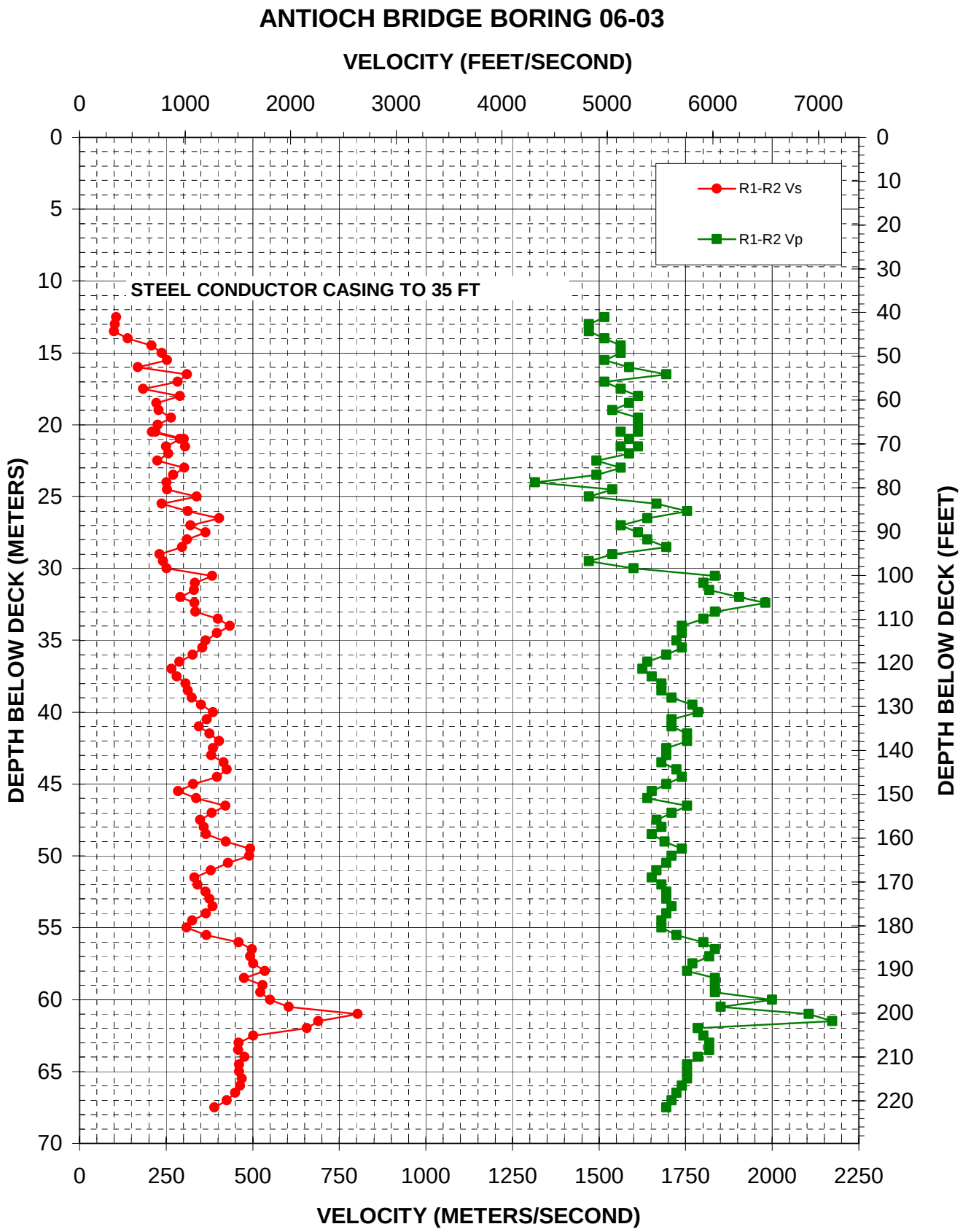


Figure 5. Boring 06-03, Suspension P- and S_H-wave velocities

Depth		Pick Times						Velocity			
(m)	(feet)	Far-Hn (millisec)	Far-Hr (millisec)	Far-V (millisec)	Near-Hn (millisec)	Near-Hr (millisec)	Near-V (millisec)	$V\text{-}S_H$ (m/sec)	V-P (m/sec)	$V\text{-}S_H$ (ft/sec)	V-P (ft/sec)
10.0	32.8										
10.5	34.4										
11.0	36.1										
11.5	37.7										
12.0	39.4										
12.5	41.0	31.40	31.40	5.06	21.90	22.00	4.40	106	1515	347	4971
13.0	42.7	29.50	29.60	5.08	19.80	19.80	4.40	103	1471	336	4825
13.5	44.3	41.70	42.00	5.10	31.80	31.90	4.42	100	1471	328	4825
14.0	45.9	34.00	34.00	5.22	26.80	26.80	4.56	139	1515	456	4971
14.5	47.6	25.00	25.30	5.14	20.20	20.50	4.50	208	1563	684	5126
15.0	49.2	23.90	23.90	5.24	19.70	19.70	4.60	238	1563	781	5126
15.5	50.9	21.75	22.05	5.37	17.70	18.20	4.71	253	1515	831	4971
16.0	52.5	24.90	23.10	5.18	17.95	18.20	4.55	169	1587	554	5208
16.5	54.1	21.55	21.90	5.33	18.55	18.45	4.74	310	1695	1017	5561
17.0	55.8	17.55	17.60	5.11	13.75	14.35	4.45	284	1515	931	4971
17.5	57.4	24.25	24.65	5.14	18.85	19.15	4.50	183	1562	602	5126
18.0	59.1	22.05	21.70	5.11	18.25	18.60	4.49	290	1613	951	5292
18.5	60.7	21.55	21.55	4.94	17.05	17.05	4.31	222	1587	729	5208
19.0	62.3	20.70	20.80	4.98	16.20	16.55	4.33	229	1538	750	5047
19.5	64.0	20.50	20.80	4.97	16.75	17.00	4.35	265	1613	869	5292
20.0	65.6	21.15	21.30	4.96	16.70	16.90	4.34	226	1613	741	5292
20.5	67.3	21.30	21.10	4.84	16.75	16.55	4.22	220	1613	721	5292
21.0	68.9	22.15	22.40	4.95	19.00	18.90	4.32	301	1587	987	5208
21.5	70.5	22.80	23.00	4.97	19.50	19.75	4.33	305	1563	1002	5126
22.0	72.2										
18.0	59.1										
18.5	60.7										
19.0	62.3										
19.5	64.0										
20.0	65.6										
20.5	67.3	21.85	21.90	4.93	16.95	17.25	4.29	209	1563	687	5126
21.0	68.9	21.05	21.20	4.96	17.60	17.75	4.33	290	1587	951	5208
21.5	70.5	22.55	22.80	5.02	18.50	18.85	4.40	250	1613	820	5292
22.0	72.2	23.10	23.20	4.97	19.20	19.30	4.34	256	1587	841	5208
22.5	73.8	24.05	23.95	4.98	19.50	19.60	4.31	225	1493	737	4897
23.0	75.5	21.60	21.75	4.95	18.30	18.45	4.31	303	1563	994	5126
23.5	77.1	16.70	16.85	4.89	13.10	13.05	4.22	270	1493	887	4897
24.0	78.7	17.05	17.20	5.00	13.15	13.15	4.24	252	1316	825	4317
24.5	80.4	17.45	17.90	4.91	13.65	13.80	4.26	253	1538	831	5047
25.0	82.0	16.85	16.85	4.94	13.85	13.95	4.26	339	1471	1112	4825
25.5	83.7	16.35	16.55	4.91	12.00	12.50	4.31	238	1667	781	5468
26.0	85.3	14.50	14.65	4.90	11.30	11.45	4.33	313	1754	1025	5756
26.5	86.9	15.05	15.20	4.94	12.55	12.75	4.33	404	1639	1326	5378
27.0	88.6	15.20	15.30	4.94	12.15	12.10	4.30	320	1563	1050	5126
27.5	90.2	15.10	14.20	4.90	11.95	11.85	4.28	364	1613	1193	5292
28.0	91.9	15.80	15.90	4.82	12.55	12.70	4.21	310	1639	1017	5378
28.5	93.5	15.90	16.00	4.89	12.50	12.65	4.30	296	1695	972	5561
29.0	95.1	15.95	16.05	4.88	11.60	11.75	4.23	231	1538	759	5047
29.5	96.8	13.60	13.75	4.86	9.45	9.60	4.18	241	1471	791	4825

Table 4. Boring 06-03, Suspension R1-R2 depth, pick times, and velocities

Depth		Pick Times						Velocity			
(m)	(feet)	Far-Hn (millisec)	Far-Hr (millisec)	Far-V (millisec)	Near-Hn (millisec)	Near-Hr (millisec)	Near-V (millisec)	$V\text{-}S_H$ (m/sec)	V-P (m/sec)	$V\text{-}S_H$ (ft/sec)	V-P (ft/sec)
30.0	98.4	13.48	13.68	4.80	9.54	9.68	4.18	252	1600	826	5249
30.5	100.1	12.98	12.98	4.78	10.32	10.42	4.24	383	1835	1257	6020
31.0	101.7	12.24	12.36	4.70	9.24	9.36	4.15	333	1802	1094	5911
31.5	103.3	11.50	11.64	4.71	8.54	8.56	4.16	331	1818	1086	5965
32.0	105.0	11.68	11.78	4.72	8.28	8.32	4.19	292	1905	957	6249
32.4	106.3	11.18	11.30	4.72	8.20	8.26	4.21	332	1980	1090	6497
33.0	108.3	10.96	11.02	4.78	7.94	8.06	4.24	334	1835	1097	6020
33.5	109.9	10.88	11.04	4.79	8.40	8.52	4.24	400	1802	1312	5911
34.0	111.5	11.26	11.40	4.81	8.98	9.08	4.23	435	1739	1426	5706
34.5	113.2	11.92	12.06	4.81	9.40	9.54	4.24	397	1739	1302	5706
35.0	114.8	12.60	12.72	4.86	9.84	9.98	4.28	364	1724	1193	5657
35.5	116.5	12.80	12.96	4.86	9.98	10.14	4.28	355	1739	1163	5706
36.0	118.1	13.02	13.12	4.85	9.94	10.08	4.26	327	1695	1072	5561
36.5	119.8	13.12	13.26	4.88	9.66	9.78	4.27	288	1639	945	5378
37.0	121.4	13.02	13.12	4.88	9.26	9.34	4.27	265	1626	870	5335
37.5	123.0	12.52	12.62	4.85	8.96	9.06	4.25	281	1653	922	5423
38.0	124.7	11.90	12.00	4.82	8.64	8.74	4.22	307	1681	1006	5514
38.5	126.3	11.74	11.84	4.82	8.54	8.64	4.22	313	1681	1025	5514
39.0	128.0	11.54	11.66	4.81	8.46	8.58	4.23	325	1709	1065	5608
39.5	129.6	11.22	11.36	4.79	8.38	8.50	4.22	351	1770	1151	5807
40.0	131.2	11.10	11.20	4.83	8.50	8.62	4.27	386	1786	1267	5859
40.5	132.9	11.14	11.32	4.77	8.46	8.56	4.19	368	1709	1206	5608
41.0	134.5	11.00	11.10	4.84	8.10	8.20	4.25	345	1709	1131	5608
41.5	136.2	10.68	10.78	4.77	8.02	8.12	4.20	376	1754	1233	5756
42.0	137.8	10.56	10.78	4.81	8.12	8.26	4.24	403	1754	1323	5756
42.5	139.4	10.66	10.76	4.79	8.06	8.18	4.20	386	1695	1267	5561
43.0	141.1	11.00	11.06	4.82	8.36	8.44	4.23	380	1695	1247	5561
43.5	142.7	11.56	11.62	4.89	9.14	9.24	4.29	417	1681	1367	5514
44.0	144.4	11.30	11.46	4.94	8.98	9.08	4.36	426	1724	1396	5657
44.5	146.0	11.32	11.46	4.82	8.80	8.94	4.24	397	1739	1302	5706
45.0	147.6	11.56	11.68	4.81	8.50	8.64	4.22	328	1695	1076	5561
45.5	149.3	11.74	11.84	4.83	8.22	8.34	4.23	285	1653	935	5423
46.0	150.9	11.44	11.60	4.88	8.46	8.64	4.27	337	1639	1105	5378
46.5	152.6	11.16	11.22	4.86	8.78	8.86	4.29	422	1754	1384	5756
47.0	154.2	10.88	10.98	4.88	8.26	8.36	4.29	382	1709	1252	5608
47.5	155.8	10.78	10.88	4.87	7.90	8.02	4.27	348	1667	1143	5468
48.0	157.5	10.36	10.48	4.84	7.56	7.70	4.25	358	1681	1176	5514
48.5	159.1	10.14	10.26	4.83	7.40	7.52	4.22	365	1653	1197	5423
49.0	160.8	10.22	10.31	4.84	7.84	7.96	4.25	423	1689	1387	5542
49.5	162.4	10.39	10.51	4.83	8.35	8.49	4.25	493	1739	1616	5706
50.0	164.0	10.66	10.77	4.85	8.63	8.72	4.27	490	1709	1608	5608
50.5	165.7	11.01	11.19	4.87	8.70	8.84	4.28	429	1695	1408	5561
51.0	167.3	11.28	11.42	4.85	8.64	8.78	4.25	379	1667	1243	5468
51.5	169.0	11.47	11.57	4.87	8.44	8.58	4.26	332	1653	1090	5423
52.0	170.6	11.56	11.72	4.84	8.63	8.78	4.25	341	1681	1118	5514
52.5	172.2	11.63	11.73	4.86	8.87	8.99	4.27	364	1695	1193	5561
53.0	173.9	11.62	11.72	4.87	8.94	9.07	4.28	375	1695	1231	5561
53.5	175.5	11.35	11.47	4.87	8.75	8.87	4.28	385	1709	1262	5608
54.0	177.2	11.21	11.31	4.82	8.48	8.56	4.23	365	1695	1197	5561
54.5	178.8	10.86	10.98	4.82	7.78	7.91	4.23	325	1681	1067	5514

Table 4, continued. Boring 06-03, Suspension R1-R2 depth, pick times, and velocities

Depth		Pick Times						Velocity			
(m)	(feet)	Far-Hn (millisec)	Far-Hr (millisec)	Far-V (millisec)	Near-Hn (millisec)	Near-Hr (millisec)	Near-V (millisec)	$V\text{-}S_H$ (m/sec)	V-P (m/sec)	$V\text{-}S_H$ (ft/sec)	V-P (ft/sec)
55.0	180.4	10.57	10.71	4.81	7.34	7.47	4.22	309	1681	1014	5514
55.5	182.1	10.01	10.13	4.75	7.29	7.40	4.17	367	1724	1204	5657
56.0	183.7	9.34	9.44	4.74	7.15	7.28	4.19	460	1802	1508	5911
56.5	185.4	9.06	9.17	4.75	7.04	7.17	4.20	498	1835	1632	6020
57.0	187.0	8.79	8.93	4.76	6.76	6.90	4.21	493	1818	1616	5965
57.5	188.6	8.57	8.66	4.75	6.57	6.67	4.18	501	1770	1645	5807
58.0	190.3	8.23	8.28	4.79	6.32	6.45	4.22	535	1754	1754	5756
58.5	191.9	8.27	8.36	4.63	6.12	6.30	4.09	475	1835	1559	6020
59.0	193.6	7.82	8.03	4.60	5.97	6.10	4.06	529	1835	1736	6020
59.5	195.2	8.04	8.18	4.60	6.13	6.26	4.05	522	1835	1713	6020
60.0	196.9	8.92	9.09	4.60	7.09	7.29	4.10	551	2000	1808	6562
60.5	198.5	8.22	8.35	4.72	6.58	6.68	4.18	604	1852	1982	6076
61.0	200.1	8.28	8.40	4.66	7.01	7.18	4.18	803	2105	2635	6907
61.5	201.8	8.65	8.78	4.65	7.19	7.34	4.19	690	2174	2263	7132
62.0	203.4	9.12	9.27	4.76	7.59	7.75	4.20	656	1786	2151	5859
62.5	205.1	9.48	9.60	4.76	7.48	7.61	4.20	501	1802	1645	5911
63.0	206.7	9.58	9.64	4.78	7.37	7.50	4.23	460	1818	1508	5965
63.5	208.3	9.51	9.68	4.76	7.34	7.49	4.21	459	1818	1505	5965
64.0	210.0	9.52	9.67	4.75	7.43	7.56	4.19	476	1786	1562	5859
64.5	211.6	9.65	9.77	4.79	7.49	7.59	4.22	461	1754	1512	5756
65.0	213.3	9.93	10.07	4.79	7.77	7.89	4.22	461	1754	1512	5756
65.5	214.9	10.12	10.24	4.80	7.98	8.11	4.23	468	1754	1537	5756
66.0	216.5	10.22	10.35	4.81	8.07	8.18	4.23	463	1739	1519	5706
66.5	218.2	10.23	10.37	4.82	8.01	8.14	4.24	449	1724	1475	5657
67.0	219.8	10.30	10.37	4.83	7.96	8.01	4.24	426	1709	1396	5608
67.5	221.5	10.14	10.24	4.80	7.57	7.67	4.21	389	1695	1277	5561

Table 4, continued. Boring 06-03, Suspension R1-R2 depth, pick times, and velocities

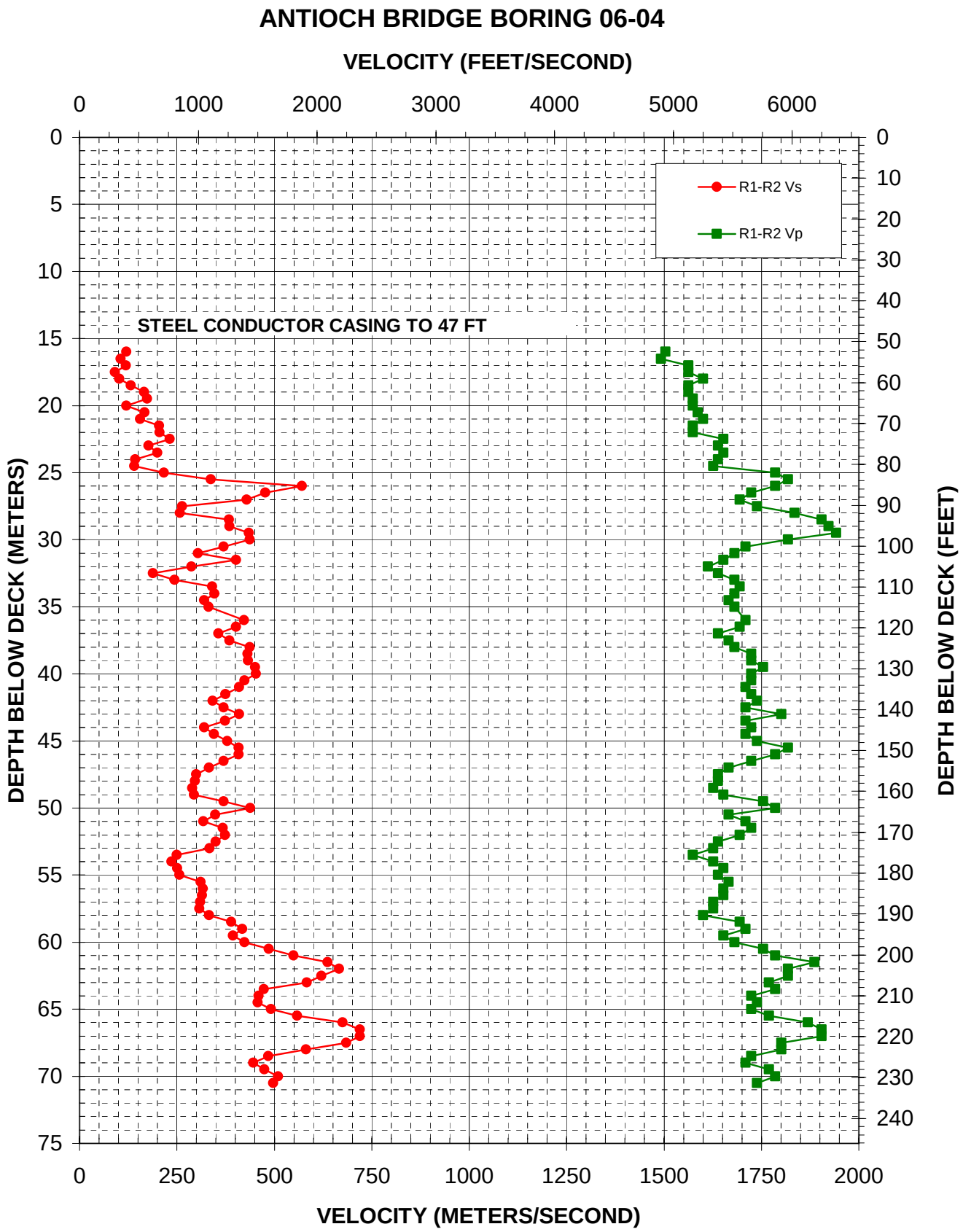


Figure 6. Boring 06-04, Suspension P- and S_H-wave velocities

Depth		Pick Times						Velocity			
(m)	(feet)	Far-Hn (millisec)	Far-Hr (millisec)	Far-V (millisec)	Near-Hn (millisec)	Near-Hr (millisec)	Near-V (millisec)	$V\text{-}S_H$ (m/sec)	V-P (m/sec)	$V\text{-}S_H$ (ft/sec)	V-P (ft/sec)
14.0	45.9										
14.5	47.6										
15.0	49.2										
15.5	50.9										
16.0	52.5	36.10		5.01	27.75		4.34	120	1504	393	4934
16.5	54.1		38.35	5.03		28.85	4.36	105	1493	345	4897
17.0	55.8	33.50		4.97	25.10		4.33	119	1563	391	5126
17.5	57.4	32.00	31.45	4.97	20.75	20.70	4.33	91	1562	298	5126
18.0	59.1	27.40	28.15	4.96	17.90	18.10	4.34	102	1600	336	5249
18.5	60.7	26.20	25.80	4.97	18.20	18.55	4.33	131	1563	430	5126
19.0	62.3	23.45	23.25	4.97	17.30	17.30	4.33	165	1562	542	5126
19.5	64.0		22.40	4.96	16.20	16.65	4.32	174	1575	571	5167
20.0	65.6	25.10	25.10	5.00	16.75	16.80	4.36	120	1575	394	5167
20.5	67.3	22.85	22.85	4.96	16.80	16.95	4.33	167	1587	549	5208
21.0	68.9	23.25	23.45	4.96	16.80	17.00	4.34	155	1600	509	5249
21.5	70.5	22.90	23.15	4.96	18.00	18.25	4.32	204	1575	670	5167
22.0	72.2	22.95	22.35	4.95	17.70	17.85	4.32	205	1575	673	5167
22.5	73.8	20.85	21.10	4.90	16.55	16.75	4.29	231	1653	759	5423
23.0	75.5	20.25	20.45	4.88	14.65	14.75	4.27	177	1639	581	5378
23.5	77.1	17.25	17.50	4.84	12.35	12.40	4.23	200	1653	656	5423
24.0	78.7	17.05	17.20	4.81	10.10	10.20	4.20	143	1639	470	5378
24.5	80.4	15.84	16.00	4.82	8.76	8.86	4.20	141	1626	461	5335
25.0	82.0	14.46	14.58	4.80	9.86	9.96	4.24	217	1786	712	5859
25.5	83.7	12.74	12.86	4.79	9.76	9.90	4.24	337	1818	1105	5965
26.0	85.3	11.88	11.88	4.77	10.10	10.16	4.21	571	1786	1875	5859
26.5	86.9	12.14	12.24	4.76	10.04	10.14	4.18	476	1724	1562	5657
27.0	88.6	12.22	12.32	4.75	9.90	9.98	4.16	429	1695	1408	5561
27.5	90.2	12.42	12.52	4.78	8.64	8.72	4.21	264	1739	866	5706
28.0	91.9	12.88	12.98	4.71	9.00	9.10	4.16	258	1835	846	6020
28.5	93.5	12.20	12.32	4.70	9.60	9.70	4.18	383	1905	1257	6249
29.0	95.1	12.58	12.72	4.75	10.00	10.10	4.23	385	1923	1262	6309
29.5	96.8	13.90	13.98	4.93	11.58	11.70	4.42	435	1942	1426	6371
30.0	98.4	14.38	14.52	4.86	12.10	12.22	4.31	437	1818	1433	5965
30.5	100.1	13.92	13.96	4.88	11.18	11.30	4.29	370	1709	1215	5608
31.0	101.7	14.02	14.04	4.86	10.70	10.78	4.26	304	1681	997	5514
31.5	103.3	13.72	13.86	4.87	11.24	11.36	4.27	402	1653	1318	5423
32.0	105.0	12.62	12.82	4.86	9.22	9.26	4.24	287	1613	943	5292
32.5	106.6	14.44	14.44	4.85	9.08	9.16	4.24	188	1639	617	5378
33.0	108.3	12.96	13.02	4.84	8.84	8.94	4.24	244	1681	800	5514
33.5	109.9	11.74	11.80	4.84	8.78	8.88	4.25	340	1695	1116	5561
34.0	111.5	11.30	11.40	4.81	8.40	8.52	4.22	346	1681	1135	5514
34.5	113.2	11.44	11.54	4.82	8.32	8.42	4.22	321	1667	1052	5468
35.0	114.8	11.28	11.38	4.83	8.26	8.36	4.23	331	1681	1086	5514
36.0	118.1	10.42	10.54	4.84	8.06	8.16	4.25	422	1709	1384	5608
36.5	119.8	10.34	10.50	4.84	7.86	8.00	4.25	402	1695	1318	5561
37.0	121.4	10.38	10.50	4.86	7.58	7.68	4.25	356	1639	1168	5378
37.5	123.0	10.16	10.24	4.82	7.56	7.64	4.22	385	1667	1262	5468
38.0	124.7	10.08	10.08	4.75	7.74	7.84	4.16	437	1681	1433	5514
38.5	126.3	10.10	10.22	4.79	7.78	7.90	4.21	431	1724	1414	5657
39.0	128.0	10.44	10.50	4.75	8.10	8.22	4.17	433	1724	1420	5657

Table 5. Boring 06-04, Suspension R1-R2 depth, pick times, and velocities

Depth		Pick Times						Velocity			
(m)	(feet)	Far-Hn (millisec)	Far-Hr (millisec)	Far-V (millisec)	Near-Hn (millisec)	Near-Hr (millisec)	Near-V (millisec)	$V\text{-}S_H$ (m/sec)	V-P (m/sec)	$V\text{-}S_H$ (ft/sec)	V-P (ft/sec)
39.5	129.6	10.66	10.80	4.79	8.46	8.56	4.22	450	1754	1478	5756
40.0	131.2	10.73	10.90	4.82	8.53	8.68	4.24	452	1724	1485	5657
40.5	132.9	11.07	11.19	4.84	8.69	8.84	4.26	423	1724	1387	5657
41.0	134.5	11.28	11.41	4.84	8.87	8.94	4.25	410	1709	1345	5608
41.5	136.2	11.63	11.75	4.83	8.95	9.09	4.25	375	1724	1229	5657
42.0	137.8	11.78	11.88	4.81	8.84	8.96	4.24	341	1739	1120	5706
42.5	139.4	11.54	11.62	4.87	8.86	8.90	4.28	370	1709	1215	5608
43.0	141.1	11.26	11.40	4.83	8.84	8.94	4.27	410	1802	1345	5911
43.5	142.7	11.30	11.32	4.81	8.58	8.68	4.23	373	1709	1224	5608
44.0	144.4	11.46	11.56	4.84	8.34	8.44	4.26	321	1724	1052	5657
44.5	146.0	11.28	11.36	4.80	8.38	8.46	4.21	345	1709	1131	5608
45.0	147.6	11.36	11.42	4.82	8.70	8.80	4.25	379	1739	1243	5706
45.5	149.3	11.62	11.76	4.82	9.18	9.30	4.27	408	1818	1339	5965
46.0	150.9	12.06	12.16	4.82	9.62	9.70	4.26	408	1786	1339	5859
46.5	152.6	12.56	12.70	4.90	9.88	9.98	4.32	370	1724	1215	5657
47.0	154.2	12.84	12.94	4.91	9.82	9.94	4.31	332	1667	1090	5468
47.5	155.8	12.58	12.64	4.92	9.26	9.28	4.31	299	1639	982	5378
48.0	157.5	12.28	12.34	4.89	8.88	8.98	4.28	296	1639	971	5378
48.5	159.1	12.24	12.36	4.93	8.78	8.90	4.31	289	1626	948	5335
49.0	160.8	12.06	12.14	4.88	8.66	8.74	4.28	294	1653	965	5423
49.5	162.4	11.64	11.72	4.84	8.94	9.02	4.27	370	1754	1215	5756
50.0	164.0	11.38	11.46	4.85	9.10	9.18	4.29	439	1786	1439	5859
50.5	165.7	11.68	11.76	4.83	8.80	8.90	4.23	348	1667	1143	5468
51.0	167.3	12.24	12.34	4.82	9.08	9.20	4.24	317	1709	1042	5608
51.5	169.0	12.96	13.02	4.90	10.22	10.32	4.32	368	1724	1206	5657
52.0	170.6	13.10	13.22	4.87	10.42	10.54	4.28	373	1695	1224	5561
52.5	172.2	14.00	14.16	4.91	11.12	11.32	4.30	350	1639	1147	5378
53.0	173.9	14.12	14.22	4.91	11.12	11.22	4.29	333	1626	1094	5335
53.5	175.5	14.32	14.42	4.93	10.30	10.42	4.29	249	1575	818	5167
54.0	177.2	14.36	14.50	4.93	10.12	10.26	4.31	236	1626	774	5335
54.5	178.8	13.56	13.68	4.90	9.56	9.70	4.30	251	1653	822	5423
55.0	180.4	13.40	13.48	4.88	9.50	9.58	4.27	256	1639	841	5378
55.5	182.1	12.70	12.80	4.87	9.48	9.58	4.27	311	1667	1019	5468
56.0	183.7	12.52	12.60	4.88	9.34	9.46	4.27	316	1653	1038	5423
56.5	185.4	12.14	12.26	4.87	8.96	9.08	4.26	314	1653	1032	5423
57.0	187.0	11.76	11.92	4.86	8.52	8.70	4.25	310	1626	1016	5335
57.5	188.6	11.64	11.70	4.87	8.36	8.48	4.26	308	1626	1009	5335
58.0	190.3	10.88	11.00	4.89	7.86	8.00	4.26	332	1600	1090	5249
58.5	191.9	10.21	10.33	4.85	7.61	7.79	4.26	389	1695	1277	5561
59.0	193.6	9.65	9.73	4.81	7.24	7.35	4.23	418	1709	1370	5608
59.5	195.2	9.16	9.22	4.79	6.60	6.70	4.19	394	1653	1292	5423
60.0	196.9	8.62	8.72	4.77	6.24	6.38	4.18	424	1681	1390	5514
60.5	198.5	8.16	8.32	4.77	6.10	6.26	4.20	485	1754	1593	5756
61.0	200.1	8.20	8.36	4.77	6.38	6.54	4.21	549	1786	1803	5859
61.5	201.8	8.36	8.52	4.70	6.80	6.94	4.17	637	1887	2090	6190
62.0	203.4	8.54	8.52	4.73	7.02	7.04	4.18	667	1818	2187	5965
62.5	205.1	9.10	9.13	4.74	7.45	7.56	4.19	621	1818	2038	5965
63.0	206.7	9.78	9.87	4.75	8.08	8.14	4.19	583	1770	1913	5807
63.5	208.3	9.77	9.85	4.75	7.65	7.74	4.19	473	1786	1551	5859
64.0	210.0	8.79	8.91	4.76	6.63	6.72	4.18	460	1724	1508	5657

Table 5, continued. Boring 06-04, Suspension R1-R2 depth, pick times, and velocities

Depth		Pick Times						Velocity			
(m)	(feet)	Far-Hn (millisec)	Far-Hr (millisec)	Far-V (millisec)	Near-Hn (millisec)	Near-Hr (millisec)	Near-V (millisec)	$V\text{-}S_H$ (m/sec)	V-P (m/sec)	$V\text{-}S_H$ (ft/sec)	V-P (ft/sec)
64.5	211.6	8.56	8.68	4.80	6.36	6.51	4.23	458	1739	1502	5706
65.0	213.3	8.23	8.32	4.74	6.18	6.30	4.16	491	1724	1612	5657
65.5	214.9	7.96	8.07	4.74	6.18	6.27	4.17	559	1770	1833	5807
66.0	216.5	7.92	8.06	4.67	6.44	6.58	4.13	676	1869	2217	6132
66.5	218.2	8.20	8.33	4.71	6.81	6.94	4.19	719	1905	2360	6249
67.0	219.8	8.63	8.76	4.74	7.24	7.37	4.21	719	1905	2360	6249
67.5	221.5	8.85	8.99	4.74	7.39	7.53	4.19	685	1802	2247	5911
68.0	223.1	9.18	9.29	4.74	7.46	7.57	4.19	581	1802	1907	5911
68.5	224.7	9.43	9.53	4.80	7.35	7.48	4.22	484	1724	1589	5657
69.0	226.4	9.76	9.87	4.83	7.52	7.63	4.24	446	1709	1465	5608
69.5	228.0	9.82	9.92	4.81	7.70	7.82	4.24	474	1770	1555	5807
70.0	229.7	9.75	9.81	4.81	7.79	7.85	4.25	510	1786	1674	5859
70.5	231.3	9.81	9.90	4.81	7.79	7.90	4.24	498	1739	1632	5706

Table 5, continued. Boring 06-04, Suspension R1-R2 depth, pick times, and velocities

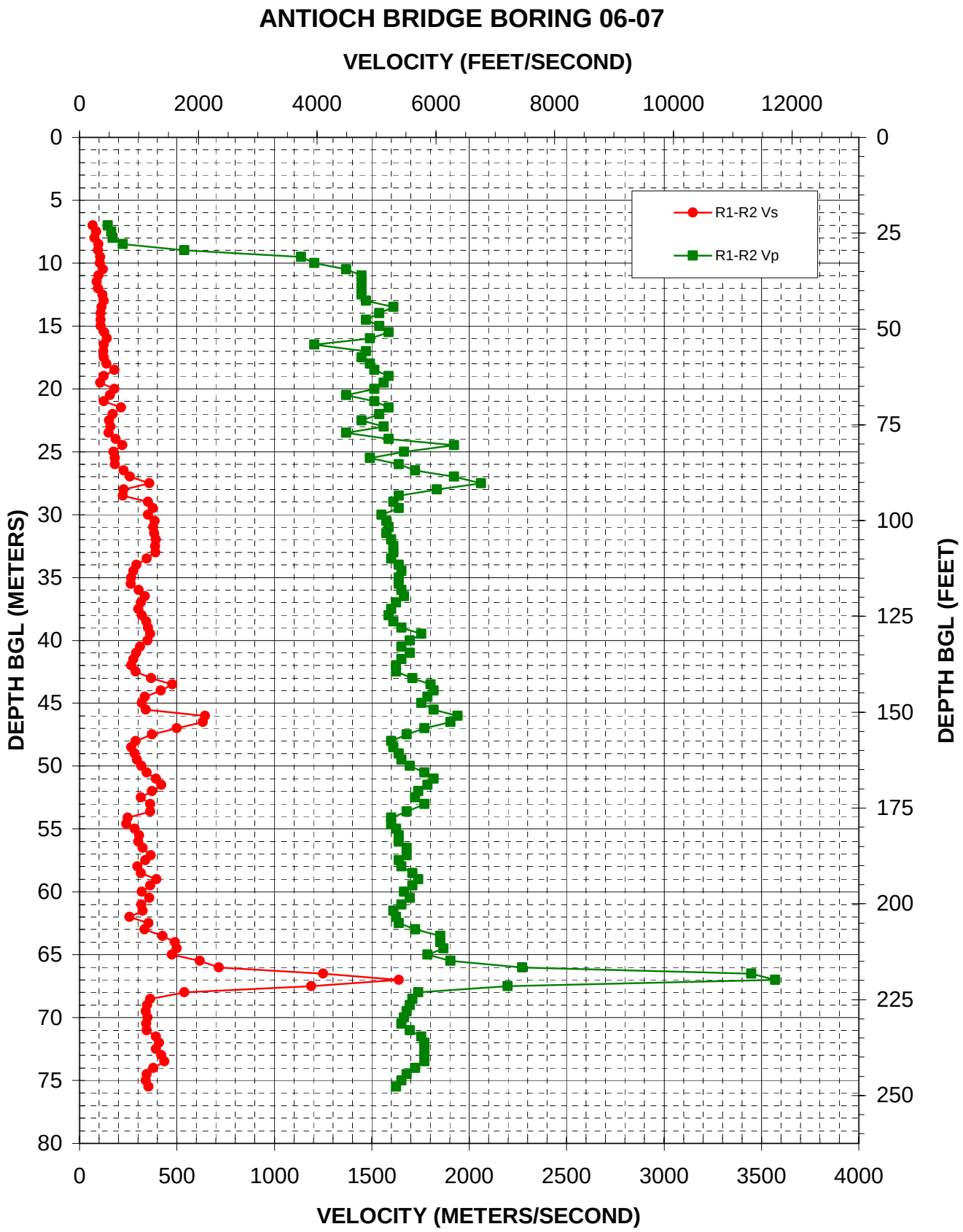


Figure 7. Boring 06-07, Suspension P- and S_H-wave velocities

Depth		Pick Times						Velocity			
(m)	(feet)	Far-Hn (millisec)	Far-Hr (millisec)	Far-V (millisec)	Near-Hn (millisec)	Near-Hr (millisec)	Near-V (millisec)	$V\text{-}S_H$ (m/sec)	V-P (m/sec)	$V\text{-}S_H$ (ft/sec)	V-P (ft/sec)
7.0	23.0	67.10	67.40	18.90	51.90	52.80	12.00	67	145	220	475
7.5	24.6	60.20	60.20	16.00	48.40	48.60	9.40	85	163	280	533
8.0	26.2	55.40	54.70	13.10	41.80	42.30	7.20	77	169	252	556
8.5	27.9	46.30	46.30	10.63	35.90	36.10	6.15	97	223	319	732
9.0	29.5	43.20	44.50	7.82	32.60	34.00	5.96	95	538	311	1764
9.5	31.2	41.10	41.80	6.83	31.50	32.50	5.95	106	1136	347	3728
10.0	32.8	34.90	34.90	6.45	25.30	25.30	5.62	104	1205	342	3953
10.5	34.4	34.20	33.90	6.35	25.50	25.90	5.62	120	1370	393	4494
11.0	36.1	35.20	34.50	6.34	24.60	24.70	5.65	98	1449	322	4755
11.5	37.7	35.50	35.55	6.29	24.35	24.15	5.60	89	1449	291	4755
12.0	39.4	33.15	33.50	6.24	22.75	23.10	5.55	96	1449	315	4755
12.5	41.0	30.80	31.00	6.21	22.30	22.60	5.52	118	1449	388	4755
13.0	42.7	30.85	31.25	6.25	22.85	23.30	5.57	125	1471	411	4825
13.5	44.3	30.35	31.40	6.38	21.45	22.65	5.76	113	1613	372	5292
14.0	45.9	34.60	34.95	6.30	25.70	25.60	5.65	110	1538	360	5047
14.5	47.6	32.40	32.30	6.28	23.30	23.05	5.60	109	1471	358	4825
15.0	49.2	31.65	31.85	6.24	22.75	22.40	5.59	109	1538	358	5047
15.5	50.9	31.45	31.70	6.26	23.85	23.50	5.63	127	1587	415	5208
16.0	52.5	30.40	30.40	6.18	23.15	23.35	5.51	140	1493	459	4897
16.5	54.1	30.45	30.40	6.25	22.35	22.50	5.42	125	1205	410	3953
17.0	55.8	31.10	31.40	6.12	23.05	23.10	5.44	122	1471	401	4825
17.5	57.4	30.20	30.30	6.18	22.40	22.20	5.49	126	1449	413	4755
18.0	59.1	30.55	30.60	6.14	23.35	23.40	5.47	139	1493	456	4897
18.5	60.7	34.10	31.90	6.07	28.55	26.35	5.41	180	1515	591	4971
19.0	62.3	34.55	34.95	6.04	26.25	27.35	5.41	126	1587	413	5208
19.5	64.0	36.30	36.35	6.19	26.65	27.20	5.55	106	1563	349	5126
20.0	65.6	32.35	32.25	6.08	26.65	26.80	5.42	179	1515	588	4971
20.5	67.3	32.45	32.40	6.24	25.95	26.15	5.51	157	1370	515	4494
21.0	68.9	34.25	34.25	6.23	26.25	26.35	5.57	126	1515	413	4971
21.5	70.5	32.35	33.55	6.13	28.50	28.00	5.50	213	1587	698	5208
22.0	72.2	27.45	27.50	6.21	21.60	21.65	5.56	171	1538	561	5047
22.5	73.8	26.90	27.00	6.02	20.35	20.40	5.33	152	1449	499	4755
23.0	75.5	25.15	25.05	5.93	18.75	18.95	5.29	160	1563	525	5126
23.5	77.1	26.45	26.65	6.07	19.75	20.00	5.34	150	1370	492	4494
24.0	78.7	21.90	21.80	5.97	16.45	16.55	5.34	187	1587	613	5208
24.5	80.4	19.90	19.95	5.68	15.40	15.40	5.16	221	1923	725	6309
25.0	82.0	19.50	19.65	5.87	13.80	13.85	5.27	174	1667	571	5468
25.5	83.7	18.85	18.90	5.95	13.35	13.40	5.28	182	1493	597	4897
26.0	85.3	17.60	17.45	5.85	12.00	12.10	5.24	183	1639	599	5378
26.5	86.9	16.40	16.40	5.74	12.00	12.00	5.16	227	1724	746	5657
27.0	88.6	15.20	15.25	5.73	11.30	11.40	5.21	258	1923	847	6309
27.5	90.2	14.20	14.26	5.74	11.42	11.48	5.26	360	2062	1180	6765
28.0	91.9	13.86	13.90	5.80	9.44	9.54	5.26	228	1835	747	6020
28.5	93.5	13.98	14.02	5.88	9.44	9.56	5.27	222	1639	729	5378
29.0	95.1	12.36	12.44	5.91	9.52	9.60	5.29	352	1613	1155	5292
29.5	96.8	11.96	12.04	5.90	9.30	9.38	5.29	376	1639	1233	5378
30.0	98.4	12.18	12.26	5.92	9.34	9.40	5.28	351	1550	1151	5087
30.5	100.1	11.94	12.00	5.91	9.34	9.42	5.28	386	1575	1267	5167
31.0	101.7	11.96	12.02	5.77	9.32	9.40	5.14	380	1587	1247	5208
31.5	103.3	12.66	12.62	5.90	10.04	10.02	5.27	383	1575	1257	5167

Table 6. Boring 06-07, Suspension R1-R2 depth, pick times, and velocities

Depth		Pick Times						Velocity			
(m)	(feet)	Far-Hn (millisec)	Far-Hr (millisec)	Far-V (millisec)	Near-Hn (millisec)	Near-Hr (millisec)	Near-V (millisec)	$V\text{-}S_H$ (m/sec)	V-P (m/sec)	$V\text{-}S_H$ (ft/sec)	V-P (ft/sec)
32.0	105.0	12.88	12.98	5.90	10.34	10.42	5.28	392	1600	1287	5249
32.5	106.6	13.62	13.64	5.89	11.04	11.08	5.27	389	1613	1277	5292
33.0	108.3	14.04	14.08	5.90	11.48	11.52	5.28	391	1613	1282	5292
33.5	109.9	14.28	14.36	5.88	11.40	11.44	5.26	345	1600	1131	5249
34.0	111.5	14.52	14.56	5.88	11.10	11.16	5.27	293	1639	962	5378
34.5	113.2	14.50	14.60	5.88	10.92	10.98	5.28	278	1653	911	5423
35.0	114.8	14.32	14.44	5.87	10.56	10.66	5.26	265	1639	870	5378
35.5	116.5	14.14	14.22	5.88	10.32	10.44	5.27	263	1639	863	5378
36.0	118.1	13.62	13.74	5.89	10.32	10.46	5.28	304	1653	997	5423
36.5	119.8	13.28	13.34	5.88	10.28	10.40	5.28	337	1667	1105	5468
37.0	121.4	13.28	13.36	5.88	10.08	10.20	5.27	314	1626	1032	5335
37.5	123.0	13.28	13.32	5.87	9.96	10.00	5.25	301	1600	988	5249
38.0	124.7	13.54	13.62	5.86	10.44	10.48	5.23	321	1587	1052	5208
38.5	126.3	13.70	13.80	5.85	10.78	10.88	5.23	342	1613	1124	5292
39.0	128.0	13.74	13.82	5.84	10.92	10.96	5.23	352	1653	1155	5423
39.5	129.6	14.06	14.14	5.82	11.32	11.38	5.25	364	1754	1193	5756
40.0	131.2	14.48	14.54	5.84	11.60	11.70	5.25	350	1695	1147	5561
40.5	132.9	14.22	14.30	5.86	11.00	11.08	5.25	311	1653	1019	5423
41.0	134.5	13.76	13.82	5.84	10.30	10.38	5.25	290	1695	951	5561
41.5	136.2	13.16	13.22	5.81	9.54	9.62	5.21	277	1653	909	5423
42.0	137.8	13.02	13.12	5.81	9.22	9.36	5.19	265	1626	868	5335
42.5	139.4	12.66	12.72	5.77	9.22	9.24	5.16	289	1626	948	5335
43.0	141.1	12.40	12.56	5.76	9.72	9.80	5.17	368	1709	1206	5608
43.5	142.7	11.84	11.92	5.72	9.66	9.90	5.16	476	1802	1562	5911
44.0	144.4	12.02	12.08	5.81	9.54	9.76	5.26	417	1818	1367	5965
44.5	146.0	12.14	12.06	5.72	9.08	9.18	5.16	337	1786	1105	5859
45.0	147.6	11.20	11.40	5.68	8.14	8.20	5.11	319	1754	1048	5756
45.5	149.3	10.72	10.88	5.73	7.80	7.94	5.18	341	1818	1120	5965
46.0	150.9	11.72	11.76	5.75	10.18	10.20	5.23	645	1942	2117	6371
46.5	152.6	12.36	12.52	5.78	10.80	10.92	5.25	633	1905	2076	6249
47.0	154.2	13.32	13.46	5.82	11.34	11.44	5.26	500	1770	1640	5807
47.5	155.8	13.88	14.00	5.85	11.20	11.30	5.26	372	1681	1220	5514
48.0	157.5	14.24	14.34	5.86	10.76	10.88	5.23	288	1600	945	5249
48.5	159.1	13.92	14.02	5.76	10.16	10.26	5.14	266	1613	873	5292
49.0	160.8	13.22	13.36	5.78	9.68	9.86	5.17	284	1639	932	5378
49.5	162.4	12.78	12.86	5.76	9.38	9.48	5.16	295	1653	968	5423
50.0	164.0	12.84	12.96	5.76	9.70	9.82	5.17	318	1695	1045	5561
50.5	165.7	12.48	12.56	5.74	9.56	9.70	5.18	346	1770	1135	5807
51.0	167.3	12.48	12.60	5.73	9.94	10.04	5.18	392	1818	1287	5965
51.5	169.0	12.88	12.98	5.75	10.48	10.62	5.19	420	1786	1379	5859
52.0	170.6	13.92	14.08	5.79	11.30	11.32	5.21	372	1739	1220	5706
52.5	172.2	14.38	14.44	5.80	11.18	11.28	5.22	314	1724	1032	5657
53.0	173.9	14.48	14.54	5.82	11.70	11.82	5.25	364	1770	1193	5807
53.6	175.9	14.42	14.60	5.84	11.70	11.82	5.24	364	1681	1193	5514
54.1	177.5	14.74	14.80	5.86	10.70	10.78	5.23	248	1600	814	5249
54.6	179.1	14.44	14.54	5.85	10.28	10.36	5.23	240	1600	787	5249
55.0	180.4	13.82	13.90	5.83	10.28	10.38	5.22	283	1626	929	5335
55.5	182.1	13.68	13.78	5.84	10.42	10.52	5.23	307	1639	1006	5378
56.0	183.7	13.54	13.64	5.84	10.24	10.34	5.23	303	1639	994	5378
56.5	185.4	13.14	13.28	5.81	10.06	10.20	5.21	325	1681	1065	5514

Table 6, continued. Boring 06-07, Suspension R1-R2 depth, pick times, and velocities

Depth		Pick Times						Velocity			
(m)	(feet)	Far-Hn (millisec)	Far-Hr (millisec)	Far-V (millisec)	Near-Hn (millisec)	Near-Hr (millisec)	Near-V (millisec)	$V\text{-}S_H$ (m/sec)	V-P (m/sec)	$V\text{-}S_H$ (ft/sec)	V-P (ft/sec)
57.1	187.3	12.94	13.02	5.80	10.18	10.30	5.20	365	1681	1197	5514
57.5	188.6	13.18	13.26	5.81	10.22	10.30	5.20	338	1639	1108	5378
58.0	190.3	13.30	13.38	5.82	9.94	10.04	5.21	299	1653	979	5423
58.5	191.9	13.24	13.32	5.80	10.04	10.16	5.22	314	1709	1032	5608
59.0	193.6	13.50	13.46	5.84	10.90	11.00	5.26	395	1739	1297	5706
59.5	195.2	12.98	13.12	5.84	10.24	10.36	5.25	364	1709	1193	5608
60.0	196.9	13.38	13.52	5.85	10.26	10.40	5.25	321	1667	1052	5468
60.5	198.5	13.36	13.46	5.84	10.56	10.68	5.25	358	1695	1176	5561
61.0	200.1	12.72	12.84	5.80	9.54	9.74	5.20	318	1653	1045	5423
61.5	201.8	12.52	12.84	5.79	9.46	9.76	5.17	326	1613	1069	5292
62.0	203.4	13.06	13.20	5.74	9.18	9.28	5.13	256	1626	841	5335
62.5	205.1	11.88	12.04	5.71	9.04	9.24	5.10	355	1639	1163	5378
63.0	206.7	11.28	11.44	5.69	8.30	8.42	5.11	333	1724	1094	5657
63.5	208.3	9.84	10.02	5.59	7.50	7.68	5.05	427	1852	1402	6076
64.0	210.0	9.24	9.26	5.52	7.16	7.26	4.98	490	1852	1608	6076
64.5	211.6	8.46	8.48	5.47	6.42	6.52	4.93	500	1869	1640	6132
65.0	213.3	8.06	8.24	5.51	5.96	6.12	4.95	474	1786	1555	5859
65.5	214.9	9.44	9.42	5.42	7.84	7.78	4.90	617	1905	2025	6249
66.0	216.5	8.46	8.70	5.41	7.12	7.24	4.97	714	2273	2343	7456
66.5	218.2	8.78	8.92	5.33	7.98	8.12	5.04	1250	3448	4101	11313
67.0	219.8	9.70	9.58	5.43	9.10	8.96	5.15	1639	3571	5378	11717
67.5	221.5	10.76	10.84	5.86	9.90	10.02	5.40	1190	2198	3906	7211
68.0	223.1	11.84	11.96	5.79	9.98	10.10	5.22	538	1739	1764	5706
68.5	224.7	12.82	12.88	5.80	10.02	10.16	5.22	362	1709	1189	5608
69.0	226.4	12.74	12.82	5.79	9.82	9.98	5.20	347	1695	1139	5561
69.5	228.0	12.60	12.70	5.80	9.62	9.82	5.20	341	1681	1120	5514
70.0	229.7	12.52	12.62	5.78	9.60	9.82	5.18	350	1667	1147	5468
70.5	231.3	12.34	12.42	5.77	9.36	9.56	5.17	342	1653	1124	5423
71.0	232.9	12.04	12.10	5.75	9.14	9.22	5.16	346	1695	1135	5561
71.5	234.6	11.88	12.00	5.74	9.28	9.50	5.17	392	1754	1287	5756
72.0	236.2	11.90	11.96	5.73	9.42	9.54	5.17	408	1770	1339	5807
72.5	237.9	12.02	12.10	5.75	9.46	9.58	5.19	394	1770	1292	5807
73.0	239.5	12.16	12.26	5.76	9.76	9.90	5.19	420	1770	1379	5807
73.5	241.1	12.26	12.38	5.78	9.98	10.06	5.22	435	1770	1426	5807
74.0	242.8	12.54	12.62	5.80	9.92	9.96	5.22	379	1724	1243	5657
74.5	244.4	12.74	12.82	5.81	9.84	9.94	5.21	346	1681	1135	5514
75.0	246.1	12.62	12.80	5.82	9.70	9.86	5.21	341	1653	1120	5423
75.5	247.7	12.56	12.66	5.84	9.72	9.86	5.22	355	1626	1163	5335

Table 6, continued. Boring 06-07, Suspension R1-R2 depth, pick times, and velocities

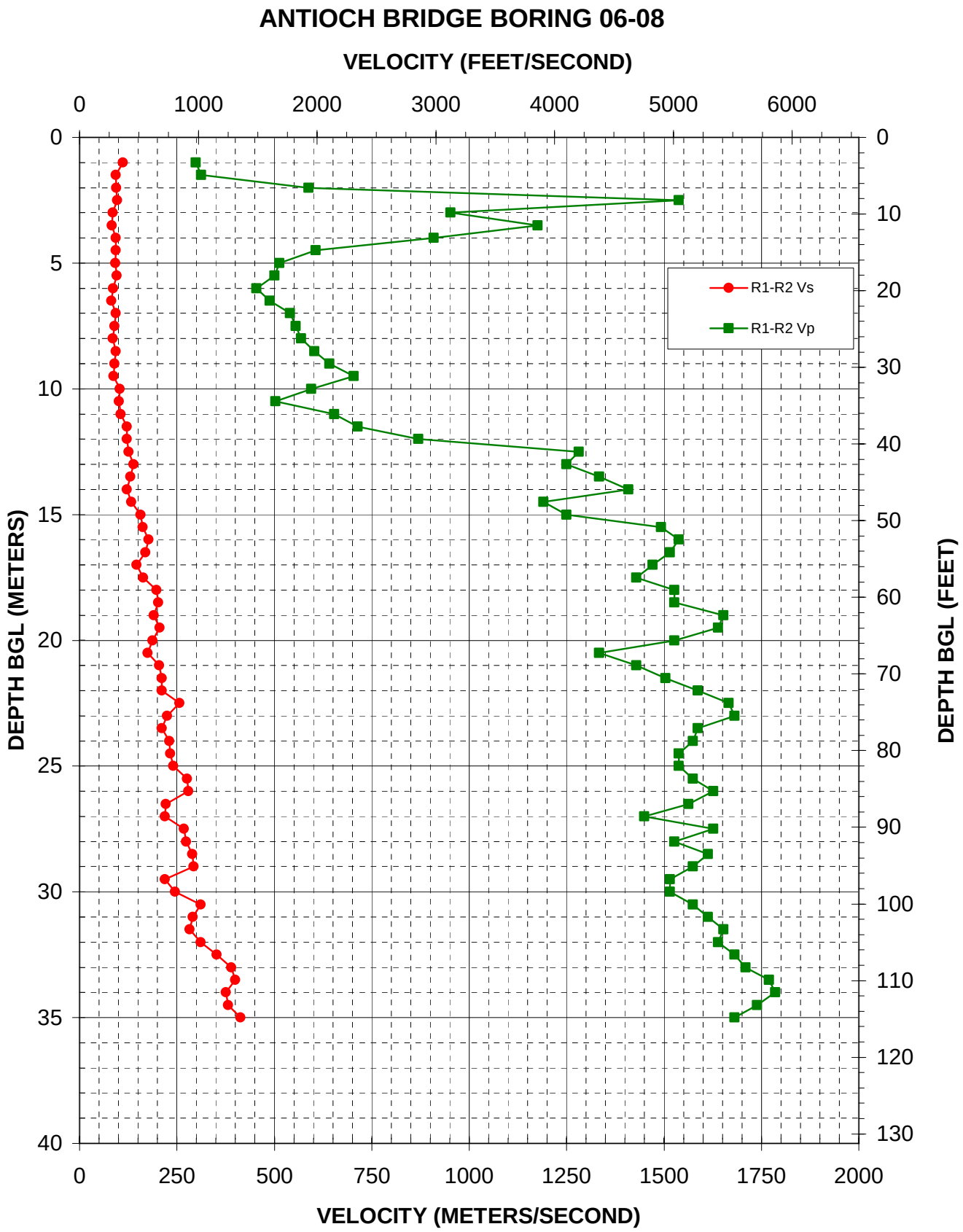


Figure 8. Boring 06-08, Suspension P- and S_H-wave velocities

Depth		Pick Times						Velocity			
(m)	(feet)	Far-Hn (millisec)	Far-Hr (millisec)	Far-V (millisec)	Near-Hn (millisec)	Near-Hr (millisec)	Near-V (millisec)	$V\text{-}S_H$ (m/sec)	V-P (m/sec)	$V\text{-}S_H$ (ft/sec)	V-P (ft/sec)
1.0	3.3	37.40	37.20	10.35	28.60	28.00	7.00	111	299	365	979
1.5	4.9	38.20	38.20	9.30	27.40	27.40	6.10	93	313	304	1025
2.0	6.6	39.20	39.10	8.40	28.50	28.60	6.70	94	588	310	1930
2.5	8.2	39.30	38.90	8.80	28.80	28.70	8.15	97	1538	317	5047
3.0	9.8	39.30	39.40	8.85	27.60	27.60	7.80	85	952	279	3125
3.5	11.5	40.40	40.60	9.65	28.40	28.50	8.80	83	1176	272	3860
4.0	13.1	39.30	39.00	10.05	28.30	28.40	8.95	93	909	304	2983
4.5	14.8	38.50	38.60	10.45	27.80	27.70	8.80	93	606	304	1988
5.0	16.4	38.60	39.00	10.65	27.90	27.90	8.70	92	513	301	1682
5.5	18.0	39.20	39.00	10.50	28.90	28.30	8.50	95	500	312	1640
6.0	19.7	39.00	38.70	10.45	27.30	27.10	8.25	86	455	282	1491
6.5	21.3	39.30	39.00	10.10	26.90	26.80	8.05	81	488	267	1600
7.0	23.0	38.50	38.10	9.70	27.80	27.40	7.85	93	541	307	1773
7.5	24.6	37.80	37.50	9.25	26.60	26.30	7.45	89	556	293	1823
8.0	26.2	36.70	36.60	9.28	25.00	24.95	7.52	86	568	281	1864
8.5	27.9	36.70	36.50	9.46	25.85	25.80	7.80	93	602	304	1976
9.0	29.5	34.90	34.85	9.20	23.70	23.80	7.64	90	641	295	2103
9.5	31.2	34.20	34.00	9.20	22.70	22.60	7.78	87	704	287	2310
10.0	32.8	32.70	32.70	8.82	23.05	23.00	7.14	103	595	339	1953
10.5	34.4	31.30	31.05	8.65	21.40	21.25	6.66	102	503	333	1649
11.0	36.1	30.95	30.85	8.18	21.45	21.35	6.65	105	654	345	2144
11.5	37.7	30.15	29.90	7.52	21.95	21.70	6.12	122	714	400	2343
12.0	39.4	28.75	28.65	7.22	20.60	20.40	6.07	122	870	400	2853
12.5	41.0	27.70	27.55	6.93	19.80	19.60	6.15	126	1282	414	4206
13.0	42.7	26.90	26.75	6.84	19.70	19.45	6.04	138	1250	453	4101
13.5	44.3	26.15	25.90	6.81	18.45	18.30	6.06	131	1333	429	4374
14.0	45.9	25.70	25.45	6.74	17.45	17.25	6.03	122	1408	399	4621
14.5	47.6	25.50	25.30	6.74	17.95	17.85	5.90	133	1190	437	3906
15.0	49.2	23.75	23.65	6.64	17.35	17.25	5.84	156	1250	513	4101
15.5	50.9	22.85	22.80	6.53	16.70	16.65	5.86	163	1493	533	4897
16.0	52.5	22.75	22.60	6.54	17.10	16.95	5.89	177	1538	581	5047
16.5	54.1	22.15	22.00	6.54	16.20	16.10	5.88	169	1515	554	4971
17.0	55.8	22.10	22.00	6.54	15.20	15.20	5.86	146	1471	479	4825
17.5	57.4	21.55	21.45	6.59	15.35	15.40	5.89	163	1429	536	4687
18.0	59.1	20.45	20.40	6.54	15.40	15.35	5.89	198	1527	650	5009
18.5	60.7	20.30	20.15	6.53	15.35	15.20	5.87	202	1527	663	5009
19.0	62.3	20.40	20.30	6.50	15.20	15.00	5.89	190	1653	625	5423
19.5	64.0	20.05	20.00	6.45	15.20	15.10	5.84	205	1639	673	5378
20.0	65.6	19.55	19.50	6.46	14.20	14.15	5.81	187	1527	613	5009
20.5	67.3	19.75	19.65	6.52	14.00	13.95	5.77	175	1333	573	4374
21.0	68.9	19.30	19.30	6.51	14.45	14.35	5.81	204	1429	670	4687
21.5	70.5	18.40	18.40	6.43	13.70	13.65	5.76	212	1504	694	4934
22.0	72.2	18.30	18.35	6.36	13.60	13.60	5.73	212	1587	694	5208
22.5	73.8	17.80	17.85	6.25	13.95	13.90	5.65	256	1667	841	5468
23.0	75.5	17.40	17.40	6.27	13.00	12.90	5.68	225	1681	737	5514
23.5	77.1	17.70	17.60	6.29	13.00	12.85	5.66	212	1587	694	5208
24.0	78.7	17.85	17.75	6.34	13.50	13.40	5.70	230	1575	754	5167
24.5	80.4	17.55	17.45	6.31	13.25	13.15	5.66	233	1538	763	5047
25.0	82.0	17.10	17.00	6.36	12.95	12.85	5.71	241	1538	791	5047
25.5	83.7	17.14	17.04	6.45	13.58	13.34	5.81	275	1575	904	5167

Table 7. Boring 06-08, Suspension R1-R2 depth, pick times, and velocities

Depth		Pick Times						Velocity			
(m)	(feet)	Far-Hn (millisec)	Far-Hr (millisec)	Far-V (millisec)	Near-Hn (millisec)	Near-Hr (millisec)	Near-V (millisec)	$V\text{-}S_H$ (m/sec)	V-P (m/sec)	$V\text{-}S_H$ (ft/sec)	V-P (ft/sec)
26.0	85.3	16.54	16.52	5.93	12.96	12.94	5.32	279	1626	916	5335
26.5	86.9	16.96	16.82	6.34	12.46	12.28	5.70	221	1562	726	5126
27.0	88.6	17.66	17.52	6.70	13.12	12.94	6.01	219	1449	719	4755
27.5	90.2	15.90	15.72	6.23	12.16	11.98	5.61	267	1626	877	5335
28.0	91.9	15.38	15.32	6.32	11.74	11.66	5.67	274	1527	899	5009
28.5	93.5	15.40	15.20	6.27	11.96	11.74	5.65	290	1613	951	5292
29.0	95.1	15.10	14.96	6.26	11.70	11.54	5.62	293	1575	962	5167
29.5	96.8	15.24	15.10	5.83	10.72	10.50	5.17	219	1515	719	4971
30.0	98.4	14.60	14.46	6.21	10.52	10.38	5.55	245	1515	804	4971
30.5	100.1	13.32	13.24	6.12	10.16	9.96	5.49	311	1575	1019	5167
31.0	101.7	13.12	13.02	6.12	9.70	9.56	5.50	291	1613	954	5292
31.5	103.3	13.10	12.82	6.10	9.54	9.30	5.50	282	1653	927	5423
32.0	105.0	12.60	12.46	6.09	9.46	9.16	5.48	311	1639	1019	5378
32.5	106.6	12.22	12.16	6.09	9.46	9.24	5.50	352	1681	1155	5514
33.0	108.3	12.12	11.94	6.07	9.52	9.40	5.48	389	1709	1277	5608
33.5	109.9	12.58	12.38	6.09	10.06	9.90	5.52	400	1770	1312	5807
34.0	111.5	13.22	13.08	6.08	10.56	10.42	5.52	376	1786	1233	5859
34.5	113.2	13.64	13.54	6.16	11.02	10.92	5.58	382	1739	1252	5706
35.0	114.8	13.78	13.74	6.18	11.40	11.28	5.58	413	1681	1356	5514

Table 7, continued. Boring 06-08, Suspension R1-R2 depth, pick times, and velocities

APPENDIX A

SUSPENSION VELOCITY MEASUREMENT QUALITY ASSURANCE SUSPENSION SOURCE TO RECEIVER ANALYSIS RESULTS

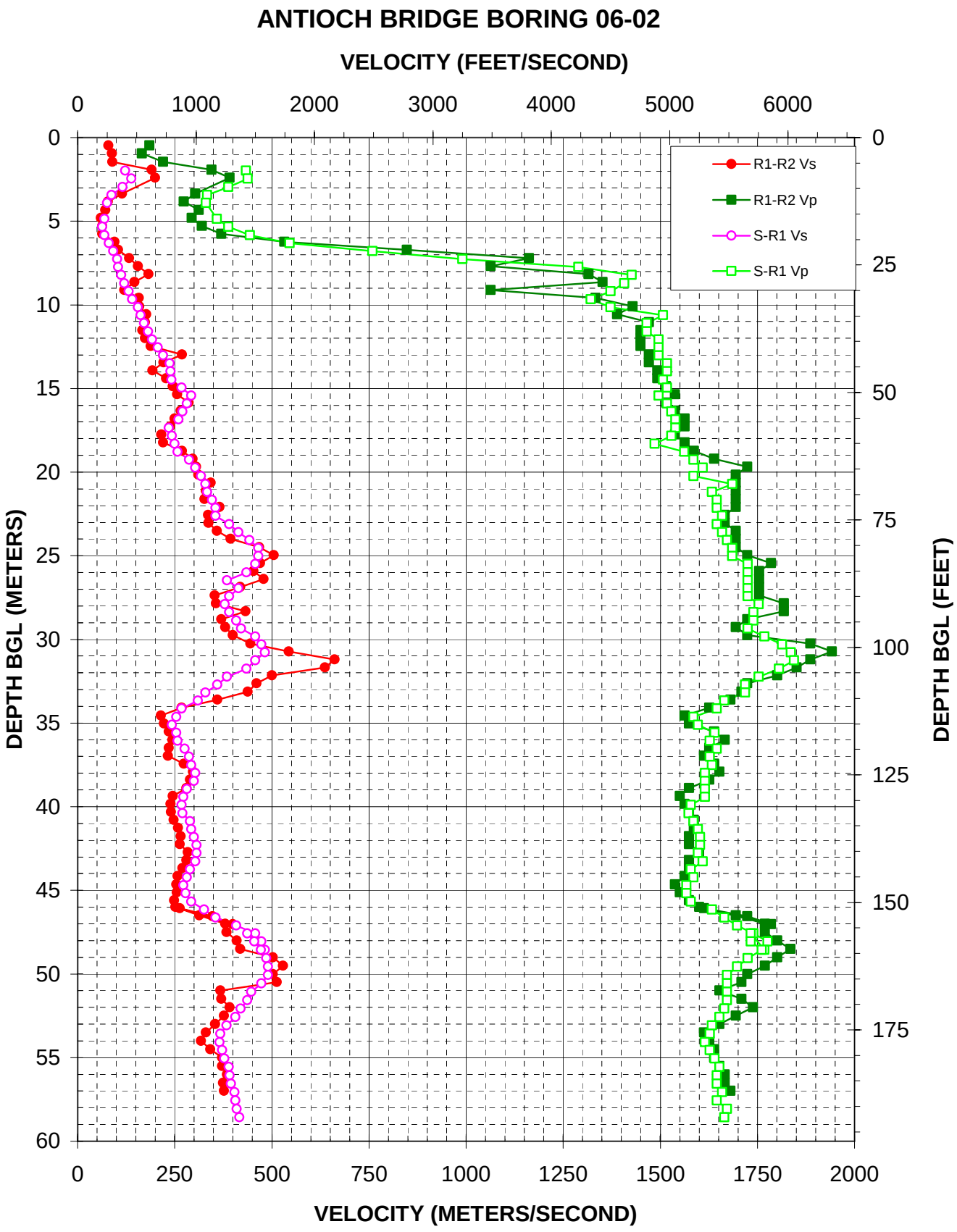


Figure A-1. Boring 06-02, R1 - R2 high resolution analysis and S-R1 quality assurance analysis P- and S_H-wave data

Depth (meters)	Velocity V-S_H (m/sec)	Velocity V-p (m/sec)	Depth (feet)	Velocity V- S_H (ft/sec)	Velocity V-p (ft/sec)
2.0	122	433	6.5	402	1421
2.5	139	439	8.1	455	1439
2.9	116	388	9.7	379	1272
3.4	87	333	11.2	285	1094
3.9	76	331	12.8	248	1085
4.9	69	358	16.0	227	1176
5.3	64	388	17.5	209	1272
5.8	69	444	19.1	228	1457
6.3	80	546	20.7	264	1791
6.8	92	759	22.3	301	2490
7.3	102	991	23.8	334	3250
7.7	105	1289	25.4	344	4230
8.2	113	1427	27.0	369	4681
8.7	120	1408	28.6	394	4619
9.2	131	1372	30.1	430	4501
9.7	141	1321	31.7	461	4334
10.1	156	1372	33.3	512	4501
10.6	162	1507	34.9	531	4944
11.1	171	1466	36.4	561	4809
11.6	181	1466	38.0	594	4809
12.1	192	1497	39.6	629	4910
12.5	206	1497	41.2	677	4910
13.0	220	1497	42.7	722	4910
13.5	237	1518	44.3	778	4979
14.0	239	1518	45.9	784	4979
14.5	241	1507	47.5	792	4944
14.9	268	1518	49.0	878	4979
15.4	293	1497	50.6	962	4910
15.9	281	1518	52.2	923	4979
16.4	270	1529	53.8	886	5015
16.9	260	1540	55.3	852	5051
17.3	235	1540	56.9	770	5051
17.8	243	1529	58.5	798	5015
18.3	250	1486	60.1	820	4876
18.8	257	1562	61.6	844	5125
19.3	287	1585	63.2	941	5201
19.7	303	1609	64.8	994	5279
20.2	318	1585	66.4	1042	5201
20.7	329	1685	67.9	1080	5528
21.2	333	1634	69.5	1094	5360
21.7	346	1646	71.1	1136	5401
22.1	355	1646	72.7	1166	5401
22.6	355	1659	74.2	1166	5443
23.1	391	1646	75.8	1281	5401
23.6	415	1659	77.4	1361	5443
24.1	442	1672	79.0	1451	5485
24.5	465	1685	80.5	1526	5528
25.0	465	1685	82.1	1526	5528
25.5	457	1726	83.7	1500	5662
26.0	435	1726	85.3	1427	5662
26.5	385	1726	86.8	1263	5662
26.9	415	1726	88.4	1361	5662
27.4	391	1726	90.0	1281	5662
27.9	379	1754	91.6	1245	5755
28.4	391	1740	93.1	1281	5708
28.9	408	1740	94.7	1340	5708
29.3	421	1726	96.3	1382	5662
29.8	457	1769	97.9	1500	5802
30.3	473	1814	99.4	1553	5950
30.8	482	1837	101.0	1581	6027
31.3	457	1845	102.6	1500	6053
31.7	435	1806	104.2	1427	5925
32.2	385	1754	105.7	1263	5755
32.7	360	1719	107.3	1182	5639
33.2	329	1719	108.9	1080	5639
33.7	310	1665	110.5	1018	5464
34.1	268	1646	112.0	878	5401
34.6	255	1585	113.6	836	5201
35.1	243	1597	115.2	798	5240
35.6	255	1640	116.8	836	5380
36.1	257	1627	118.3	844	5339
36.5	276	1646	119.9	904	5401
37.0	287	1627	121.5	942	5339
37.5	293	1634	123.1	962	5360
38.0	303	1615	124.6	995	5299
38.5	300	1615	126.2	983	5299
38.9	282	1615	127.8	924	5299
39.4	273	1615	129.4	896	5299
39.9	268	1579	130.9	878	5182
40.4	270	1574	132.5	886	5162
40.9	290	1585	134.1	951	5201
41.3	293	1597	135.7	962	5240
41.8	300	1603	137.2	983	5259
42.3	307	1603	138.8	1006	5259
42.8	307	1597	140.4	1006	5240
43.3	303	1609	142.0	994	5279
43.7	290	1579	143.5	951	5182
44.2	282	1585	145.1	924	5201
44.7	273	1568	146.7	896	5144
45.2	279	1568	148.3	914	5144
45.7	293	1579	149.8	962	5182
46.1	325	1634	151.4	1067	5360
46.6	355	1665	153.0	1166	5464
47.1	408	1698	154.6	1340	5572
47.6	457	1740	156.1	1500	5708
48.1	473	1776	157.7	1553	5827
48.5	482	1769	159.3	1581	5802
47.6	437	1733	156.1	1433	5685
48.1	455	1733	157.7	1494	5685

Table A-1. Boring 06-02, S - R1 quality assurance analysis P- and S_H-wave data

Depth (meters)	Velocity V-S_H (m/sec)	Velocity V-p (m/sec)	Depth (feet)	Velocity V- S_H (ft/sec)	Velocity V-p (ft/sec)
48.6	472	1761	161.0	1550	5779
49.1	486	1726	162.6	1596	5662
49.6	491	1698	164.3	1610	5572
50.1	490	1672	165.9	1608	5485
50.6	473	1672	167.6	1553	5485
51.1	448	1672	169.2	1469	5485
51.6	437	1672	170.8	1433	5485
52.1	420	1665	172.5	1377	5464
52.6	407	1653	174.1	1335	5422
53.1	384	1634	175.8	1258	5360
53.6	368	1627	177.4	1206	5339
54.1	365	1615	179.0	1198	5299
54.6	373	1627	180.7	1223	5339
55.1	378	1640	182.3	1240	5380
55.6	389	1653	184.0	1277	5422
56.1	392	1646	185.6	1286	5401
56.6	395	1646	187.2	1295	5401
57.1	404	1659	188.9	1325	5443
57.6	407	1646	190.5	1335	5401
58.1	410	1672	192.2	1345	5485
58.6	416	1665	161.0	1366	5464

Table A-1, continued. Boring 06-02, S - R1 quality assurance analysis P- and S_H-wave data

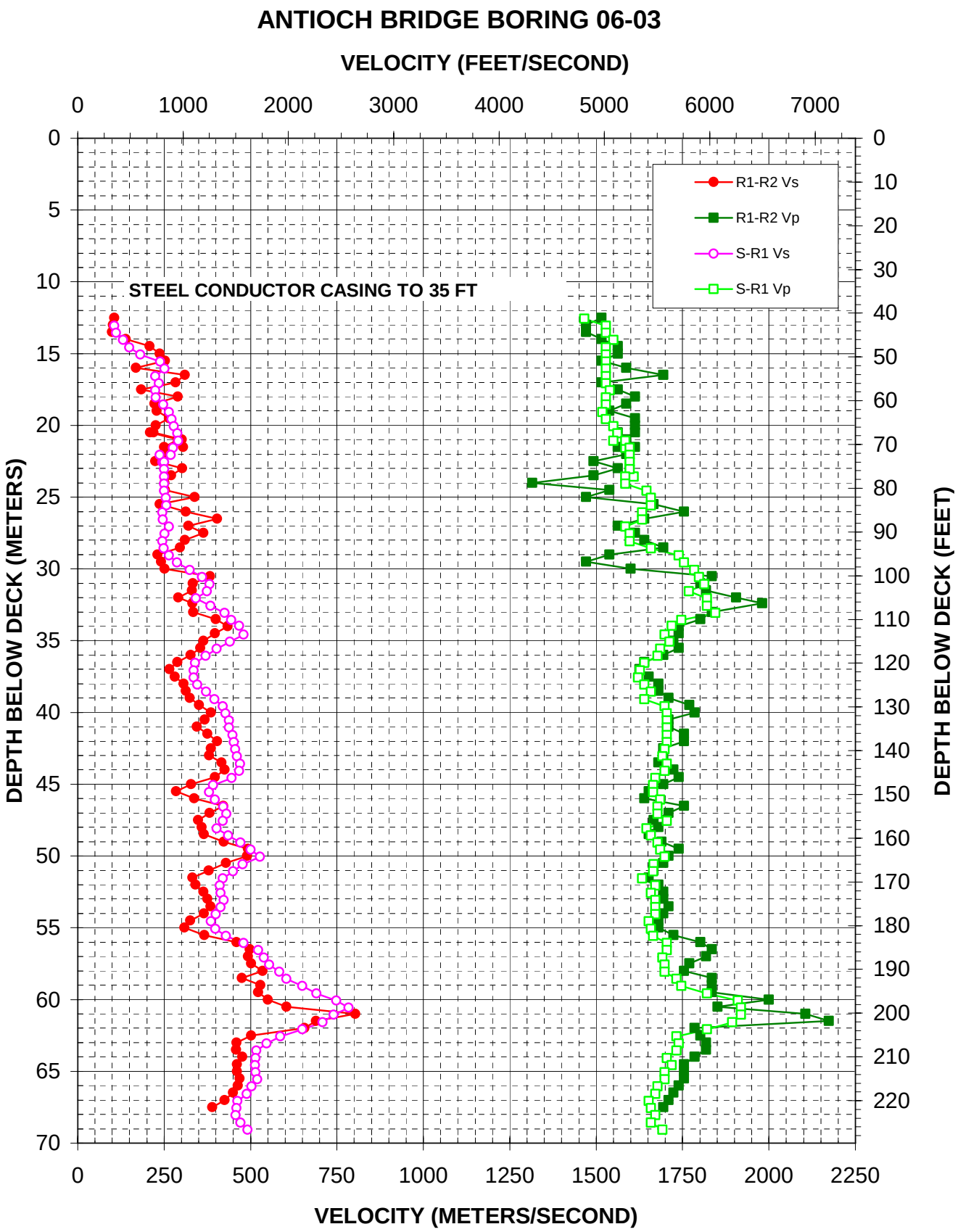


Figure A-2. Boring 06-03, R1 - R2 high resolution analysis and S-R1 quality assurance analysis

Depth (meters)	Velocity		Depth (feet)	Velocity	
	$V\text{-}S_H$ (m/sec)	V-p (m/sec)		$V\text{-}S_H$ (ft/sec)	V-p (ft/sec)
11.6			38.0		
12.1			39.6		
12.6		1466	41.2		4809
13.1	106	1529	42.9	348	5015
13.6	111	1529	44.5	366	5015
14.1	131	1551	46.2	430	5088
14.6	150	1529	47.8	491	5015
15.1	181	1529	49.4	595	5015
15.6	238	1529	51.1	782	5015
16.1	252	1529	52.7	826	5015
16.6	225	1529	54.4	739	5015
17.1	235	1529	56.0	772	5015
17.6	225	1540	57.6	739	5051
18.1	226	1529	59.3	743	5015
18.6	247	1529	60.9	812	5015
19.1	264	1518	62.6	867	4979
19.6	273	1529	64.2	894	5015
20.1	278	1551	65.8	912	5088
20.6	289	1562	67.5	949	5125
21.1	291	1551	69.1	955	5088
21.6	276	1585	70.8	906	5201
22.1	269	1597	72.4	883	5240
22.6	245	1597	74.0	802	5240
23.1		1597	75.7		5240
23.6		1609	77.3		5279
19.6			64.2		
20.1			65.8		
20.6			67.5		
21.1		1585	69.1		5201
21.6		1597	70.8		5240
22.1	238	1597	72.4	780	5240
22.6	250	1597	74.0	819	5240
23.1	250	1597	75.7	821	5240
23.6	251	1585	77.3	822	5201
24.1	250	1585	79.0	821	5201
24.6	250	1646	80.6	821	5401
25.1	255	1659	82.3	836	5443
25.6	256	1659	83.9	841	5443
26.1	245	1634	85.5	802	5360
26.6	246	1634	87.2	807	5360
27.1	264	1585	88.8	867	5201
27.6	252	1597	90.5	826	5240
28.1	245	1597	92.1	802	5240
28.6	249	1659	93.7	816	5443
29.1	264	1740	95.4	867	5708
29.6	287	1754	97.0	942	5755
30.1	324	1783	98.7	1064	5851
30.6	360	1798	100.3	1180	5900
31.1	382	1814	101.9	1254	5950

Depth (meters)	Velocity		Depth (feet)	Velocity	
	$V\text{-}S_H$ (m/sec)	V-p (m/sec)		$V\text{-}S_H$ (ft/sec)	V-p (ft/sec)
31.6	374	1769	103.6	1227	5802
32.1	343	1821	105.2	1124	5975
32.6	385	1821	106.9	1263	5975
33.1	425	1845	108.5	1393	6053
33.6	444	1747	110.1	1457	5731
34.0	467	1719	111.5	1533	5639
34.6	480	1698	113.4	1574	5572
35.1	440	1712	115.1	1445	5617
35.6	402	1685	116.7	1320	5528
36.1	370	1678	118.3	1215	5507
36.6	340	1640	120.0	1114	5380
37.1	335	1627	121.6	1100	5339
37.6	336	1621	123.3	1104	5319
38.1	346	1640	124.9	1136	5380
38.6	372	1659	126.5	1219	5443
39.1	396	1640	128.2	1300	5380
39.6	420	1698	129.8	1377	5572
40.1	428	1705	131.5	1404	5594
40.6	439	1705	133.1	1439	5594
41.1	439	1705	134.7	1439	5594
41.6	448	1705	136.4	1469	5594
42.1	451	1705	138.0	1481	5594
42.6	455	1698	139.7	1494	5572
43.1	461	1692	141.3	1513	5550
43.6	469	1705	142.9	1540	5594
44.1	467	1698	144.6	1533	5572
44.6	446	1672	146.2	1463	5485
45.1	392	1665	147.9	1287	5464
45.6	381	1665	149.5	1249	5464
46.1	398	1685	151.1	1305	5528
46.6	421	1678	152.8	1382	5507
47.1	430	1678	154.4	1410	5507
47.6	420	1705	156.1	1377	5594
48.1	402	1646	157.7	1320	5401
48.6	435	1659	159.4	1427	5443
49.1	471	1678	161.0	1546	5507
49.6	500	1685	162.6	1640	5528
50.1	527	1698	164.3	1729	5572
50.6	478	1667	165.9	1567	5468
51.1	450	1665	167.6	1475	5464
51.6	420	1634	169.2	1379	5360
52.1	412	1672	170.8	1350	5485
52.6	414	1659	172.5	1358	5443
53.1	423	1672	174.1	1388	5485
53.6	413	1672	175.8	1355	5485
54.1	399	1672	177.4	1310	5485
54.6	386	1653	179.0	1265	5422
55.1	398	1659	180.7	1306	5443
55.6	429	1665	182.3	1407	5464
56.1	480	1705	184.0	1574	5594

Table A-2. Boring 06-03, S - R1 quality assurance analysis P- and S_H-wave data

Depth (meters)	Velocity		Depth (feet)	Velocity	
	$V\text{-}S_H$ (m/sec)	V-p (m/sec)		$V\text{-}S_H$ (ft/sec)	V-p (ft/sec)
56.6	523	1705	185.6	1715	5594
57.1	539	1692	187.2	1769	5550
57.6	554	1698	188.9	1819	5572
58.1	583	1698	190.5	1913	5572
58.6	605	1733	192.2	1983	5685
59.1	650	1747	193.8	2134	5731
59.6	690	1821	195.4	2265	5975
60.1	748	1911	197.1	2455	6269
60.6	784	1919	198.7	2572	6297
61.1	740	1919	200.4	2429	6297
61.6	709	1894	202.0	2325	6213
62.1	650	1821	203.6	2134	5975
62.6	586	1733	205.3	1924	5685
63.1	546	1740	206.9	1791	5708
63.6	517	1733	208.6	1696	5685
64.1	514	1705	210.2	1688	5594
64.6	513	1719	211.8	1684	5639
65.1	514	1698	213.5	1688	5572
65.6	519	1698	215.1	1704	5572
66.1	504	1678	216.8	1652	5507
66.6	489	1672	218.4	1603	5485
67.1	462	1653	220.0	1516	5422
67.6	460	1659	221.7	1510	5443
68.1	457	1672	223.3	1500	5485
68.6	471	1659	225.0	1546	5443
69.1	492	1692	226.6	1614	5550

Table A-2, continued. Boring 06-03, S - R1 quality assurance analysis P- and S_H-wave data

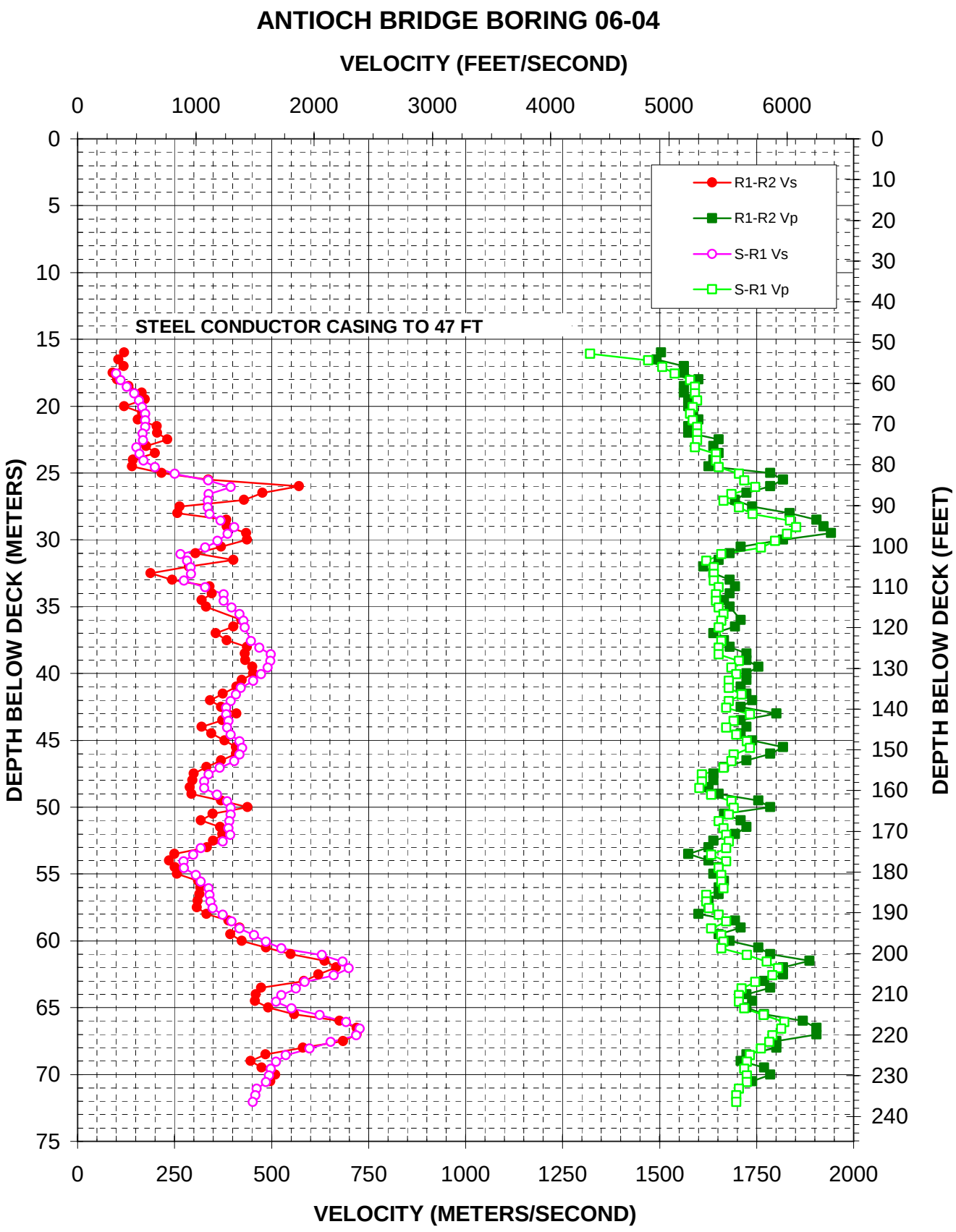


Figure A-3. Boring 06-04, R1 - R2 high resolution analysis and S-R1 quality assurance analysis

Depth (meters)	Velocity V-S_H (m/sec)	Velocity V-p (m/sec)	Depth (feet)	Velocity V- S_H (ft/sec)	Velocity V-p (ft/sec)
15.6			51.1		
16.1		1321	52.7		4334
16.6		1471	54.4		4825
17.1		1507	56.0		4944
17.6	100	1540	57.6	327	5051
18.1	111	1579	59.3	365	5182
18.6	127	1591	60.9	417	5220
19.1	146	1591	62.6	479	5220
19.6	159	1597	64.2	520	5240
20.1	167	1585	65.8	546	5201
20.6	175	1579	67.5	573	5182
21.1	175	1585	69.1	573	5201
21.6	175	1597	70.8	573	5240
22.1	168	1597	72.4	551	5240
22.6	169	1597	74.0	555	5240
23.1	152	1591	75.7	500	5220
23.6	160	1646	77.3	524	5401
24.1	171	1646	79.0	559	5401
24.6	200	1653	80.6	656	5422
25.1	250	1705	82.3	821	5594
25.6	337	1719	83.9	1106	5639
26.1	395	1747	85.5	1295	5731
26.6	339	1685	87.2	1111	5528
27.1	336	1665	88.8	1104	5464
27.6	336	1705	90.5	1104	5594
28.1	340	1740	92.1	1117	5708
28.6	369	1837	93.7	1211	6027
29.1	404	1853	95.4	1325	6079
29.6	387	1829	97.0	1271	6001
30.1	361	1798	98.7	1186	5900
30.6	329	1761	100.3	1080	5779
31.1	266	1659	101.9	873	5443
31.6	283	1621	103.6	929	5319
32.1	292	1640	105.2	957	5380
32.6	293	1640	106.9	962	5380
33.1	275	1640	108.5	902	5380
33.6	329	1653	110.1	1080	5422
34.1	377	1646	111.8	1236	5401
34.6	377	1646	113.4	1236	5401
35.1	398	1653	115.1	1305	5422
35.6	418	1665	116.7	1371	5464
36.1	428	1659	118.3	1404	5443
36.6	431	1653	120.0	1416	5422
37.6	448	1659	123.3	1469	5443
38.1	469	1653	124.9	1540	5422
38.6	498	1653	126.5	1635	5422
39.1	498	1705	128.2	1633	5594
39.6	491	1685	129.8	1610	5528
40.1	473	1698	131.5	1553	5572
40.6	453	1678	133.1	1487	5507

Depth (meters)	Velocity V-S_H (m/sec)	Velocity V-p (m/sec)	Depth (feet)	Velocity V- S_H (ft/sec)	Velocity V-p (ft/sec)
41.1	421	1678	134.7	1382	5507
41.6	409	1712	136.4	1342	5617
42.1	395	1678	138.0	1295	5507
42.6	384	1672	139.7	1261	5485
43.1	384	1733	141.3	1261	5685
43.6	389	1692	142.9	1277	5550
44.1	386	1672	144.6	1267	5485
44.6	395	1698	146.2	1295	5572
45.1	418	1726	147.9	1371	5662
45.6	425	1733	149.5	1393	5685
46.1	418	1692	151.1	1371	5550
46.6	404	1685	152.8	1325	5528
47.1	366	1665	154.4	1202	5464
47.6	339	1609	156.1	1111	5279
48.1	327	1609	157.7	1074	5279
48.6	327	1603	159.4	1074	5259
49.1	360	1634	161.0	1182	5360
49.6	386	1685	162.6	1267	5528
50.1	395	1692	164.3	1295	5550
50.6	395	1678	165.9	1295	5507
51.1	392	1653	167.6	1286	5422
51.6	389	1665	169.2	1277	5464
52.1	393	1672	170.8	1291	5485
52.6	374	1678	172.5	1227	5507
53.1	318	1672	174.1	1042	5485
53.6	298	1634	175.8	978	5360
54.1	274	1672	177.4	898	5485
54.6	275	1653	179.0	902	5422
55.1	306	1659	180.7	1003	5443
55.6	318	1659	182.3	1042	5443
56.1	339	1665	184.0	1111	5464
56.6	341	1621	185.6	1118	5319
57.1	343	1621	187.2	1125	5319
57.6	349	1627	188.9	1143	5339
58.1	374	1653	190.5	1227	5422
58.6	398	1672	192.2	1305	5485
59.1	418	1634	193.8	1371	5360
59.6	455	1659	195.4	1494	5443
60.1	485	1665	197.1	1592	5464
60.6	526	1659	198.7	1725	5443
61.1	629	1726	200.4	2065	5662
61.6	684	1776	202.0	2243	5827
62.1	699	1806	203.6	2294	5925
62.6	660	1791	205.3	2167	5875
63.1	585	1747	206.9	1921	5731
63.6	563	1712	208.6	1848	5617
64.1	526	1705	210.2	1725	5594
64.6	512	1705	211.8	1680	5594
65.1	552	1719	213.5	1810	5639
65.6	624	1769	215.1	2047	5802

Table A-3. Boring 06-04, S - R1 quality assurance analysis P- and S_H-wave data

Depth (meters)	Velocity V-S_H (m/sec)	Velocity V-p (m/sec)	Depth (feet)	Velocity V- S_H (ft/sec)	Velocity V-p (ft/sec)
66.1	693	1821	216.8	2272	5975
66.6	728	1814	218.4	2388	5950
67.1	718	1791	220.0	2356	5875
67.6	652	1783	221.7	2141	5851
68.1	598	1761	223.3	1961	5779
68.6	536	1733	225.0	1760	5685
69.1	512	1726	226.6	1680	5662
69.6	499	1719	228.2	1637	5639
70.1	494	1726	229.9	1621	5662
70.6	485	1726	231.5	1592	5662
71.1	462	1705	233.2	1516	5594
71.6	458	1698	234.8	1503	5572
72.1	451	1698	236.5	1481	5572

Table A-3, continued. Boring 06-04, S - R1 quality assurance analysis P- and S_H-wave data

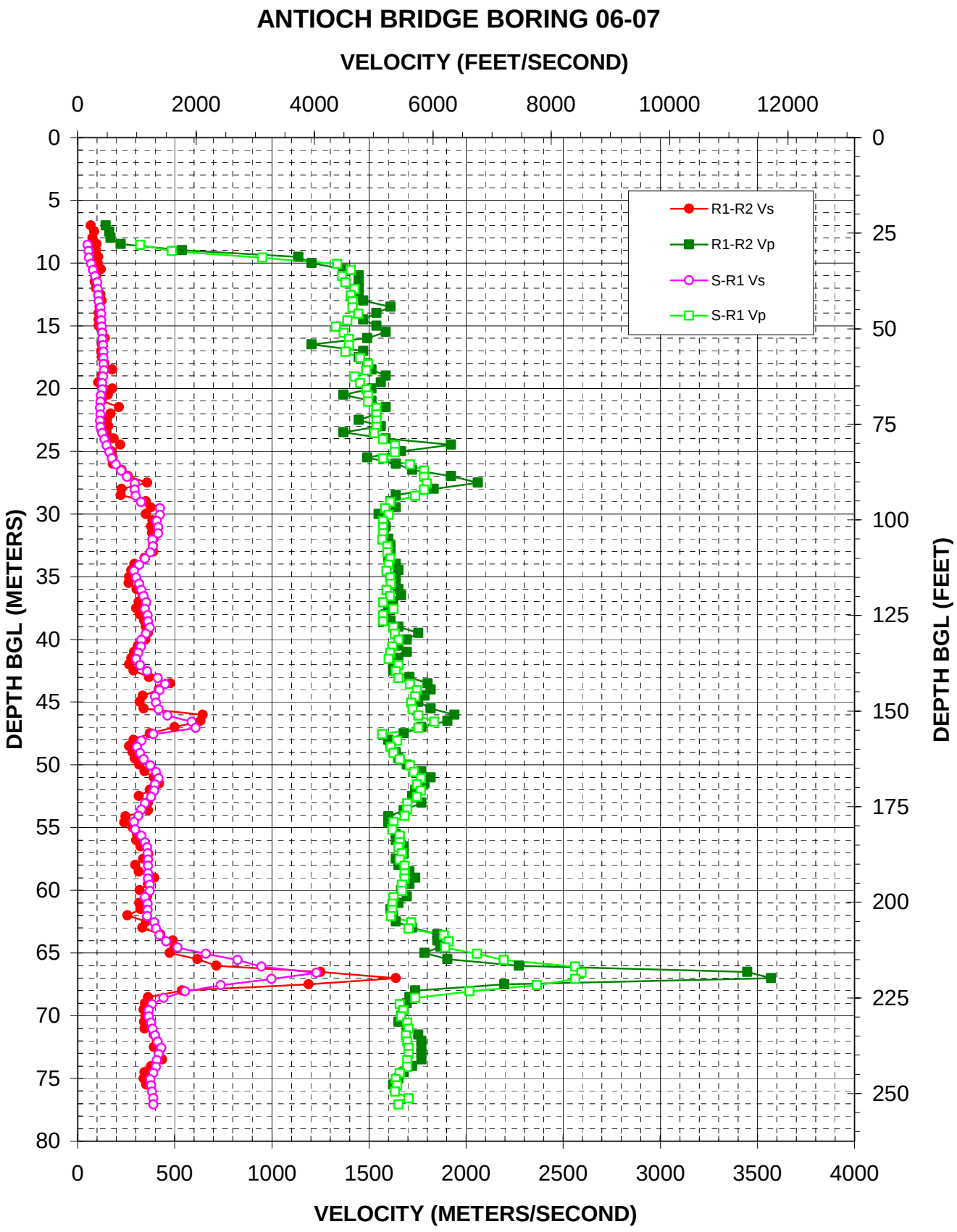


Figure A-4. Boring 06-07, R1 - R2 high resolution analysis and S-R1 quality assurance analysis

Depth (meters)	Velocity		Depth (feet)	Velocity	
	$V\text{-}S_H$ (m/sec)	V-p (m/sec)		$V\text{-}S_H$ (ft/sec)	V-p (ft/sec)
8.6	53	322	28.1	174	1056
9.1	57	486	29.8	188	1596
9.6	60	951	31.4	196	3120
10.1	69	1338	33.0	228	4388
10.6	78	1408	34.7	257	4619
11.1	90	1363	36.3	296	4472
11.6	102	1381	38.0	334	4530
12.1	105	1427	39.6	344	4681
12.6	106	1408	41.2	348	4619
13.1	109	1417	42.9	359	4650
13.6	119	1417	44.5	389	4650
14.1	124	1446	46.2	406	4744
14.6	122	1390	47.8	399	4559
15.1	125	1329	49.4	409	4361
15.6	128	1372	51.1	419	4501
16.1	127	1399	52.7	417	4589
16.6	131	1399	54.4	429	4589
17.1	134	1381	56.0	439	4530
17.6	135	1456	57.6	442	4776
18.1	135	1497	59.3	442	4910
18.6	135	1486	60.9	444	4876
19.1	132	1427	62.6	432	4681
19.6	126	1456	64.2	414	4776
20.1	127	1486	65.8	417	4876
20.6	121	1497	67.5	396	4910
21.1	117	1497	69.1	385	4910
21.6	117	1540	70.8	383	5051
22.1	118	1540	72.4	387	5051
22.6	116	1540	74.0	381	5051
23.1	117	1540	75.7	385	5051
23.6	127	1529	77.3	417	5015
24.1	139	1574	79.0	456	5162
24.6	151	1634	80.6	494	5360
25.1	163	1634	82.3	536	5360
25.6	177	1574	83.9	580	5162
26.1	198	1712	85.5	650	5617
26.6	224	1783	87.2	735	5851
27.1	253	1783	88.8	831	5851
27.6	295	1798	90.5	968	5900
28.1	295	1783	92.1	968	5851
28.6	299	1740	93.7	982	5708
29.1	327	1609	95.4	1074	5279
29.6	425	1585	97.0	1393	5201
30.1	425	1603	98.7	1393	5259
30.6	408	1574	100.3	1340	5162
31.1	416	1574	101.9	1366	5162
31.6	416	1574	103.6	1366	5162
32.1	386	1568	105.2	1267	5144
32.6	388	1597	106.9	1272	5240
33.1	375	1597	108.5	1232	5240
33.6	347	1609	110.1	1140	5279
34.1	318	1603	111.8	1042	5259
34.6	291	1591	113.4	954	5220
35.1	302	1609	115.1	992	5279
35.6	318	1615	116.7	1042	5299
36.1	329	1591	118.3	1080	5220
36.6	341	1609	120.0	1118	5279
37.1	354	1574	121.6	1162	5162
37.6	347	1627	123.3	1140	5339
38.1	360	1574	124.9	1182	5162
38.6	364	1574	126.5	1194	5162
39.1	372	1627	128.2	1219	5339
39.6	351	1634	129.8	1151	5360
40.1	329	1653	131.5	1080	5422
40.6	326	1621	133.1	1070	5319
41.1	313	1609	134.7	1026	5279
41.6	302	1603	136.4	992	5259
42.1	323	1653	138.0	1061	5422
42.6	358	1640	139.7	1174	5380
43.1	413	1653	141.3	1355	5422
43.6	452	1712	142.9	1484	5617
44.1	421	1747	144.6	1382	5731
44.6	399	1740	146.2	1310	5708
45.1	404	1719	147.9	1325	5639
45.6	417	1726	149.5	1369	5662
46.1	463	1754	151.1	1520	5755
46.6	588	1837	152.8	1929	6027
47.1	608	1754	154.4	1995	5755
47.6	391	1568	156.1	1281	5144
48.1	329	1646	157.7	1080	5401
48.6	307	1615	159.4	1009	5299
49.1	323	1627	161.0	1061	5339
49.6	341	1659	162.6	1118	5443
50.1	375	1712	164.3	1232	5617
50.6	404	1733	165.9	1325	5685
51.1	418	1769	167.6	1371	5802
51.6	399	1747	169.2	1310	5731
52.1	395	1769	170.8	1295	5802
52.6	379	1747	172.5	1245	5731
53.1	347	1698	174.1	1140	5572
53.6	329	1698	175.8	1080	5572
54.1	313	1685	177.4	1026	5528
54.6	291	1627	179.0	954	5339
55.2	297	1621	181.0	975	5319
55.7	329	1659	182.6	1079	5443
56.2	347	1659	184.3	1140	5443
56.6	358	1653	185.6	1174	5422
57.1	360	1672	187.2	1182	5485
57.6	364	1659	188.9	1195	5443
58.1	364	1685	190.5	1194	5528

Table A-4. Boring 06-07, S - R1 quality assurance analysis P- and S_H-wave data

Depth (meters)	Velocity V-S_H (m/sec)	Velocity V-p (m/sec)	Depth (feet)	Velocity V- S_H (ft/sec)	Velocity V-p (ft/sec)
58.7	364	1685	192.5	1194	5528
59.1	364	1685	193.8	1194	5528
59.6	372	1672	195.4	1219	5485
60.1	372	1672	197.1	1219	5485
60.6	347	1627	198.7	1140	5339
61.1	360	1621	200.4	1182	5319
61.6	360	1621	202.0	1182	5319
62.1	358	1615	203.6	1174	5299
62.6	395	1719	205.3	1295	5639
63.1	404	1705	206.9	1325	5594
63.6	421	1885	208.6	1382	6186
64.1	457	1911	210.2	1500	6269
64.6	514	1894	211.8	1688	6213
65.1	660	2058	213.5	2167	6751
65.6	823	2195	215.1	2700	7201
66.1	947	2563	216.8	3107	8408
66.6	1230	2594	218.4	4035	8510
67.1	1000	2563	220.0	3281	8408
67.6	738	2365	221.7	2421	7758
68.1	553	2019	223.3	1814	6624
68.6	442	1740	225.0	1451	5708
69.1	384	1659	226.6	1258	5443
69.6	368	1678	228.2	1206	5507
70.1	368	1665	229.9	1206	5464
70.6	379	1698	231.5	1245	5572
71.1	386	1705	233.2	1267	5594
71.6	399	1692	234.8	1310	5550
72.1	413	1698	236.5	1355	5572
72.6	431	1705	238.1	1416	5594
73.1	418	1705	239.7	1371	5594
73.6	408	1698	241.4	1340	5572
74.1	404	1698	243.0	1325	5572
74.6	391	1659	244.7	1281	5443
75.1	375	1640	246.3	1232	5380
75.6	379	1646	247.9	1245	5401
76.1	384	1634	249.6	1258	5360
76.6	391	1705	251.2	1281	5594
77.1	391	1653	252.9	1281	5422

Table A-4, continued. Boring 06-07, S - R1 quality assurance analysis P- and S_H-wave data

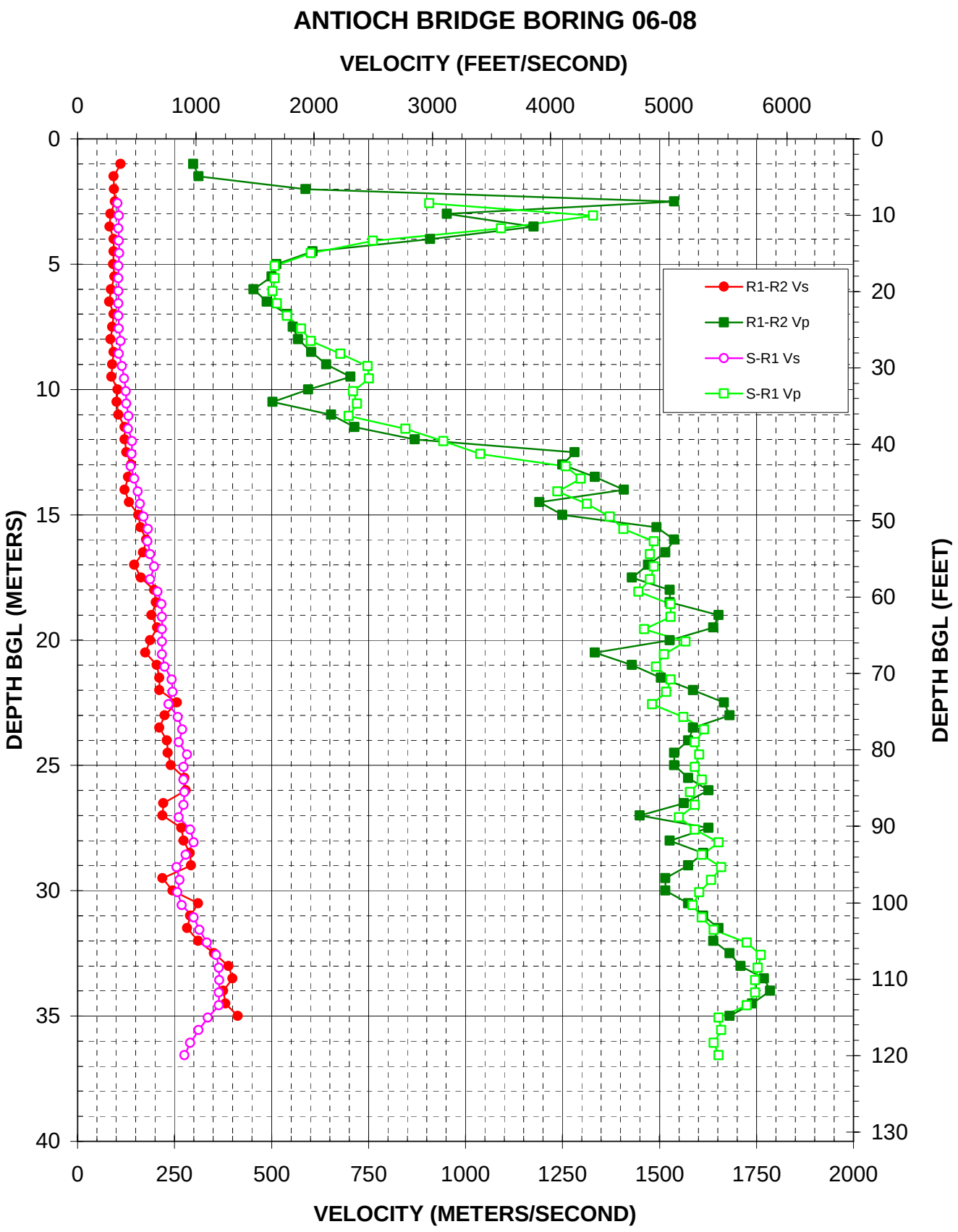


Figure A-5. Boring 06-08, R1 - R2 high resolution analysis and S-R1 quality assurance analysis

Depth (meters)	Velocity		Depth (feet)	Velocity	
	$V\text{-}S_H$ (m/sec)	V-p (m/sec)		$V\text{-}S_H$ (ft/sec)	V-p (ft/sec)
2.6	104	907	8.4	341	2975
3.1	107	1329	10.1	351	4361
3.6	105	1092	11.7	346	3582
4.1	107	762	13.4	351	2499
4.6	107	601	15.0	353	1972
5.1	106	508	16.6	347	1668
5.6	106	508	18.3	347	1668
6.1	106	502	19.9	347	1648
6.6	106	514	21.6	347	1688
7.1	106	540	23.2	347	1773
7.6	107	577	24.8	351	1892
8.1	111	601	26.5	364	1972
8.6	107	677	28.1	351	2222
9.1	115	748	29.8	377	2455
9.6	120	751	31.4	394	2464
10.1	125	711	33.0	409	2333
10.6	127	721	34.7	415	2364
11.1	131	699	36.3	430	2294
11.6	131	846	38.0	430	2775
12.1	141	943	39.6	462	3093
12.6	140	1039	41.2	459	3408
13.1	138	1259	42.9	452	4130
13.6	147	1297	44.5	482	4255
14.1	156	1237	46.2	510	4058
14.6	161	1313	47.8	529	4307
15.1	170	1372	49.4	559	4501
15.6	181	1408	51.1	594	4619
16.1	180	1486	52.7	592	4876
16.6	188	1476	54.4	615	4842
17.1	198	1486	56.0	649	4876
17.6	187	1476	57.6	613	4842
18.1	207	1446	59.3	678	4744
18.6	217	1529	60.9	712	5015
19.1	218	1529	62.6	716	5015
19.6	218	1461	64.2	716	4792
20.1	218	1568	65.8	716	5144
20.6	218	1512	67.5	716	4962
21.1	225	1491	69.1	738	4893
21.6	243	1529	70.8	797	5015
22.1	246	1518	72.4	806	4979
22.6	235	1481	74.0	771	4859
23.1	259	1562	75.7	849	5125
23.6	271	1615	77.3	888	5299
24.1	261	1591	79.0	855	5220
24.6	283	1603	80.6	929	5259
25.1	274	1591	82.3	899	5220
25.6	274	1609	83.9	899	5279
26.1	276	1579	85.5	905	5182
26.6	274	1591	87.2	899	5220
27.1	261	1551	88.8	857	5088
27.6	290	1591	90.5	953	5220
28.1	300	1653	92.1	985	5422
28.6	280	1609	93.7	918	5279
29.1	256	1659	95.4	839	5443
29.6	264	1634	97.0	865	5360
30.1	258	1603	98.7	847	5259
30.6	269	1585	100.3	881	5201
31.1	300	1609	101.9	985	5279
31.6	314	1640	103.6	1031	5380
32.1	334	1726	105.2	1095	5662
32.6	357	1761	106.9	1172	5779
33.1	365	1754	108.5	1196	5755
33.6	366	1747	110.1	1200	5731
34.1	365	1747	111.8	1196	5731
34.6	365	1726	113.4	1196	5662
35.1	336	1653	115.1	1102	5422
35.6	312	1659	116.7	1025	5443
36.1	290	1640	118.3	953	5380
36.6	275	1653	120.0	904	5422

Table A-5. Boring 06-08, S - R1 quality assurance analysis P- and S_H-wave data

APPENDIX B

OYO 170 VELOCITY LOGGING SYSTEM

NIST TRACEABLE

CALIBRATION PROCEDURE

CALIBRATION PROCEDURE FOR

GEOVision SEISMIC RECORDER/LOGGER

Reviewed 4/6/06

Objective

The timing/sampling accuracy of seismic recorders or data loggers is required for several GEOVision field procedures including Seismic Refraction, Downhole Seismic Velocity Logging, and P-S Suspension Logging. This procedure describes the method for measuring the timing accuracy of a seismic data logger, such as the OYO Model 170, OYO/Robertson Model 3403, Geometrics Strataview or Geometrics Geode. The objective of this procedure is to verify that the timing accuracy of the recorder is accurate to within 1%.

Frequency of Calibration

The calibration of each GEOVision seismic data logger is twelve (12) months. In the case of rented seismic data loggers, calibration must be performed prior to use.

Test Equipment Required

The following equipment is required. Item #2 must have current NIST traceable calibration.

1. Function generator, Krohn Hite 5400B or equivalent
2. Frequency counter, HP 5315A or equivalent
3. Test cables, from item 1 to item 2, and from item 1 to subject data logger.

Procedure

This procedure is designed to be performed using the accompanying Seismograph Calibration Data Sheet with the same revision number. All data must be entered and the procedure signed by the technician performing the test.

1. Record all identification data on the form provided.
2. Connect function generator to data logger (such as OYO Model 170) using test cable
3. Connect the function generator to the frequency counter using test cable.

4. Set up generator to produce a 100.0 Hz, 0.25 volt (amplitude is approximate, modify as necessary to yield less than full scale waveforms on logger display) peak square wave or sine wave. Verify frequency using the counter and initial space on the data sheet.

5. Initialize data logger and record a data record of at least 0.1 second using a 100 microsecond or less sample period.

6. Measure the recorded square wave frequency by measuring the duration of 9 cycles of data. This measurement can be made using the data logger display device, or by printing out a paper tape. If a paper tape can be printed, the resulting printout must be attached to this procedure. Record the data in the space provided.

7. Repeat steps 5 and 6 three more times using separate files.

Criteria

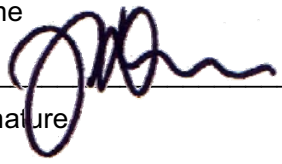
The duration for 9 cycles in any file must be 90.0 milliseconds plus or minus 0.9 milliseconds, corresponding to an average frequency for the nine cycles of 100.0 Hz plus or minus 1 Hz (obtained by dividing 9 cycles by the duration in milliseconds).

If the results are outside this range, the data logger must be marked with a GEOVision REJECT tag until it can be repaired and retested.

If results are acceptable affix label indicating the initials of the person performing the calibration, the date of calibration, and the due date for the next calibration (12 months).

Procedure Approval

Approved by:

John G. Diehl	President
Name	Title
	April 6, 2006
Signature	Date

Client Approval (if required):

_____	_____
Name	Title
_____	_____
Signature	Date

United States Department of Commerce
National Institute of Standards and Technology

NVLAP®

Certificate of Accreditation to ISO/IEC 17025:1999

NVLAP LAB CODE: 105014-0

Southern California Edison Company
Westminster, CA

is recognized by the National Voluntary Laboratory Accreditation Program for conformance with criteria set forth in NIST Handbook 150:2001 and all requirements of ISO/IEC 17025:1999.
Accreditation is granted for specific services, listed on the Scope of Accreditation, for:

CALIBRATION LABORATORIES

2006-04-01 through 2007-03-31
Effective dates

DEPARTMENT OF COMMERCE * UNITED STATES OF AMERICA *

For the National Institute of Standards and Technology

NVLAP-01C (REV. 2005-05-19)

National Voluntary Laboratory Accreditation Program

SCOPE OF ACCREDITATION TO ISO/IEC 17025:1999

Southern California Edison Company
7300 Fenwick Lane
Westminster, CA 92683
Ms. Jennifer E. Smith
Phone: 714-895-0133 Fax: 714-895-0781
E-mail: Jennifer.Smith@sce.com
URL: http://www.edisonmetrology.com

CALIBRATION LABORATORIES **NVLAP LAB CODE 105014-0**

NVLAP Code: 20/A01 ANSI/NCSL Z540-1-1994; Part 1 Compliant

DIMENSIONAL

NVLAP Code: 20/D03
Gage Blocks

Nominal Length in in	*Best Uncertainty (±) in µin* [note 1]
0.01 to < 0.05	1.9
0.05 to < 0.1	1.7
0.1 to < 1.0	1.2
1.0	1.4
2.0	1.8
3.0	2.2
4.0	2.9
5.0	5.4
6.0	5.6
7.0	5.8
8.0	6.0
10.0	6.8
12.0	7.2
16.0	8.1
20.0	9.4

2006-04-01 through 2007-03-31

Effective dates

For the National Institute of Standards and Technology

CALIBRATION LABORATORIES **NVLAP LAB CODE 105014-0**

Nominal Length in mm	*Best Uncertainty (±) in nm* note 1
0.5 to < 1.0	52
1.0 to < 2.5	44
2.5 to < 25.0	39
25.0	44
50.0	47
75.0	60
100.0	80

NVLAP Code: 20/D11
Spherical Diameter; Ring Gages

Range in inches	*Best Uncertainty (±) in µin* note 1	*Remarks*
0.040 to 0.825	6	Comparison to gage blocks
> 0.825 to 1.510	7	Comparison to gage blocks
> 1.510 to 2.510	8	Comparison to gage blocks
> 2.510 to 4.510	12	Comparison to gage blocks
> 4.510 to 6.510	14	Comparison to gage blocks
> 6.510 to 9.010	16	Comparison to gage blocks
> 9.010 to 12.010	19	Comparison to gage blocks
> 12.010 to 13.25	31	Comparison to gage blocks

ELECTROMAGNETICS - DC/LOW FREQUENCY

NVLAP Code: 20/E02
AC Current

Range	*Best Uncertainty (±) in ppm* note 1 *Frequency in Hz*			
	10	*20*	*40*	*400 to 10 k*
10 mA	270	199	127	116
20 mA	270	199	127	116
30 mA	270	199	127	116
50 mA	286	208	141	130
100 mA	270	199	127	116

2006-04-01 through 2007-03-31

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For the National Institute of Standards and Technology

CALIBRATION LABORATORIES **NVLAP LAB CODE 105014-0**

200 mA		270		199	127		116
300 mA		270		199	127		116
500 mA		270		208	141		130
	10	***20***	***40***	***400 to 5 k***	***10 k***		
1A	270	199	127	116	130		
	10	***20***	***40***	***400 to 10 k***			
2A	271	200	129	118			
3A	271	200	129	118			
	10	***20***	***40***	***400 to 5 k***	***10 k***		
5A	286	209	142	132	148		
	10	***20***	***40***	***400***	***1 k***	***5 k***	***10 k***
10A	273	233	132	121	121	143	143
							400 to 10 k
20A							144

NVLAP Code: 20/E05
DC Current

Range	***Best Uncertainty (±) in ppm*** [note 1]
10 nA	2.9
100 nA	2.3
1 µA	2.0
10 µA	2.0
100 µA	2.0
1 mA	1.9
10 mA	1.9
100 mA	1.9
1 A	10.4
10 A	10.4
30 A	20.6

2006-04-01 through 2007-03-31

Effective dates

For the National Institute of Standards and Technology

CALIBRATION LABORATORIES **NVLAP LAB CODE 105014-0**

DC Resistance

Nominal Value in Ω	*Best Uncertainty (±) in ppm* [note 1]	*Remarks*
100 μ	8.20	Automated DC Resistance Calibration System
1 m	5.50	Automated DC Resistance Calibration System
10 m	3.70	Automated DC Resistance Calibration System
100 m	2.10	Automated DC Resistance Calibration System
1	0.40	Automated DC Resistance Calibration System
10	0.40	Automated DC Resistance Calibration System
25	0.50	Automated DC Resistance Calibration System
100	0.50	Automated DC Resistance Calibration System
1 k	0.50	Automated DC Resistance Calibration System
10 k	0.50	Automated DC Resistance Calibration System
100 k	1.50	Automated DC Resistance Calibration System
1 M	2.30	Automated DC Resistance Calibration System
10 M	3.30	Automated DC Resistance Calibration System
100 M	4.00	Automated DC Resistance Calibration System

NVLAP Code: 20/E06
DC Voltage

Range	*Best Uncertainty (±) in ppm* [notes 1,2]	*Remarks*
1.018 V	0.80	Automated DC Calibration System
10.00 V	0.20	Automated DC Calibration System
1.000 V	0.80	Automated DC Calibration System
1 mV to 100 mV	1.3 [note 6]	Ratiometric Measurement Techniques performed by voltage transfer utilizing a high precision voltage
100 mV	0.7	Ratiometric Measurement Techniques performed by voltage transfer utilizing a high precision voltage
1.0 V	0.3	Ratiometric Measurement Techniques performed by voltage transfer utilizing a high precision voltage

2006-04-01 through 2007-03-31

Effective dates

For the National Institute of Standards and Technology

CALIBRATION LABORATORIES **NVLAP LAB CODE 105014-0**

10.0 V	0.3	Ratiometric Measurement Techniques performed by voltage transfer utilizing a high precision voltage
20.0 V	0.5	Ratiometric Measurement Techniques performed by voltage transfer utilizing a high precision voltage
100.0 V	0.3	Ratiometric Measurement Techniques performed by voltage transfer utilizing a high precision voltage
1000.0 V	0.7	Ratiometric Measurement Techniques performed by voltage transfer utilizing a high precision voltage

NVLAP Code: 20/E09
LF AC Voltage

Best Uncertainty (±) in ppm [notes 1,3,4]
Frequency in Hz

Range	*10*	*20*	*40*	*100*	*1k*	*10k*	*20k*	*50k*	*100k*	*300k*	*500k*	*800k*	*1M*
2 mV	448	912	889	969	379	865	1073	405	1131	1265	2116	2595	2938
10 mV	119	230	102	177	245	169	180	220	343	243	676	425	488
20 mV	83	70	67	67	66	76	76	165	261	361	521	372	442
30 mV	134	111	80	78	62	63	71	133	219	345	535	688	791
100 mV	36	72	23	42	34	35	34	43	77	169	220	287	225
190 mV	36	31	22	20	21	26	21	42	80	136	124	264	215
300 mV	46	61	30	32	34	19	28	36	59	116	143	189	205
1 V	120	36	18	10	13	12	11	25	14	87	102	104	98
1.9 V	36	22	22	9	9	9	8	18	11	94	101	85	89
3 V	26	34	25	17	14	14	13	27	14	100	108	95	97
10 V	20	42	19	10	10	9	10	11	16	80	100	111	100
19 V	26	23	20	11	9	9	10	11	16	98	109	82	82
30 V	30	37	26	19	15	16	19	37	44	118			
100 V	140	46	20	16	15	19	11	40	22				
190 V	47	27	20	20	13	13	13	41	26				
300 V			37	29	18	27	22	29	46				
500 V			33	25	17	20	19	38	52				

2006-04-01 through 2007-03-31

Effective dates

For the National Institute of Standards and Technology

700 V	29	23	18	17	19	44	54
1000 V	22	23	21	19	22		

TIME AND FREQUENCY

NVLAP Code: 20/F01
Frequency Dissemination

Range	*Best Uncertainty (±)* [note 1]	*Remarks*
10 MHz	1.2×10^{-12}	GPS Receiver

MECHANICAL

NVLAP Code: 20/M05
Flow Rate

Nominal Flow Rate	*Best Uncertainty (±) in percent* [notes 1, 5]
(0.8 to 30) L/s	0.3
(0.1 to 800) mL/s	0.4
(0.006 to 0.1) mL/s	0.7

NVLAP Code: 20/M06
Force

Nominal Force in lb	*Best Uncertainty (±)* [note 1]	*Remarks*
2 to 200	0.025 %	Dead Weight
> 200 to 300	0.086 lb	Proving Ring
> 300 to 500	0.14 lb	Proving Ring
> 500 to 1000	0.28 lb	Proving Ring
> 1000 to 2000	0.55 lb	Proving Ring
> 2000 to 5000	0.84 lb	Proving Ring
> 5000 to 10 000	1.7 lb	Proving Ring
> 10 000 to 20 000	5.5 lb	Proving Ring
> 20 000 to 35 000	5.8 lb	Proving Ring
> 35 000 to 50 000	13 lb	Proving Ring

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Effective dates

For the National Institute of Standards and Technology

CALIBRATION LABORATORIES **NVLAP LAB CODE 105014-0**

> 50 000 to 60 000	16 lb	Proving Ring
> 60 000 to 100 000	26 lb	Proving Ring
> 100 000 to 300 000	113 lb	Proving Ring

NVLAP Code: 20/M08
Mass

Range	*Best Uncertainty (±) in mg* [notes 1,2]	*Remarks*
10 kg	2.3	Echelon I
5 kg	0.93	Echelon I
3 kg	0.65	Echelon I
2 kg	0.43	Echelon I
1 kg	0.052	Echelon I
500 g	0.043	Echelon I
300 g	0.041	Echelon I
200 g	0.034	Echelon I
100 g	0.020	Echelon I
50 g	0.013	Echelon I
30 g	0.013	Echelon I
20 g	0.0095	Echelon I
10 g	0.0073	Echelon I
5 g	0.0048	Echelon I
3 g	0.0038	Echelon I
2 g	0.0029	Echelon I
1 g	0.0030	Echelon I
500 mg	0.0017	Echelon I
300 mg	0.0013	Echelon I
200 mg	0.0010	Echelon I
100 mg	0.0009	Echelon I
50 mg	0.0007	Echelon I
30 mg	0.0007	Echelon I
20 mg	0.0005	Echelon I
10 mg	0.0005	Echelon I
5 mg	0.0006	Echelon I
3 mg	0.0006	Echelon I

2006-04-01 through 2007-03-31

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CALIBRATION LABORATORIES **NVLAP LAB CODE 105014-0**

2 mg	0.0005	Echelon I
1 mg	0.0005	Echelon I
30 kg	56	Echelon II
20 kg	22	Echelon II

THERMODYNAMIC

NVLAP Code: 20/T05
Pressure

Range	*Best Uncertainty (±) in ppm* [note 1]	*Remarks*
> 1.5 to 50	20	Gas
> 50 to 1450	45	Gas
> 1450 to 16 000	90	Gas
> 1000 to 10 000	60	Oil
> 10 000 to 30 000	110	Oil
> 30 000 to 50 000	210	Oil

1. Represents an expanded uncertainty using a coverage factor, k = 2, at an approximate level of confidence of 95 %.
2. Approximate value. Actual value determined by the test statistics.
3. All ACV measurements performed via AC/DC transfer system.
4. Uncertainties listed are representative of the laboratory's accredited capabilities within the stated ranges. Accreditation is not limited to only those fixed values shown.
5. Dependent upon principle of operation of device being calibrated and its performance relative to standards at the time of the test.
6. The equation: uncert. = $(A + B/mVDC^2)^{0.5}$ (where A = 0.16 and B = 0.013333) is provided in order for potential customers to calculate approximate uncertainties for values down to 1 mV. Example: uncertainty at 1 mVDC would calculate to approximately ±115.47 ppm.
7. The laboratory maintains Echelon II capability for ranges 20 kg to 1 mg and separate Echelon III for all ranges.
8. Avoirdupois mass calibration services are available by comparison to equivalent metric standards. Uncertainties may be appropriately larger.

2006-04-01 through 2007-03-31

Effective dates

For the National Institute of Standards and Technology

GEOVision Borehole Geophysics depth wheel verification

Performed by Robert Steller on September 23, 2006

	Depth reading in #1	Depth reading out	Depth reading in #2
Depth wheel S/N 101 500 pulse/revolution Circumference = 983mm (3225.07 millifeet)	100.1 feet (30.51 m)	99.95 feet (30.46 m)	100.05 feet (30.50 m)
Depth wheel S/N 102 500 pulse/revolution Circumference = 994mm (3261.15 millifeet)	100.00 feet (30.48) m	100.05 feet (30.50 m)	100.00 feet (30.48) m
Aries winch 200 pulse/revolution Circumference = 305.9mm (1003.51 millifeet)	100.05 feet (30.50) m	100.05 feet (30.50 m)	100.00 feet (30.48) m
Depth wheel S/N 103 500 pulse/revolution Circumference = 1000mm (3.281 feet)			
Comprobe winch 500 pulse/revolution Circumference = 1000mm (3.281 feet)			

All measurements taken with a Stanley 100ft flexible stainless steel tape model number 34-130, and a Keeson 300 foot fiberglass tape, both marked in feet, inches and 1/8ths of inches. Enough cable was spooled off of the winch to allow the cable and tape measures to be laid flat on the parking lot surface side-by-side. A permanent marker was used to mark a 100.0 foot interval on the cable, and the marks were also tagged with electrical tape for visibility. The cable was then spooled back onto the winch. When the first mark was at the top of the measuring wheel, a matching permanent mark was placed, and the recording system (Robertson Micrologger) was set to 0.0 feet depth. The cable was spooled in to the second mark, and the distance was recorded. The recording system was set to 0.0 feet again, and the cable spooled out to the first mark again, and the distance was recorded. The process was repeated one more time to spool the cable back onto the winch, and the distance was recorded.

Estimated accuracy is of these measurements is +/- 0.1 foot or +/- 0.03m.

GEOVision Suspension PS probe Receiver 1–Receiver 2 (R1-R2) spacing verification

Performed by Robert Steller on September 23, 2006

	R2 center to R1 center hanging dry	R2 center to R1 center hanging submerged	R1 bottom to source center hanging submerged with 1m isolation tube S/N 280068
Receiver S/N 30086	40.2in 1.02m	40.0in 1.02m	76.0in 1.93m
Receiver S/N 20042	39.8in 1.01m	39.6in 1.01m	75.7in 1.92m
Receiver S/N 12008	40.2in 1.02m	40.0in 1.02m	76.0in 1.93m

All measurements taken with a Lufkin 3.7m flexible steel tape model number HV1034DM, marked in mm and 100th of feet. Probe suspended in 3-inch diameter clear PVC pipe, using chain clamp placed between bottom and center of Receiver 2 hard section (See Figure). Probe "bounced" to establish unrestricted hanging length before measurement. Probe allowed to relax for 5 minutes prior to each measurement. Water level set to submerge bottom of Receiver 2 hard section.. Estimated accuracy due to hysterisis in rubber section approximately +/- 0.01' or +/- 0.003m.

TEST NUMBER
506737

EDISON ESI®
A SOUTHERN CALIFORNIA EDISON® Company

Calibration Report

METROLOGY
7300 Fenwick Lane
Westminster, CA 92683
866-723-2257
edisonmetrology.com

GEOVision Geophysical Services
1151 Pomona Road, Unit P
Corona, CA 92882
P.O. No.: 6303-060815-01

Manufacturer:	Oyo
Model Number:	03331-0000
Description:	Seismograph,
Asset Number:	15014
Serial Number:	15014

Calibration Date:	08/16/2006
Calibration Due Date:	08/16/2007
Calibration Interval:	12 Months
Condition As Found:	In Tolerance
Condition As Left:	In Tolerance

Remarks:
The UUT (unit under test) was calibrated using the customer's procedure. The UUT was operated by the customer's personnel and data collection was observed by SCE personnel. The UUT was found to be in tolerance to customer supplied specifications. The reference standards used are in compliance with ISO/IEC 17025:1999 and laboratory accreditation criteria established by NIST/NVLAP under the specific scope of accreditation for lab code 105014-0. Frequency is accredited.
Please see attached data.

Standards Utilized

I.D. No.	Mfg.	Model No.	Description	Cal. Date	Due Date
S1-01252	Hewlett Packard	5335A OPT 010,203040	Counter, Universal,	06/16/2006	12/16/2006
S1-03079	Hewlett Packard	3325B	Generator, Function,	04/04/2006	04/04/2007
S1-03686	Fluke	910	Standard, Frequency, Controlled, Gps	01/16/2006	01/16/2007

Procedure:	Customer
Temperature:	23° C
Humidity:	47% RH
Test No.:	506737

Calibration Performed By:			Quality Reviewer:	
Cordero, Denise M	Metrologist	714-895-0714		8/16/2006
Name	Title	Phone	Name	Date

This report may not be reproduced, except in full, without written permission of this laboratory. This report may not be used to claim product endorsement by NVLAP or any agency of the US Government. The results stated in this report relate only to the items tested or calibrated. Measurements reported herein are traceable to SI units via national standards maintained by NIST and were performed in compliance with MIL-STD-45662A, ANSI/NCSL Z540-1-1994, 10CFR50, Appendix B, and ISO 9002-94.

GEOVision
geophysical services

SEISMOGRAPH CALIBRATION DATA SHEET REV 4/6/06

INSTRUMENT DATA

SYSTEM MFR:	OYO	MODEL NO.:	3331
SERIAL NO.:	15014	CALIBRATION DATE:	8/16/2006
BY:	ROBERT STELLER	DUE DATE: 8/16/2007	8/16/2007
COUNTER MFR	HEWLETT PACKARD	MODEL NO.:	5335A
SERIAL NO.:	2626A09881	CALIBRATION DATE:	6/16/2006
BY:	SCE #S1-01252	DUE DATE:	12/16/2006
FCTN GEN MFR	HEWLETT PACKARD	MODEL NO.:	3325B
SERIAL NO.:	2847A11880	CALIBRATION DATE:	4/4/2006
BY:	SCE #S1-03073	DUE DATE:	4/4/2007

SYSTEM SETTINGS:

GAIN:	10
FILTER:	20 KHZ
RANGE:	100 MILLISEC
DELAY:	0
STACK: 1 (STD)	1
PULSE:	1.6
DISPLAY:	NA
SYSTEM: DATE = CORRECT DATE & TIME	8/16/2006, 10:38 AM

PROCEDURE:

SET FREQUENCY TO 100.0HZ SQUAREWAVE WITH AMPLITUDE APPROXIMATELY 0.25 VOLT PEAK. RECORD BOTH ON DISK AND PAPER TAPE, IF AVAILABLE. ANALYZE AND PRINT WAVEFORMS FROM ANALYSIS UTILITY. ATTACH PAPER COPIES OF PRINTOUT AND PAPER TAPES, IF AVAILABLE, TO THIS FORM. AVERAGE FREQUENCY MUST BE BETWEEN 99.0 AND 101.0 HZ.

AS FOUND 100.0 AS LEFT 100.0

WAVEFORM	FILE NO	FREQUENCY	TIME FOR 9 CYCLES Hn	TIME FOR 9 CYCLES Hr	TIME FOR 9 CYCLES V	AVERAGE FREQ.
SQUARE	501	100.0	90.0	90.0	90.0	100.0
SQUARE	502	100.0	90.0	90.0	90.0	100.0
SINE	503	100.0	90.0	90.0	90.0	100.0
SINE	504	100.0	90.0	90.0	90.0	100.0

CALIBRATED BY: ROBERT STELLER 8/16/2006 Robt Steller

NAME DATE SIGNATURE

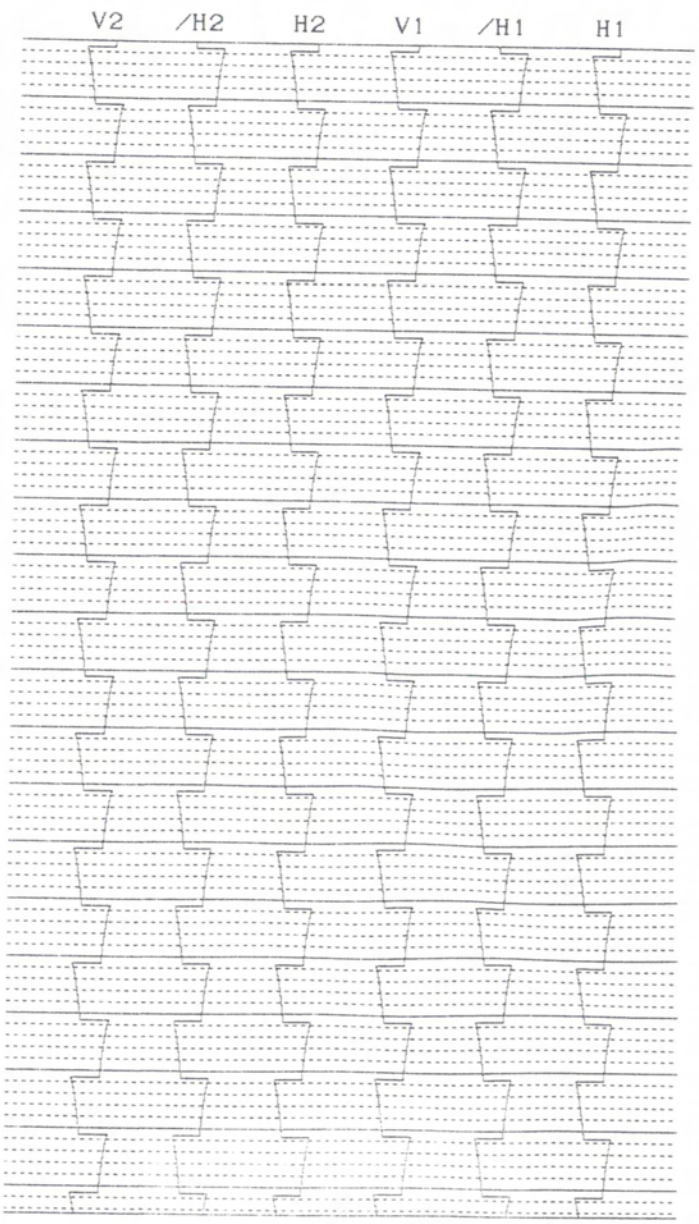
OYO S/N 15014

Suspension 170 1.42

ID_NO. : 501
HOLE NO. : 0
DEPTH : 0.0 [m]
DATE : 16/08/06 10:44:56 AM
H-SAMPLE RATE: 100 [μSEC]
V-SAMPLE RATE: 100 [μSEC]
PULSE WIDTH : 1.6 [mSEC]
DELAY TIME : 0 [mSEC]

	H1	/H1	V1	H2	/H2	V2
GAIN	X 10	X 10	X 10	X 10	X 10	X 10
LCF[Hz]	5	5	5	5	5	5
HCF[Hz]	20K	20K	20K	20K	20K	20K
STACK	1	1	1	1	1	1

TRACE SIZE : 1
H-TIME SCALE: 1.00 [mSEC/LINE]
V-TIME SCALE: 1.00 [mSEC/LINE]



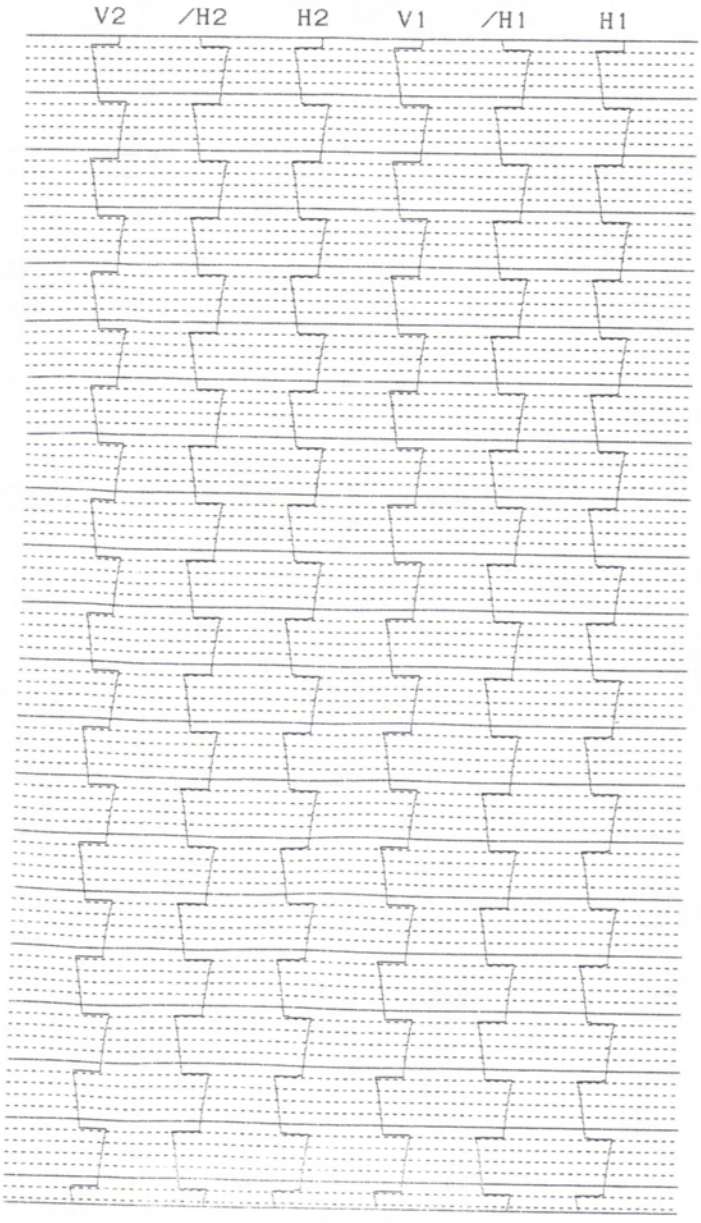
OYO S/N 15014

Suspension 170 1.42

ID_NO. : 502
HOLE NO. : 0
DEPTH : 0.0 [m]
DATE : 16/08/06 10:45:55 AM
H-SAMPLE RATE: 100 [μSEC]
V-SAMPLE RATE: 100 [μSEC]
PULSE WIDTH : 1.6 [mSEC]
DELAY TIME : 0 [mSEC]

	H1	/H1	V1	H2	/H2	V2
GAIN	X 10	X 10	X 10	X 10	X 10	X 10
LCF[Hz]	5	5	5	5	5	5
HCF[Hz]	20K	20K	20K	20K	20K	20K
STACK	1	1	1	1	1	1

TRACE SIZE : 1
H-TIME SCALE: 1.00 [mSEC/LINE]
V-TIME SCALE: 1.00 [mSEC/LINE]



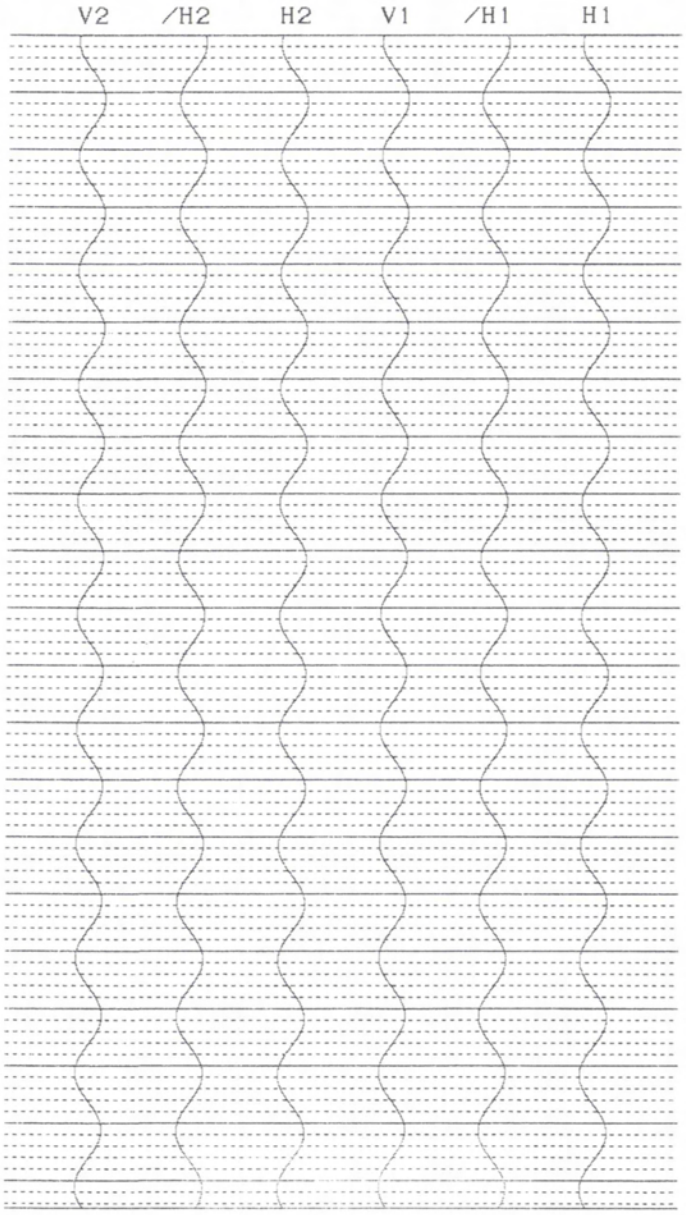
OYO

Suspension 170 1.42 S/N 15014

ID_NO. : 503
HOLE NO. : 0
DEPTH : 0.0 [m]
DATE : 16/08/06 10:46:52 AM
H-SAMPLE RATE: 100 [μSEC]
V-SAMPLE RATE: 100 [μSEC]
PULSE WIDTH : 1.6 [mSEC]
DELAY TIME : 0 [mSEC]

	H1	/H1	V1	H2	/H2	V2
GAIN	X 10	X 10	X 10	X 10	X 10	X 10
LCF[Hz]	5	5	5	5	5	5
HCF[Hz]	20K	20K	20K	20K	20K	20K
STACK	1	1	1	1	1	1

TRACE SIZE : 1
H-TIME SCALE: 1.00 [mSEC/LINE]
V-TIME SCALE: 1.00 [mSEC/LINE]



P243 # 504

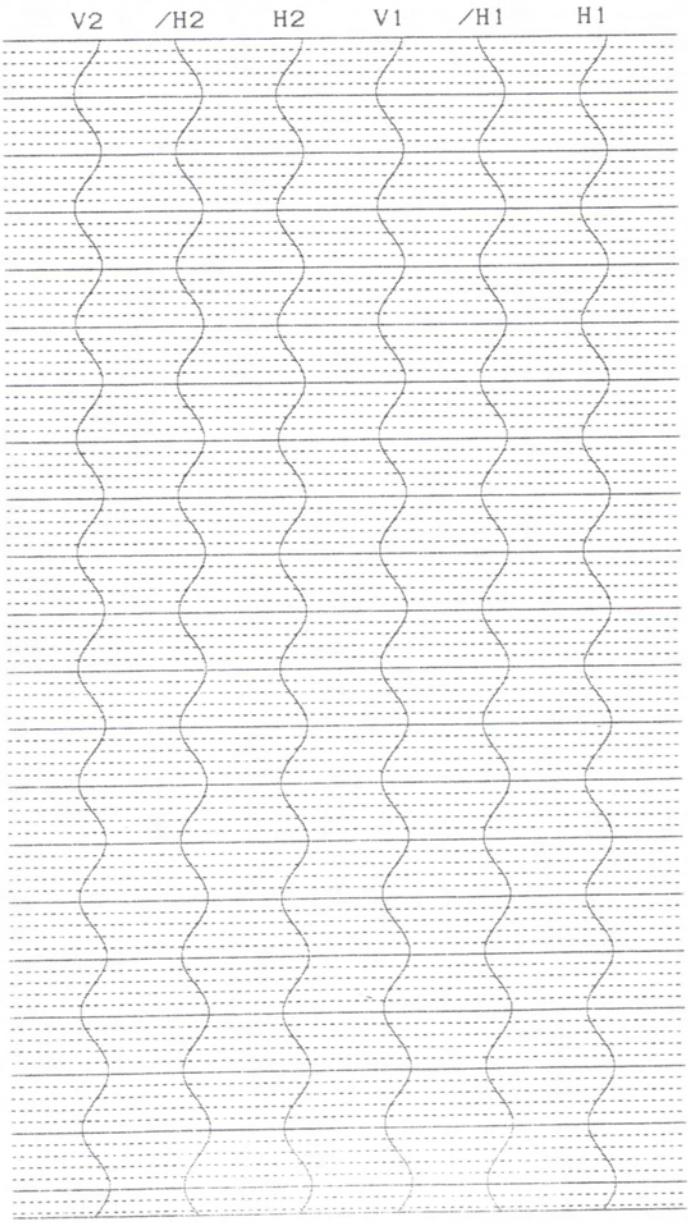
OYO S/N 15014

Suspension 170 1.42

ID_NO. : 504
HOLE NO. : 0
DEPTH : 0.0 [m]
DATE : 16/08/06 10:47:45 AM
H-SAMPLE RATE: 100 [μSEC]
V-SAMPLE RATE: 100 [μSEC]
PULSE WIDTH : 1.6 [mSEC]
DELAY TIME : 0 [mSEC]

	H1	/H1	V1	H2	/H2	V2
GAIN	X 10	X 10	X 10	X 10	X 10	X 10
LCF[Hz]	5	5	5	5	5	5
HCF[Hz]	20K	20K	20K	20K	20K	20K
STACK	1	1	1	1	1	1

TRACE SIZE : 1
H-TIME SCALE: 1.00 [mSEC/LINE]
V-TIME SCALE: 1.00 [mSEC/LINE]



EDISON ESI®

A SOUTHERN CALIFORNIA EDISON® Company

TEST NUMBER 501206

Calibration Report

METROLOGY
7300 Fenwick Lane
Westminster, CA 92683
866-723-2257
edisonmetrology.com

GEOVision Geophysical Services
1151 Pomona Road, Unit P
Corona, CA 92882
P.O. No.: 6162-060414-01

Manufacturer:	Oyo Corporation
Model Number:	3331-A
Description:	Logger, Suspension,
Asset Number:	19029
Serial Number:	19029

Calibration Date:	04/21/2006
Calibration Due Date:	04/21/2007
Calibration Interval:	12 Months
Condition As Found:	In Tolerance
Condition As Left:	In Tolerance

Remarks:
The UUT (unit under test) was calibrated using the customer's procedure. The UUT was operated by the customer's personnel and data collection was observed by SCE personnel. The UUT was found to be in tolerance to customer supplied specifications. The reference standards used are in compliance with ISO/IEC 17025:1999 and laboratory accreditation criteria established by NIST/NVLAP under the specific scope of accreditation for lab code 105014-0. Frequency is accredited.
Please see attached data.

Standards Utilized

I.D. No.	Mfg.	Model No.	Description	Cal. Date	Due Date
S1-01252	Hewlett Packard	5335A OPT 010,203040	Counter, Universal	12/09/2005	06/09/2006
S1-03355	Hewlett Packard	3325B OPT 001, 002	Generator, Function, Synthesizer	11/03/2005	11/03/2006
S1-03686	Fluke	910	Standard, Frequency, Controlled, Gps	01/16/2006	01/16/2007

Procedure: Customer
Temperature: 23° C
Humidity: 40% RH
Test No.: 501206

Calibration Performed By:			Quality Reviewer:	
Branson, Craig A CAB	Metrologist	714-895-0714	Marty J	04-21-06
Name	Title	Phone	Name	Date

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GEOVision
geophysical services

SEISMOGRAPH CALIBRATION DATA SHEET REV 4/6/06

INSTRUMENT DATA

SYSTEM MFR:	OYO	MODEL NO.:	3331A
SERIAL NO.:	19029	CALIBRATION DATE:	4/21/2006
BY:	ROBERT STELLER	DUE DATE:	4/21/2007
COUNTER MFR:	HEWLETT PACKARD	MODEL NO.:	5335A
SERIAL NO.:	2626A09881	CALIBRATION DATE:	12/9/2005
BY:	SCE #S1-01252	DUE DATE:	6/9/2006
FCTN GEN MFR:	HEWLETT PACKARD	MODEL NO.:	3325B
SERIAL NO.:	2847A14447	CALIBRATION DATE:	11/3/2005
BY:	SCE #S1-03355	DUE DATE:	11/3/2006

SYSTEM SETTINGS:

GAIN:	10
FILTER:	20 KHZ
RANGE:	100 MILLISEC
DELAY:	0
STACK: 1 (STD)	1
PULSE:	1.6
DISPLAY:	NA
SYSTEM: DATE = CORRECT DATE & TIME	4/21/2006, 10:30AM

PROCEDURE:

SET FREQUENCY TO 100.0HZ SQUAREWAVE WITH AMPLITUDE APPROXIMATELY 0.25 VOLT PEAK. RECORD BOTH ON DISK AND PAPER TAPE, IF AVAILABLE. ANALYZE AND PRINT WAVEFORMS FROM ANALYSIS UTILITY. ATTACH PAPER COPIES OF PRINTOUT AND PAPER TAPES, IF AVAILABLE, TO THIS FORM. AVERAGE FREQUENCY MUST BE BETWEEN 99.0 AND 101.0 HZ.

AS FOUND 100.0 AS LEFT 100.0

WAVEFORM	FILE NO	FREQUENCY	TIME FOR 9 CYCLES Hn	TIME FOR 9 CYCLES Hr	TIME FOR 9 CYCLES V	AVERAGE FREQ.
SQUARE	201	100.0	90.0	90.0	90.0	100.0
SQUARE	202	100.0	90.0	90.0	90.0	100.0
SINE	203	100.0	89.9	89.9	89.9	100.1
SINE	204	100.0	90.0	90.0	89.9	100.0

CALIBRATED BY: ROBERT STELLER 4/21/2006 Robt Steller

NAME DATE SIGNATURE

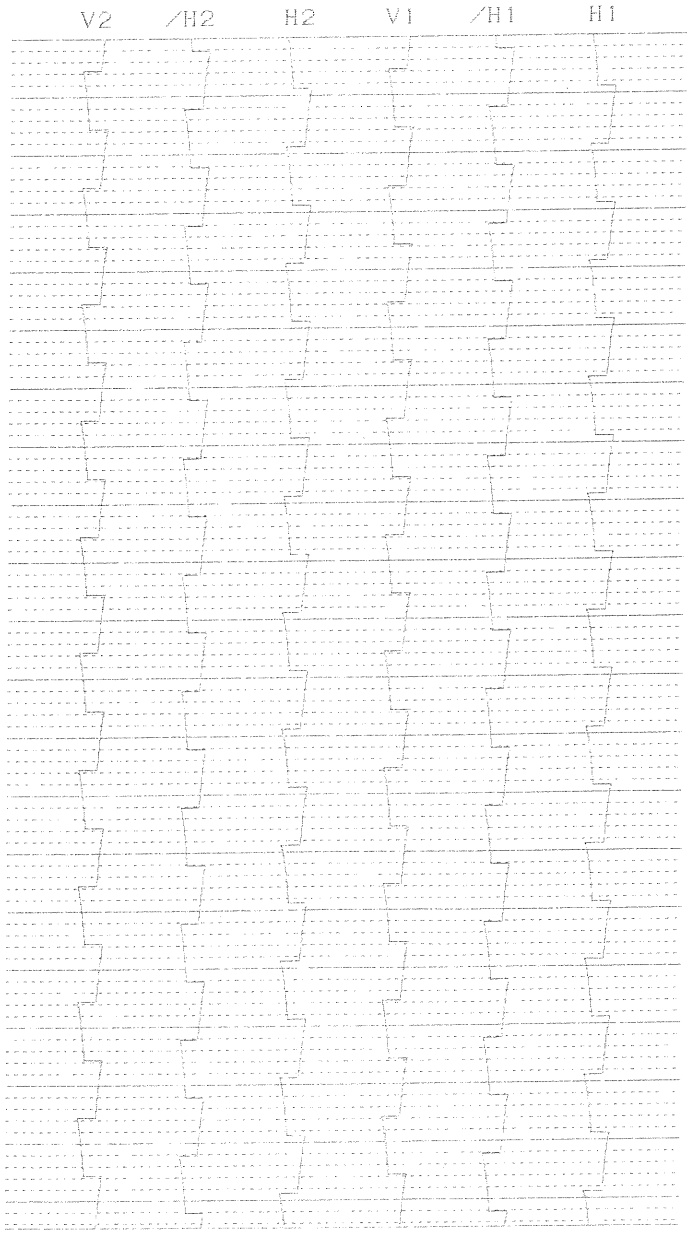
OYO S/N 19029

Suspension 170 4.25

ID_NO. : 201
HOLE NO. : 0
DEPTH : 0.0 [m]
DATE : 21/04/06 10:41:08 AM
H-SAMPLE RATE: 100 [μSEC]
V-SAMPLE RATE: 100 [μSEC]
PULSE WIDTH : 1.6 [mSEC]
DELAY TIME : 3 [mSEC]

	H1	/H1	V1	H2	/H2	V2
GAIN	X 10	X 10	X 10	X 10	X 10	X 10
LCF[Hz]	5	5	5	5	5	5
HCF[Hz]	20K	20K	20K	20K	20K	20K
STACK	1	1	1	1	1	1

TRACE SIZE : 1
H-TIME SCALE: 1.00 [mSEC/LINE]
V-TIME SCALE: 1.00 [mSEC/LINE]



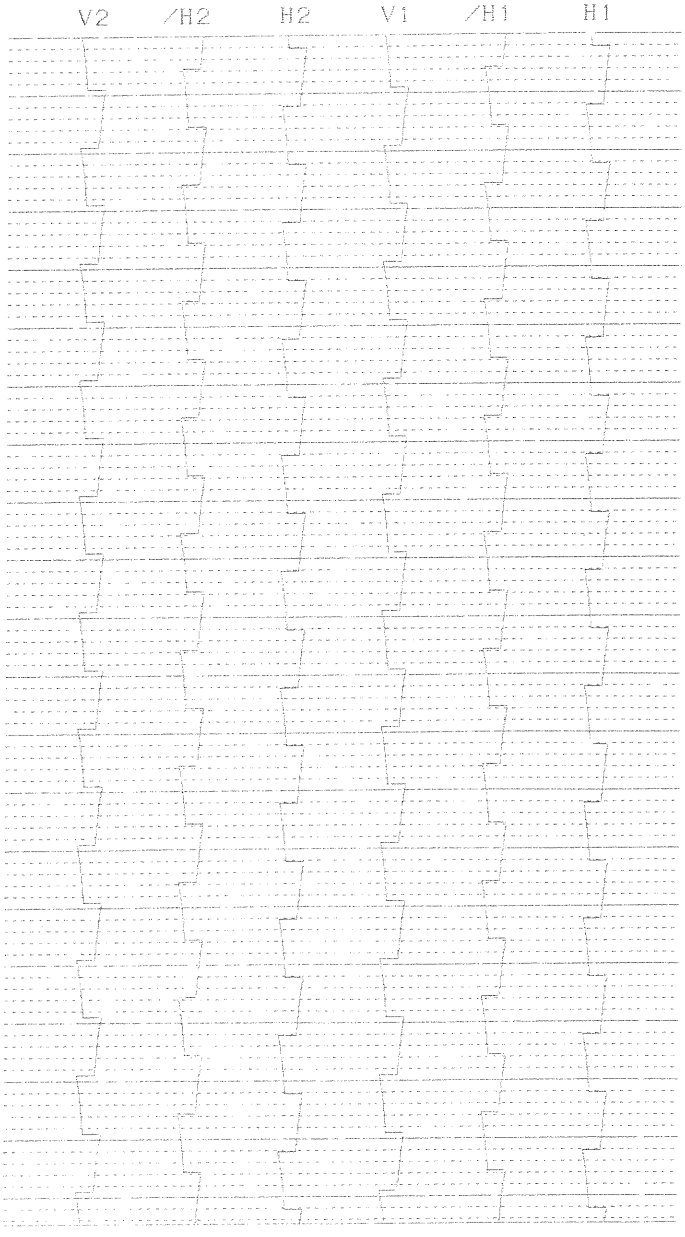
OYO S/N 19029

Suspension 170 4.25

ID_NO. : 202
HOLE NO. : 0
DEPTH : 0.0 [m]
DATE : 21/04/06 10:45:05 AM
H-SAMPLE RATE: 100 [μSEC]
V-SAMPLE RATE: 100 [μSEC]
PULSE WIDTH : 1.6 [mSEC]
DELAY TIME : 3 [mSEC]

	H1	/H1	V1	H2	/H2	V2
GAIN	X 10	X 10	X 10	X 10	X 10	X 10
LCF[Hz]	5	5	5	5	5	5
HCF[Hz]	20K	20K	20K	20K	20K	20K
STACK	1	1	1	1	1	1

TRACE SIZE : 1
H-TIME SCALE: 1.00 [mSEC/LINE]
V-TIME SCALE: 1.00 [mSEC/LINE]



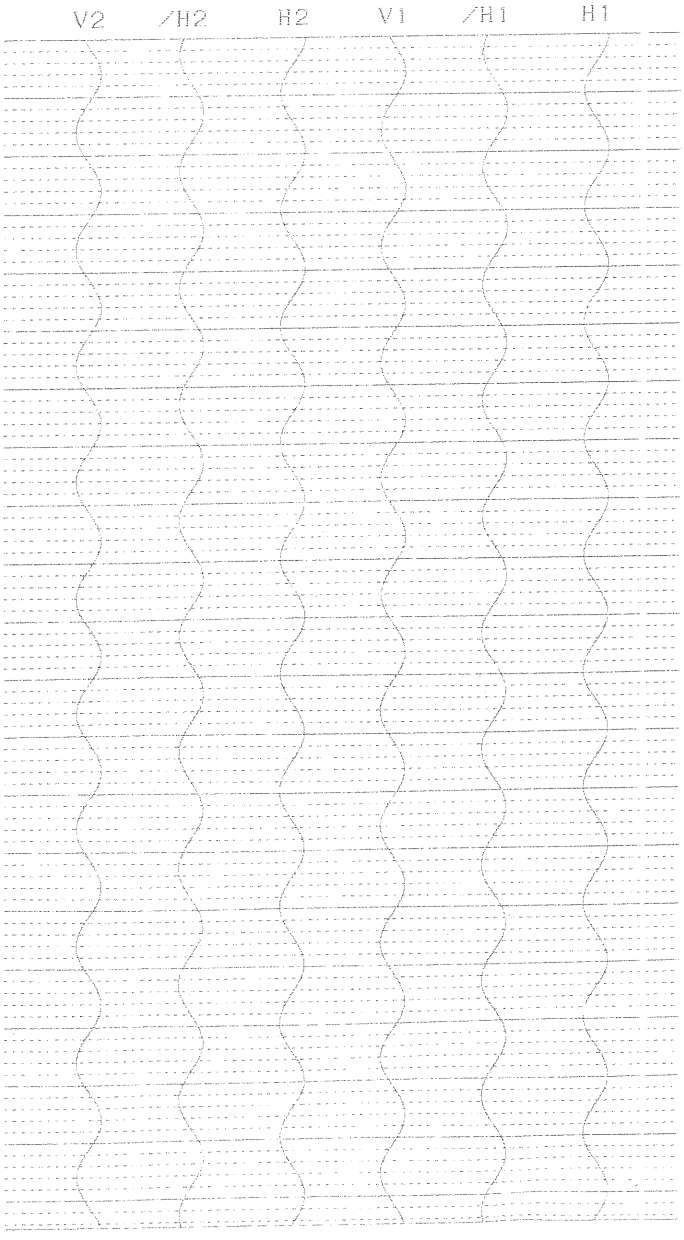
OYO S/N 19029

Suspension 170 4.25

ID_NO. : 203
HOLE NO. : 0
DEPTH : 0.0 [m]
DATE : 21/04/06 10:46:15 AM
H-SAMPLE RATE: 100 [μSEC]
V-SAMPLE RATE: 100 [μSEC]
PULSE WIDTH : 1.6 [mSEC]
DELAY TIME : 3 [mSEC]

	H1	/H1	V1	H2	/H2	V2
GAIN	X 10	X 10	X 10	X 10	X 10	X 10
LCF[Hz]	5	5	5	5	5	5
HCF[Hz]	20K	20K	20K	20K	20K	20K
STACK	1	1	1	1	1	1

TRACE SIZE : 1
H-TIME SCALE: 1.00 [mSEC/LINE]
V-TIME SCALE: 1.00 [mSEC/LINE]



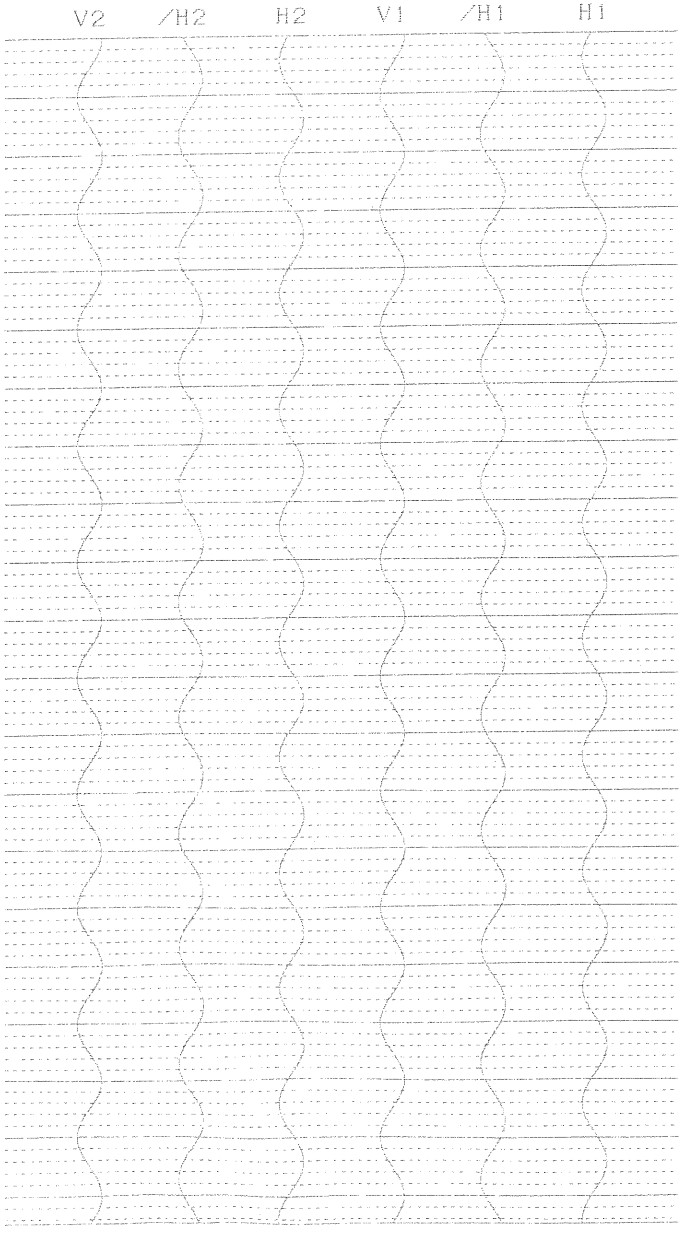
OYO S/N 19024

Suspension 170 4.25

ID_NO. : 204
HOLE NO. : 0
DEPTH : 0.0 [m]
DATE : 21/04/06 10:47:47 AM
H-SAMPLE RATE: 100 [μSEC]
V-SAMPLE RATE: 100 [μSEC]
PULSE WIDTH : 1.6 [mSEC]
DELAY TIME : 3 [mSEC]

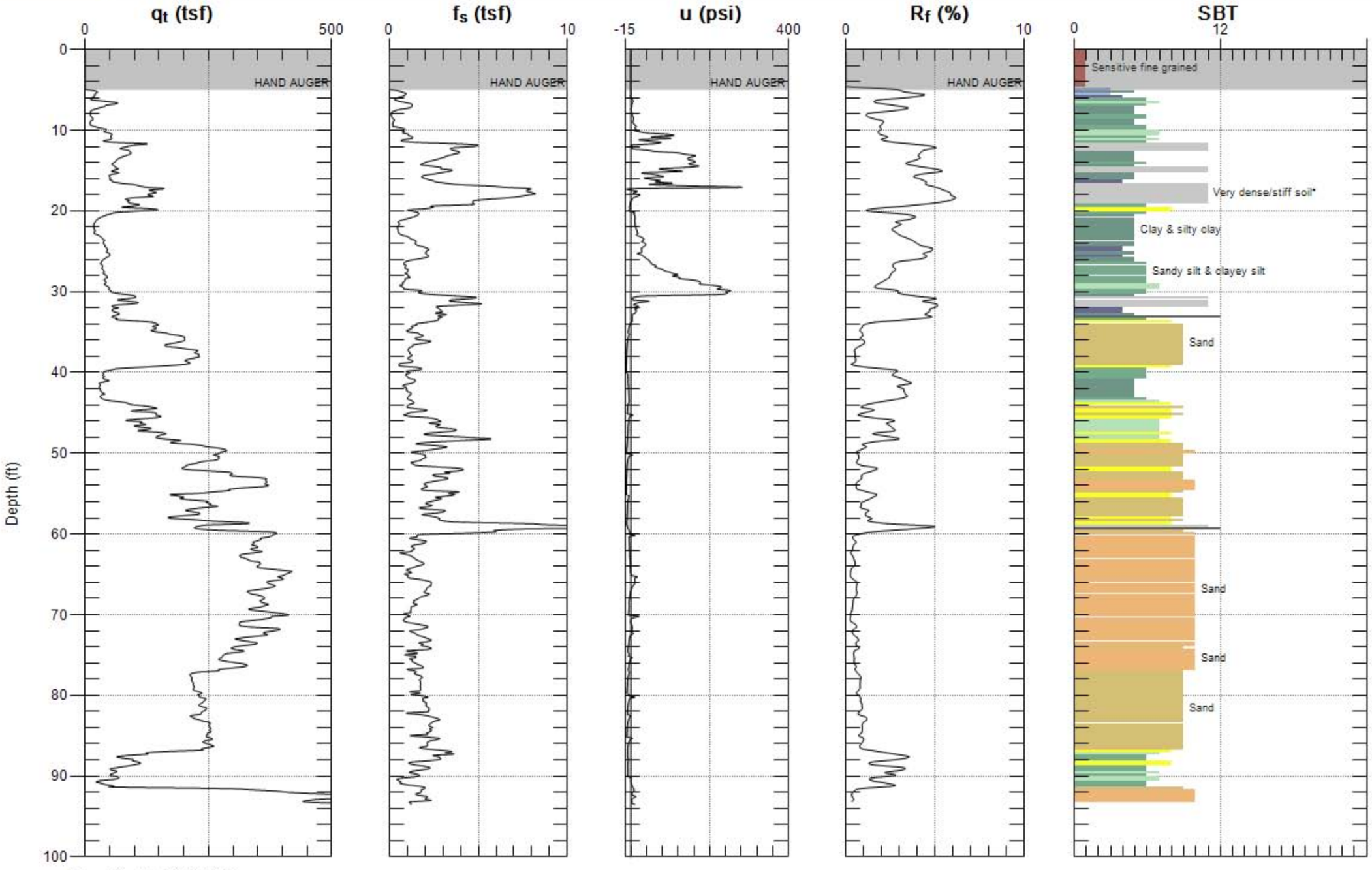
	H1	/H1	V1	H2	/H2	V2
GAIN	X 10	X 10	X 10	X 10	X 10	X 10
LCF[Hz]	5	5	5	5	5	5
HCF[Hz]	20K	20K	20K	20K	20K	20K
STACK	1	1	1	1	1	1

TRACE SIZE : 1
H-TIME SCALE: 1.00 [mSEC/LINE]
V-TIME SCALE: 1.00 [mSEC/LINE]



EARTH MECHANICS

Site: ANTIOCH BRIDGE
Engineer: J.CASTLE
Sounding: CPT-01 Seis
Date: 11/14/2006 03:09

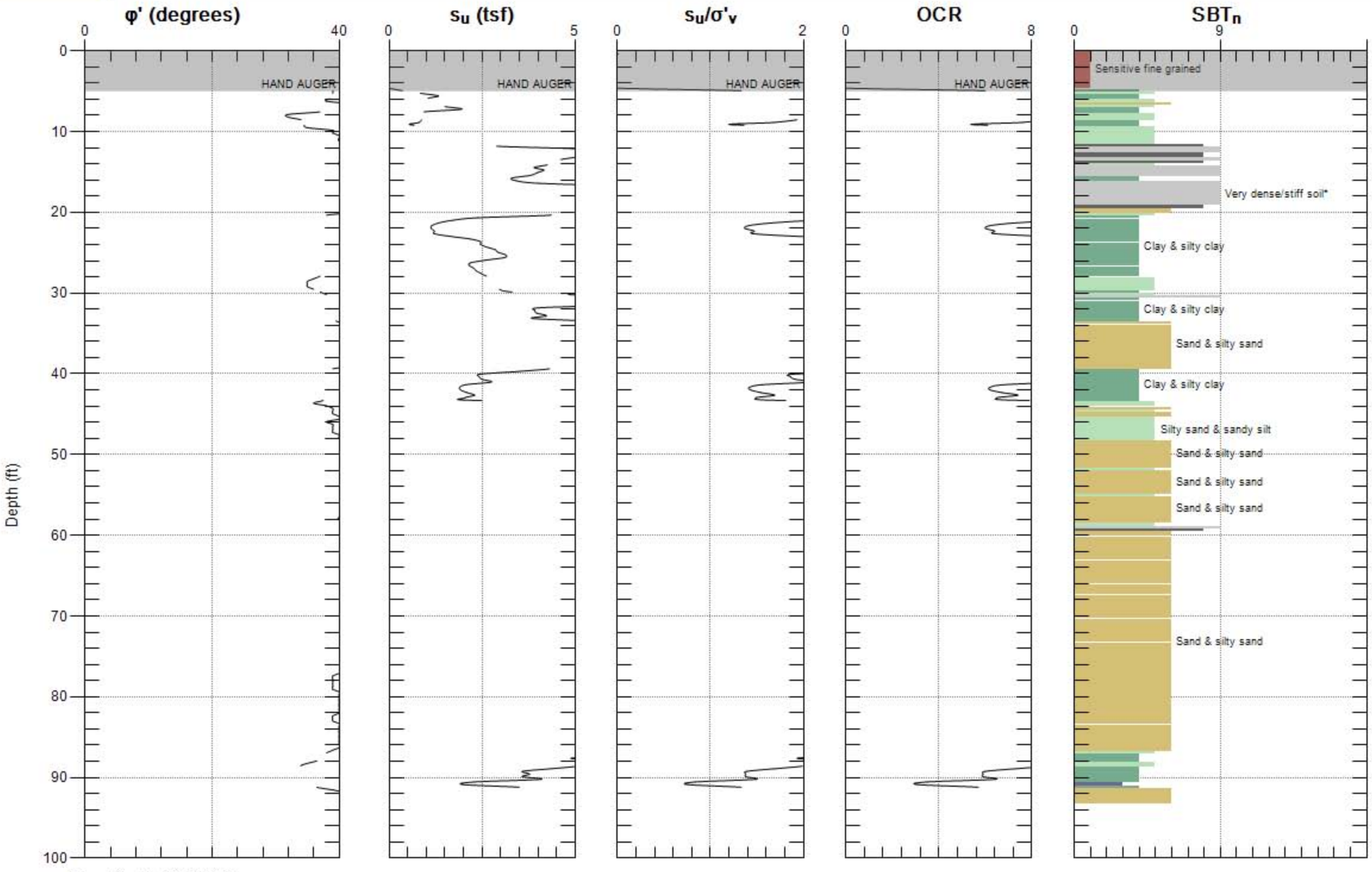


Max. Depth: 93.500 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

EARTH MECHANICS

Site: ANTIOCH BRIDGE
Sounding: CPT-01 Seis
Engineer: J.CASTLE
Date: 11/14/2006 03:09

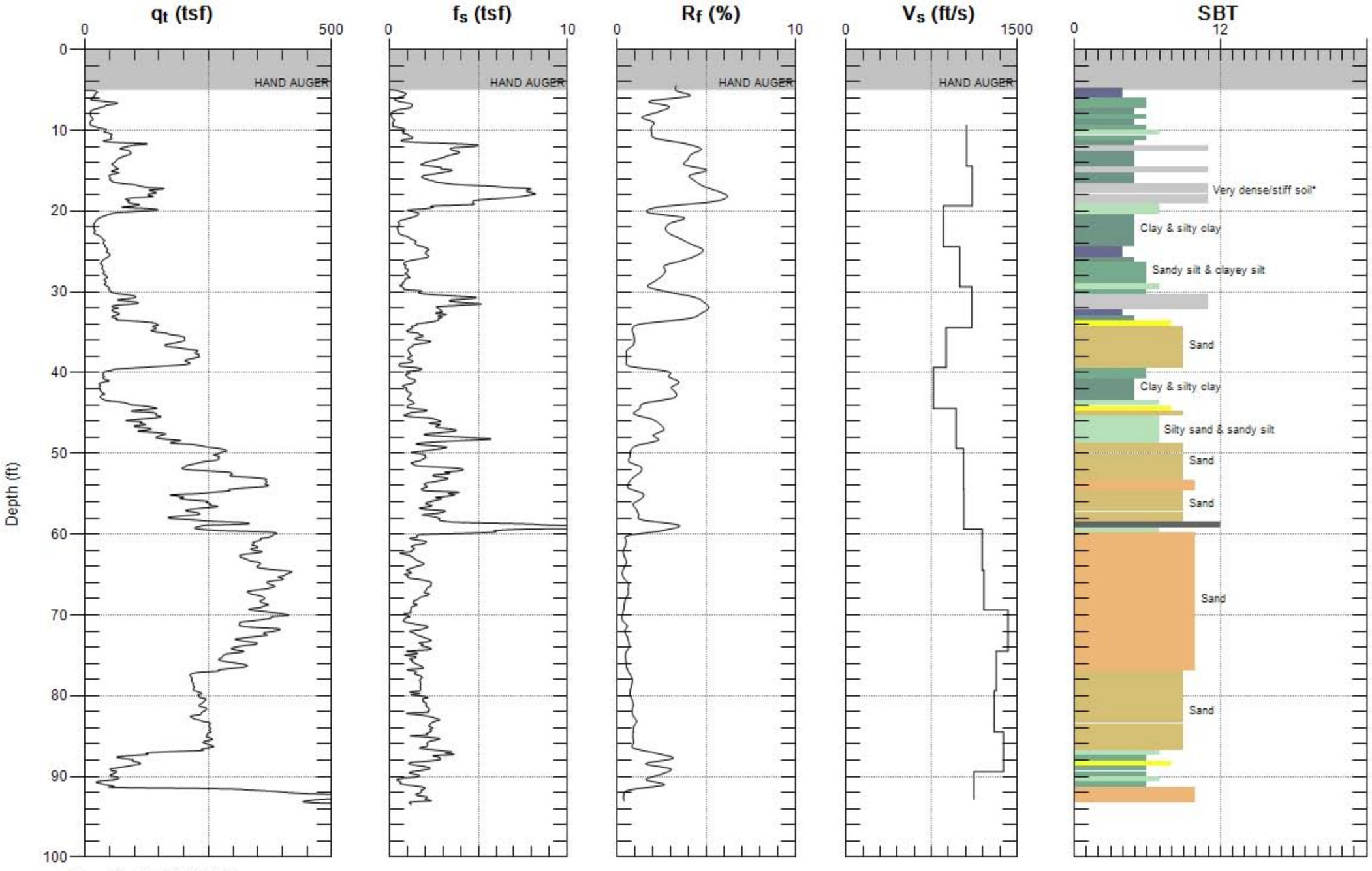


Max. Depth: 93.500 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

EARTH MECHANICS

Site: ANTIOCH BRIDGE
Sounding: CPT-01 Seis
Engineer: J.CASTLE
Date: 11/14/2006 03:09

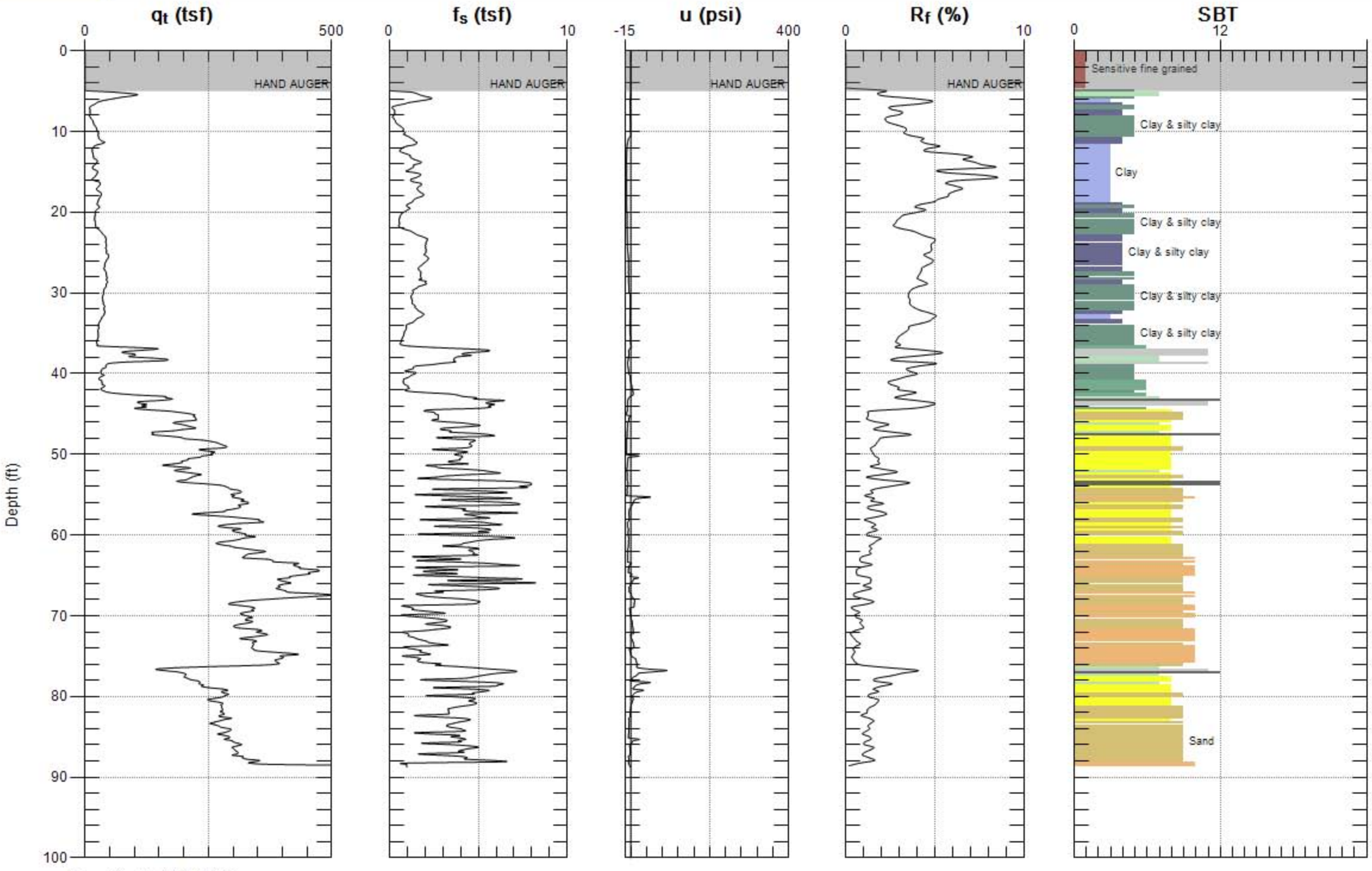


Max. Depth: 93.500 (ft)
Avg. Interval: 0.656 (ft)

SBT: Soil Behavior Type (Robertson 1990)

EARTH MECHANICS

Site: ANTIOCH BRIDGE
Sounding: CPT-02 Seis
Engineer: J.CASTLE
Date: 11/13/2006 03:59

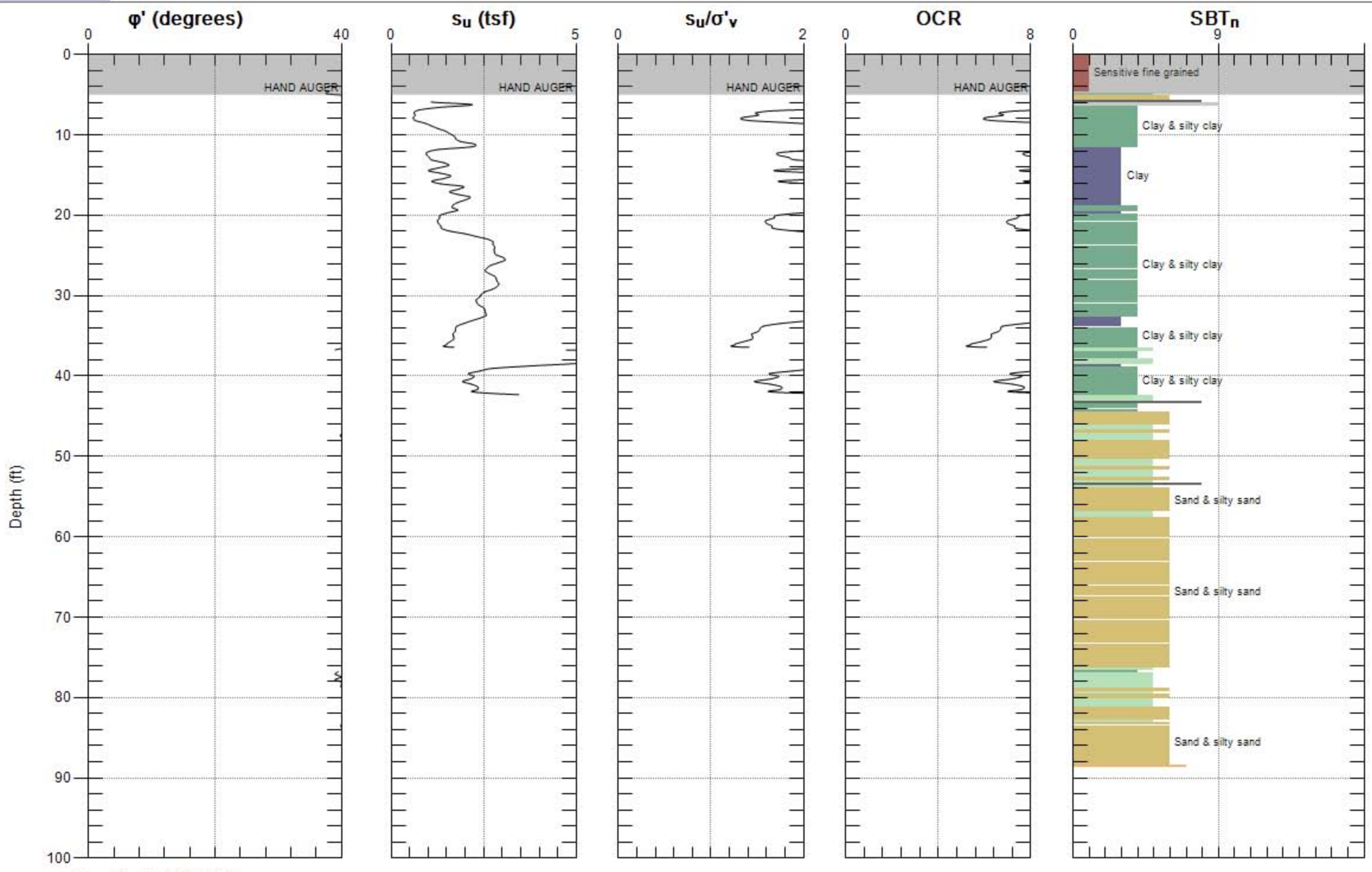


Max. Depth: 88.750 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

EARTH MECHANICS

Site: ANTIOCH BRIDGE
Sounding: CPT-02 Seis
Engineer: J.CASTLE
Date: 11/13/2006 03:59

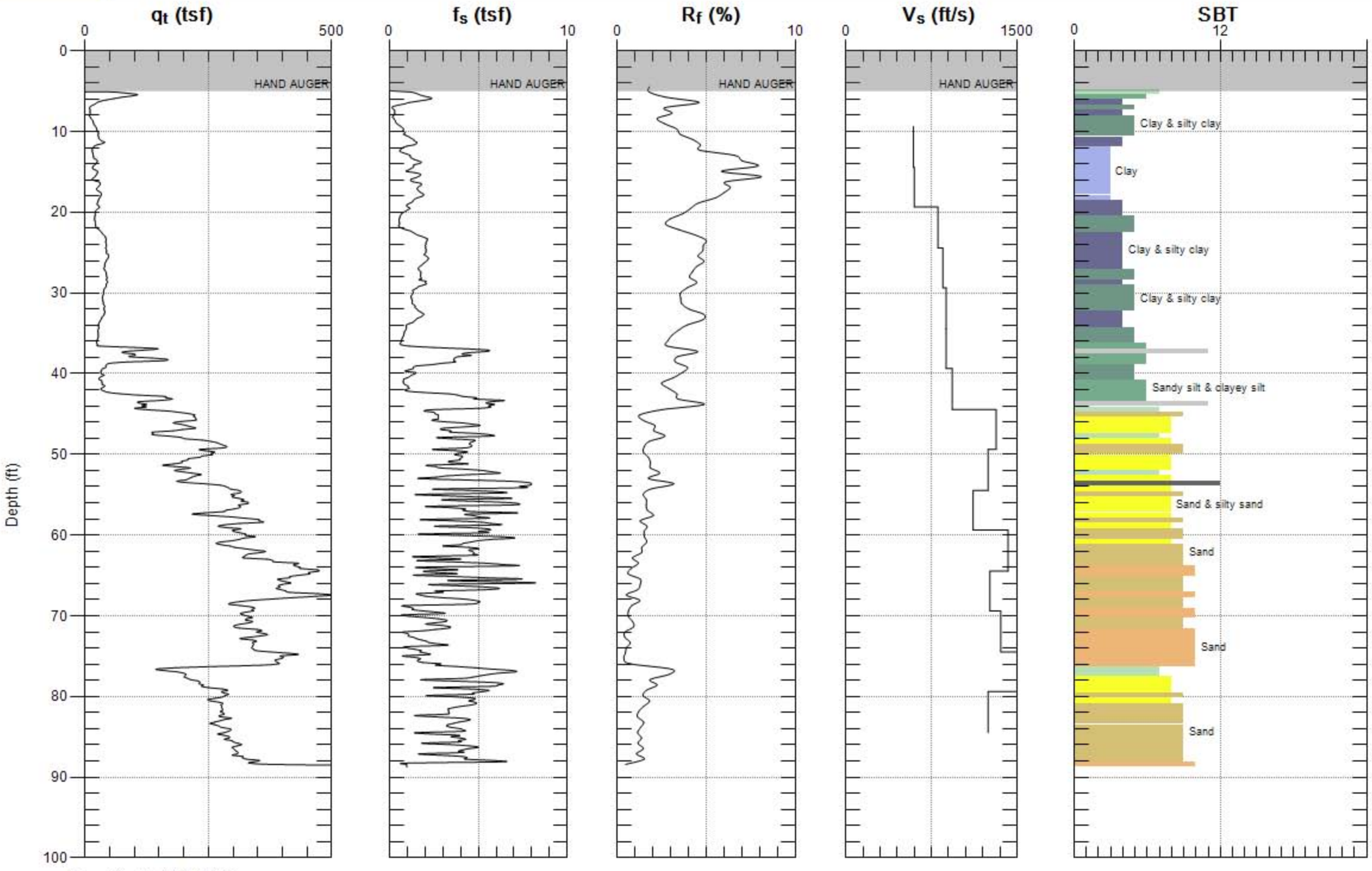


Max. Depth: 88.750 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

EARTH MECHANICS

Site: ANTIOCH BRIDGE
Sounding: CPT-02 Seis
Engineer: J.CASTLE
Date: 11/13/2006 03:59

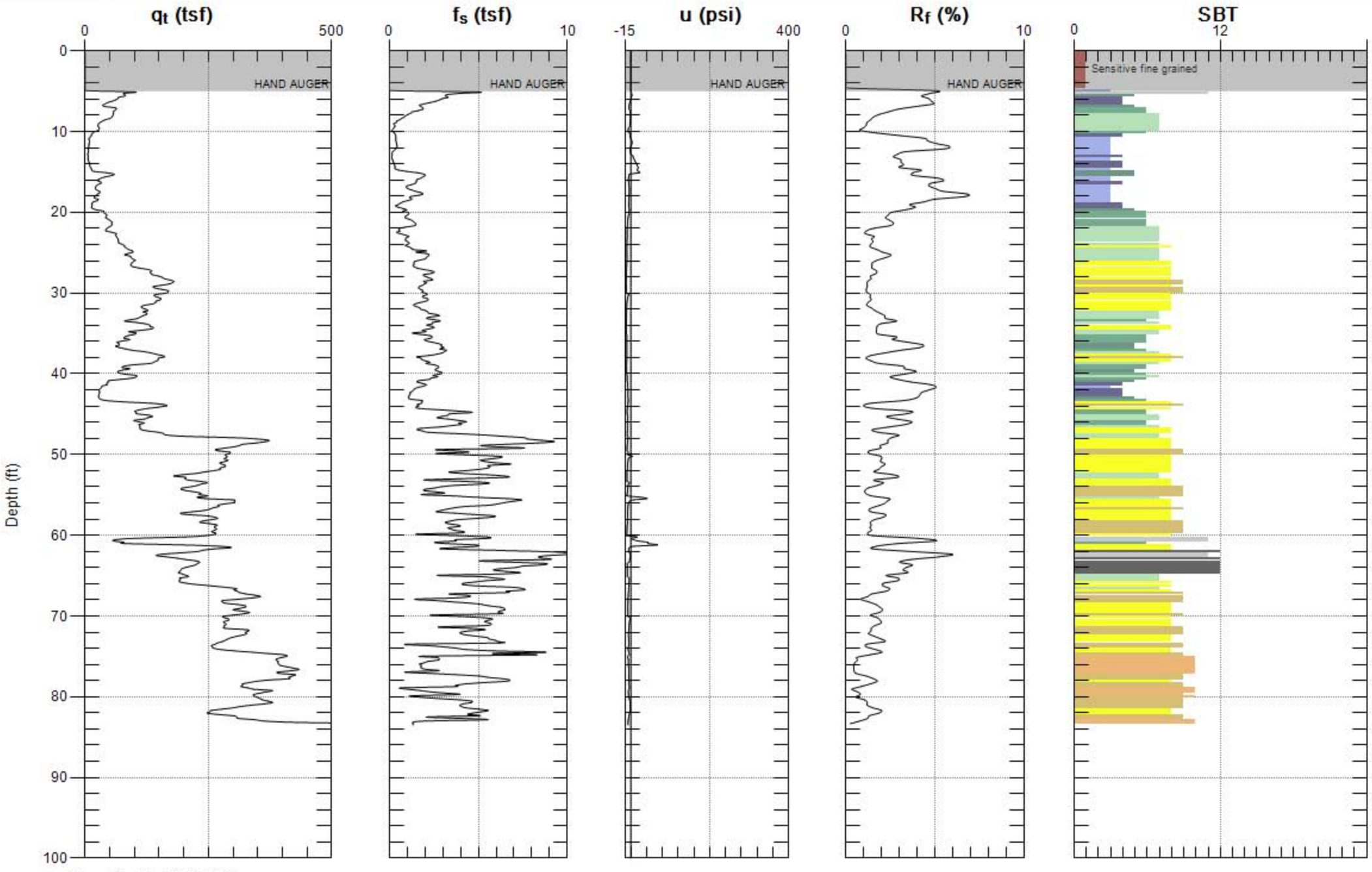


Max. Depth: 88.750 (ft)
Avg. Interval: 0.656 (ft)

SBT: Soil Behavior Type (Robertson 1990)

EARTH MECHANICS

Site: ANTIOCH BRIDGE
Sounding: CPT-03 Seis
Engineer: J.CASTLE
Date: 11/14/2006 09:14

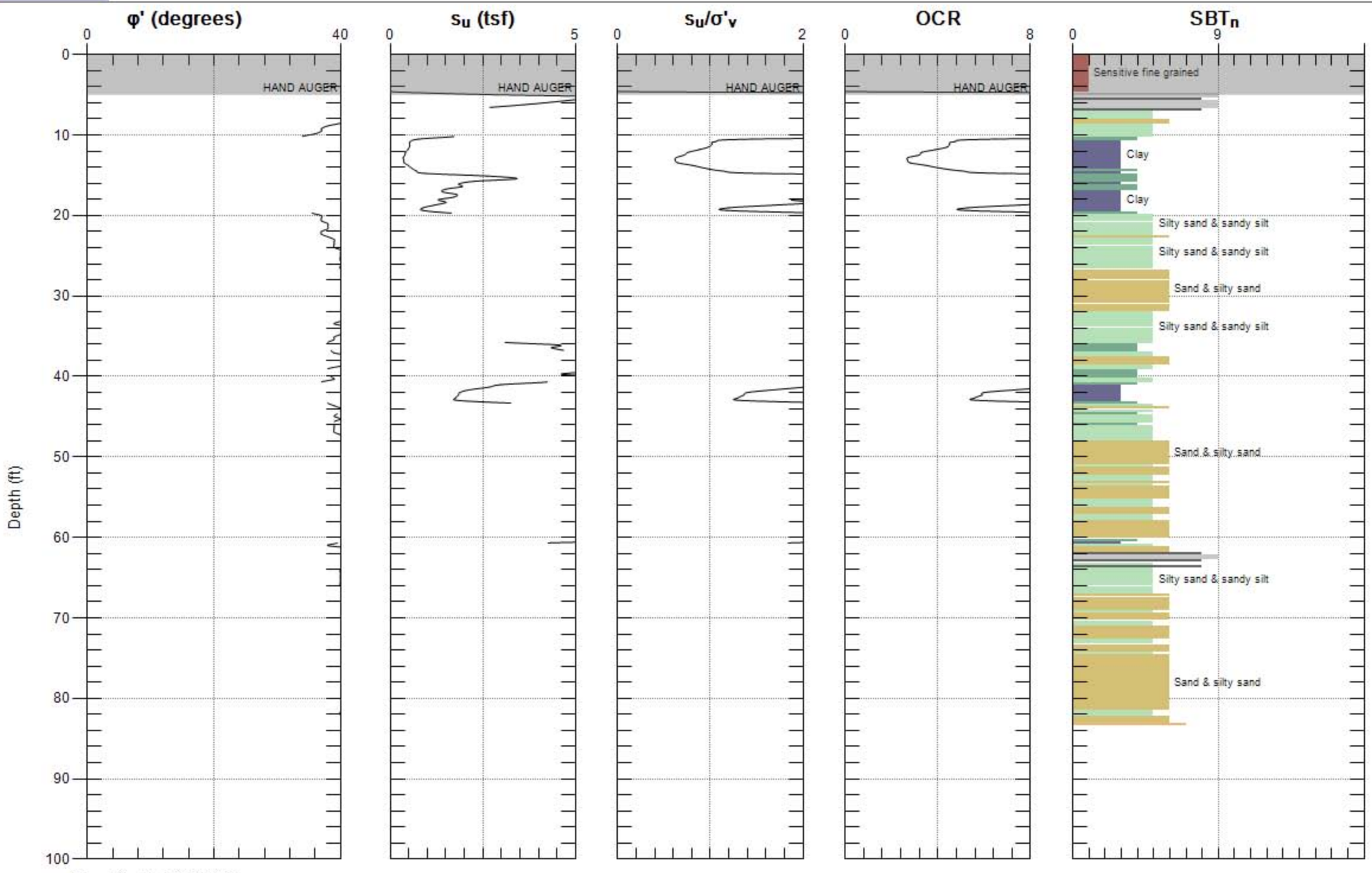


Max. Depth: 83.500 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

EARTH MECHANICS

Site: ANTIOCH BRIDGE
Sounding: CPT-03 Seis
Engineer: J.CASTLE
Date: 11/14/2006 09:14

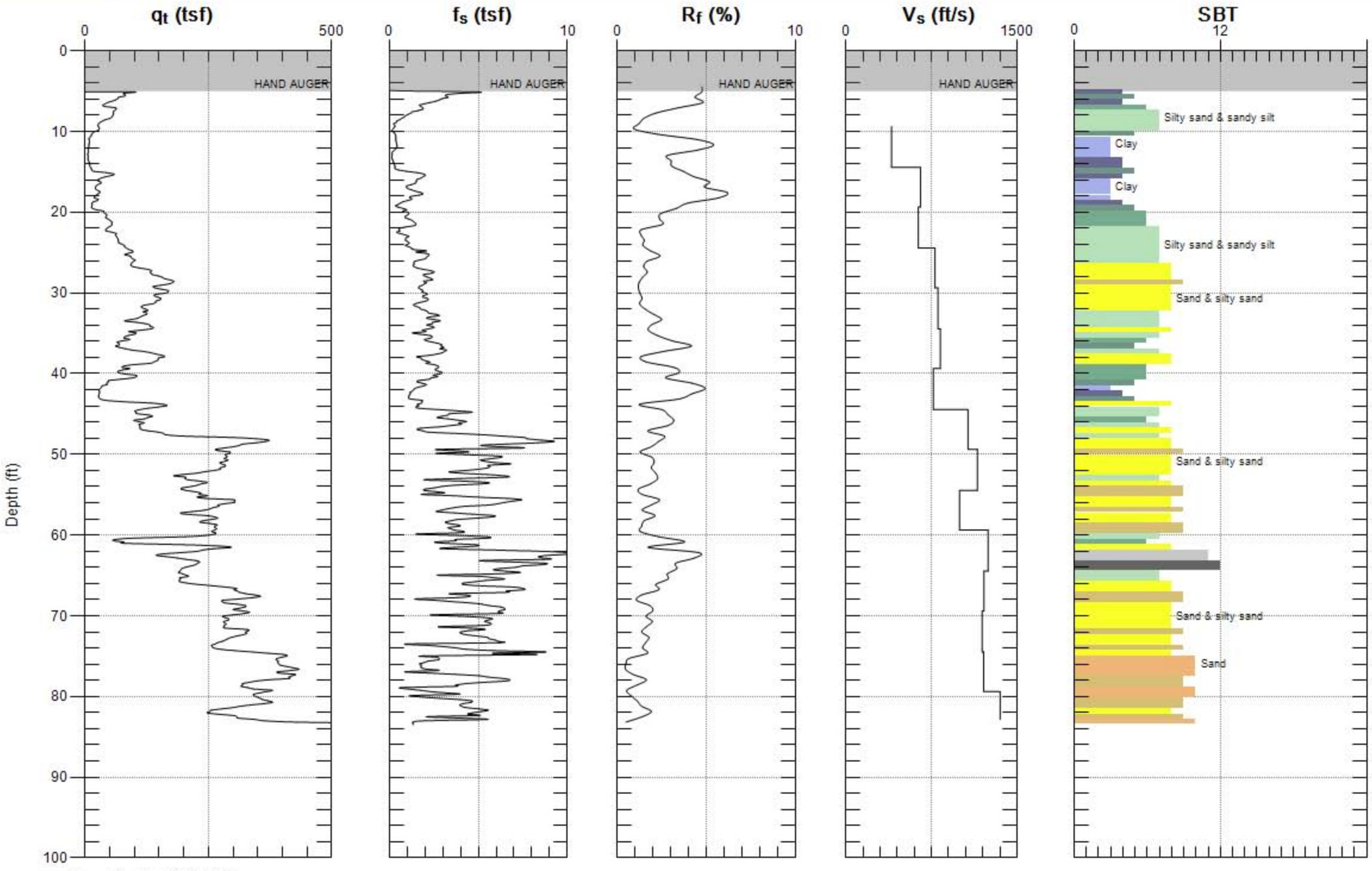


Max. Depth: 83.500 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

EARTH MECHANICS

Site: ANTIOCH BRIDGE
Sounding: CPT-03 Seis
Engineer: J.CASTLE
Date: 11/14/2006 09:14

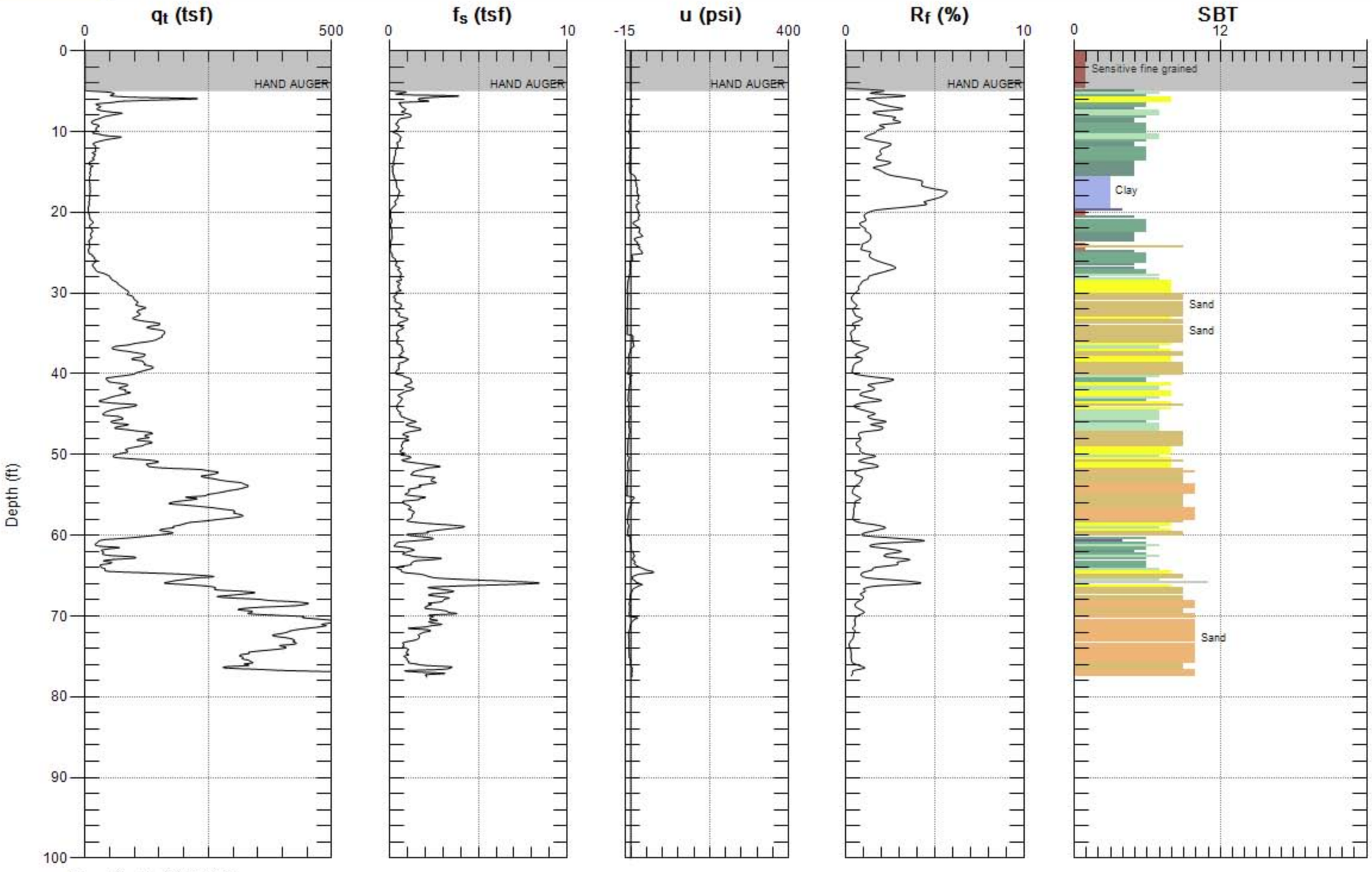


Max. Depth: 83.500 (ft)
Avg. Interval: 0.656 (ft)

SBT: Soil Behavior Type (Robertson 1990)

EARTH MECHANICS

Site: ANTIOCH BRIDGE
Sounding: CPT-04 Seis
Engineer: J.CASTLE
Date: 11/14/2006 11:34

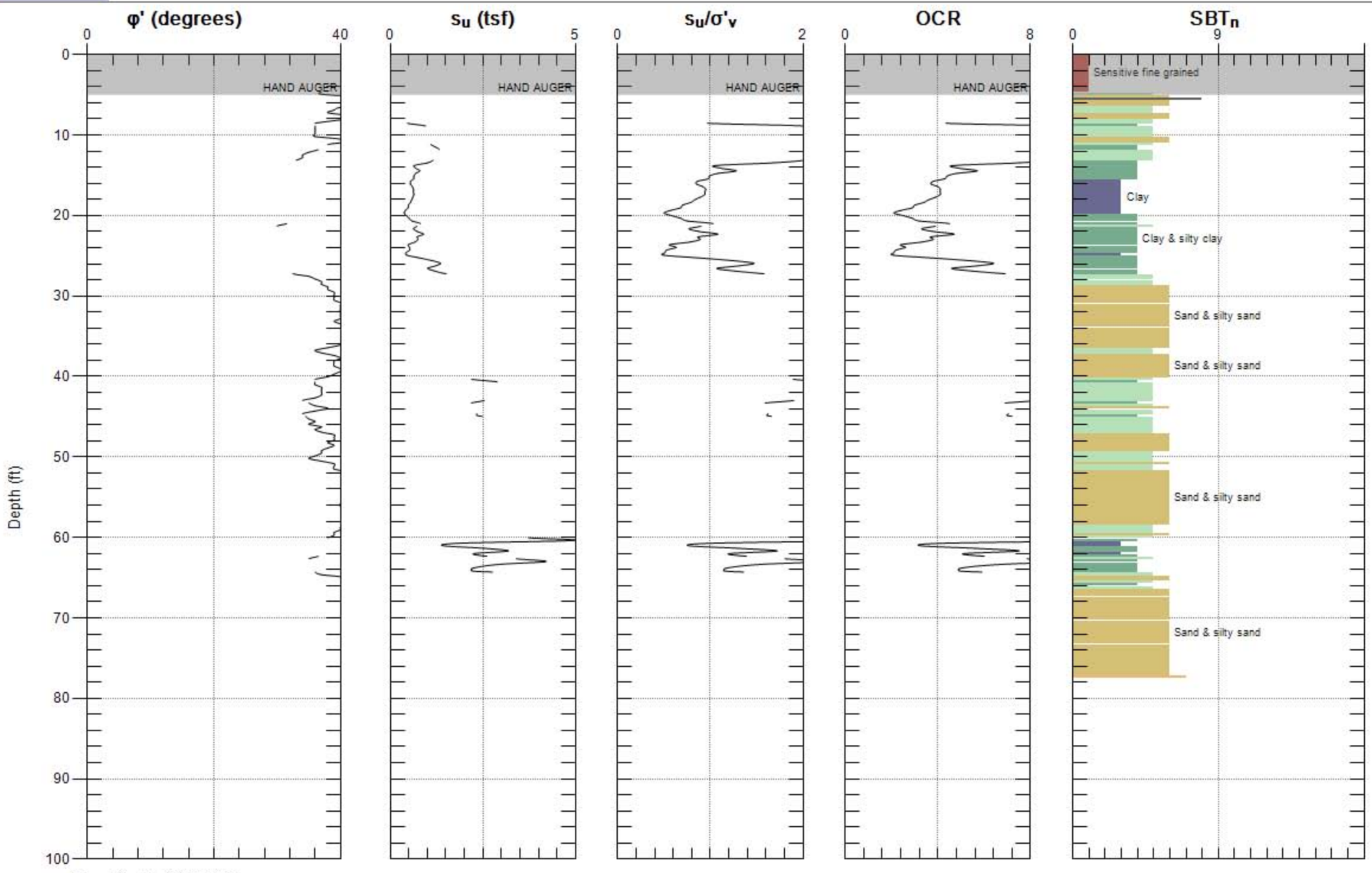


Max. Depth: 77.590 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

EARTH MECHANICS

Site: ANTIOCH BRIDGE
Engineer: J.CASTLE
Sounding: CPT-04 Seis
Date: 11/14/2006 11:34

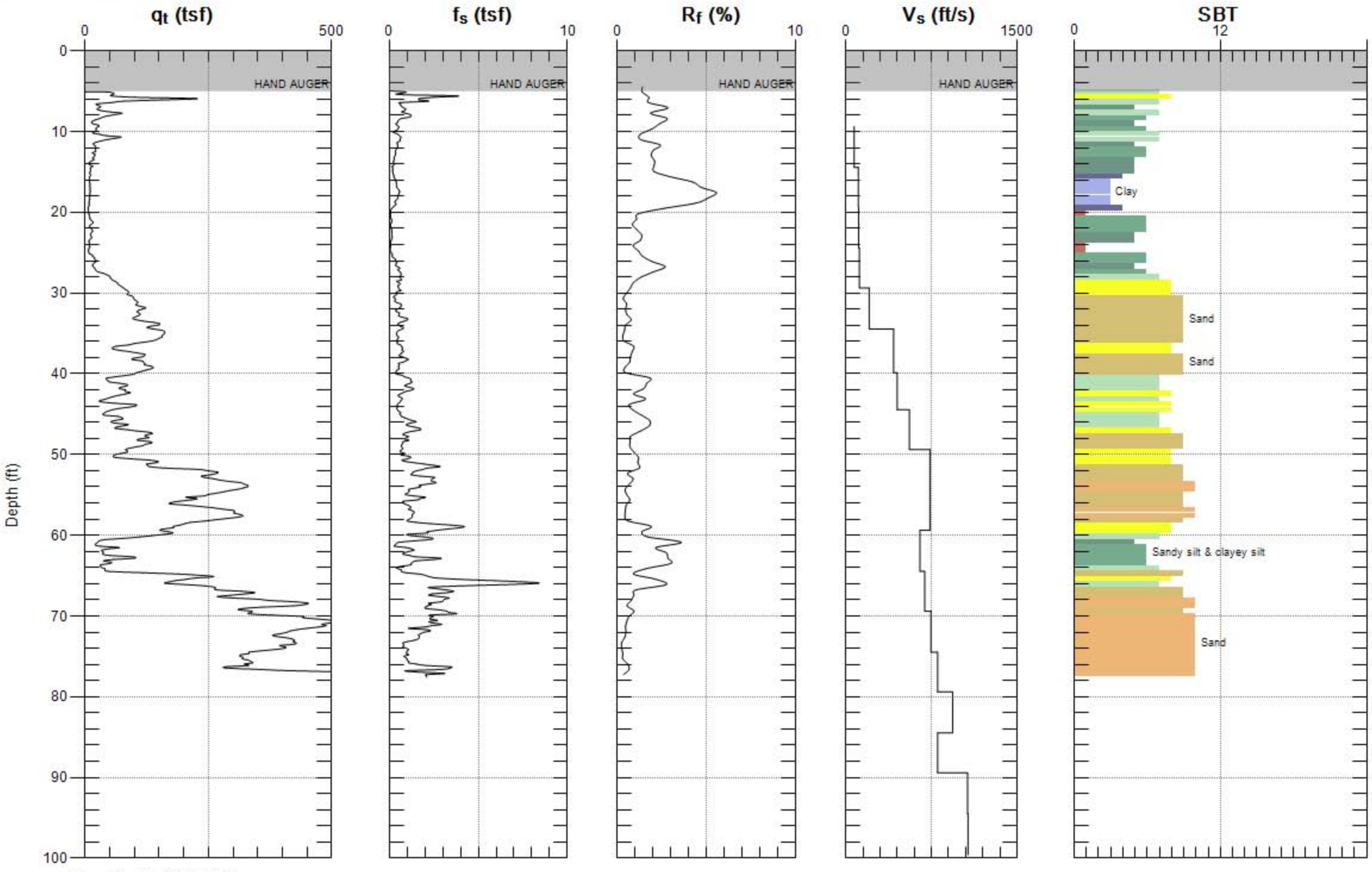


Max. Depth: 77.590 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

EARTH MECHANICS

Site: ANTIOCH BRIDGE
Sounding: CPT-04 Seis
Engineer: J.CASTLE
Date: 11/14/2006 11:34

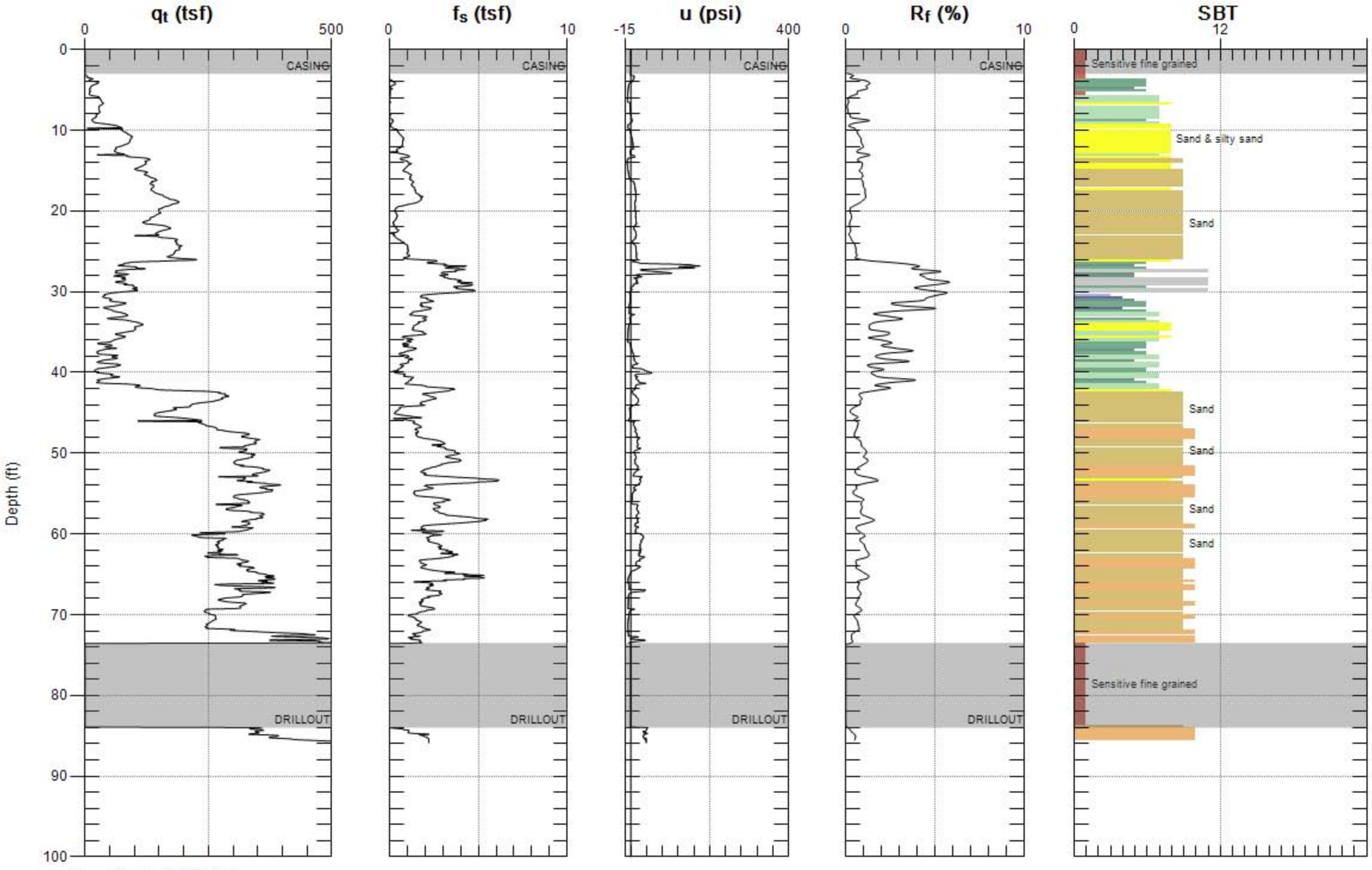


Max. Depth: 77.590 (ft)
Avg. Interval: 0.656 (ft)

SBT: Soil Behavior Type (Robertson 1990)

EARTH MECHANICS

Site: ANTIOCH BRIDGE
Sounding: 07-CPT-5
Engineer: J.CASTLE
Date: 2/5/2007 06:58



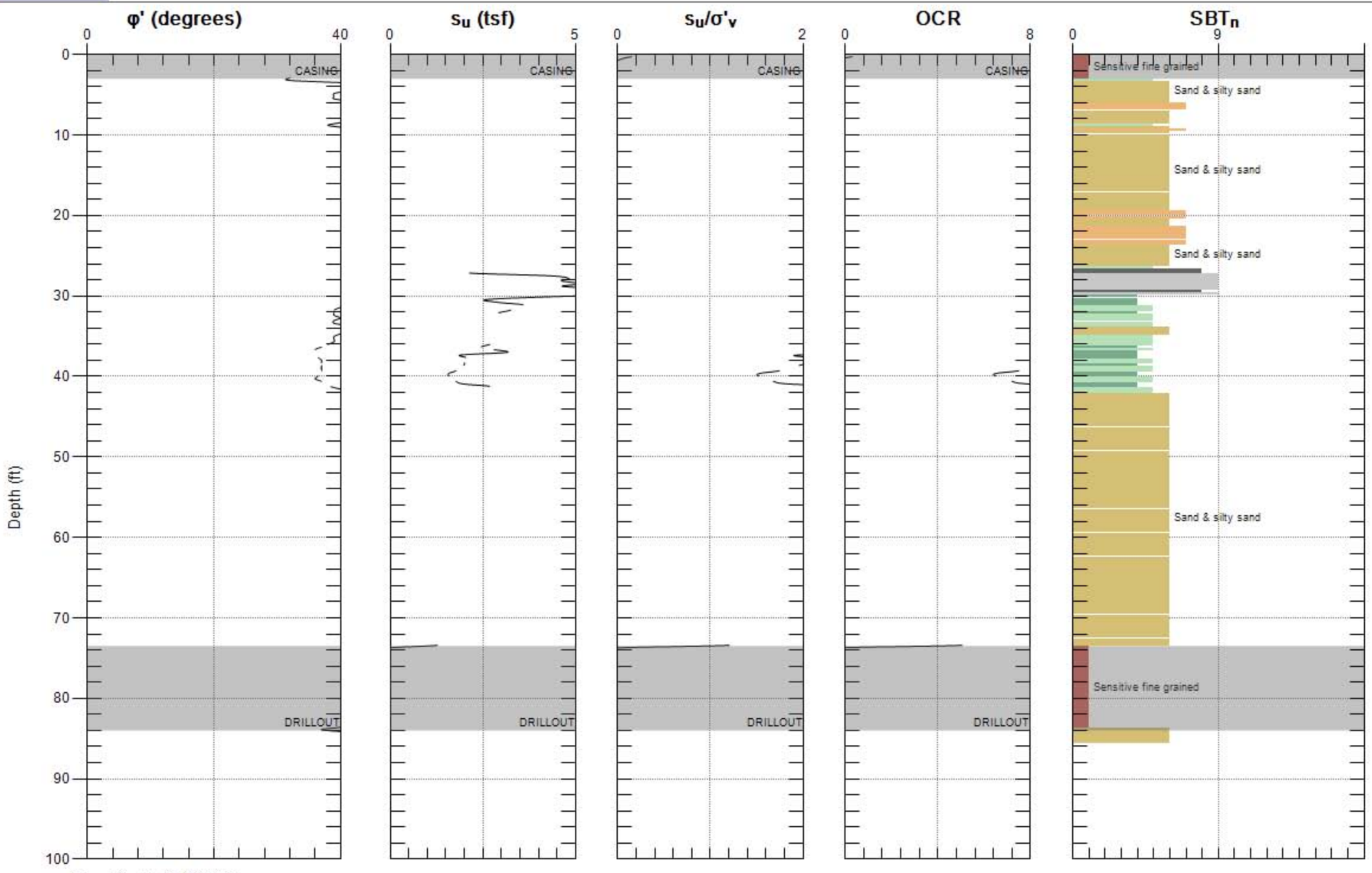
Max. Depth: 85.880 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

EARTH MECHANICS

Site: ANTIOCH BRIDGE
Sounding: 07-CPT-5

Engineer: J.CASTLE
Date: 2/5/2007 06:58

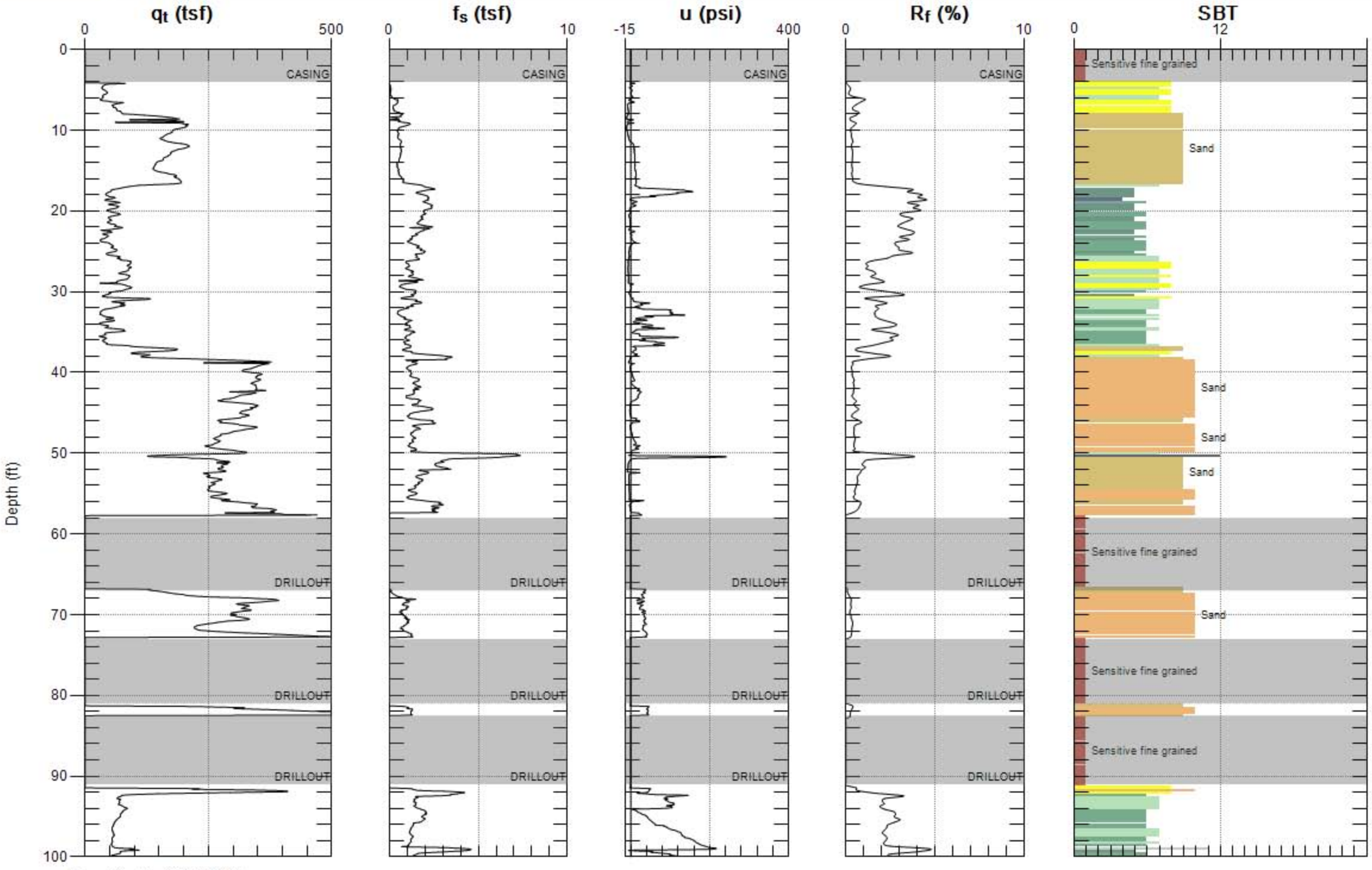


Max. Depth: 85.880 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

EARTH MECHANICS

Site: ANTIOCH BRIDGE
Sounding: 07-CPT-06
Engineer: J.CASTLE
Date: 2/3/2007 08:01

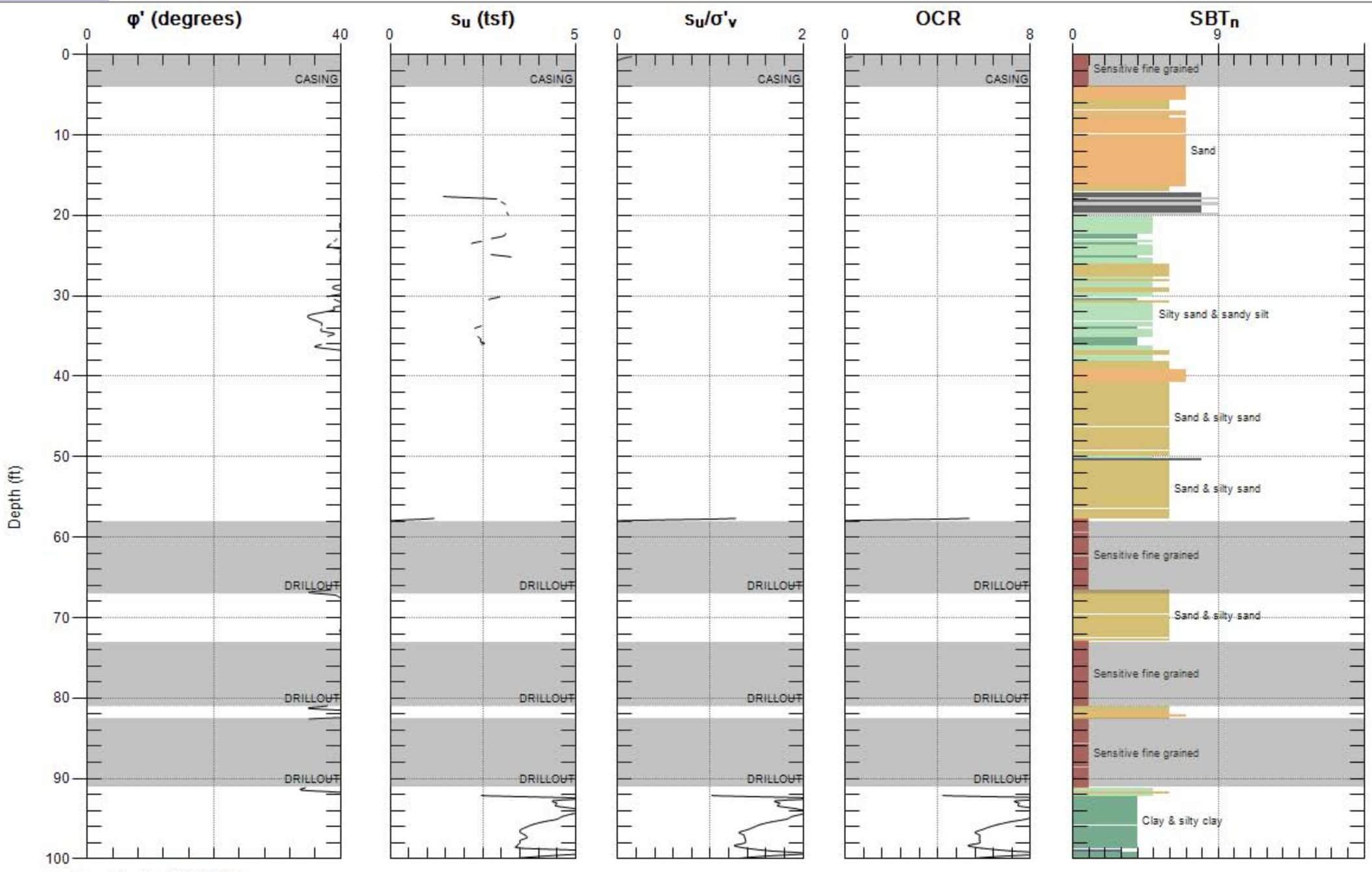


Max. Depth: 102.360 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

EARTH MECHANICS

Site: ANTIOCH BRIDGE
Sounding: 07-CPT-06
Engineer: J.CASTLE
Date: 2/3/2007 08:01

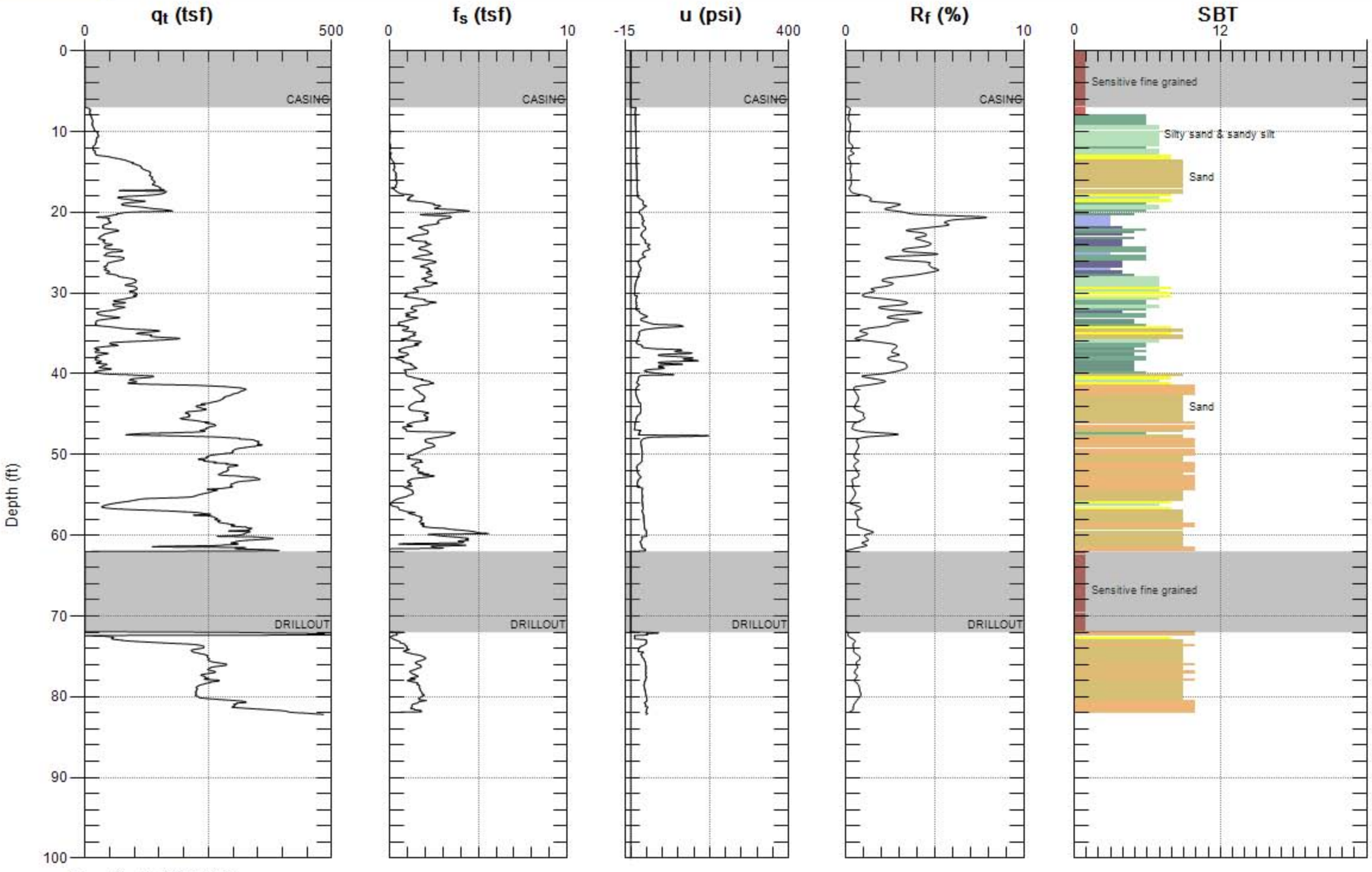


Max. Depth: 102.360 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

EARTH MECHANICS

Site: ANTIOCH BRIDGE
Sounding: 07-CPT-07
Engineer: J.CASTLE
Date: 2/10/2007 07:19

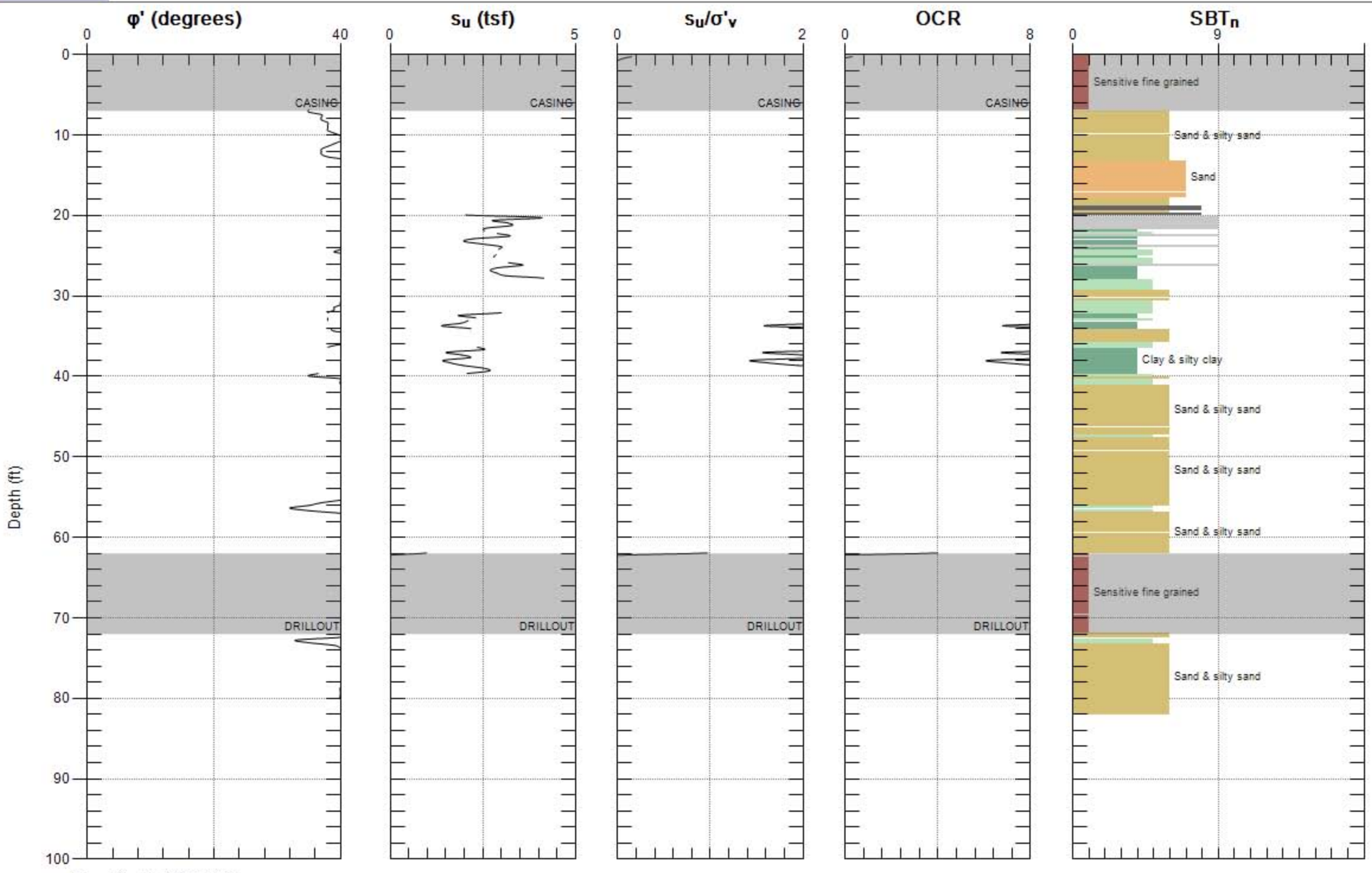


Max. Depth: 82.190 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

EARTH MECHANICS

Site: ANTIOCH BRIDGE
Sounding: 07-CPT-07
Engineer: J.CASTLE
Date: 2/10/2007 07:19

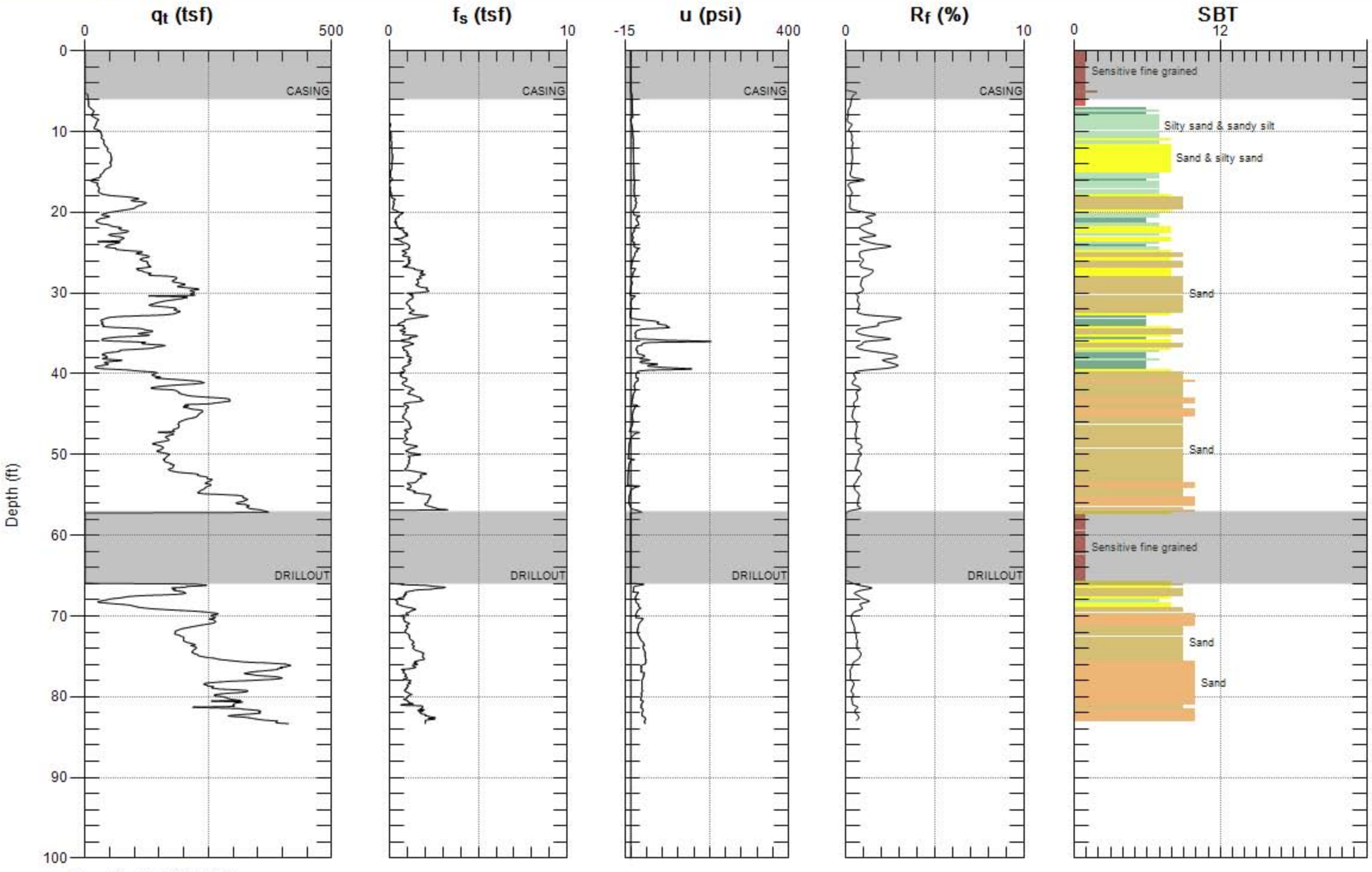


Max. Depth: 82.190 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

EARTH MECHANICS

Site: ANTIOCH BRIDGE
Sounding: 07-CPT-08
Engineer: J.CASTLE
Date: 2/9/2007 12:01

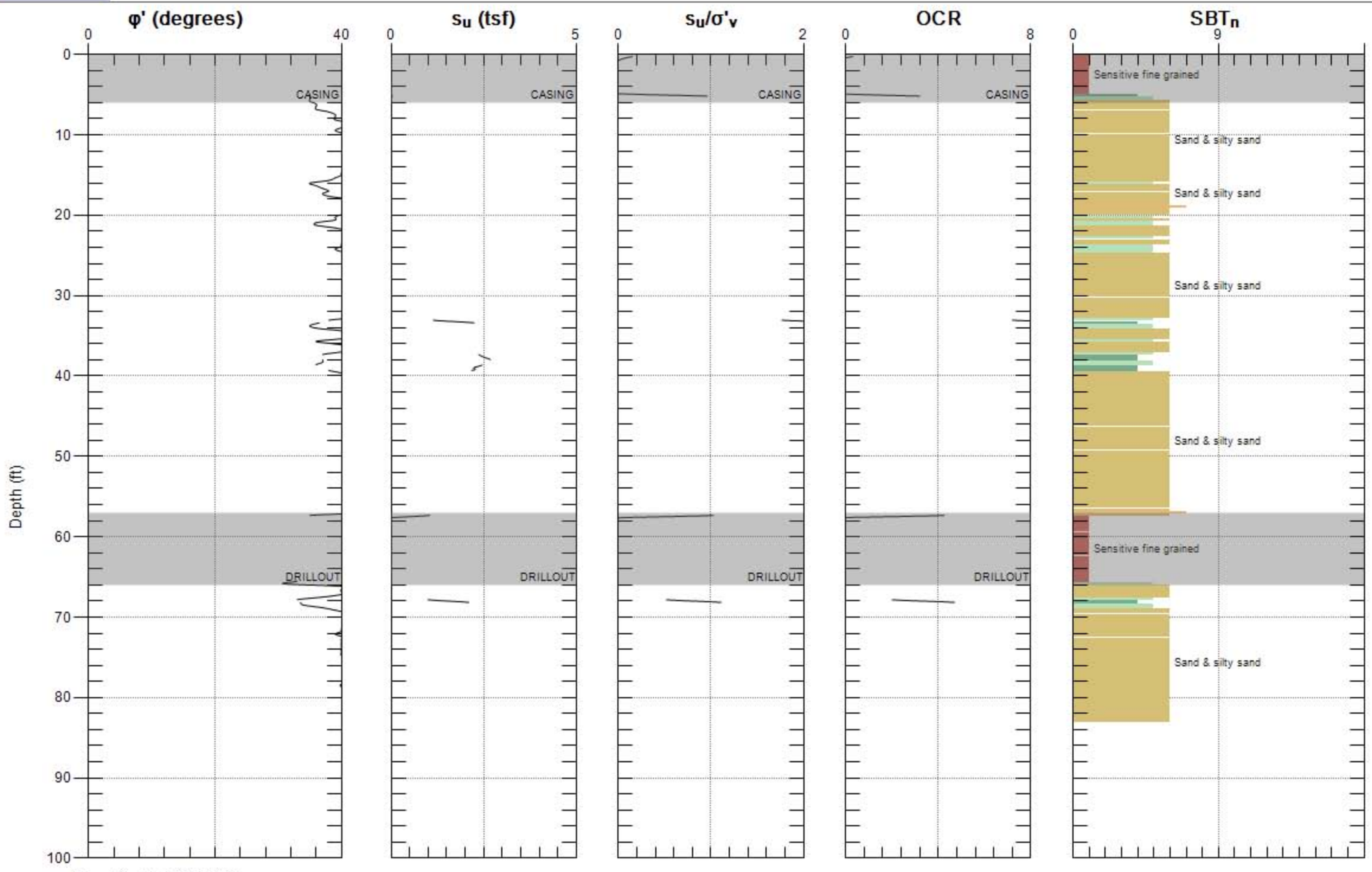


Max. Depth: 83.330 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

EARTH MECHANICS

Site: ANTIOCH BRIDGE
Sounding: 07-CPT-08
Engineer: J.CASTLE
Date: 2/9/2007 12:01

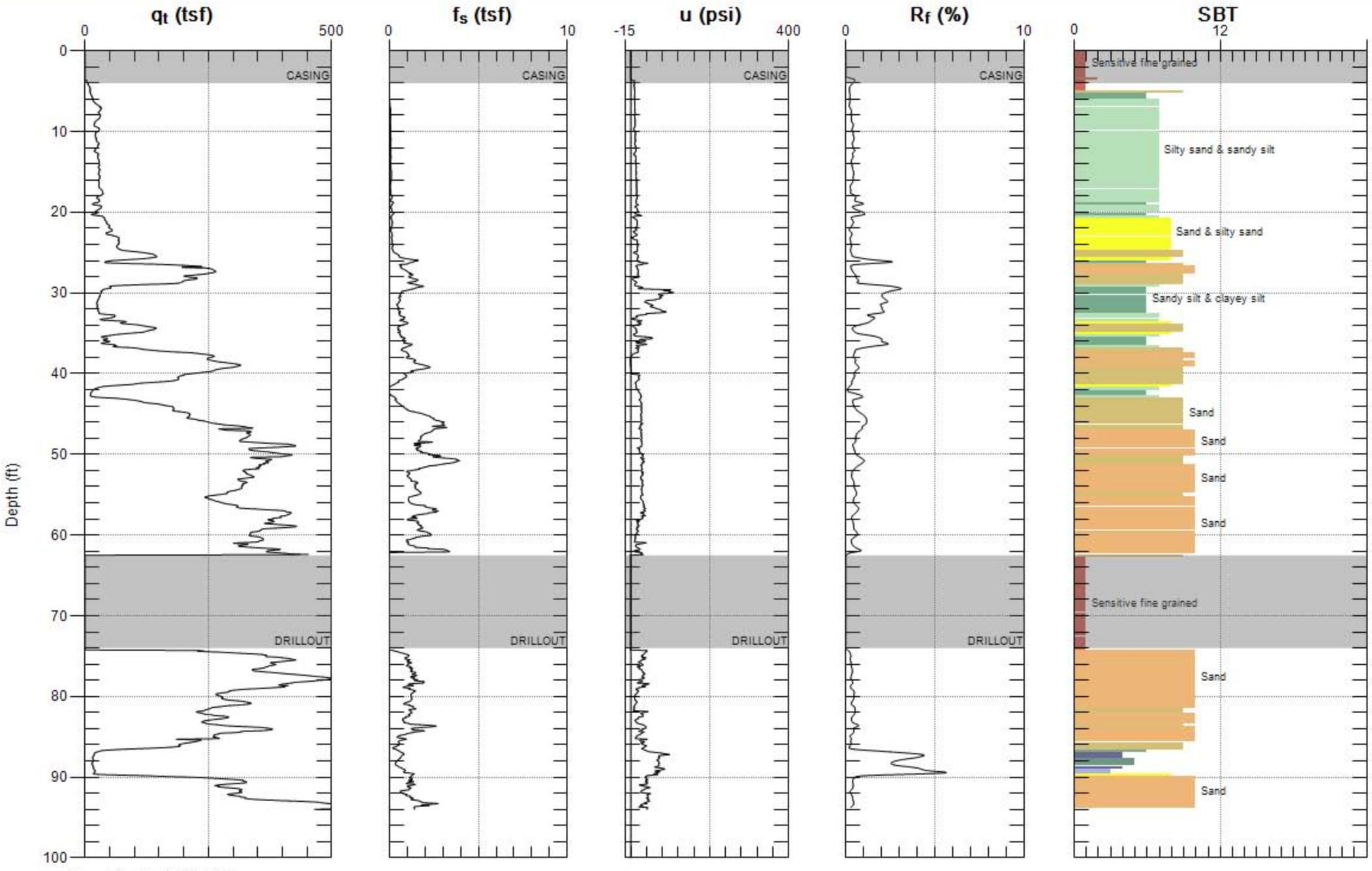


Max. Depth: 83.330 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

EARTH MECHANICS

Site: ANTIOCH BRIDGE
Sounding: 07-CPT-09
Engineer: J.CASTLE
Date: 2/9/2007 07:31

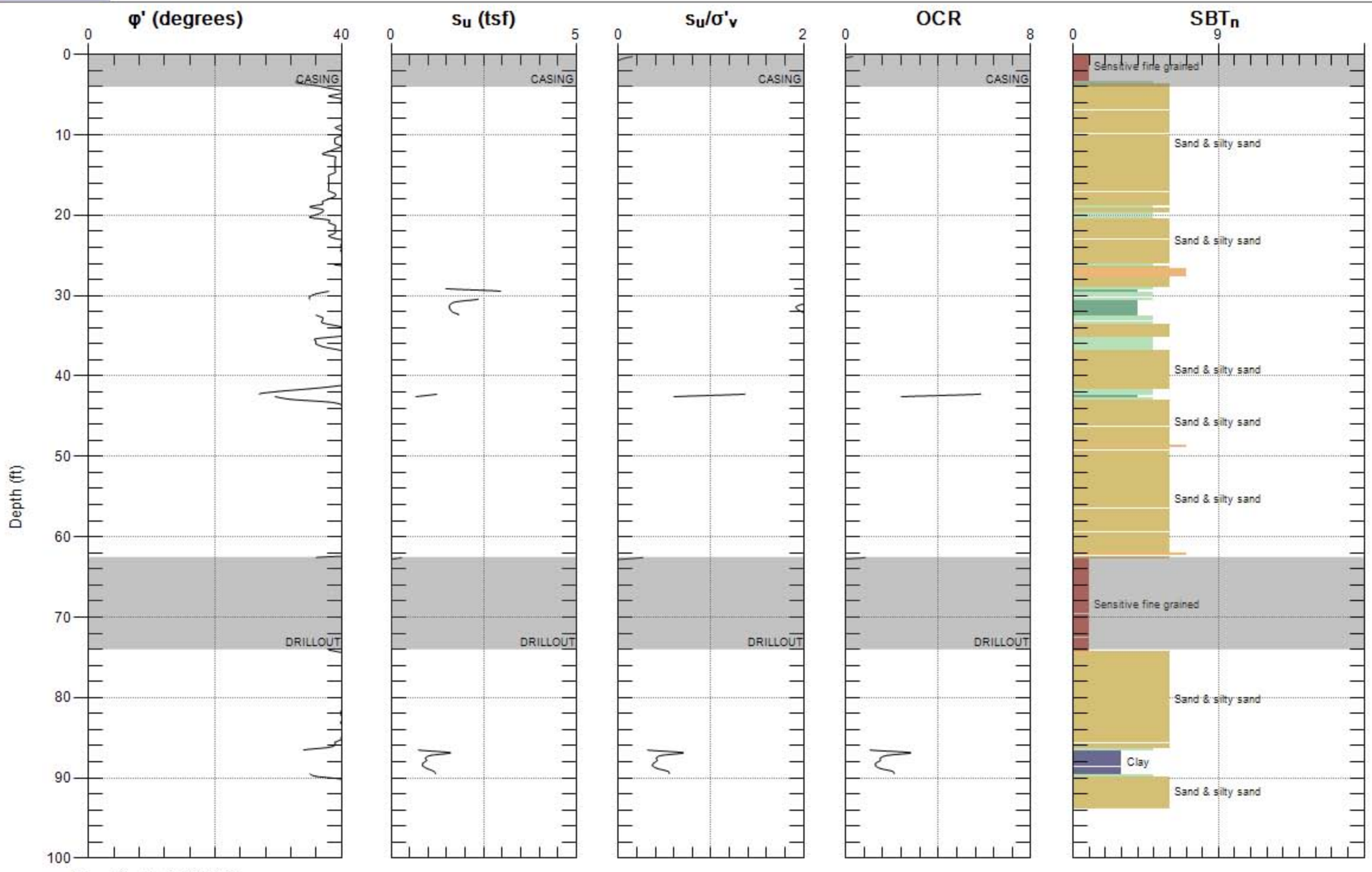


Max. Depth: 94.000 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

EARTH MECHANICS

Site: ANTIOCH BRIDGE
Sounding: 07-CPT-09
Engineer: J.CASTLE
Date: 2/9/2007 07:31

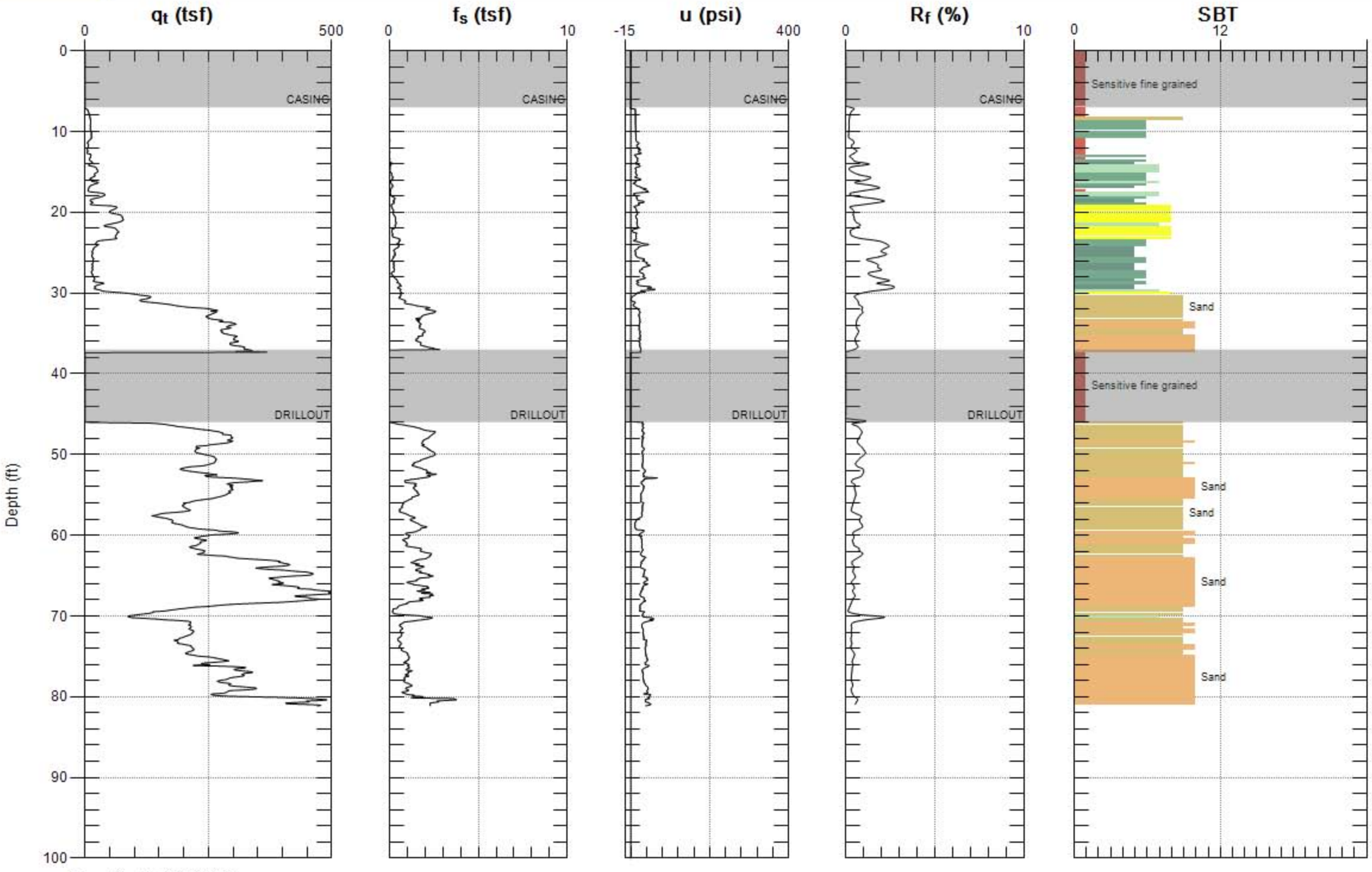


Max. Depth: 94.000 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

EARTH MECHANICS

Site: ANTIOCH BRIDGE
Sounding: 07-CPT-10
Engineer: J.CASTLE
Date: 2/8/2007 12:57

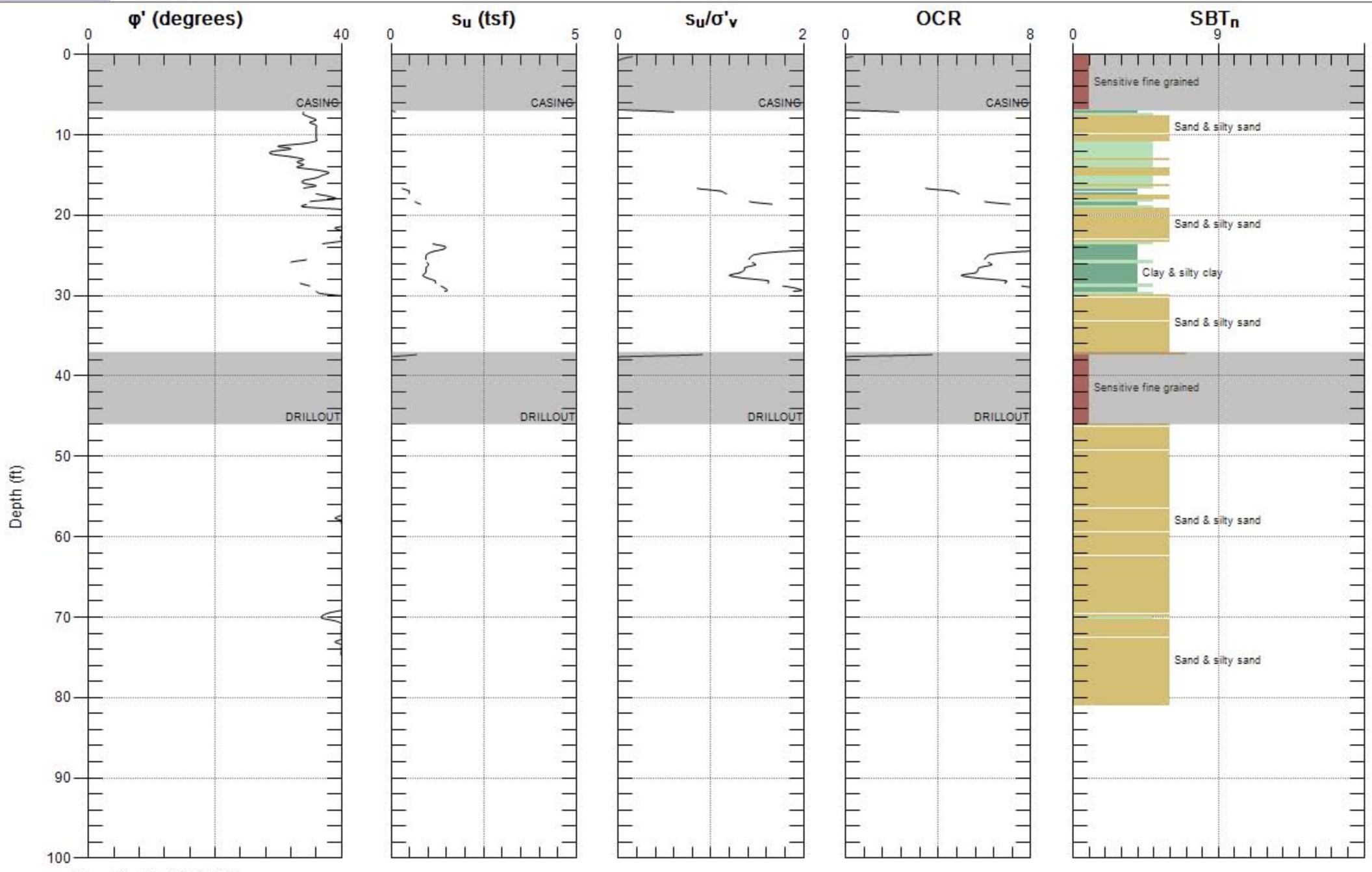


Max. Depth: 81.120 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

EARTH MECHANICS

Site: ANTIOCH BRIDGE
Sounding: 07-CPT-10
Engineer: J.CASTLE
Date: 2/8/2007 12:57

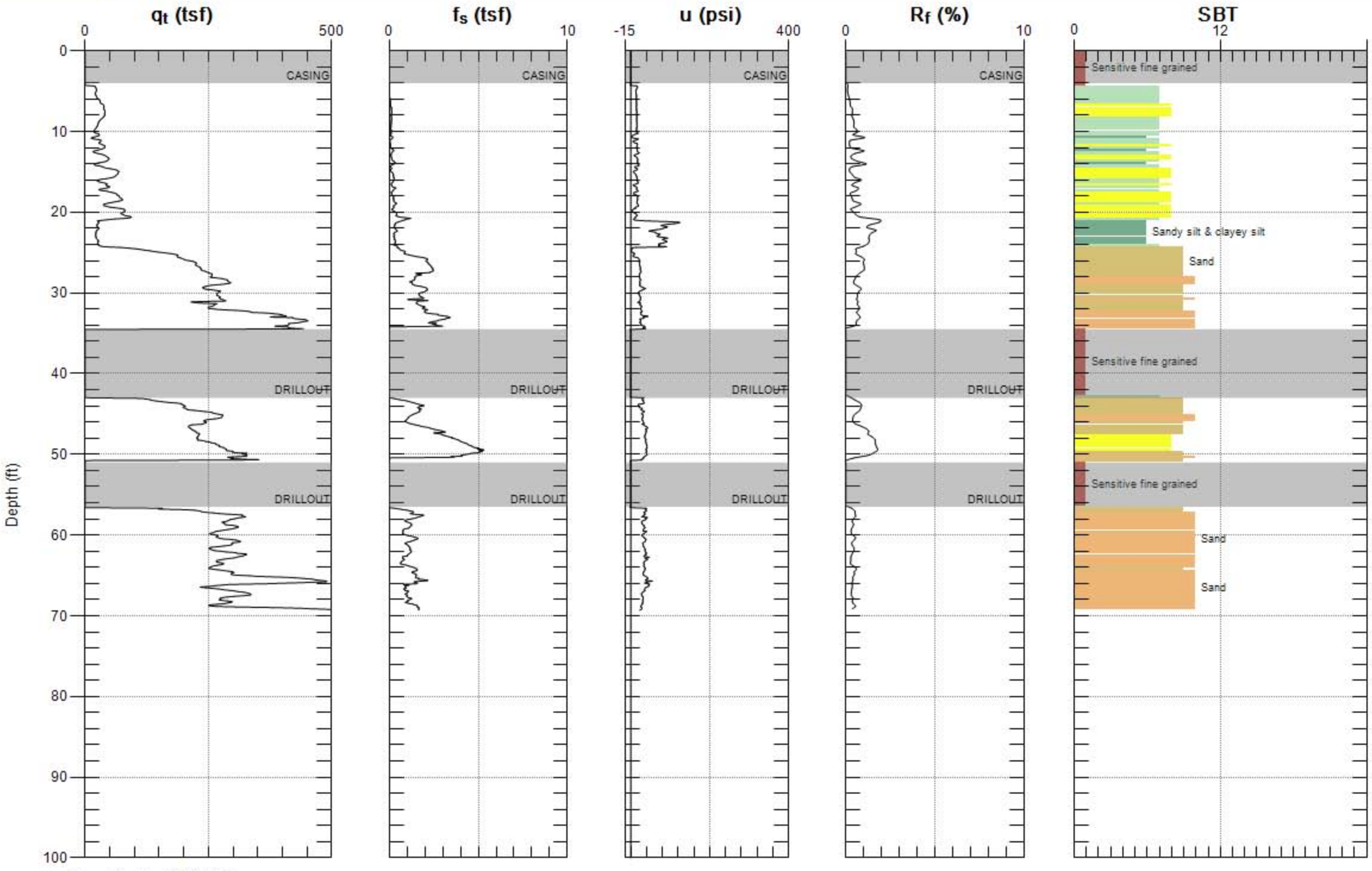


Max. Depth: 81.120 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

EARTH MECHANICS

Site: ANTIOCH BRIDGE
Sounding: 07-CPT-11
Engineer: J.CASTLE
Date: 2/8/2007 07:49

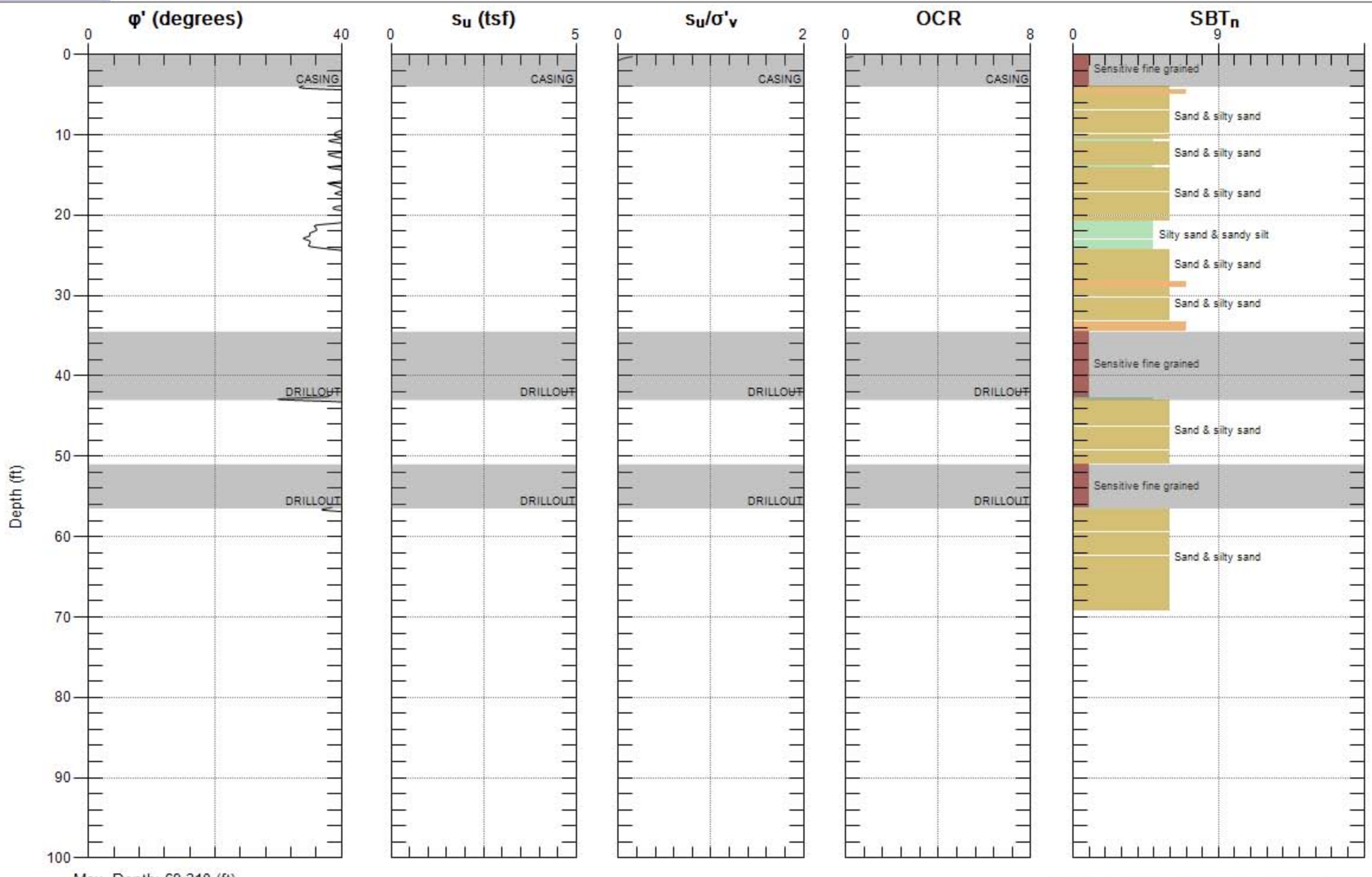


Max. Depth: 69.310 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

EARTH MECHANICS

Site: ANTIOCH BRIDGE
Sounding: 07-CPT-11
Engineer: J.CASTLE
Date: 2/8/2007 07:49

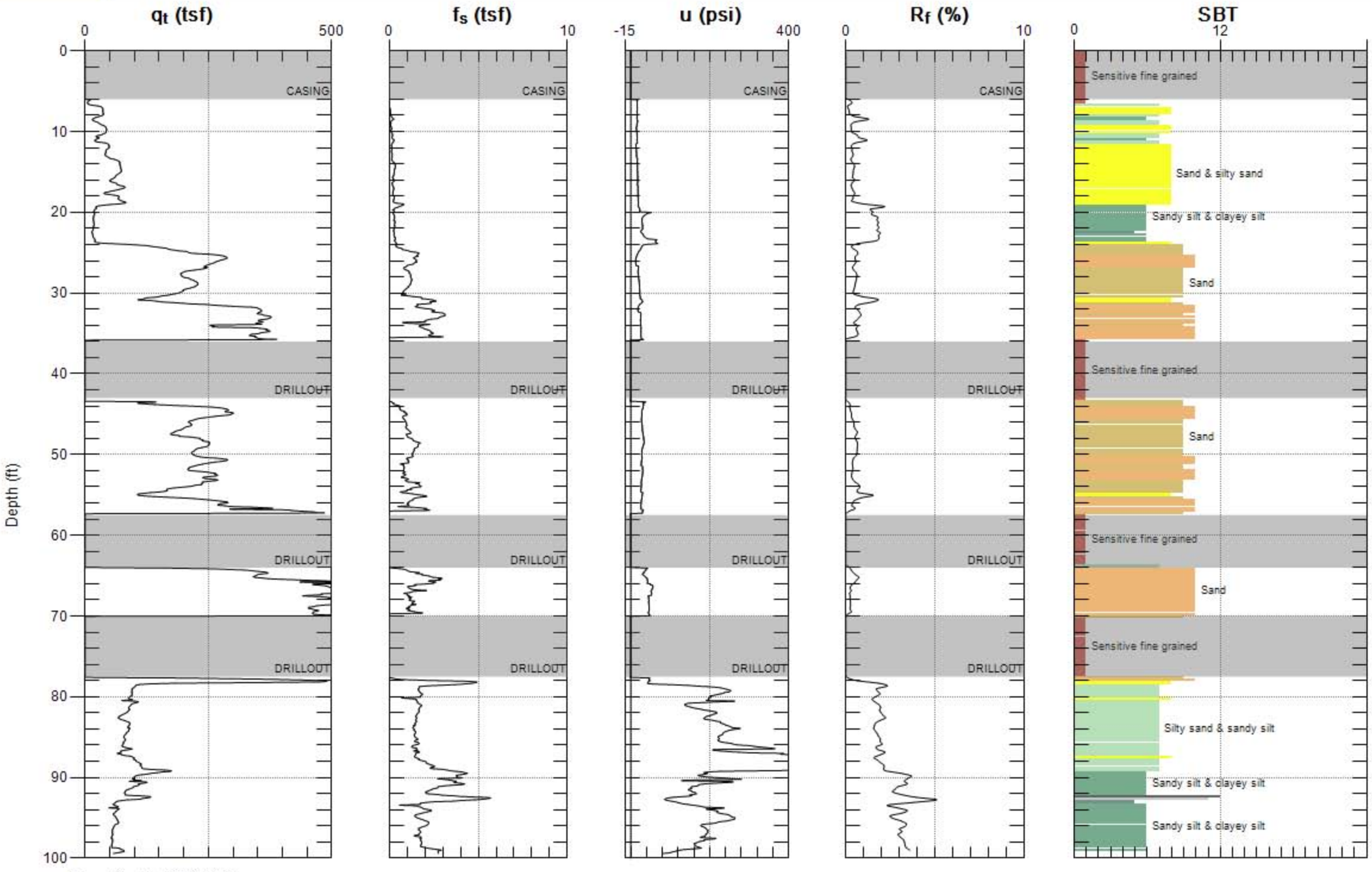


Max. Depth: 69.310 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

EARTH MECHANICS

Site: ANTIOCH BRIDGE
Sounding: 07-CPT-12
Engineer: J.CASTLE
Date: 2/7/2007 07:15

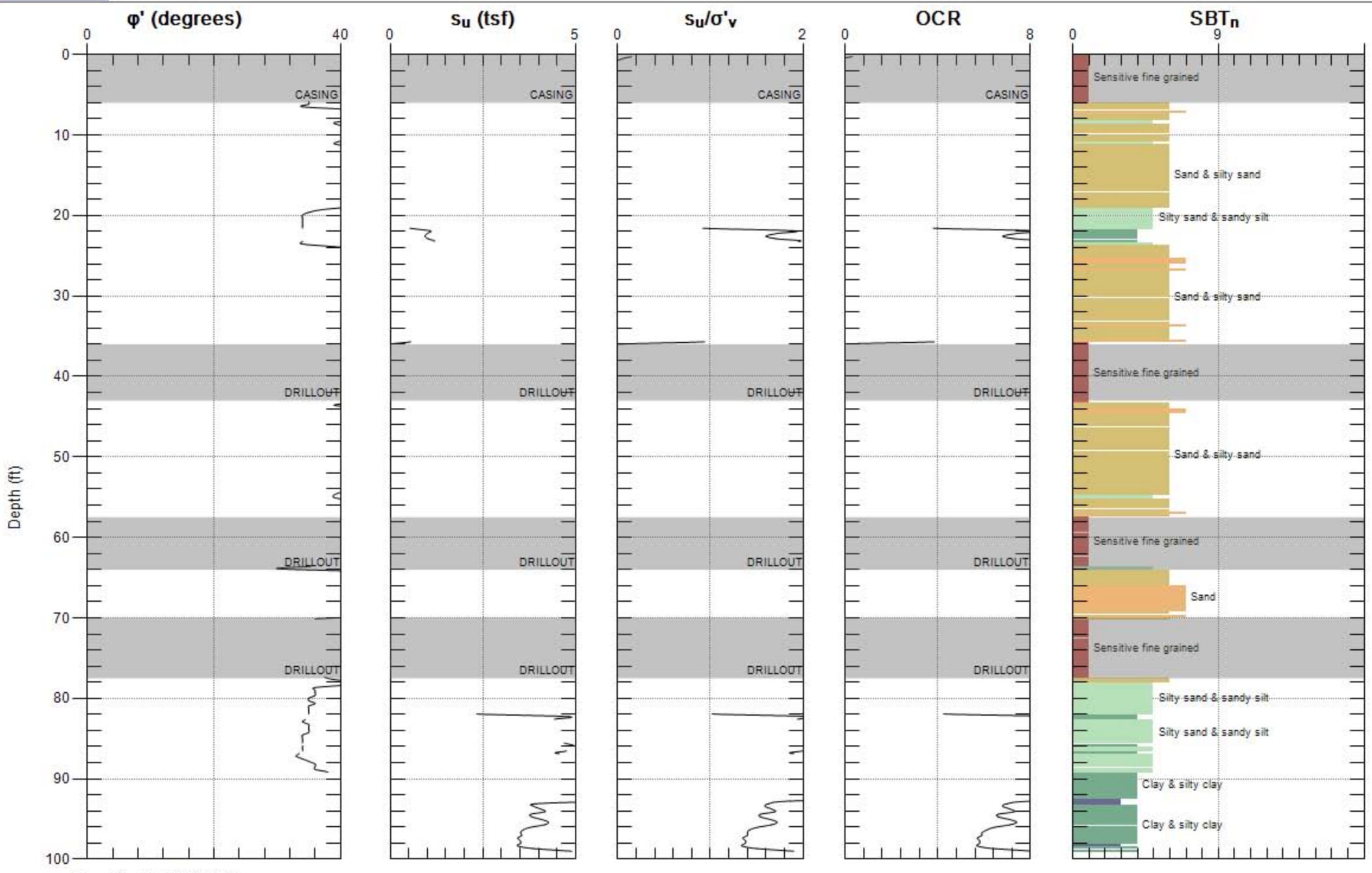


Max. Depth: 99.410 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

EARTH MECHANICS

Site: ANTIOCH BRIDGE
Sounding: 07-CPT-12
Engineer: J.CASTLE
Date: 2/7/2007 07:15

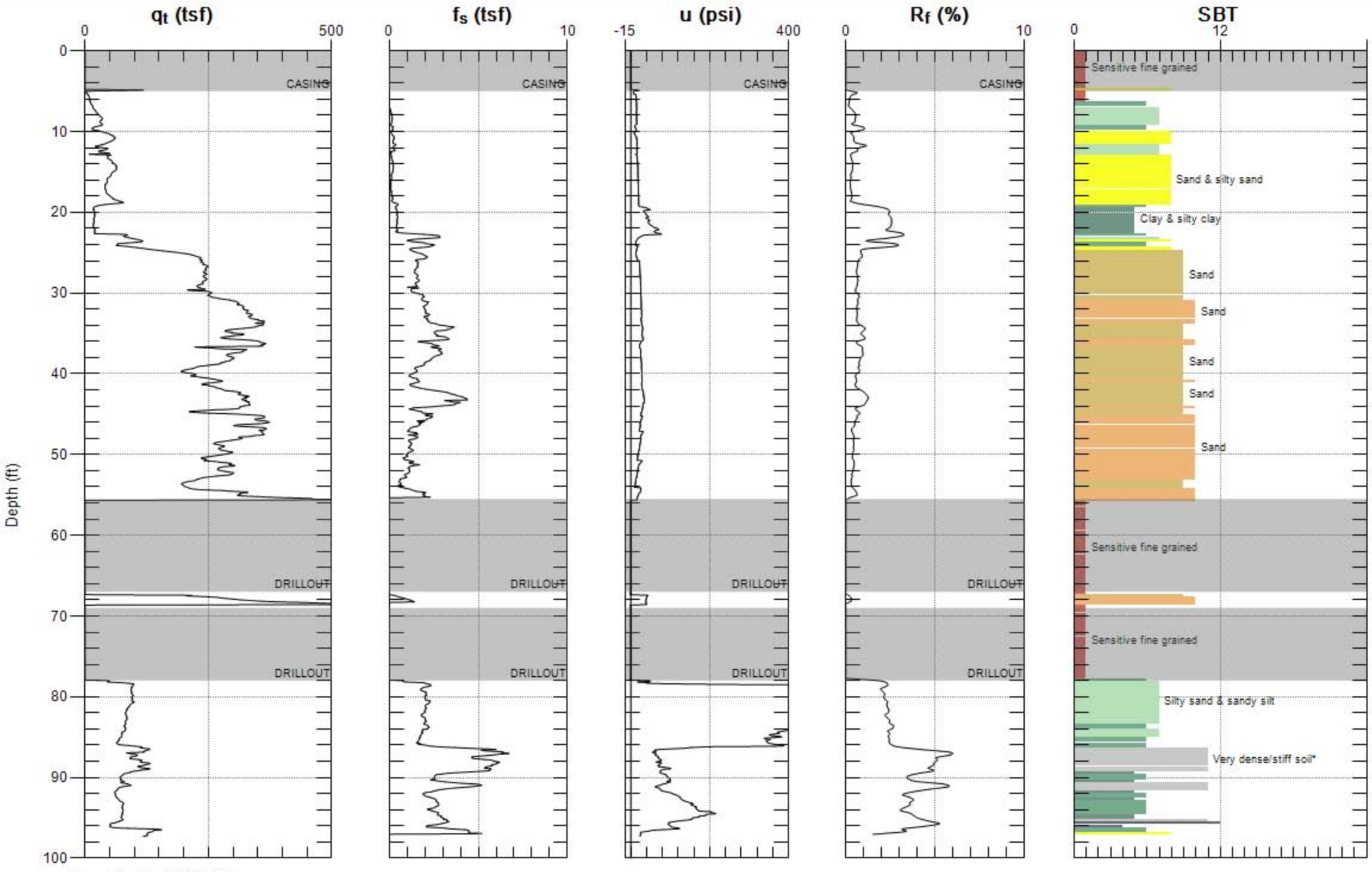


Max. Depth: 99.410 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

EARTH MECHANICS

Site: ANTIOCH BRIDGE
Sounding: 07-CPT-13
Engineer: J.CASTLE
Date: 2/6/2007 09:32

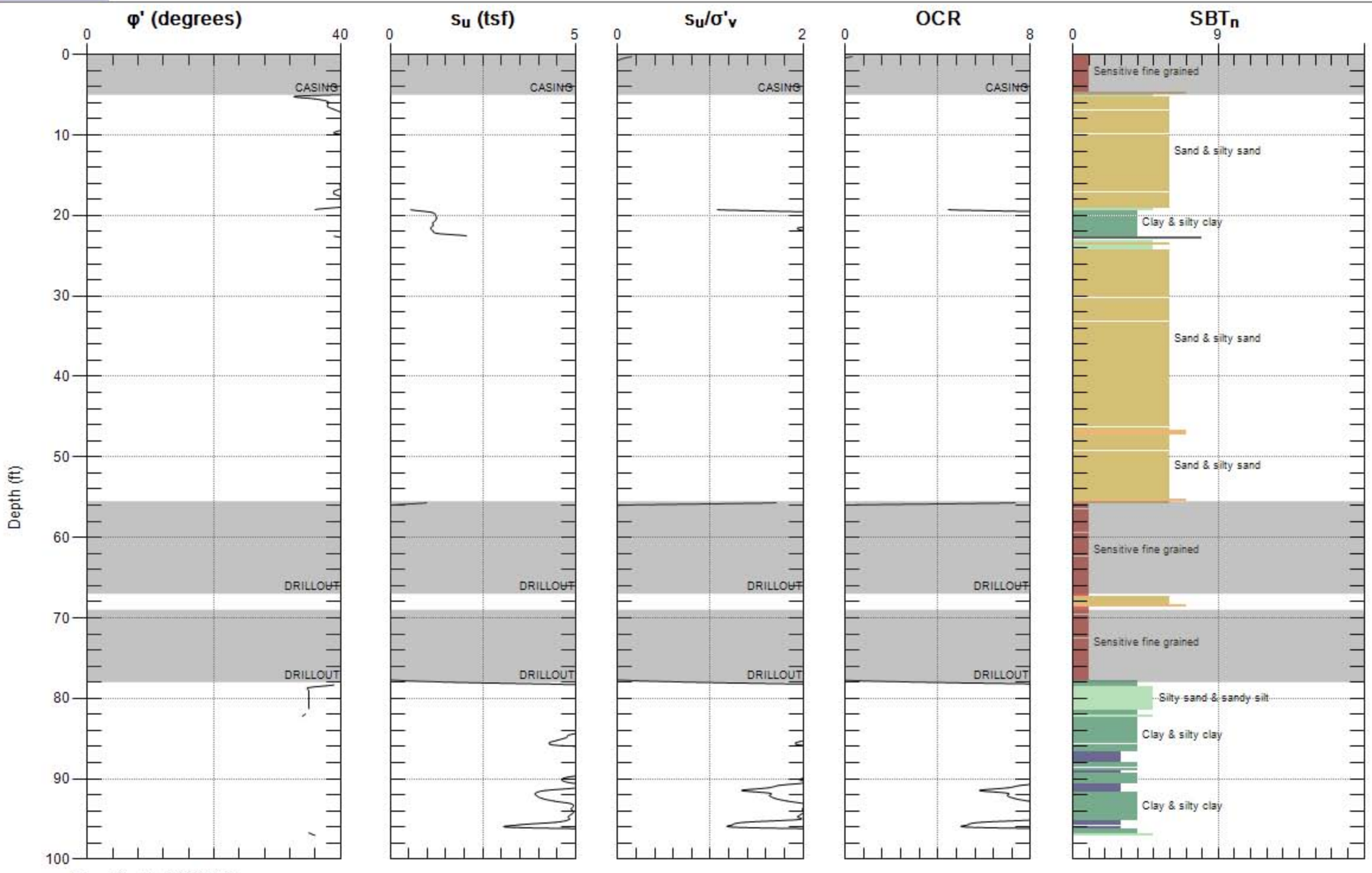


Max. Depth: 97.280 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

EARTH MECHANICS

Site: ANTIOCH BRIDGE
Sounding: 07-CPT-13
Engineer: J.CASTLE
Date: 2/6/2007 09:32

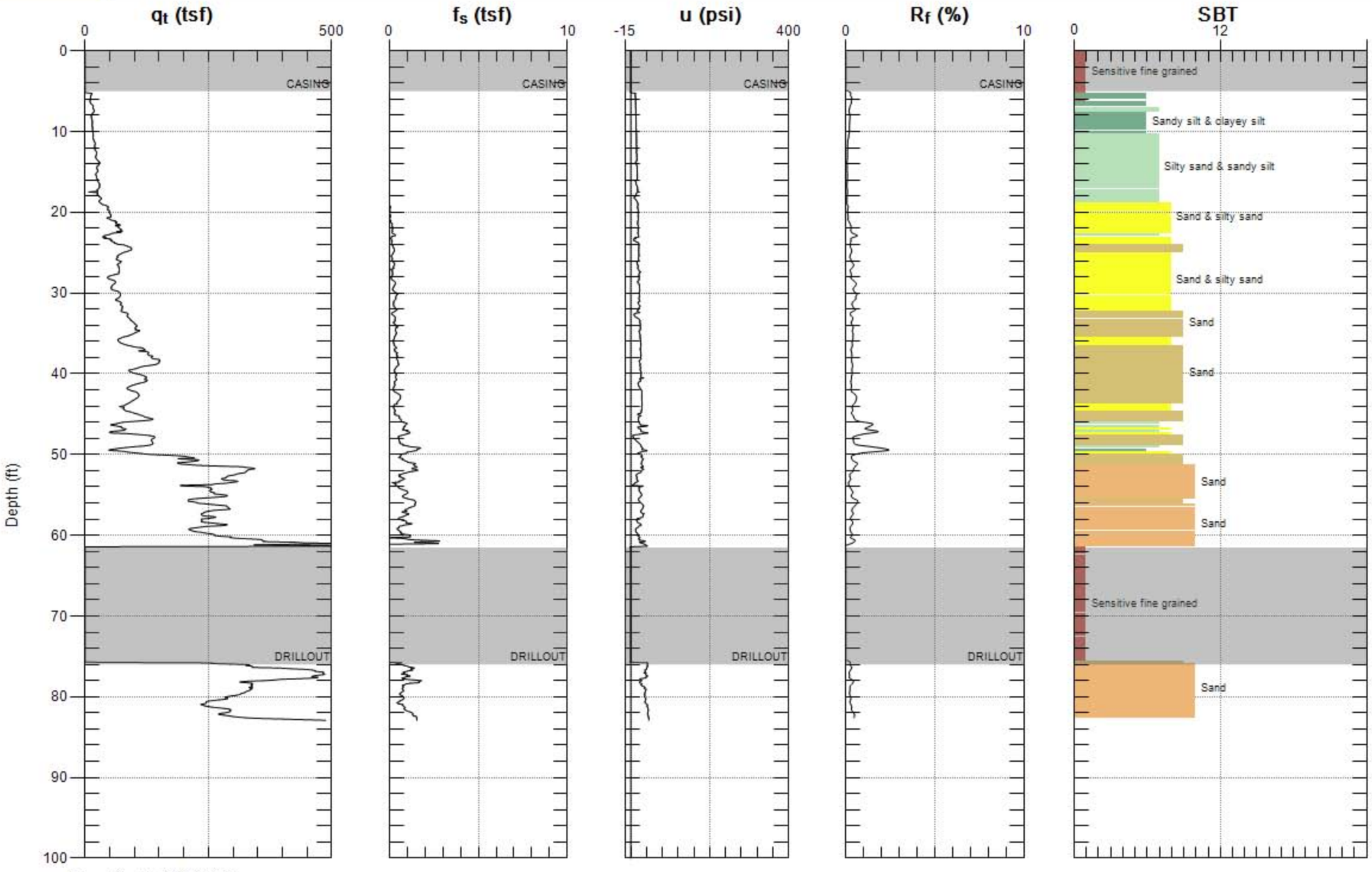


Max. Depth: 97.280 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

EARTH MECHANICS

Site: ANTIOCH BRIDGE
Sounding: 07-CPT-14
Engineer: J.CASTLE
Date: 2/5/2007 11:58



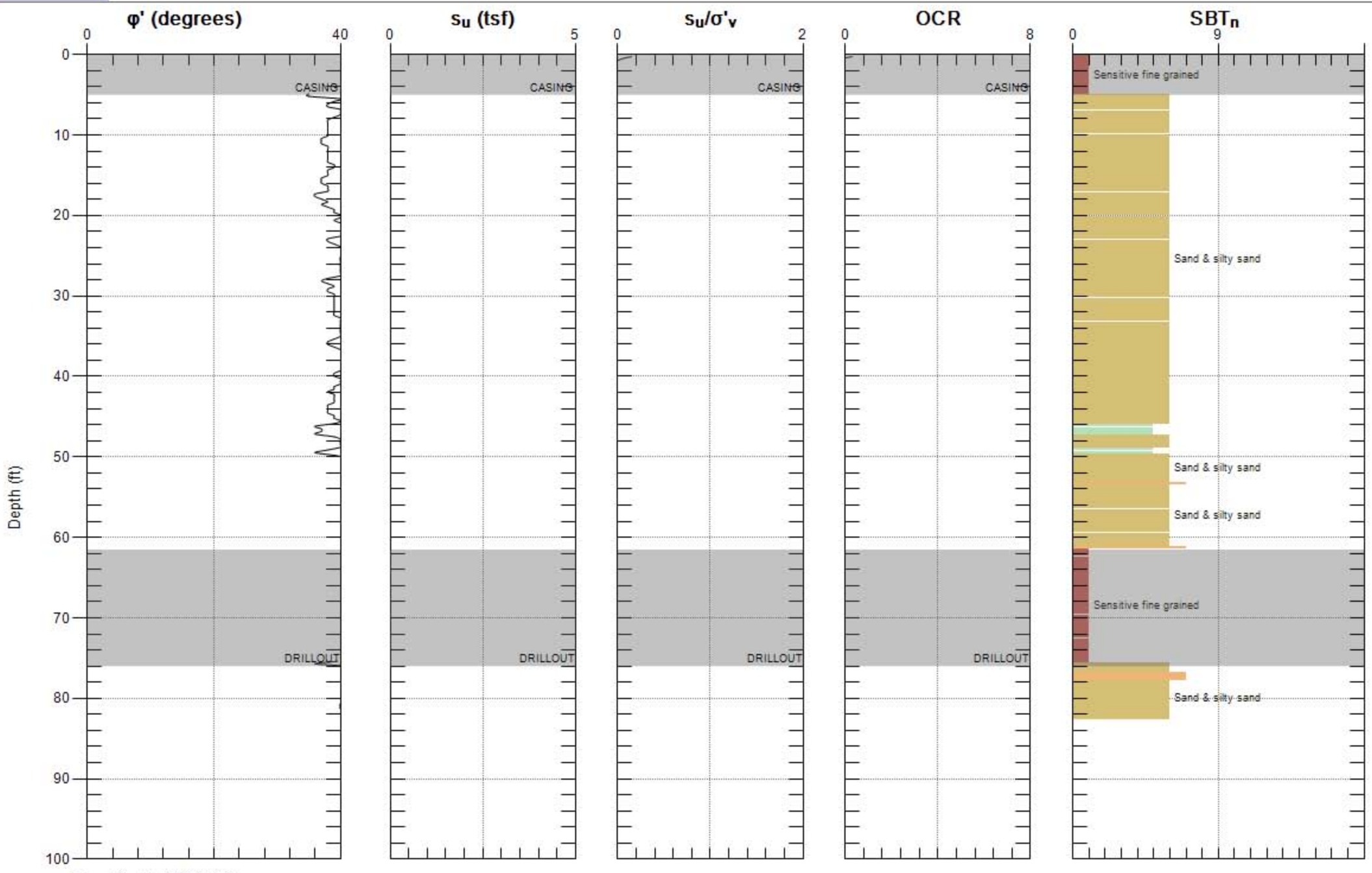
Max. Depth: 82.920 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

EARTH MECHANICS

Site: ANTIOCH BRIDGE
Sounding: 07-CPT-14

Engineer: J.CASTLE
Date: 2/5/2007 11:58

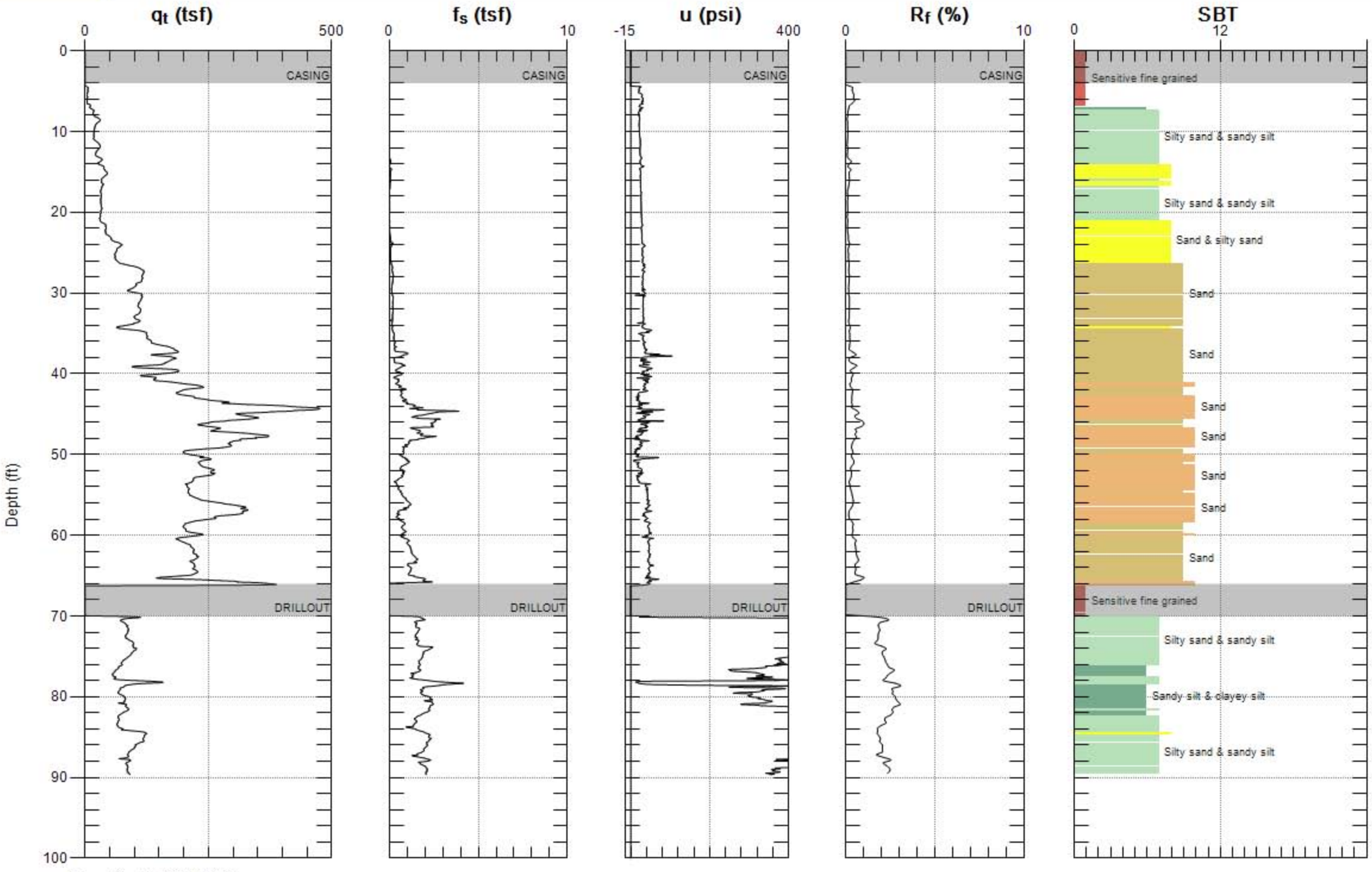


Max. Depth: 82.920 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

EARTH MECHANICS

Site: ANTIOCH BRIDGE
Sounding: 07-CPT-15
Engineer: J.CASTLE
Date: 2/12/2007 07:03

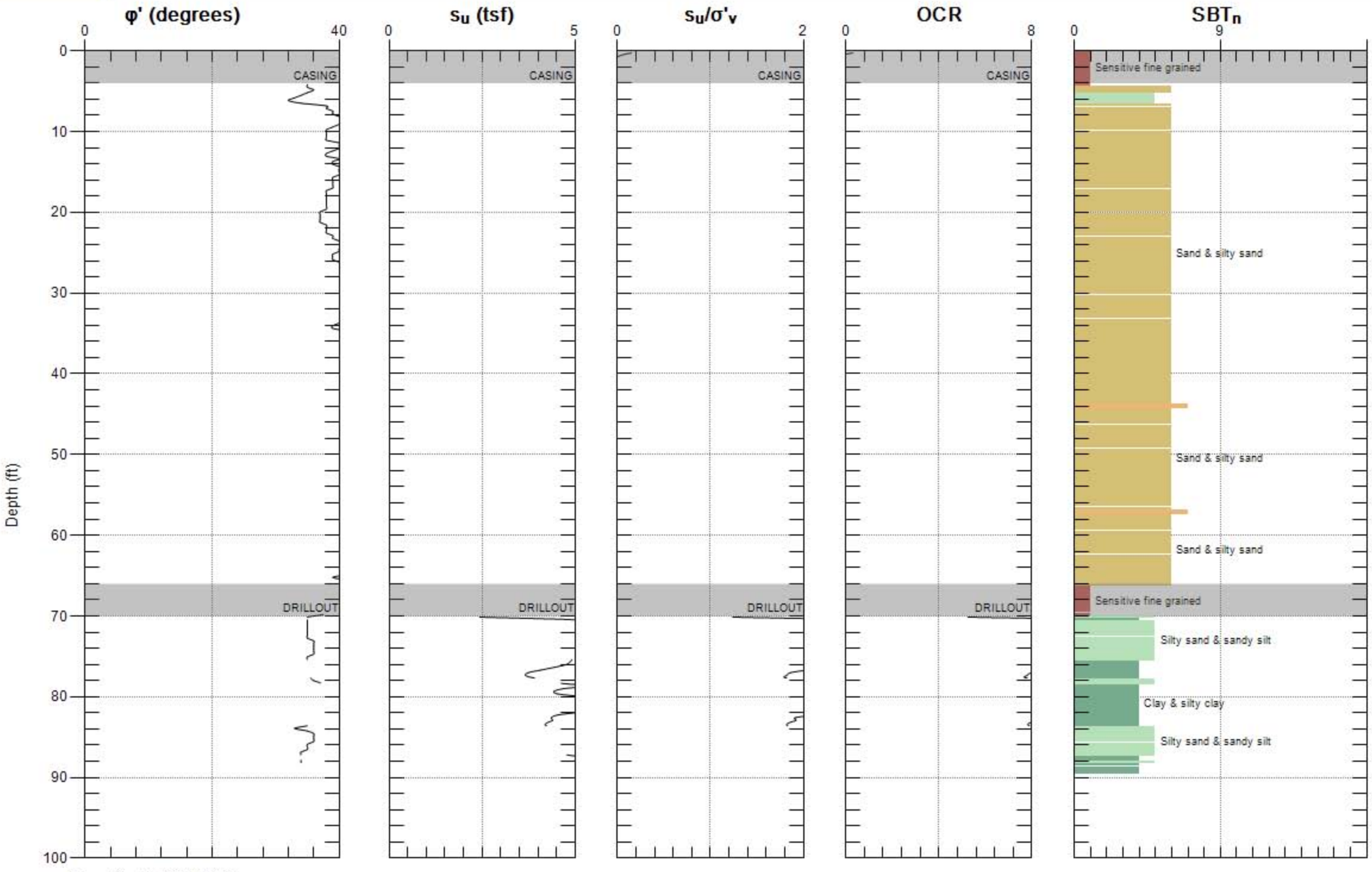


Max. Depth: 89.650 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

EARTH MECHANICS

Site: ANTIOCH BRIDGE
Sounding: 07-CPT-15
Engineer: J.CASTLE
Date: 2/12/2007 07:03

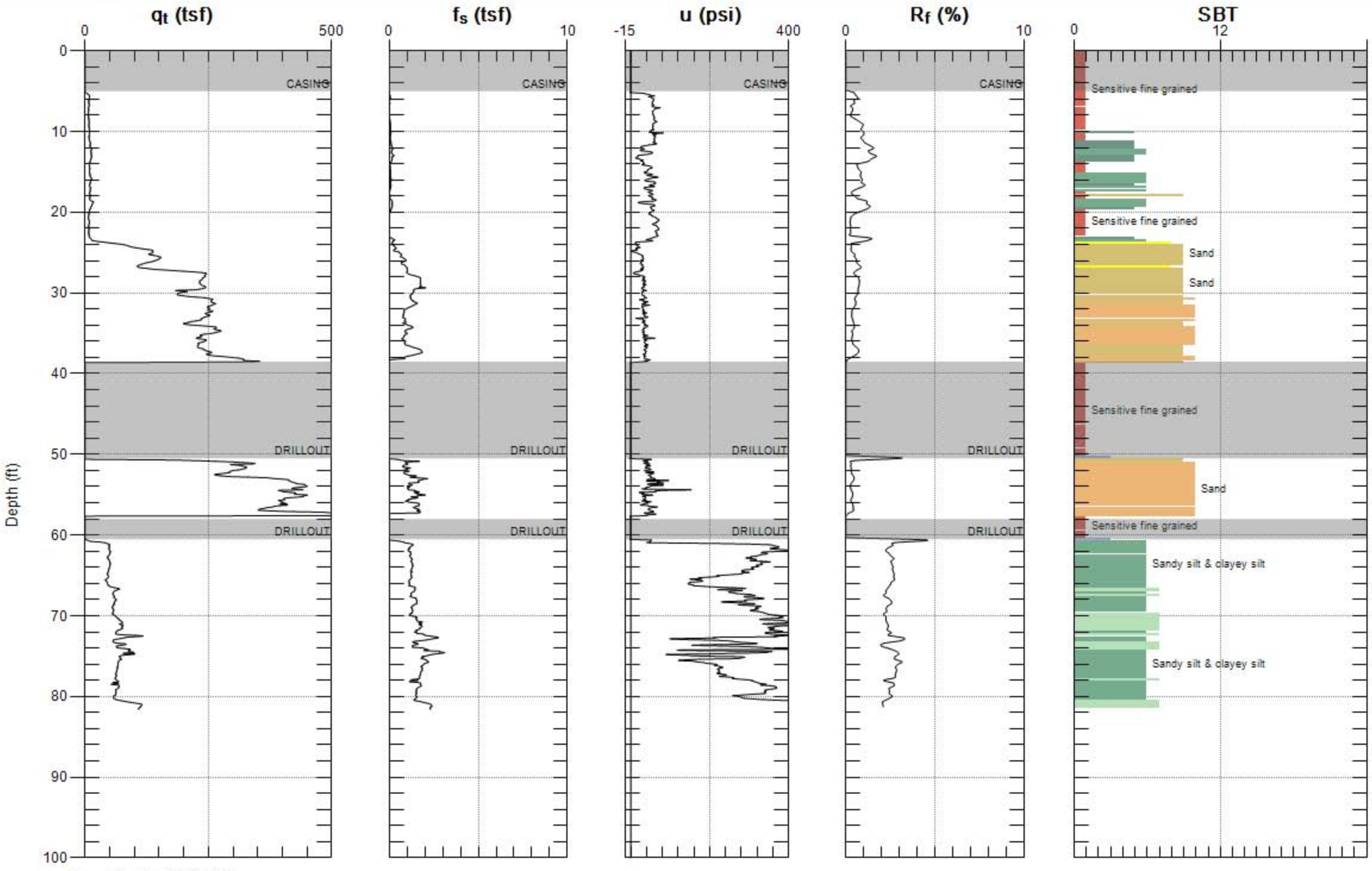


Max. Depth: 89.650 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

EARTH MECHANICS

Site: ANTIOCH BRIDGE
Sounding: 07-CPT-16
Engineer: J.CASTLE
Date: 2/11/2007 07:04

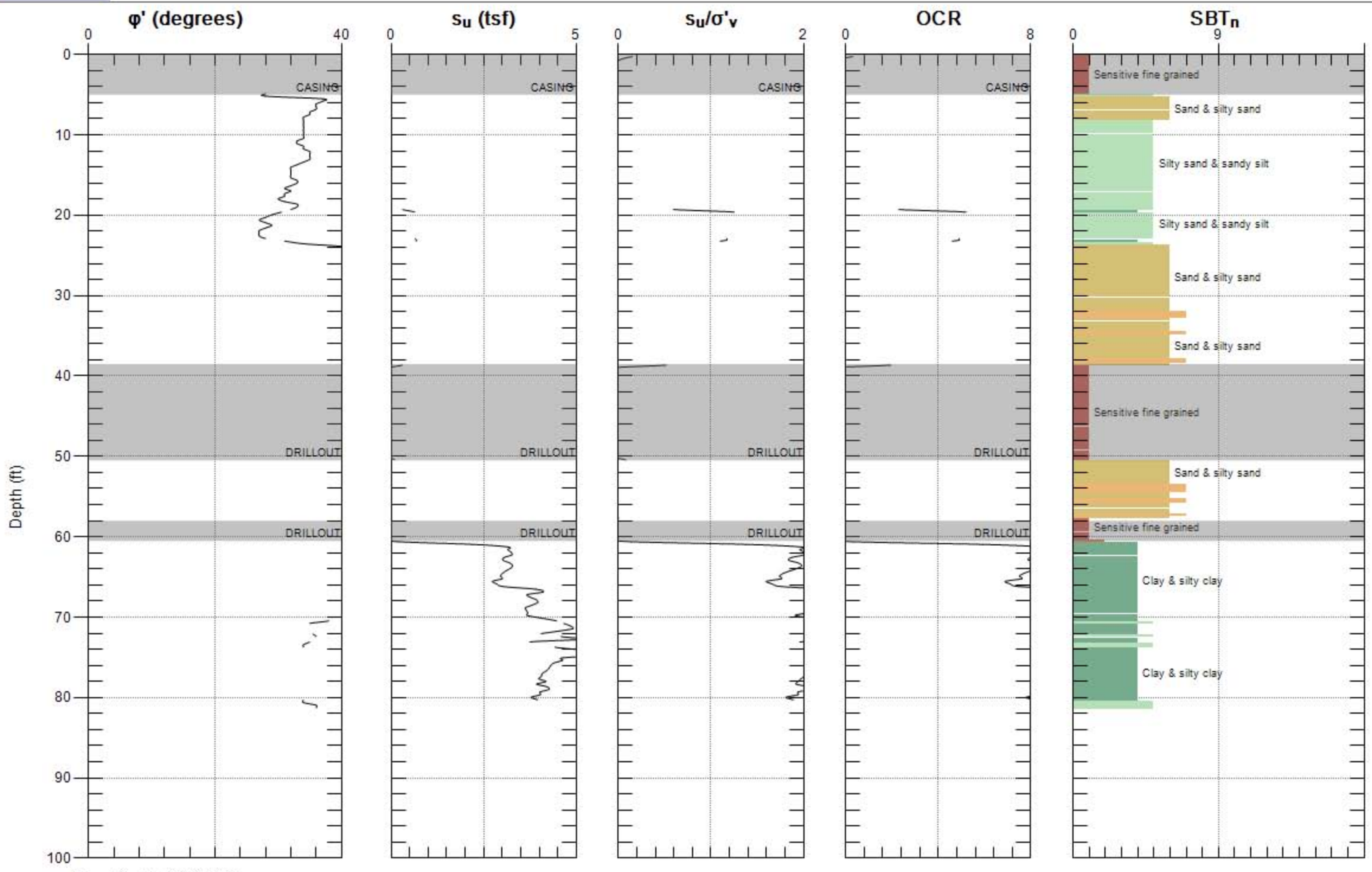


Max. Depth: 81.610 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

EARTH MECHANICS

Site: ANTIOCH BRIDGE
Sounding: 07-CPT-16
Engineer: J.CASTLE
Date: 2/11/2007 07:04

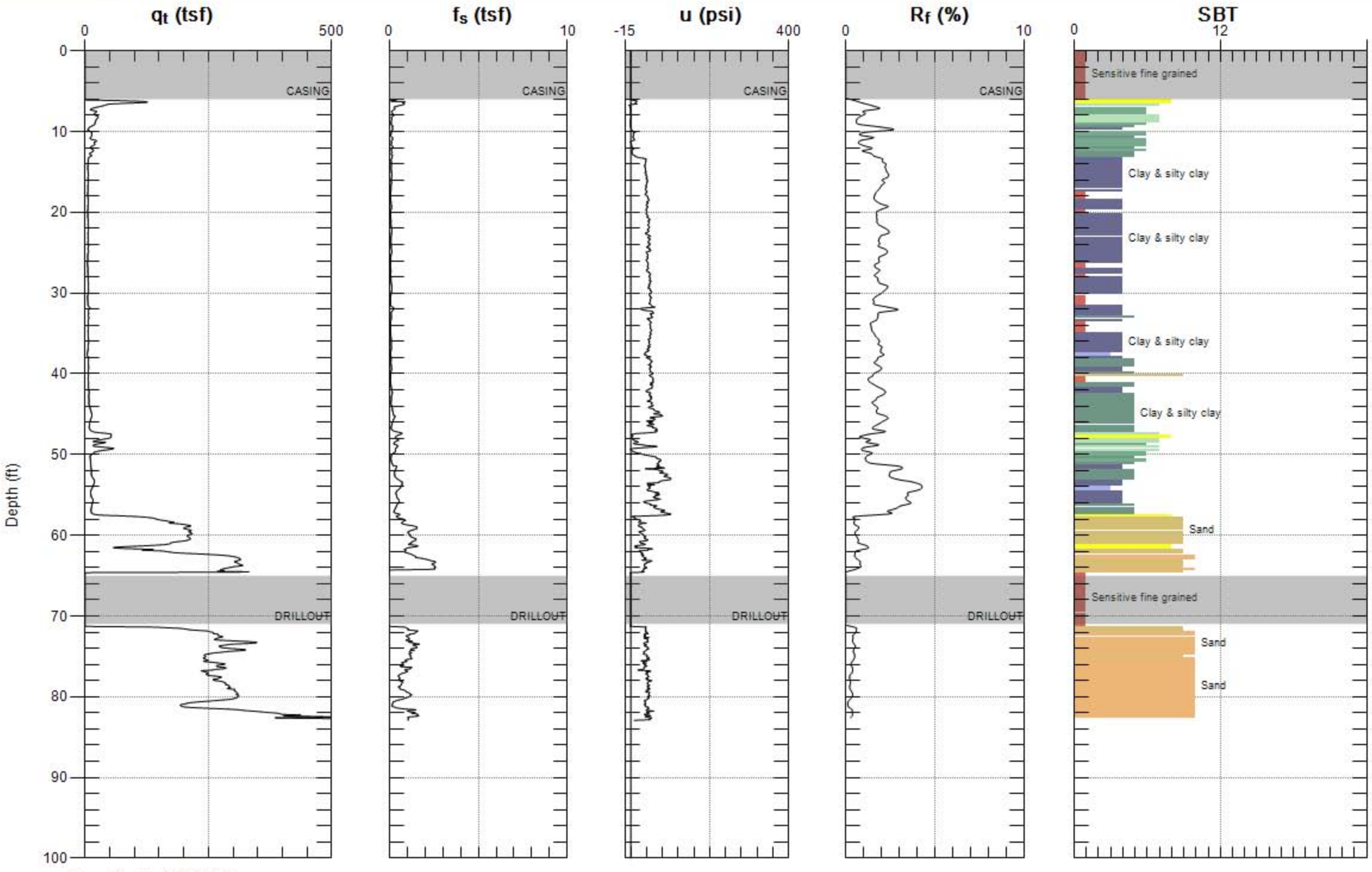


Max. Depth: 81.610 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

EARTH MECHANICS

Site: ANTIOCH BRIDGE
Sounding: 07-CPT-17
Engineer: J.CASTLE
Date: 2/11/2007 11:25

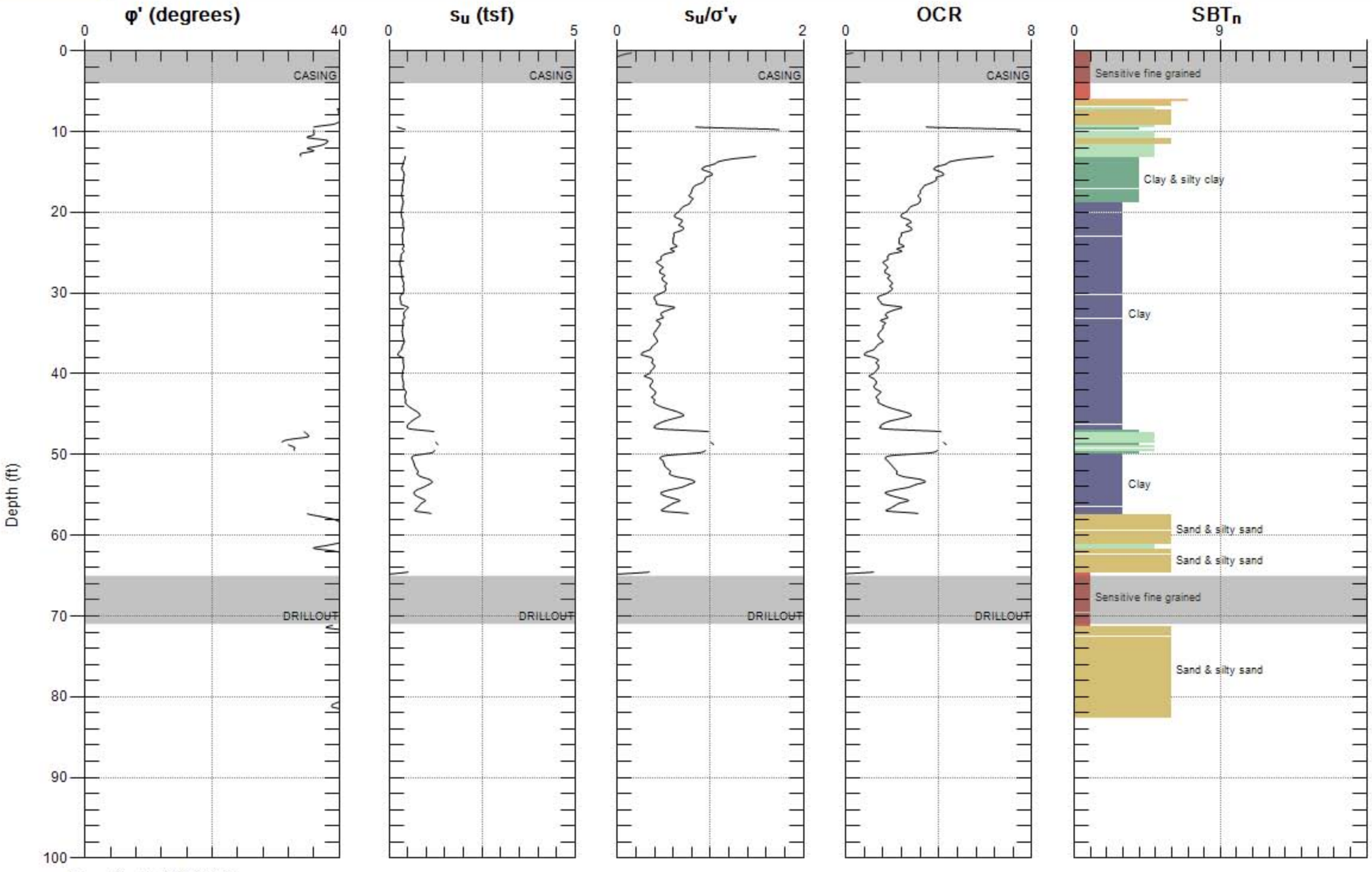


Max. Depth: 82.920 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

EARTH MECHANICS

Site: ANTIOCH BRIDGE
Sounding: 07-CPT-17
Engineer: J.CASTLE
Date: 2/11/2007 11:25

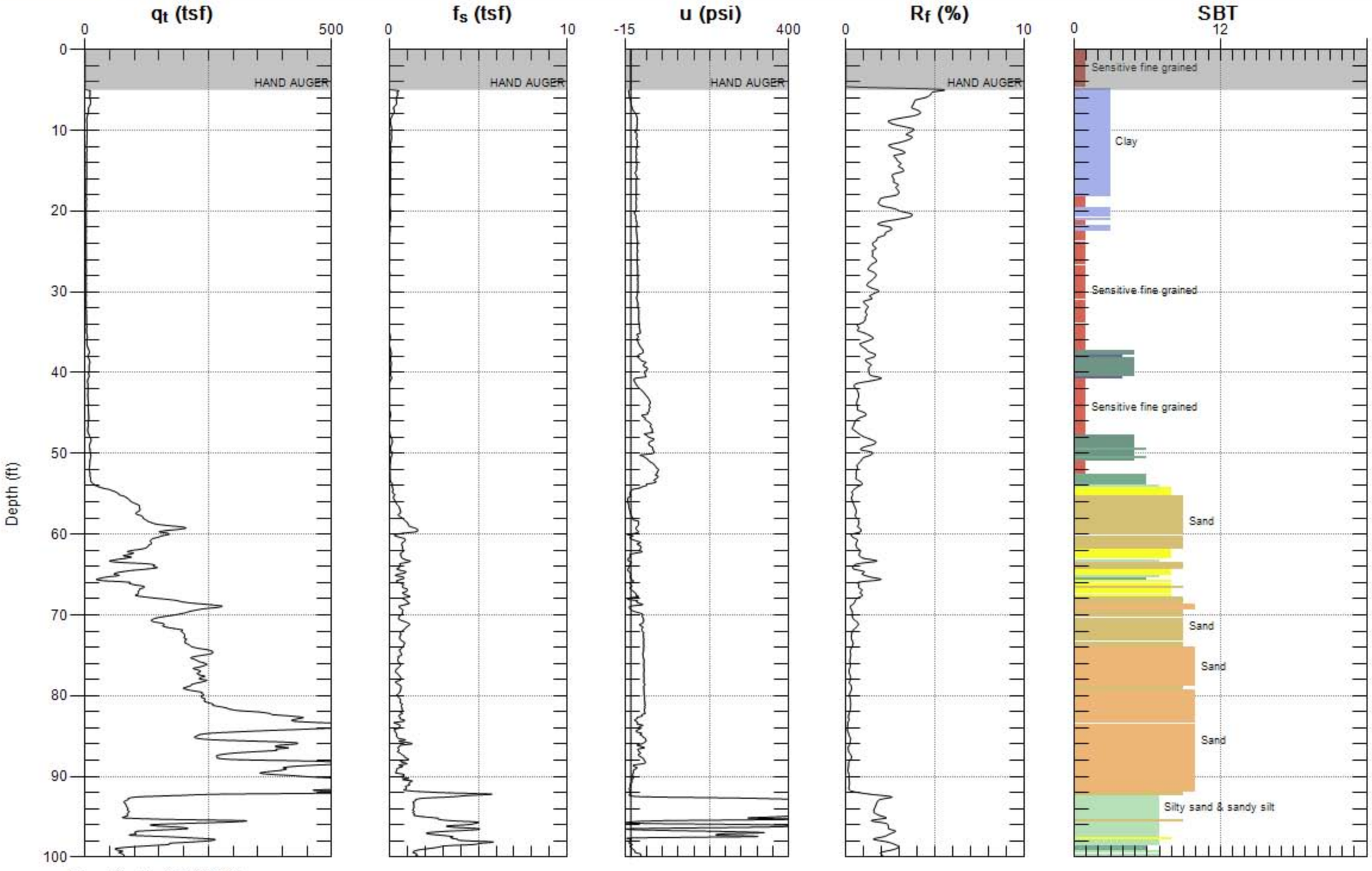


Max. Depth: 82.920 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

EARTH MECHANICS

Site: ANTIOCH BRIDGE
Sounding: CPT-18 Seis
Engineer: J.CASTLE
Date: 11/17/2006 01:50

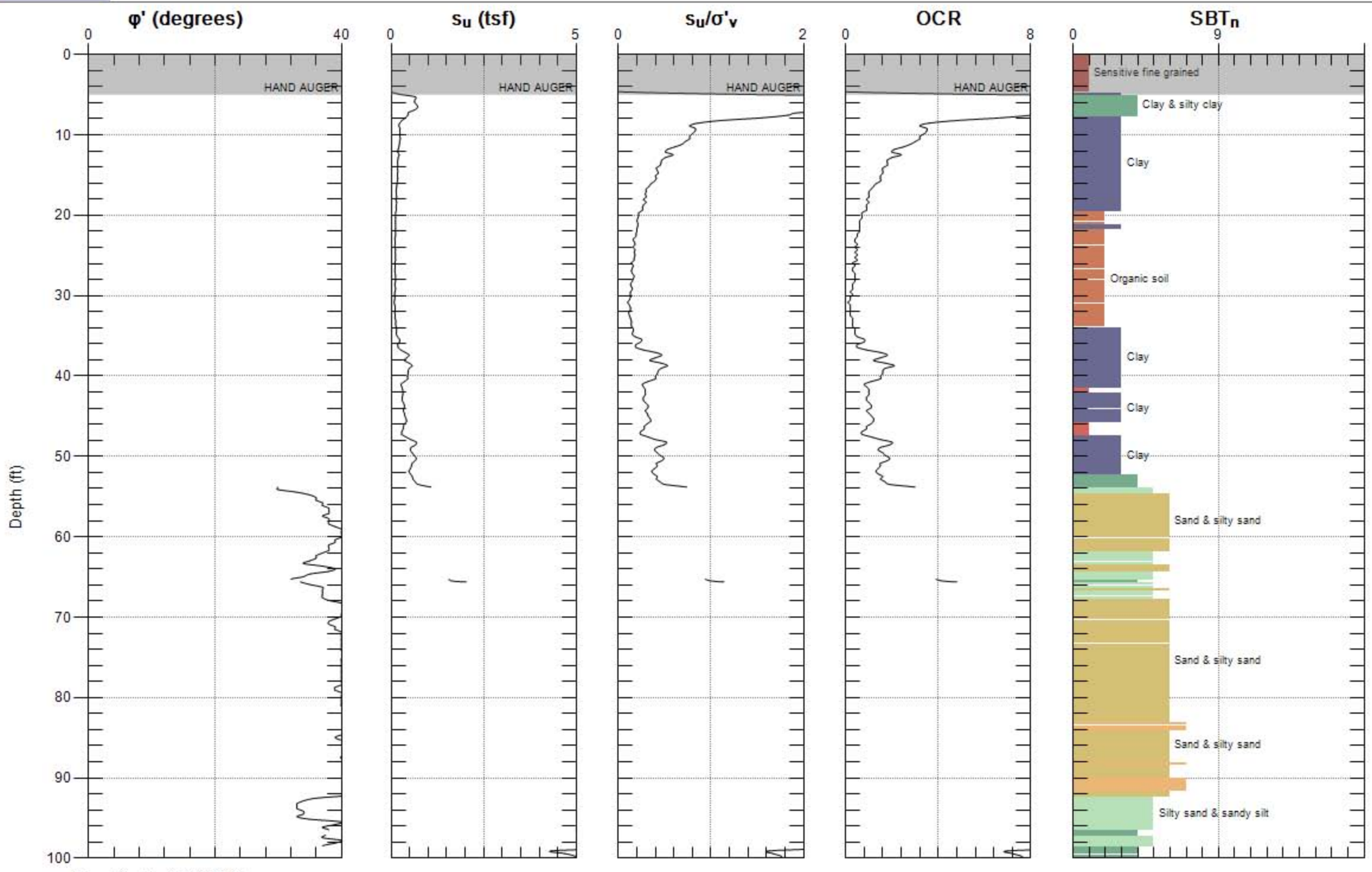


Max. Depth: 100.230 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

EARTH MECHANICS

Site: ANTIOCH BRIDGE
Sounding: CPT-18 Seis
Engineer: J.CASTLE
Date: 11/17/2006 01:50

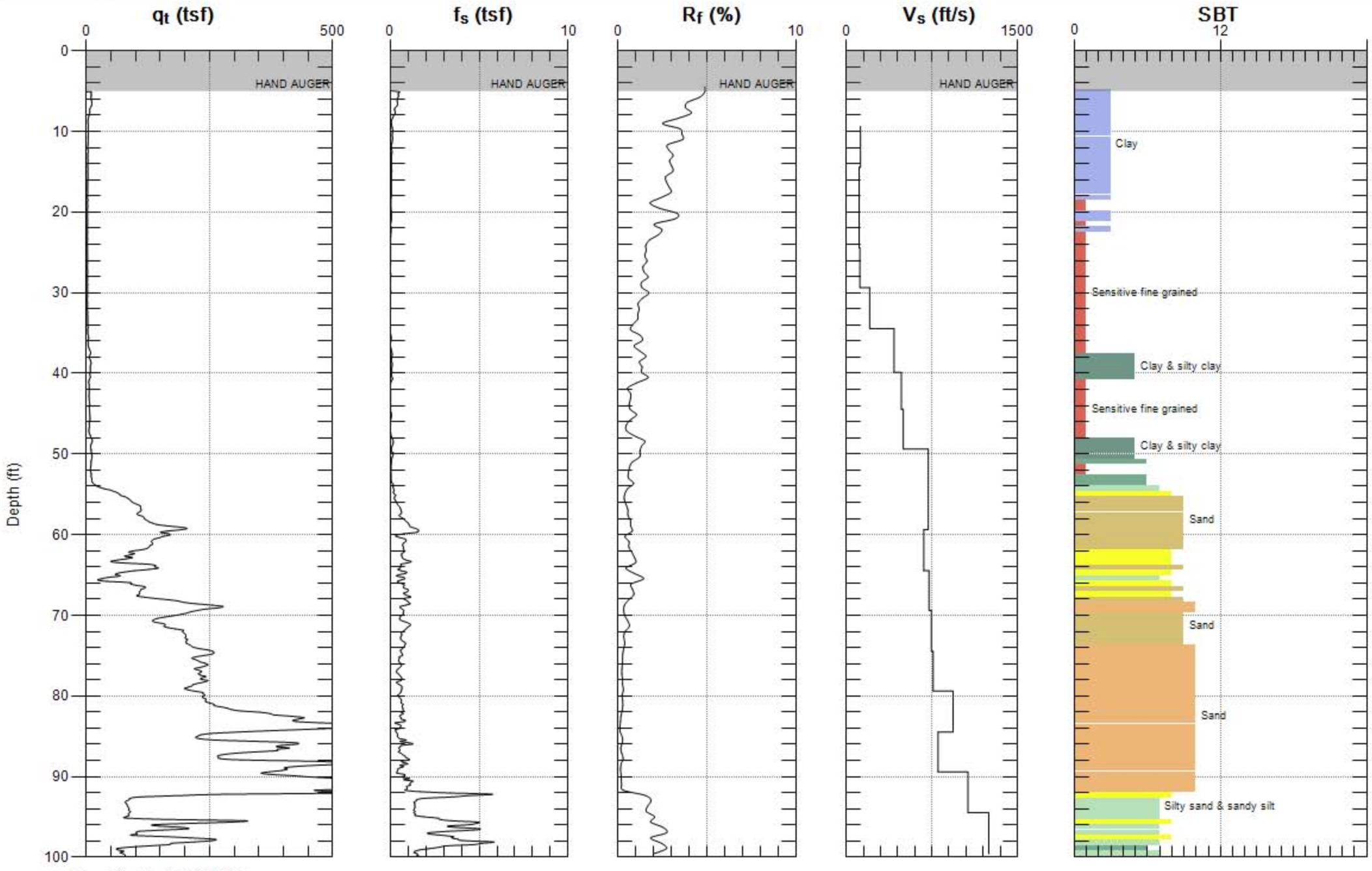


Max. Depth: 100.230 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

EARTH MECHANICS

Site: ANTIOCH BRIDGE
Sounding: CPT-18 Seis
Engineer: J.CASTLE
Date: 11/17/2006 01:50

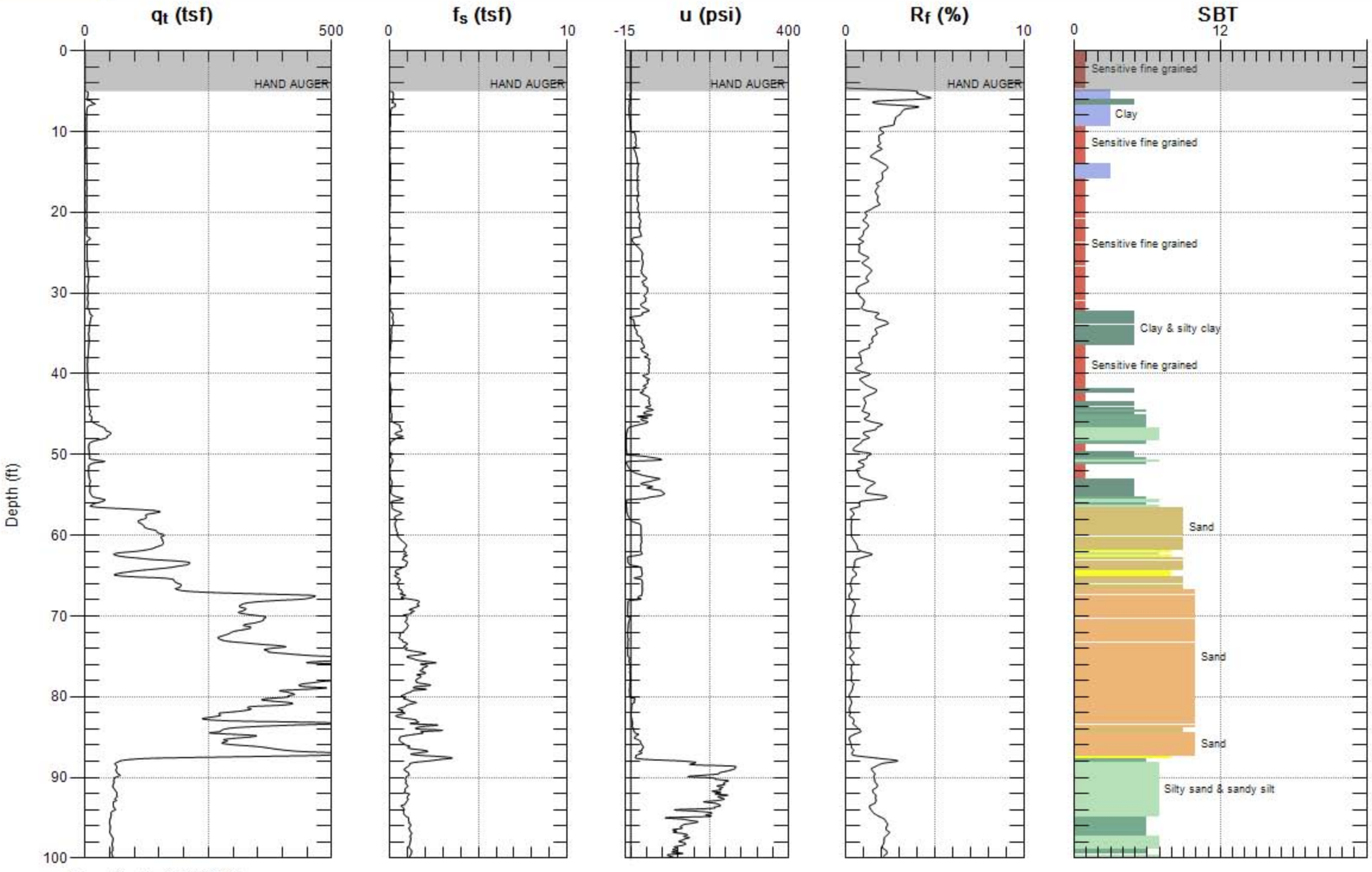


Max. Depth: 100.230 (ft)
Avg. Interval: 0.656 (ft)

SBT: Soil Behavior Type (Robertson 1990)

EARTH MECHANICS

Site: ANTIOCH BRIDGE
Sounding: CPT-20 Seis
Engineer: J.CASTLE
Date: 11/21/2006 03:06

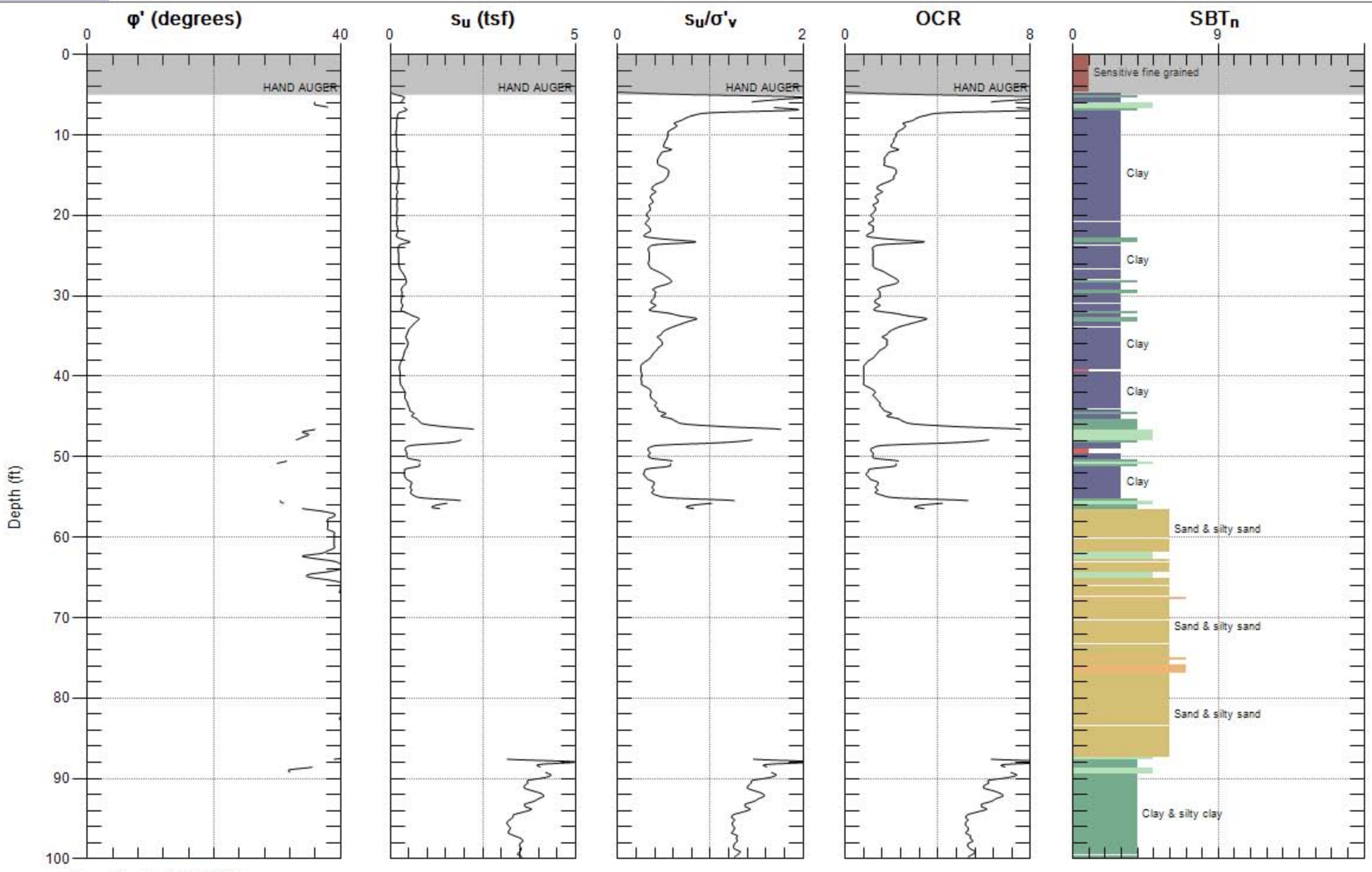


Max. Depth: 100.070 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

EARTH MECHANICS

Site: ANTIOCH BRIDGE
Sounding: CPT-20 Seis
Engineer: J.CASTLE
Date: 11/21/2006 03:06

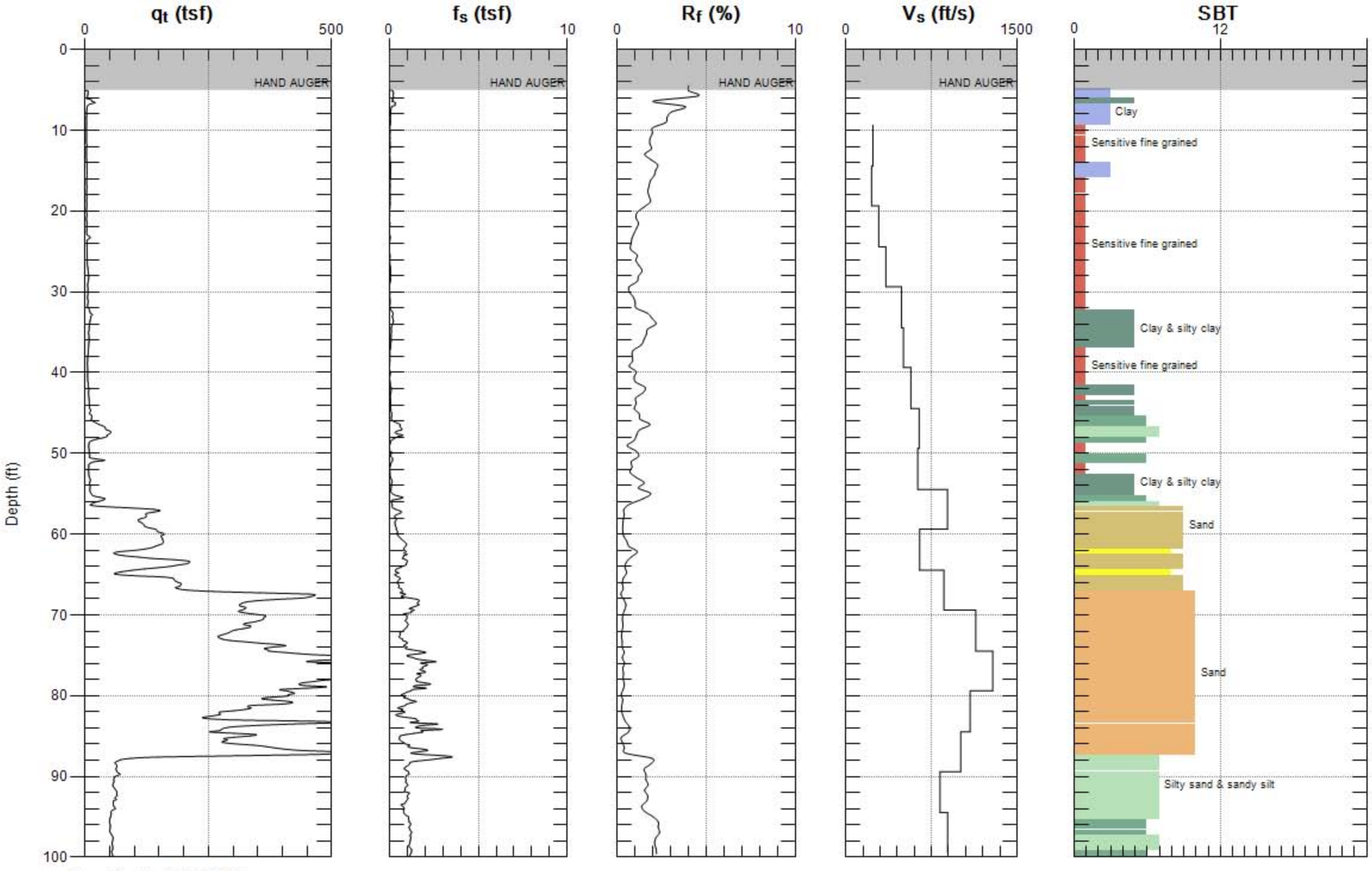


Max. Depth: 100.070 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

EARTH MECHANICS

Site: ANTIOCH BRIDGE
Sounding: CPT-20 Seis
Engineer: J.CASTLE
Date: 11/21/2006 03:06

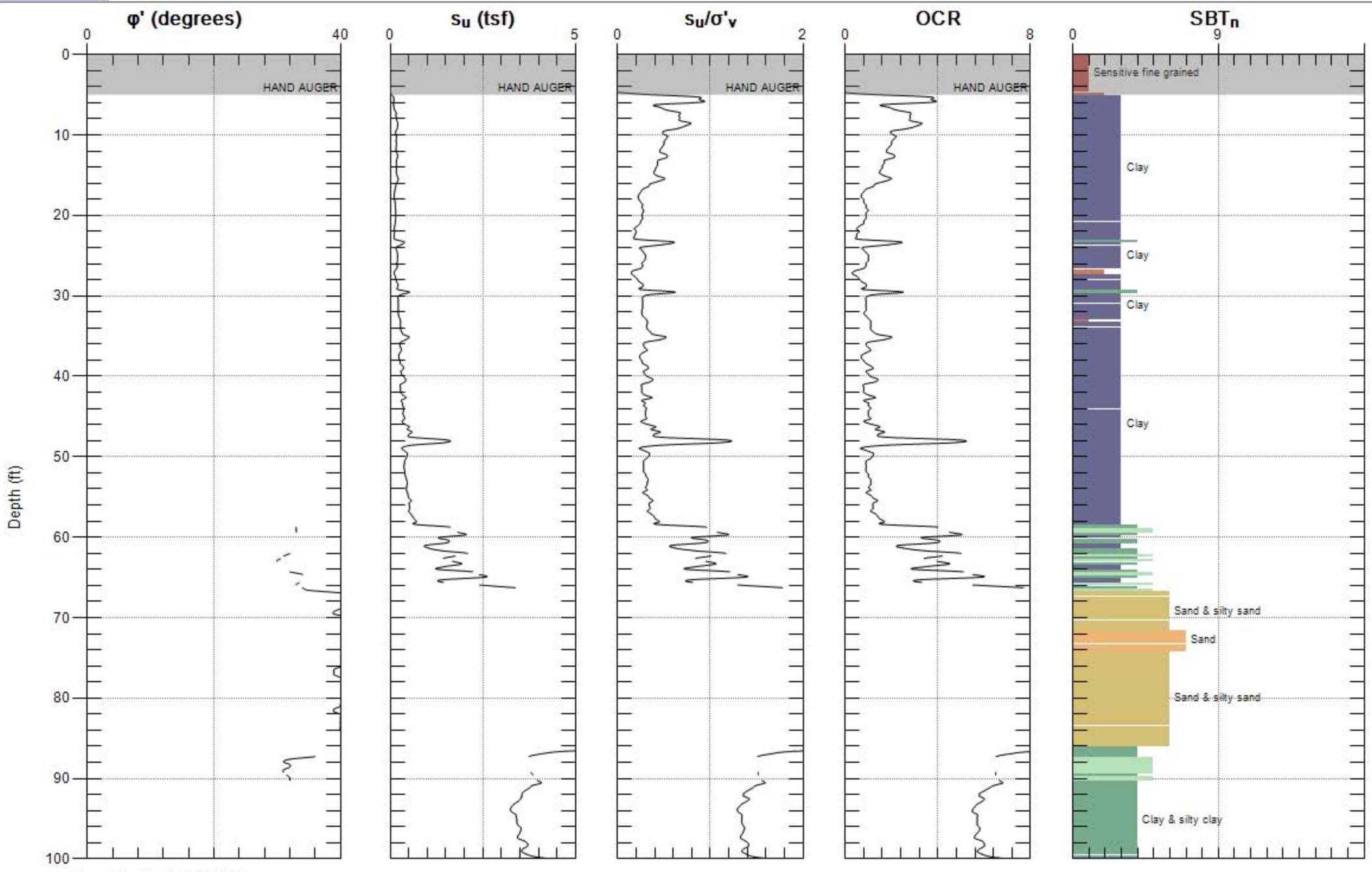


Max. Depth: 100.070 (ft)
Avg. Interval: 0.656 (ft)

SBT: Soil Behavior Type (Robertson 1990)

EARTH MECHANICS

Site: ANTIOCH BRIDGE
Sounding: CPT-21 Seis
Engineer: J.CASTLE
Date: 11/21/2006 12:10

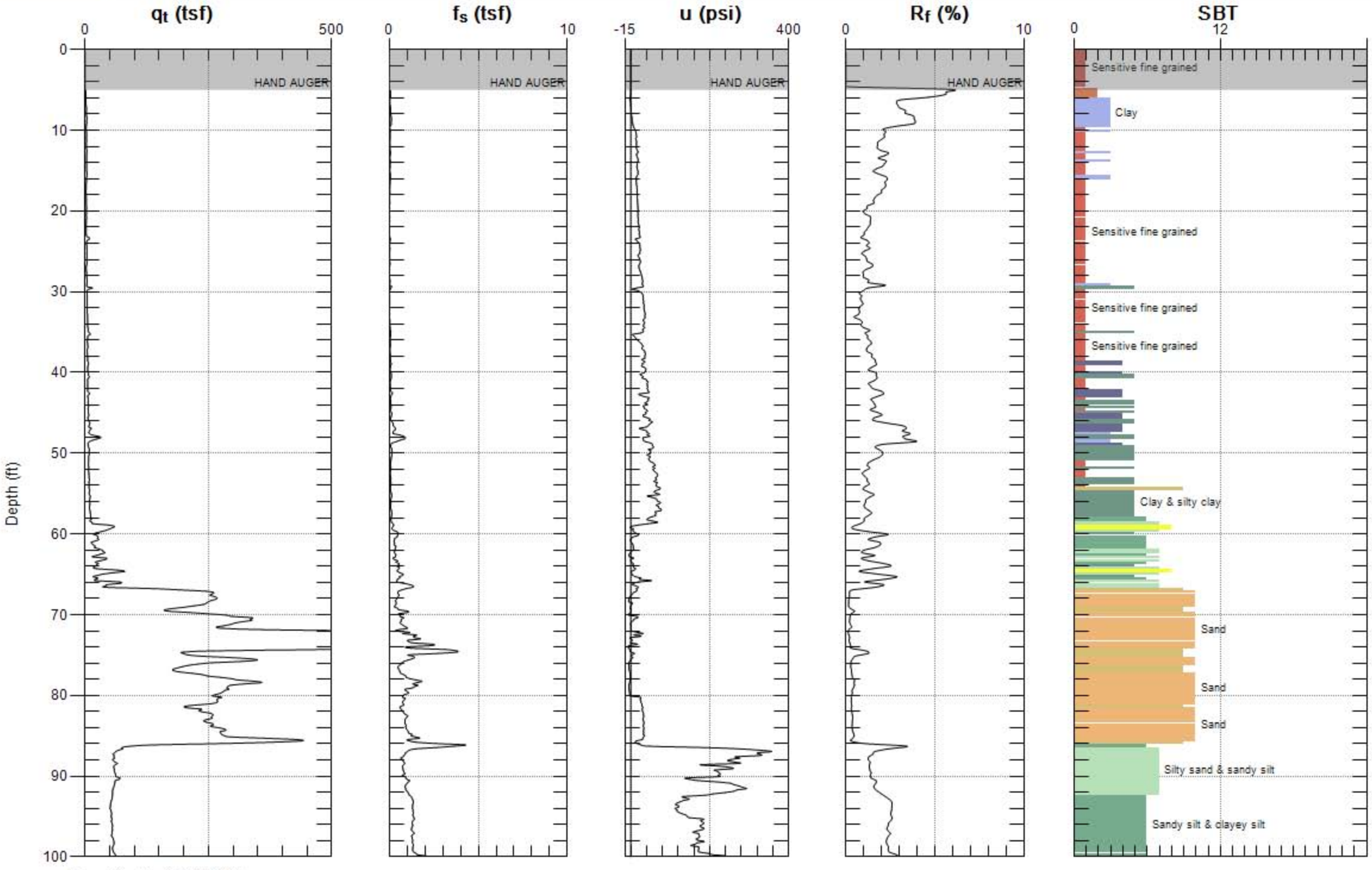


Max. Depth: 100.230 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

EARTH MECHANICS

Site: ANTIOCH BRIDGE
Sounding: CPT-21 Seis
Engineer: J.CASTLE
Date: 11/21/2006 12:10

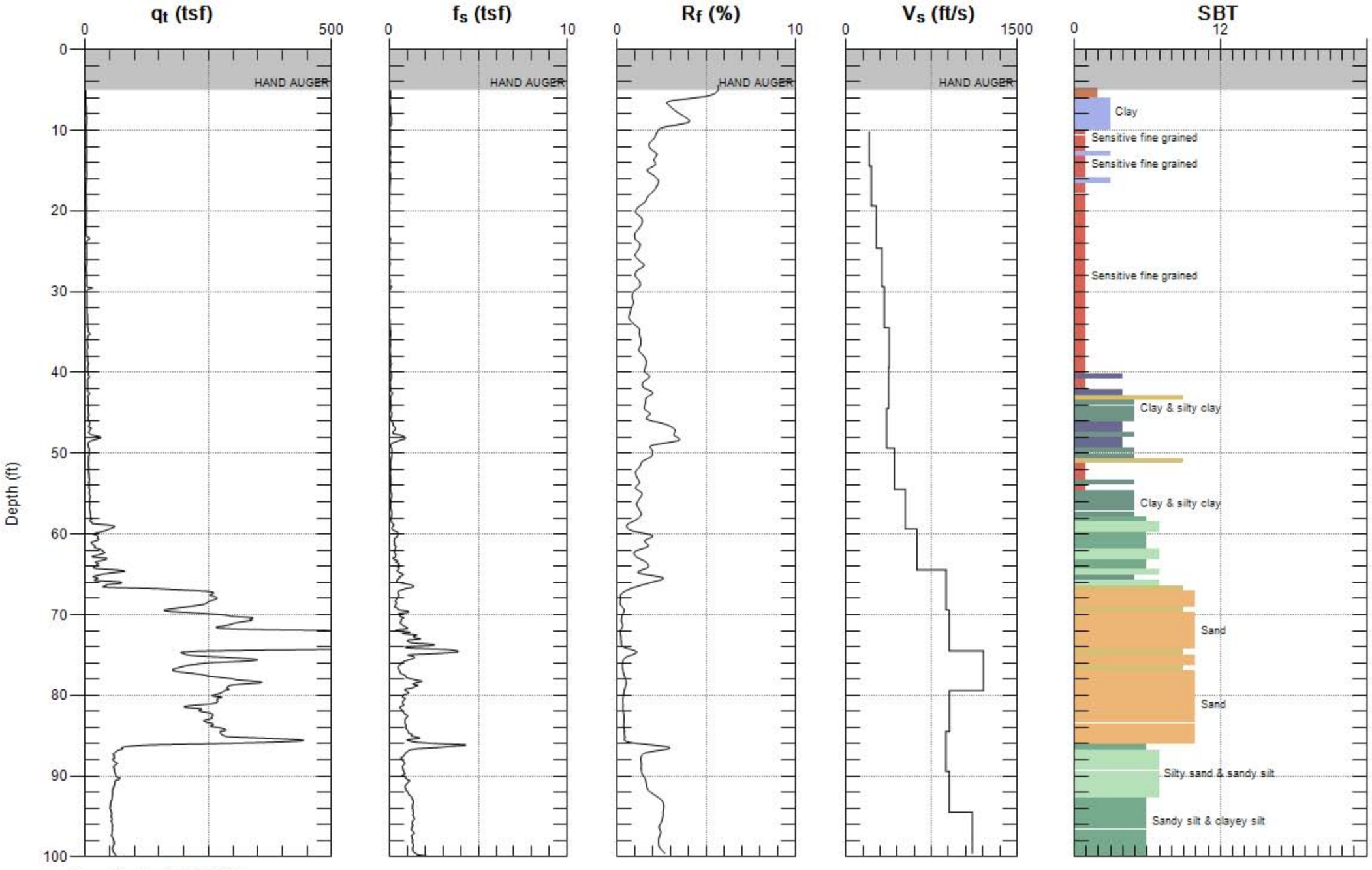


Max. Depth: 100.230 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

EARTH MECHANICS

Site: ANTIOCH BRIDGE
Sounding: CPT-21 Seis
Engineer: J.CASTLE
Date: 11/21/2006 12:10

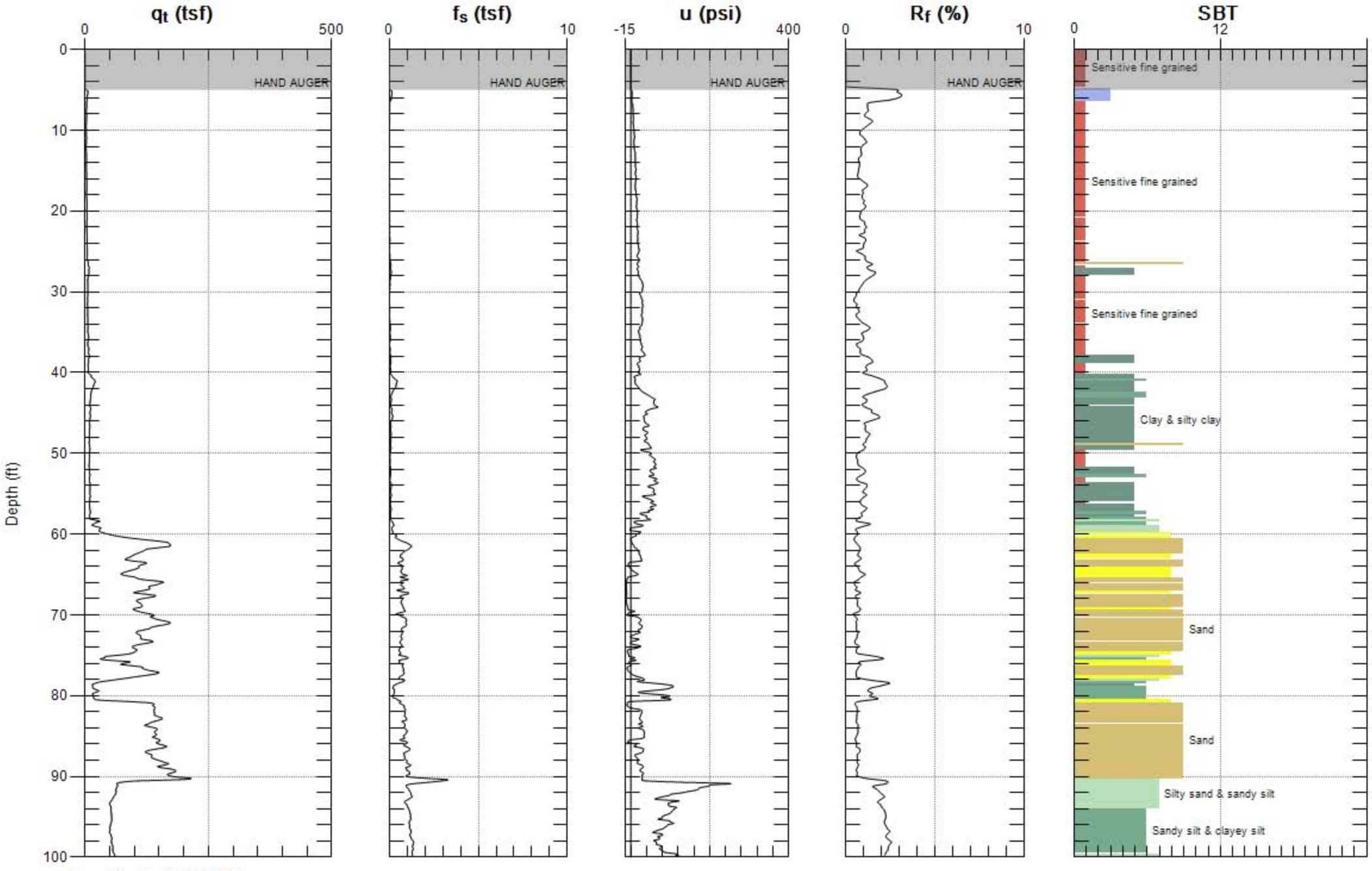


Max. Depth: 100.230 (ft)
Avg. Interval: 0.656 (ft)

SBT: Soil Behavior Type (Robertson 1990)

EARTH MECHANICS

Site: ANTIOCH BRIDGE
Sounding: CPT-22 Seis
Engineer: J.CASTLE
Date: 11/21/2006 09:46

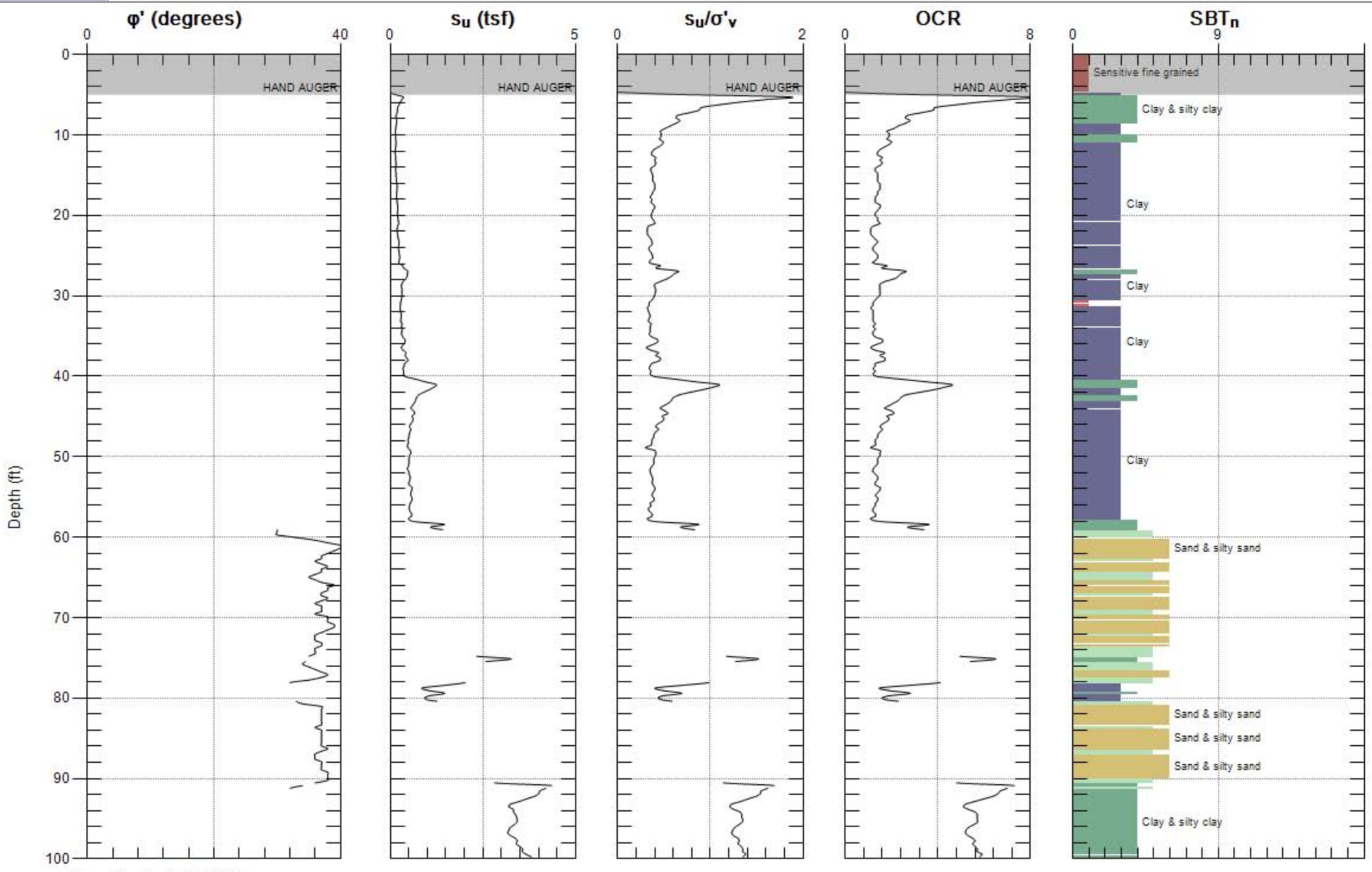


Max. Depth: 100.070 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

EARTH MECHANICS

Site: ANTIOCH BRIDGE
Sounding: CPT-22 Seis
Engineer: J.CASTLE
Date: 11/21/2006 09:46

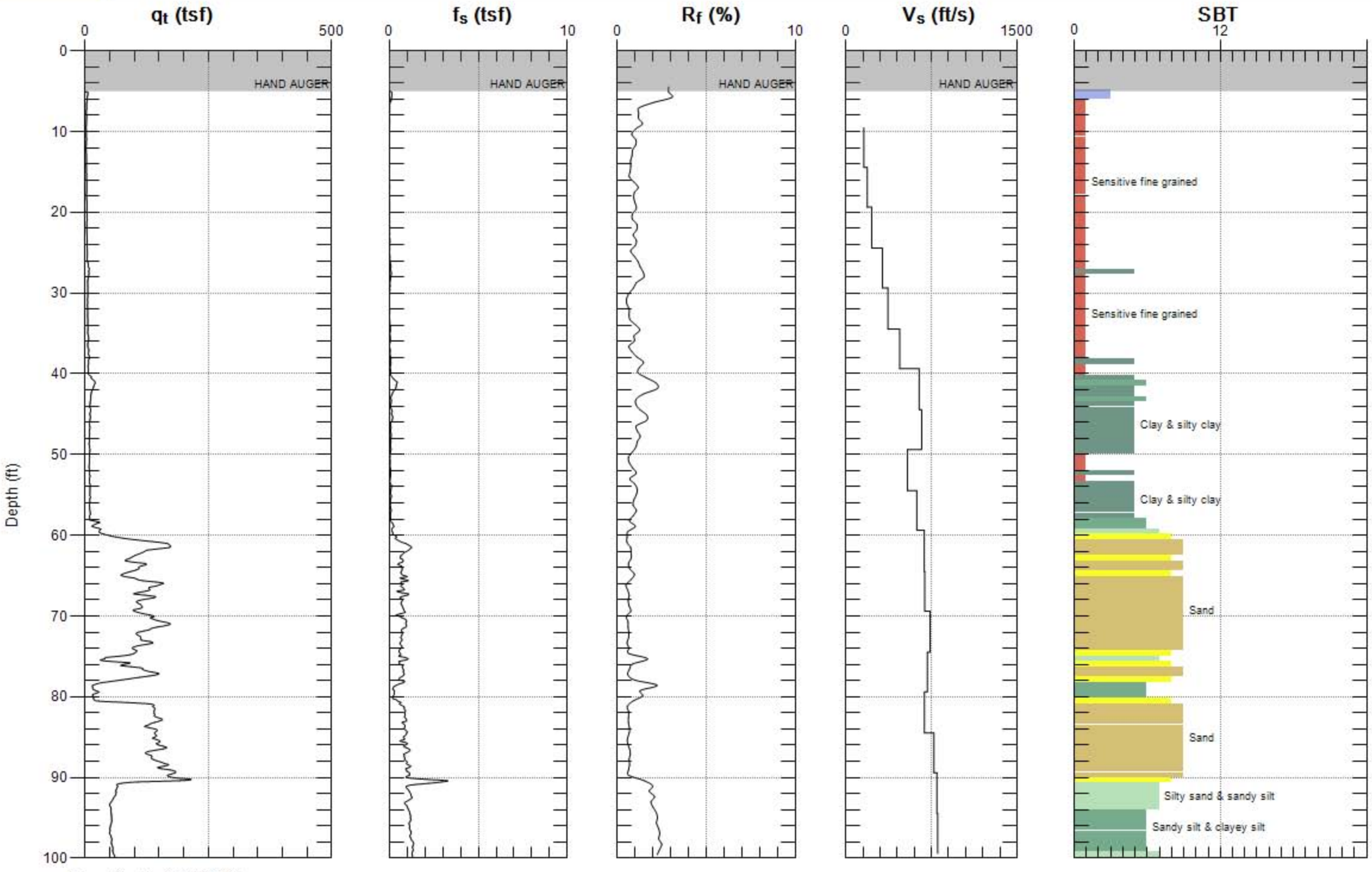


Max. Depth: 100.070 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

EARTH MECHANICS

Site: ANTIOCH BRIDGE
Sounding: CPT-22 Seis
Engineer: J.CASTLE
Date: 11/21/2006 09:46

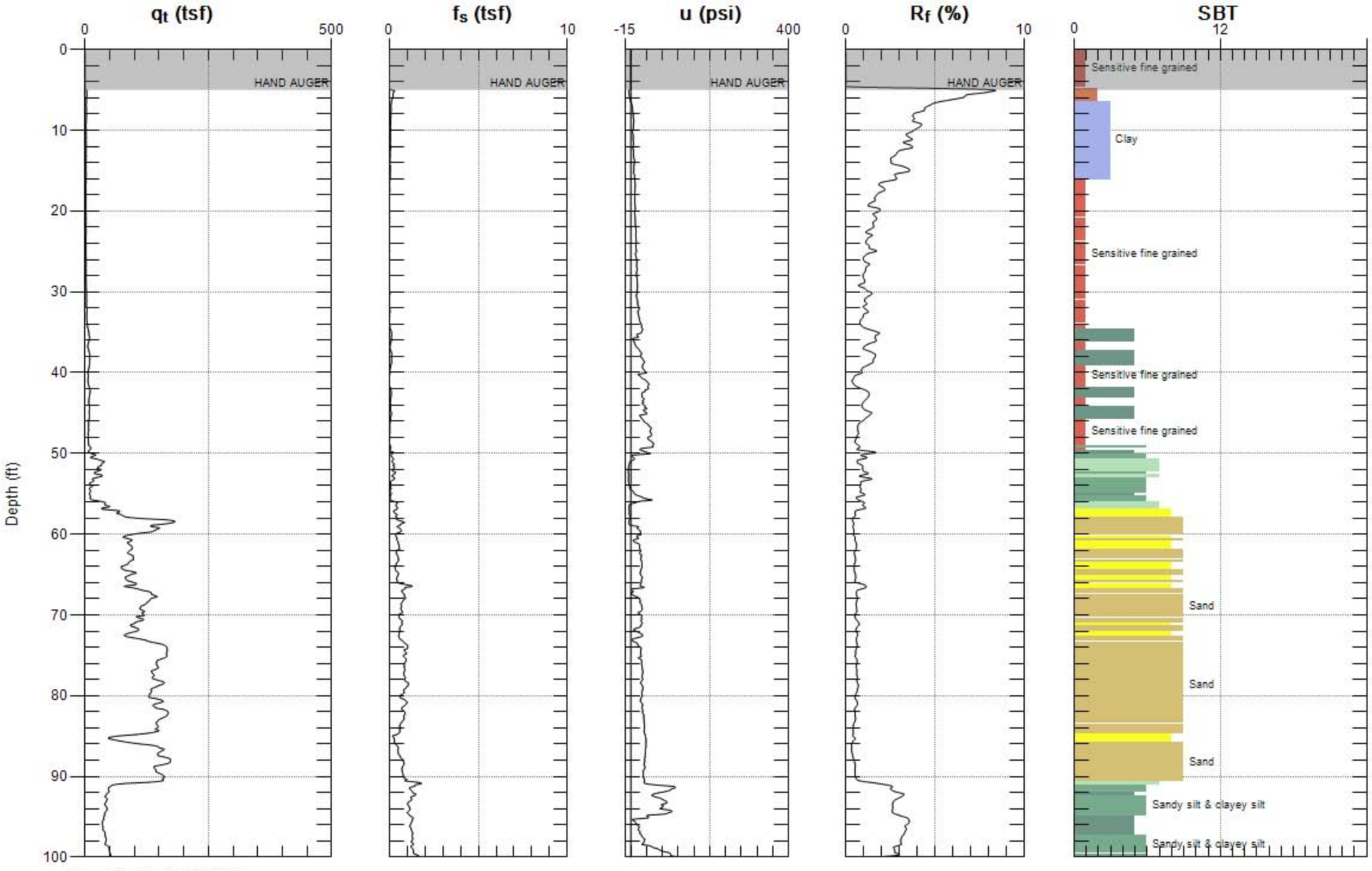


Max. Depth: 100.070 (ft)
Avg. Interval: 0.656 (ft)

SBT: Soil Behavior Type (Robertson 1990)

EARTH MECHANICS

Site: ANTIOCH BRIDGE
Sounding: CPT-23 Seis
Engineer: J.CASTLE
Date: 11/20/2006 01:50

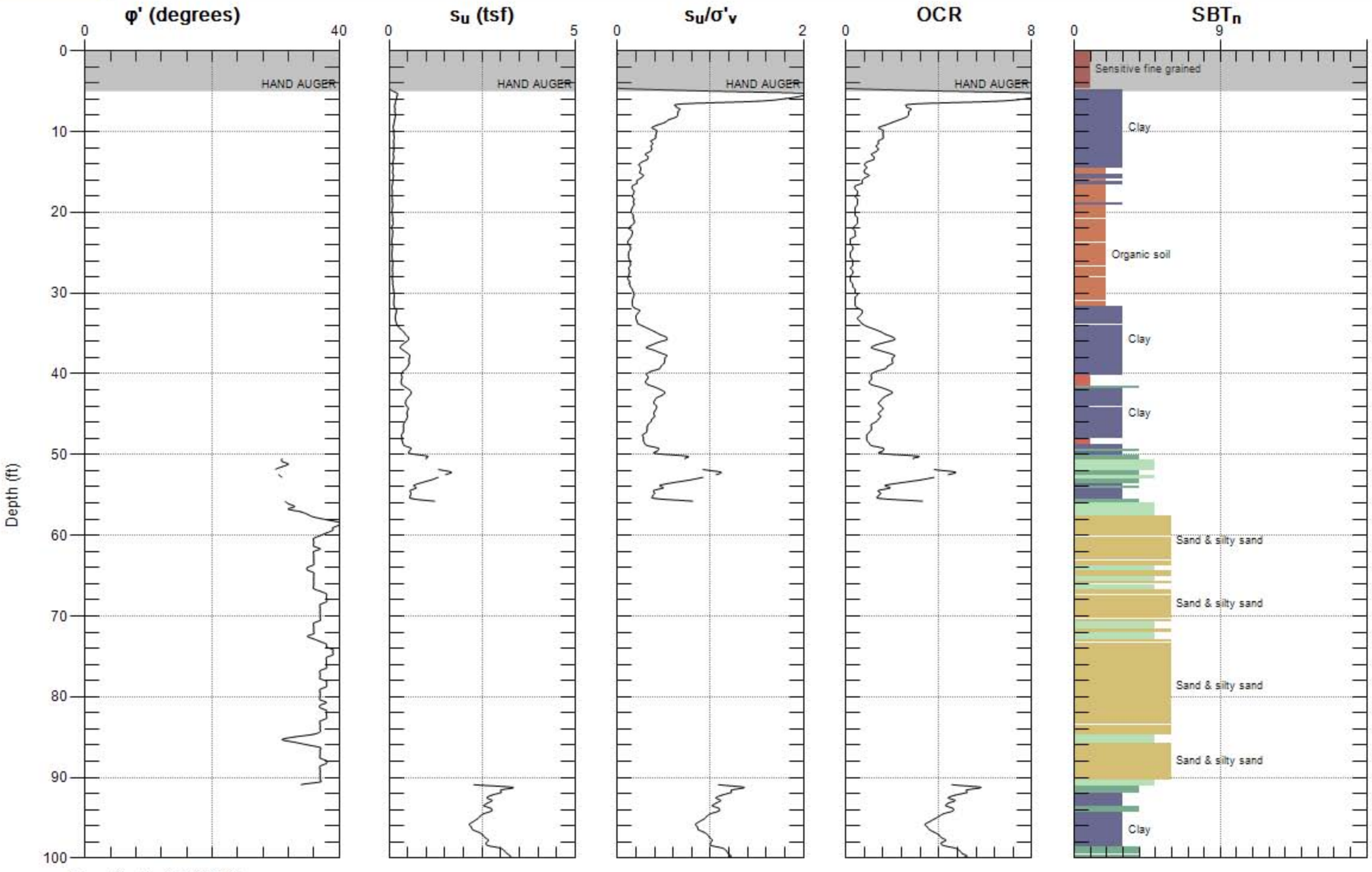


Max. Depth: 100.230 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

EARTH MECHANICS

Site: ANTIOCH BRIDGE
Sounding: CPT-23 Seis
Engineer: J.CASTLE
Date: 11/20/2006 01:50

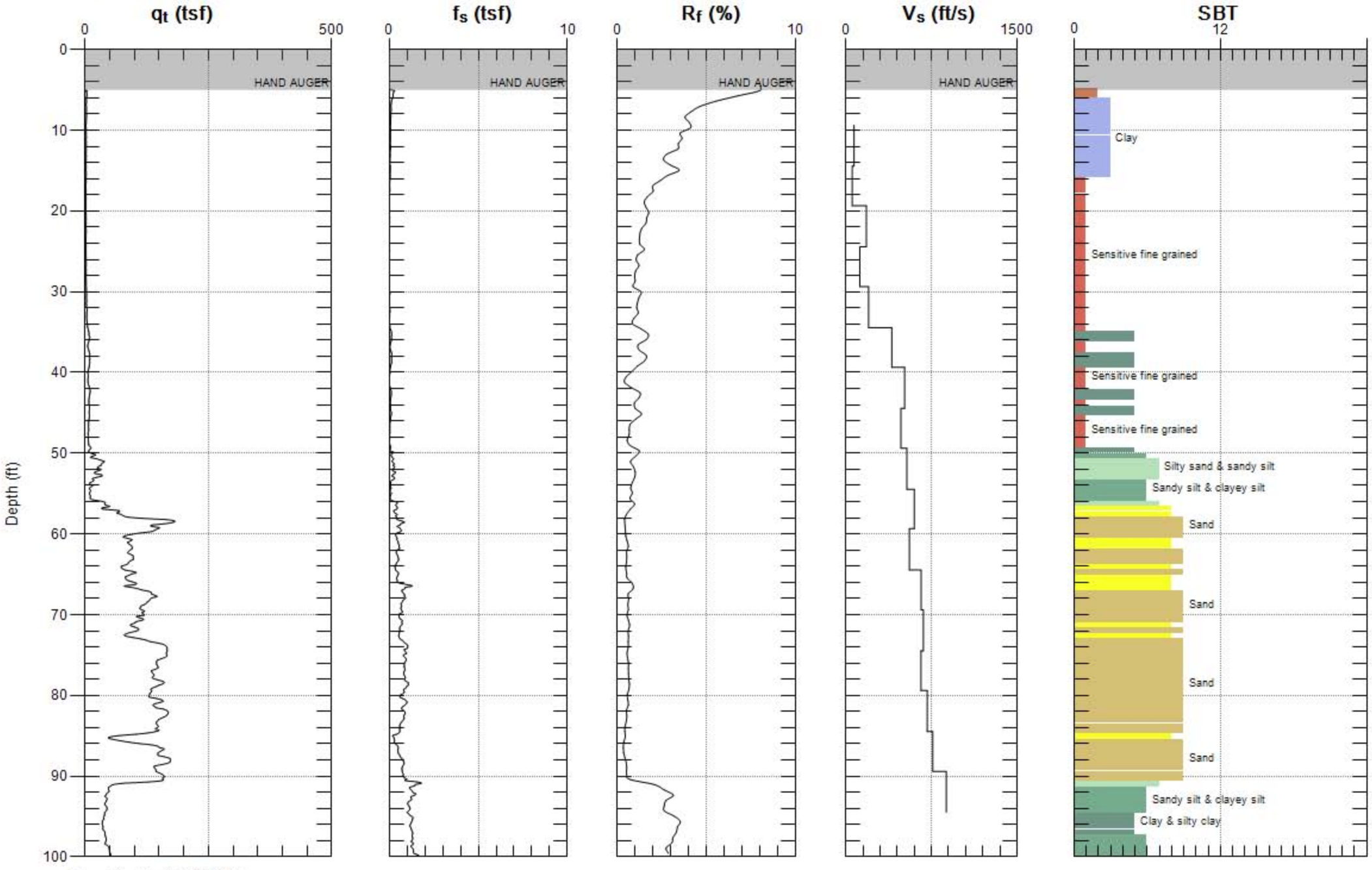


Max. Depth: 100.230 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

EARTH MECHANICS

Site: ANTIOCH BRIDGE
Sounding: CPT-23 Seis
Engineer: J.CASTLE
Date: 11/20/2006 01:50

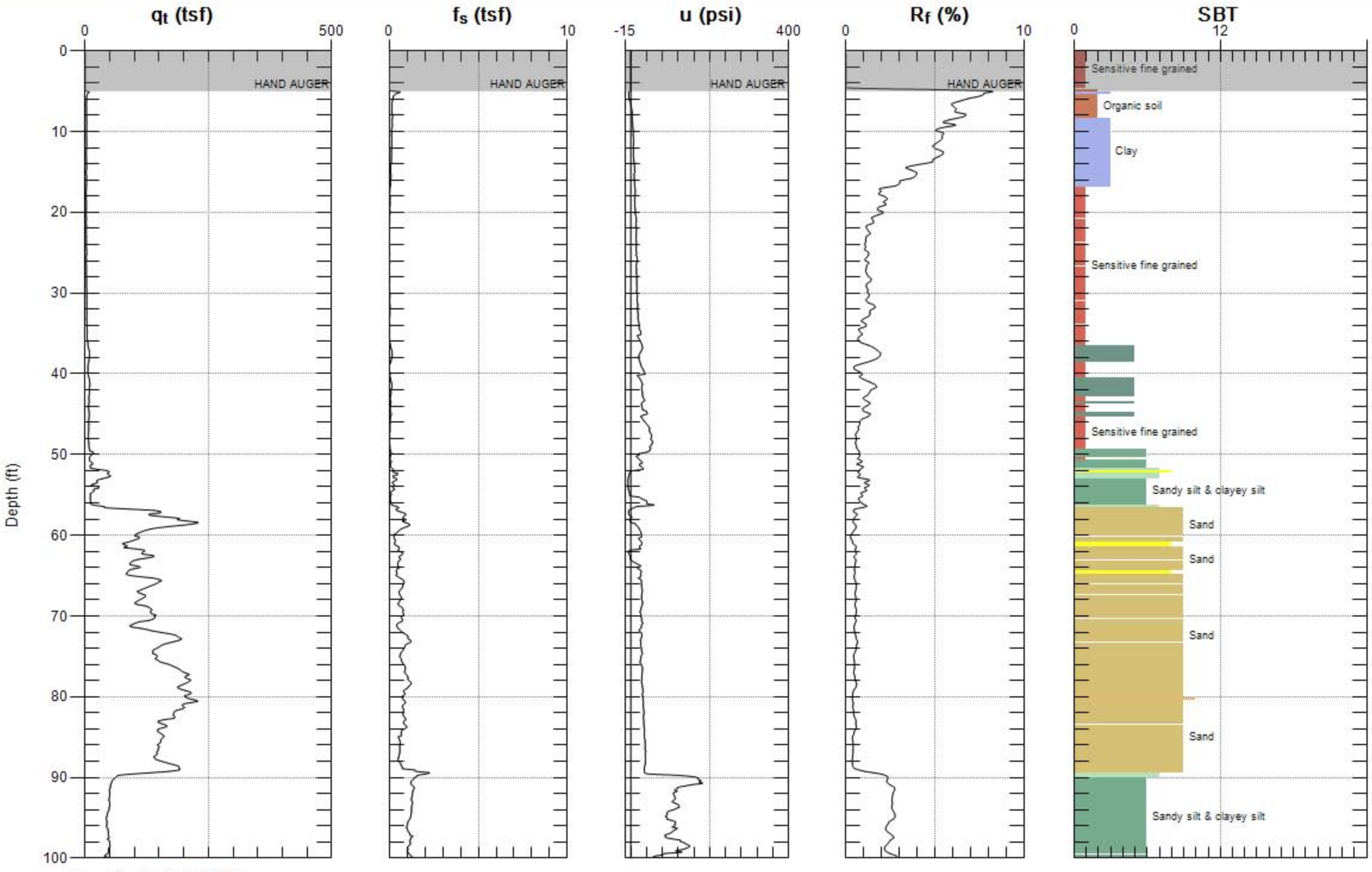


Max. Depth: 100.230 (ft)
Avg. Interval: 0.656 (ft)

SBT: Soil Behavior Type (Robertson 1990)

EARTH MECHANICS

Site: ANTIOCH BRIDGE
Sounding: CPT-24 Seis
Engineer: J.CASTLE
Date: 11/20/2006 10:42

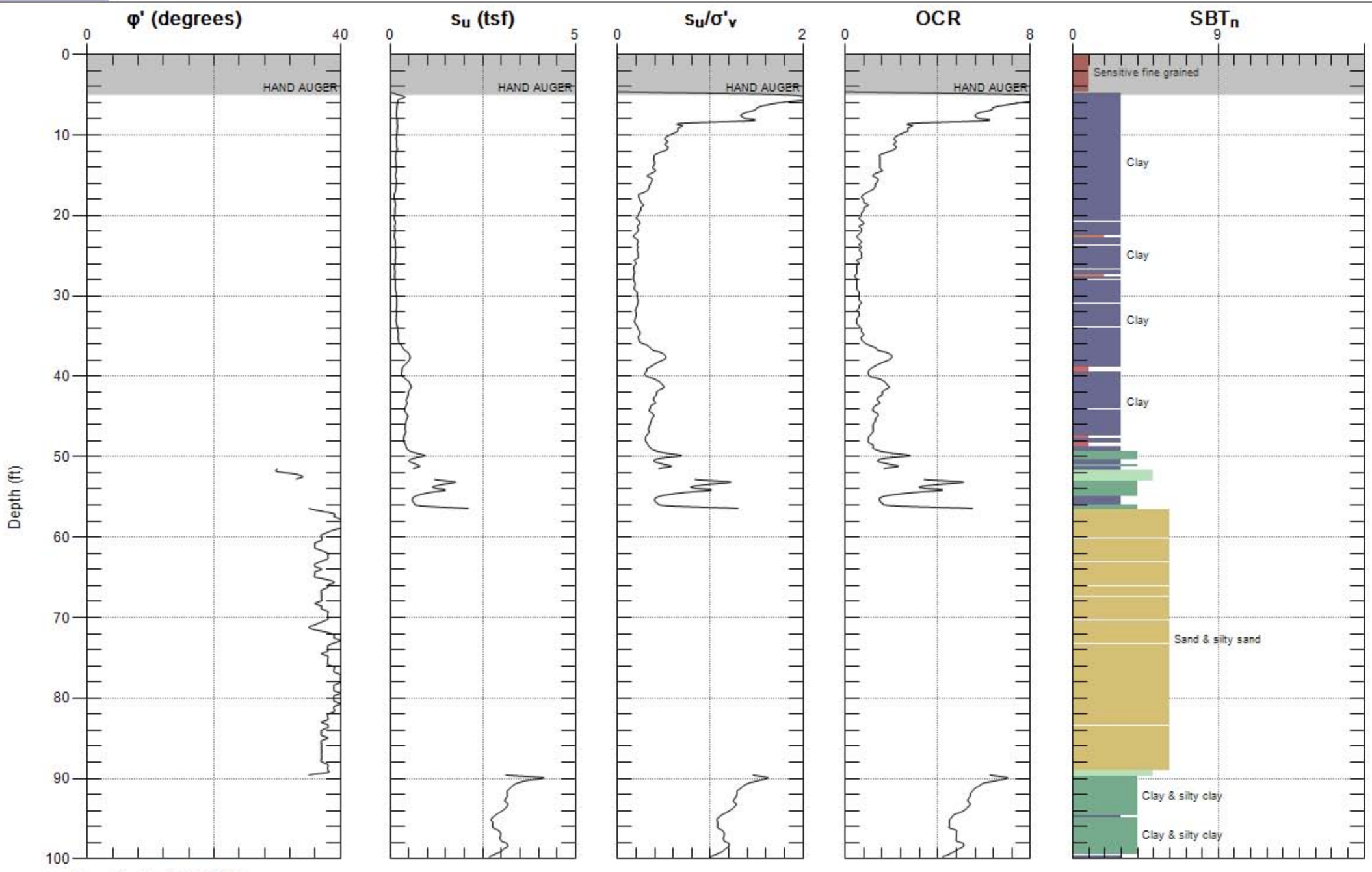


Max. Depth: 100.070 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

EARTH MECHANICS

Site: ANTIOCH BRIDGE
Sounding: CPT-24 Seis
Engineer: J.CASTLE
Date: 11/20/2006 10:42

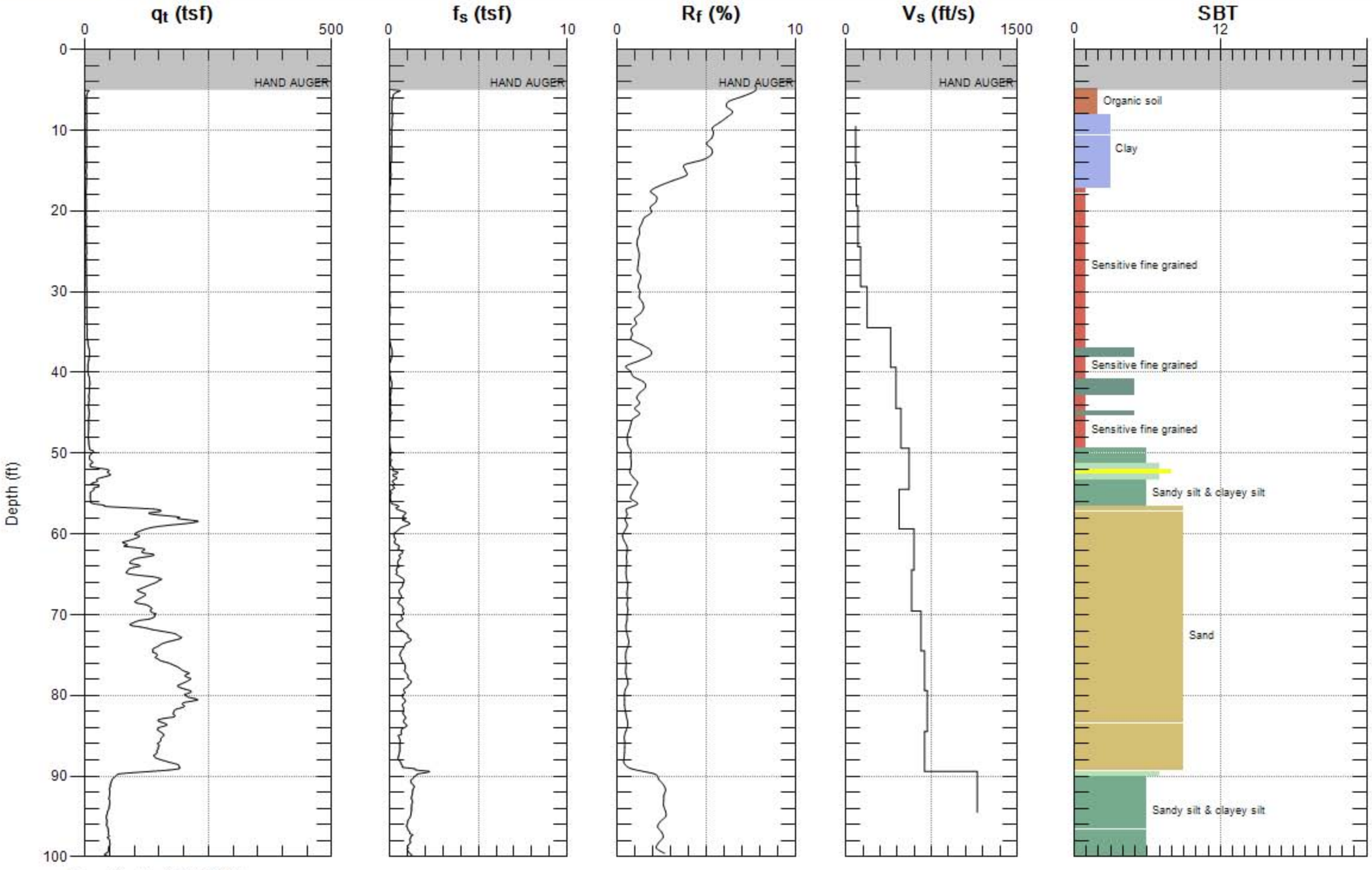


Max. Depth: 100.070 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

EARTH MECHANICS

Site: ANTIOCH BRIDGE
Sounding: CPT-24 Seis
Engineer: J.CASTLE
Date: 11/20/2006 10:42

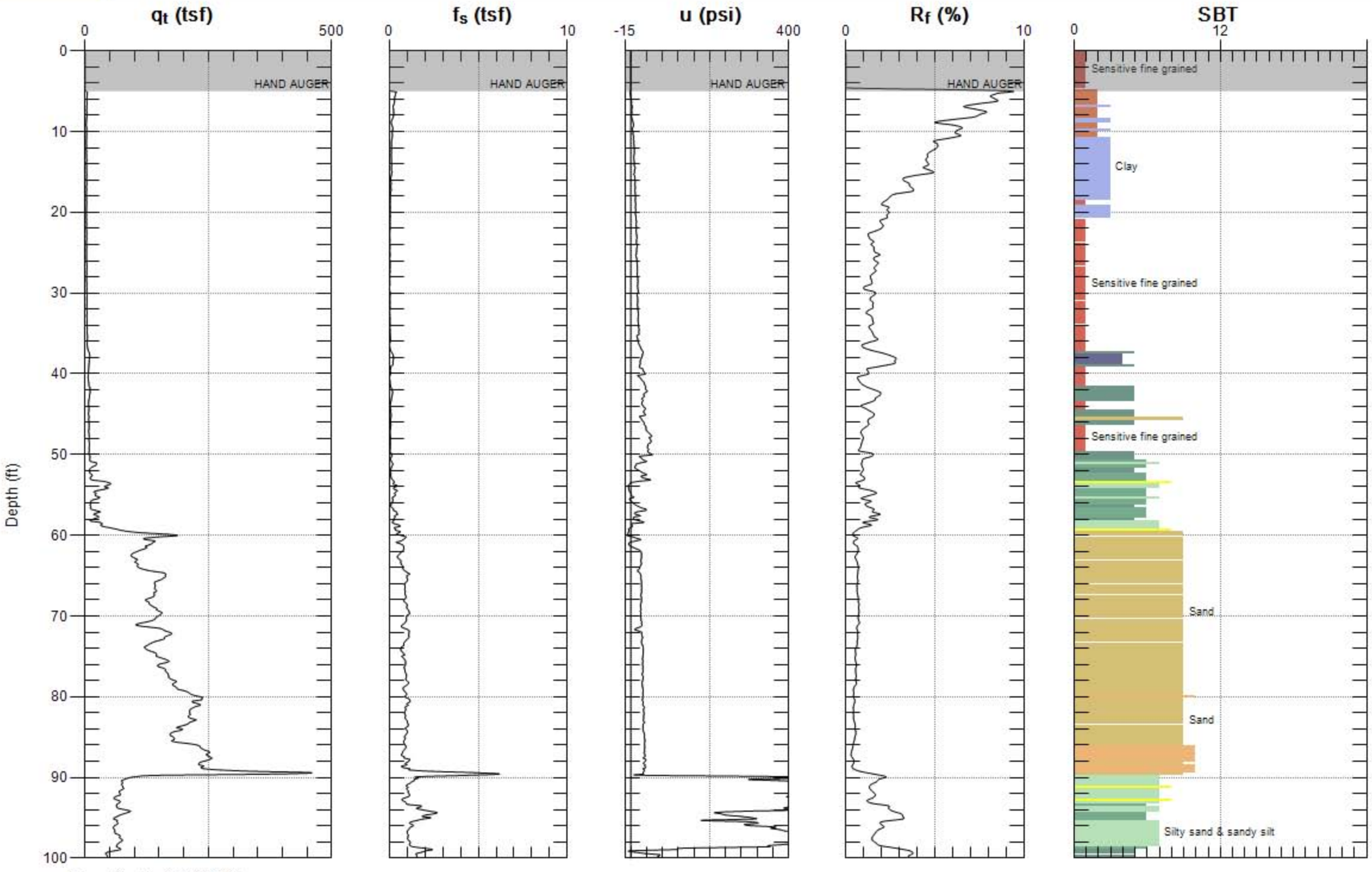


Max. Depth: 100.070 (ft)
Avg. Interval: 0.656 (ft)

SBT: Soil Behavior Type (Robertson 1990)

EARTH MECHANICS

Site: ANTIOCH BRIDGE
Sounding: CPT-25 Seis
Engineer: J.CASTLE
Date: 11/16/2006 08:36

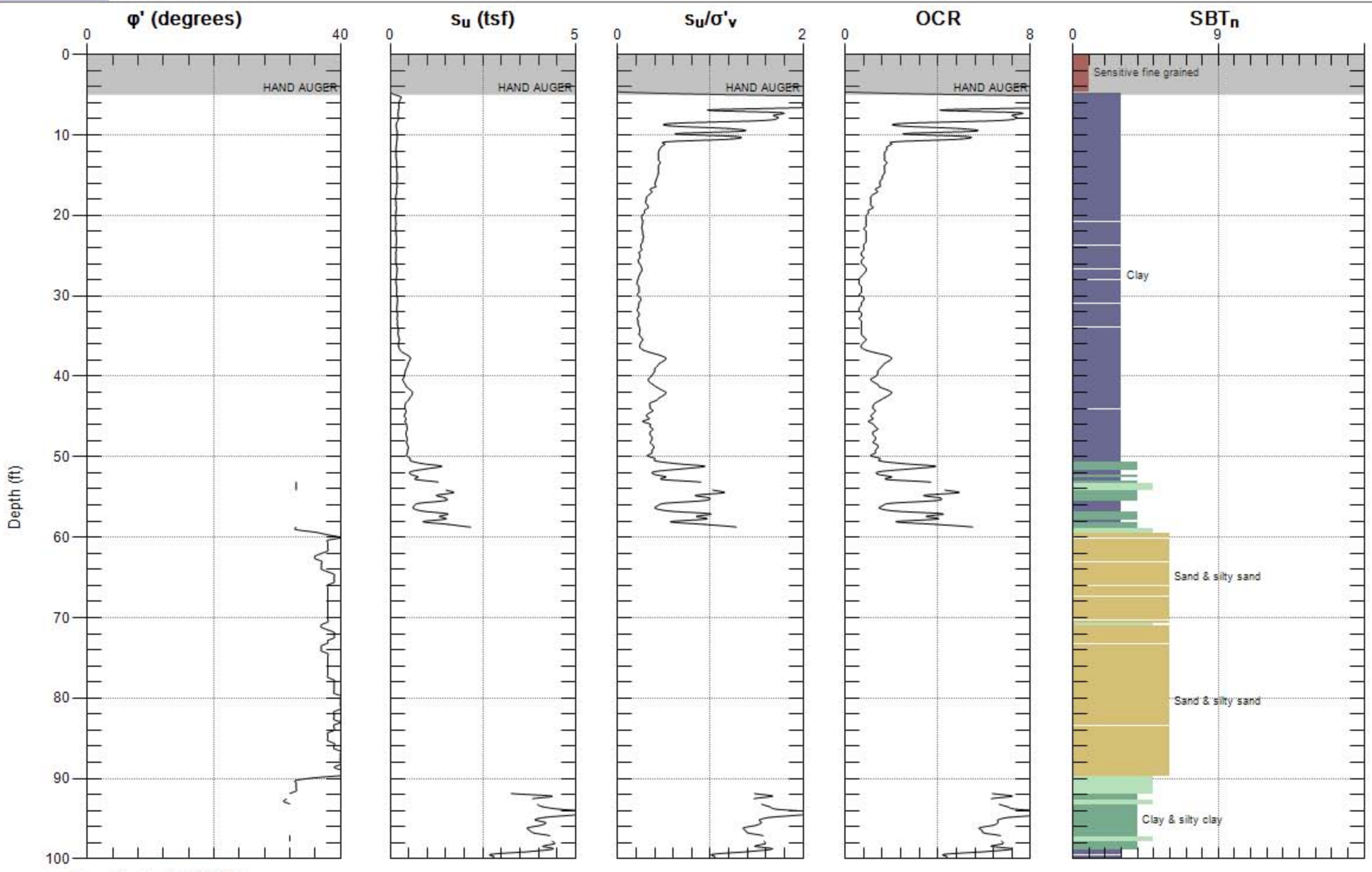


Max. Depth: 100.230 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

EARTH MECHANICS

Site: ANTIOCH BRIDGE
Sounding: CPT-25 Seis
Engineer: J.CASTLE
Date: 11/16/2006 08:36

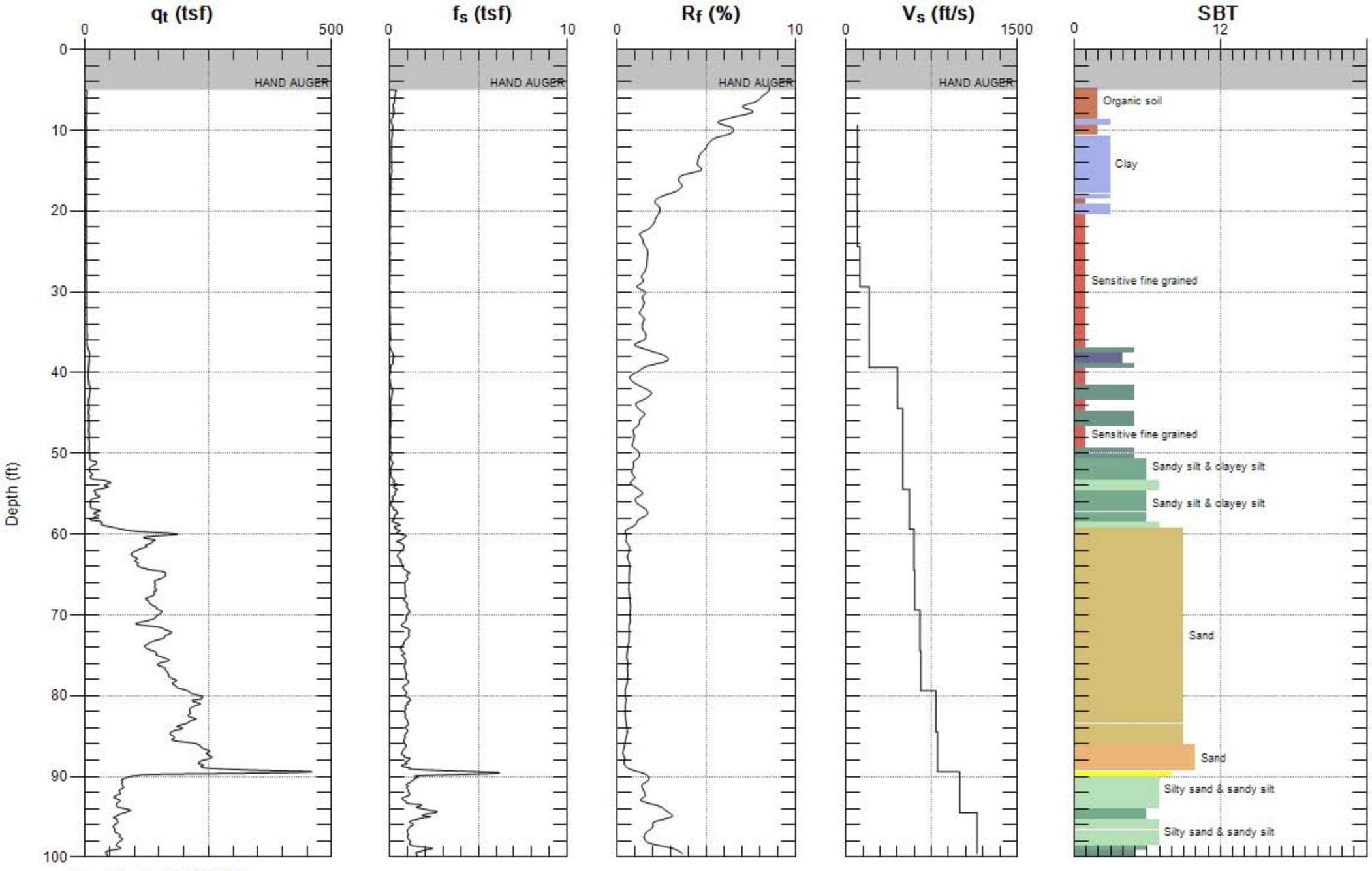


Max. Depth: 100.230 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

EARTH MECHANICS

Site: ANTIOCH BRIDGE
Sounding: CPT-25 Seis
Engineer: J.CASTLE
Date: 11/16/2006 08:36

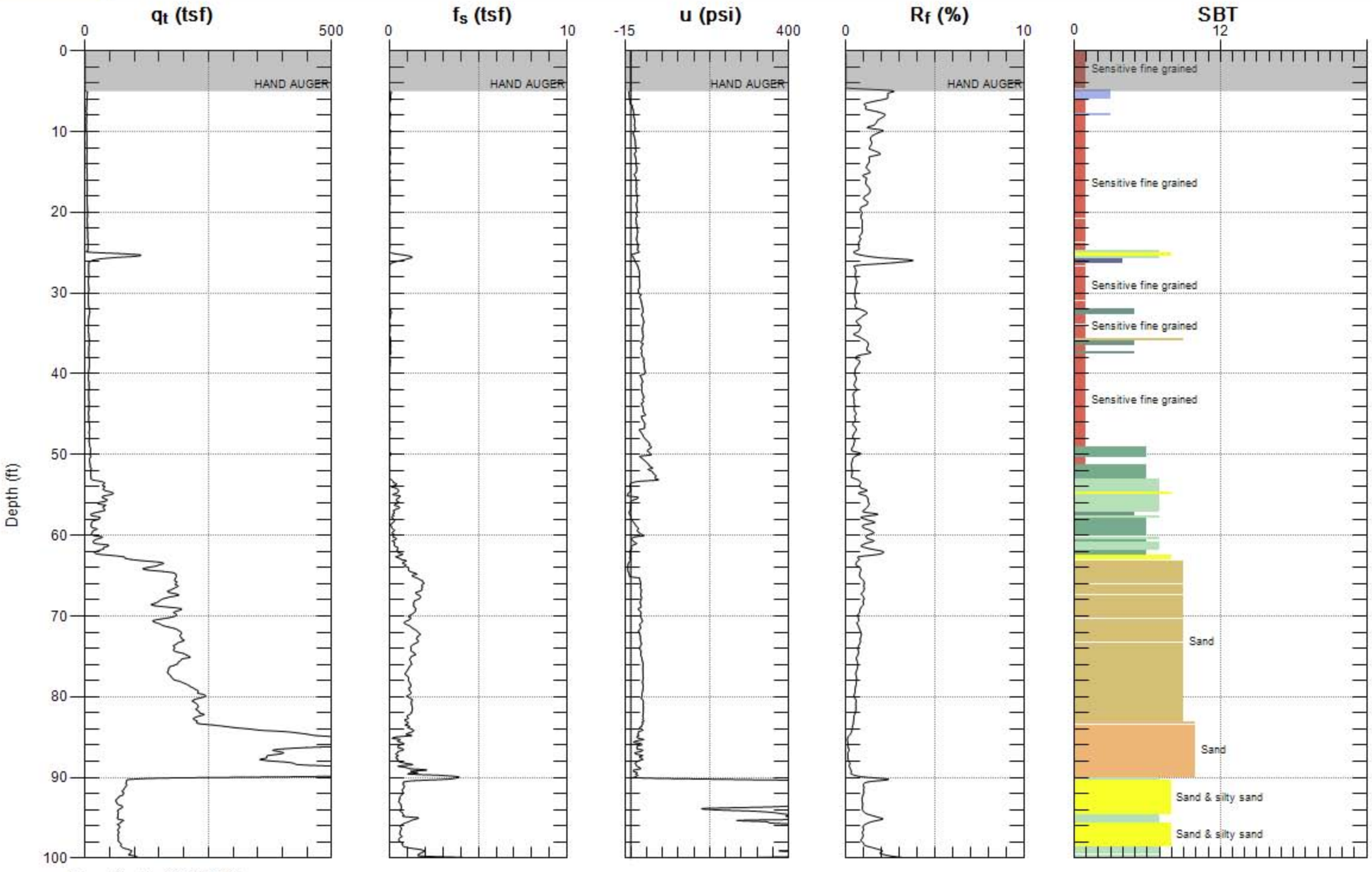


Max. Depth: 100.230 (ft)
Avg. Interval: 0.656 (ft)

SBT: Soil Behavior Type (Robertson 1990)

EARTH MECHANICS

Site: ANTIOCH BRIDGE
Sounding: CPT-26 Seis
Engineer: J.CASTLE
Date: 11/15/2006 08:19

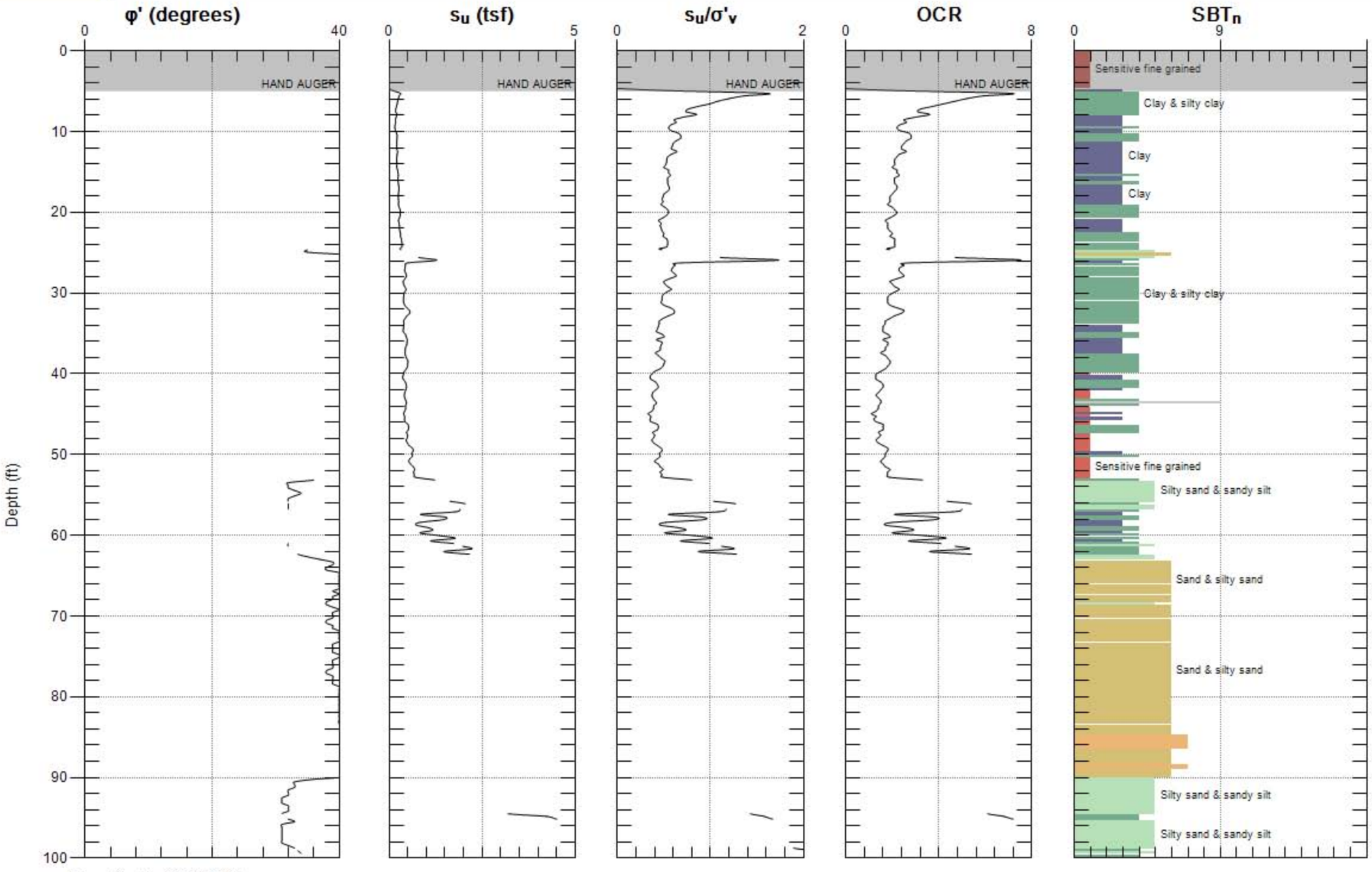


Max. Depth: 101.050 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

EARTH MECHANICS

Site: ANTIOCH BRIDGE
Sounding: CPT-26 Seis
Engineer: J.CASTLE
Date: 11/15/2006 08:19

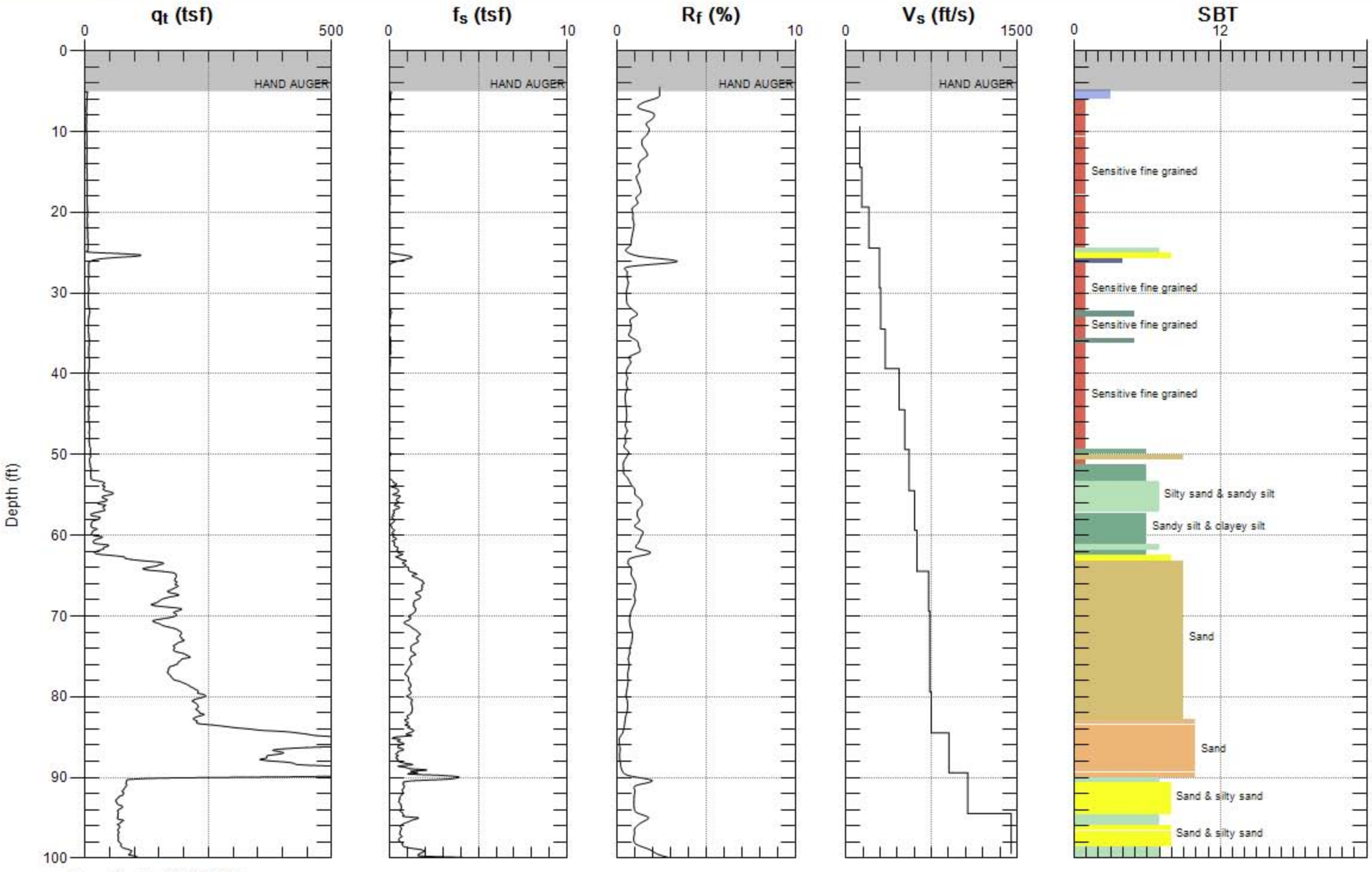


Max. Depth: 101.050 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

EARTH MECHANICS

Site: ANTIOCH BRIDGE
Sounding: CPT-26 Seis
Engineer: J.CASTLE
Date: 11/15/2006 08:19

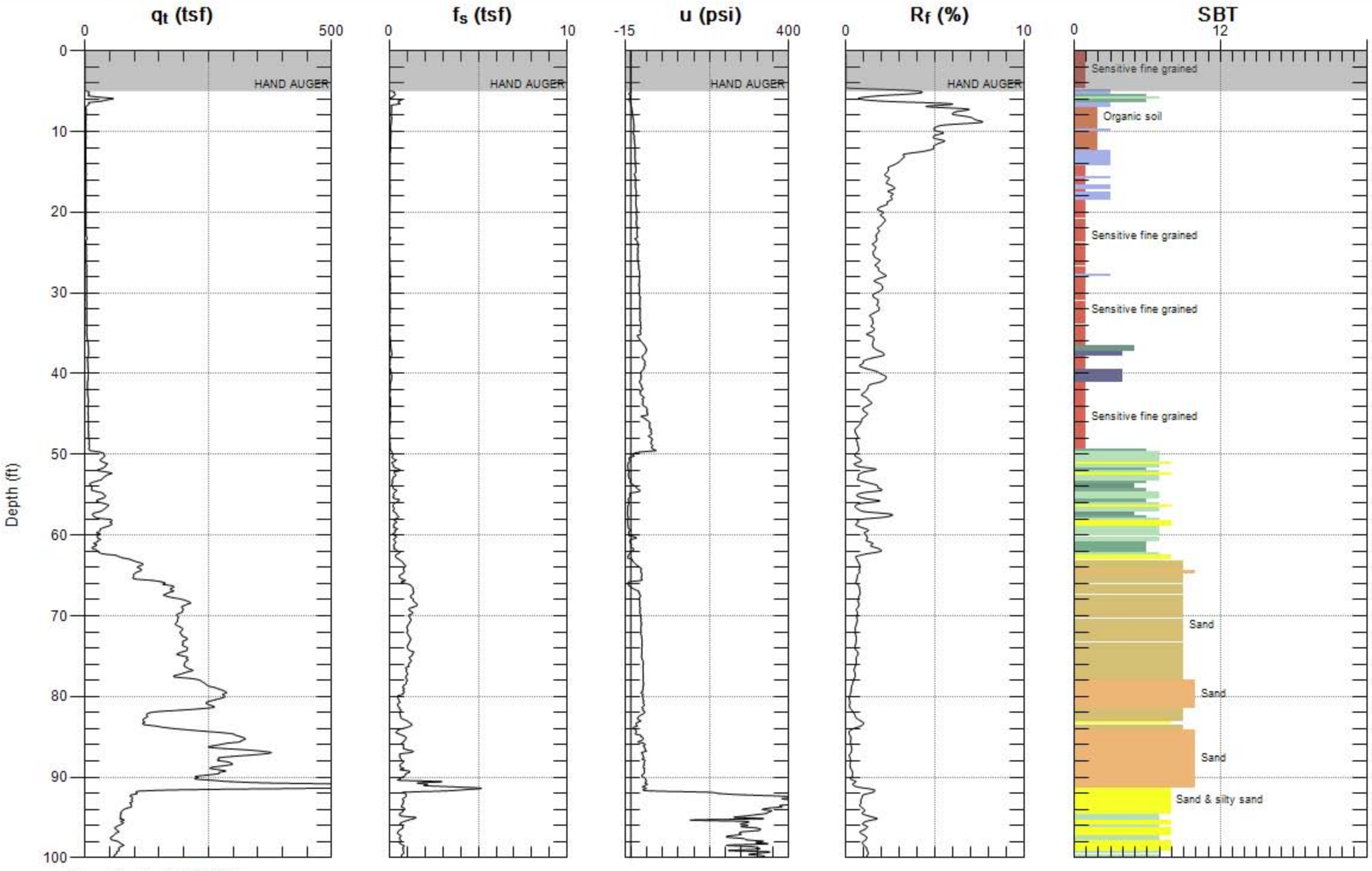


Max. Depth: 101.050 (ft)
Avg. Interval: 0.656 (ft)

SBT: Soil Behavior Type (Robertson 1990)

EARTH MECHANICS

Site: ANTIOCH BRIDGE
Sounding: CPT-27 Seis
Engineer: J.CASTLE
Date: 11/15/2006 12:22

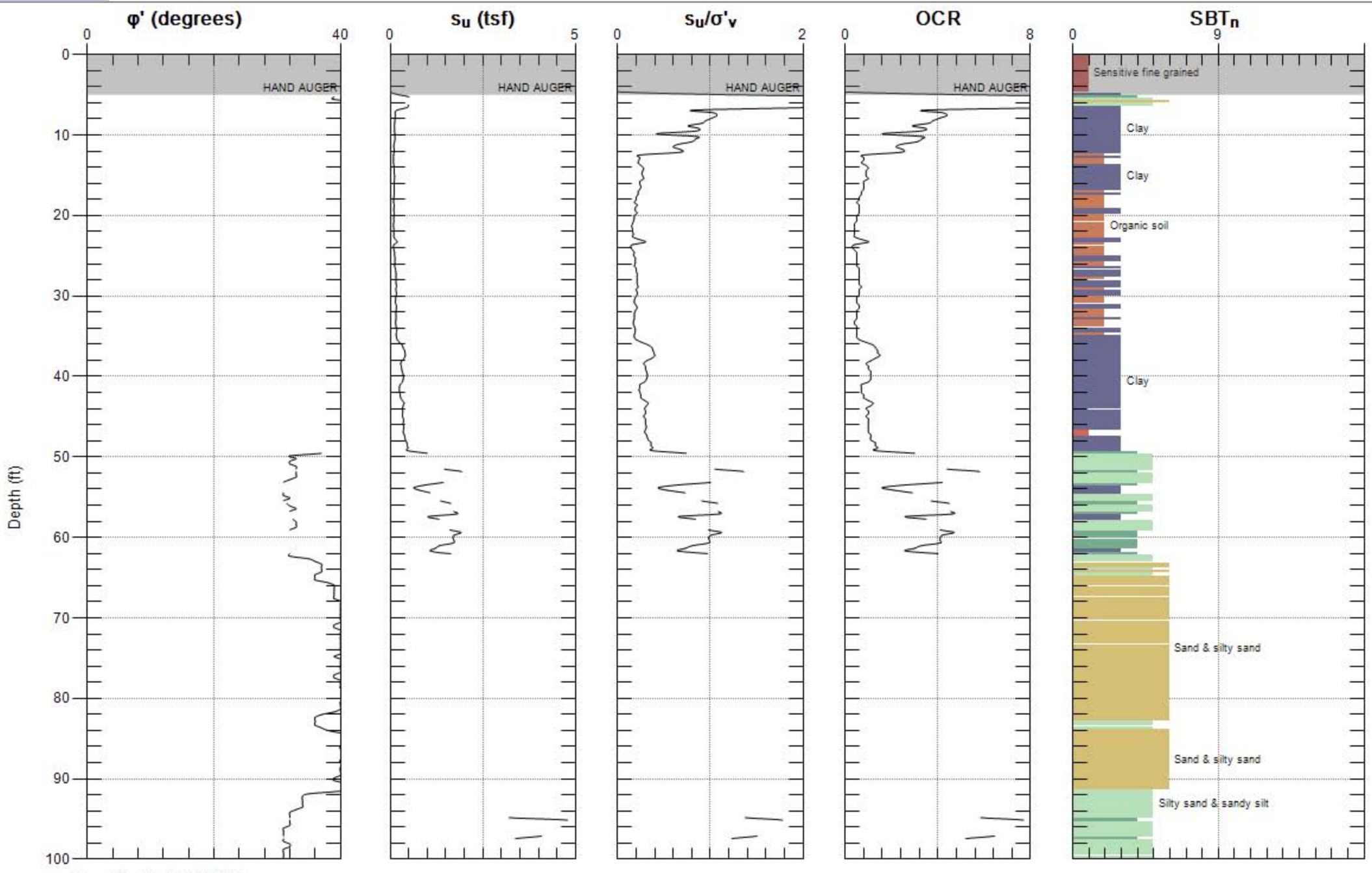


Max. Depth: 100.230 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

EARTH MECHANICS

Site: ANTIOCH BRIDGE
Sounding: CPT-27 Seis
Engineer: J.CASTLE
Date: 11/15/2006 12:22

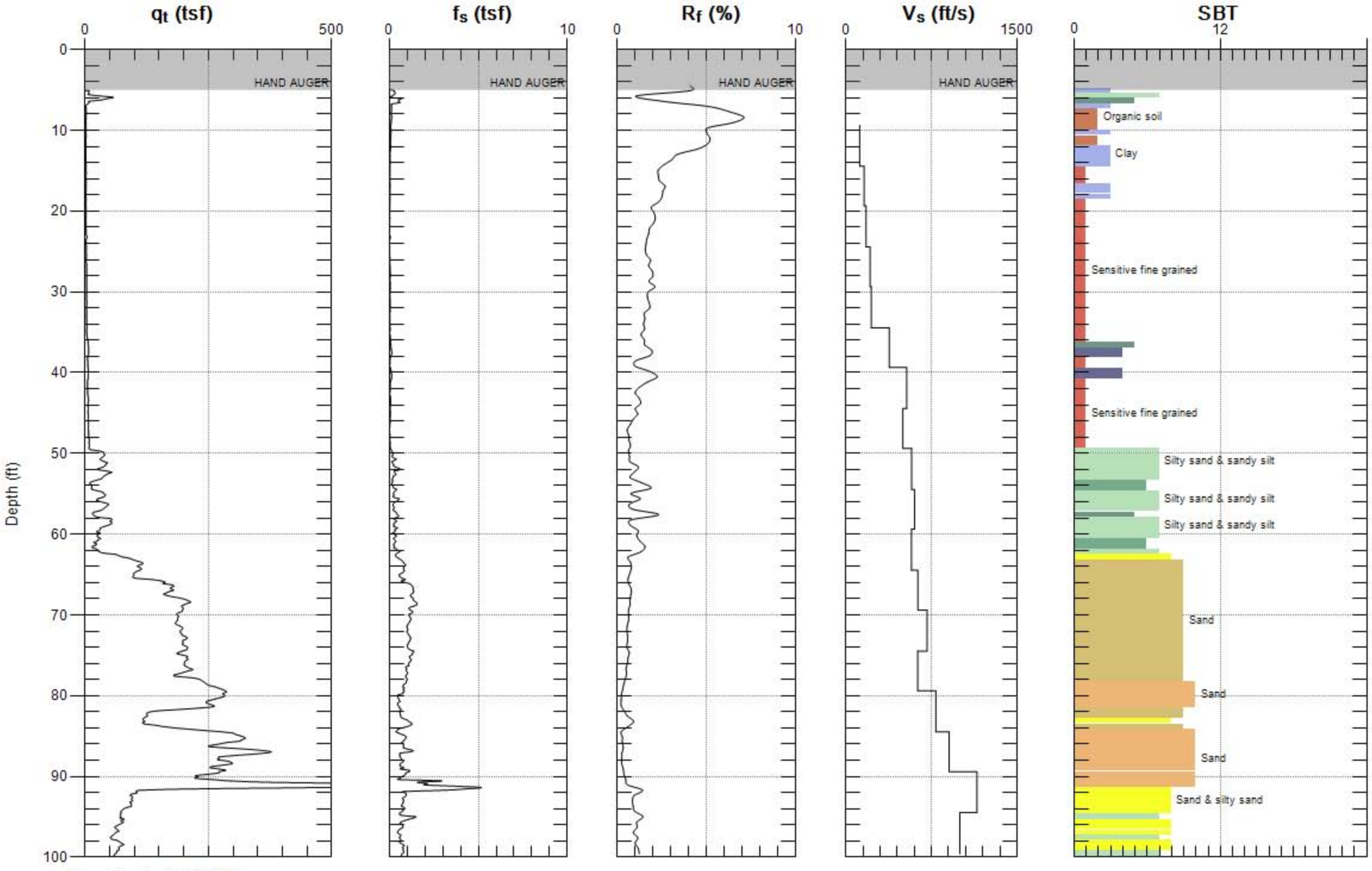


Max. Depth: 100.230 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

EARTH MECHANICS

Site: ANTIOCH BRIDGE
Sounding: CPT-27 Seis
Engineer: J.CASTLE
Date: 11/15/2006 12:22

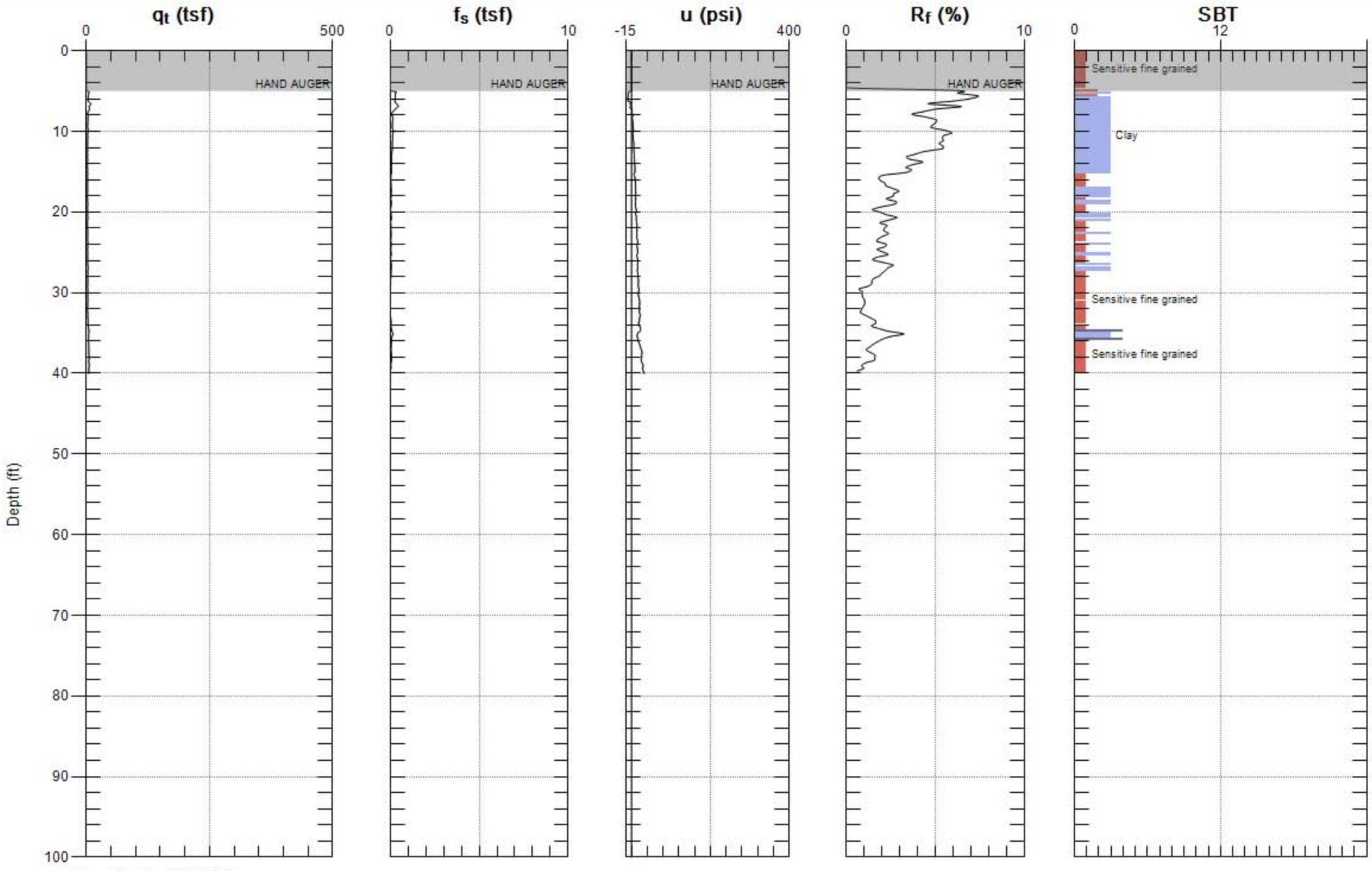


Max. Depth: 100.230 (ft)
Avg. Interval: 0.656 (ft)

SBT: Soil Behavior Type (Robertson 1990)

EARTH MECHANICS

Site: ANTIOCH BRIDGE
Sounding: CPT-28a Seis
Engineer: J.CASTLE
Date: 11/15/2006 05:34

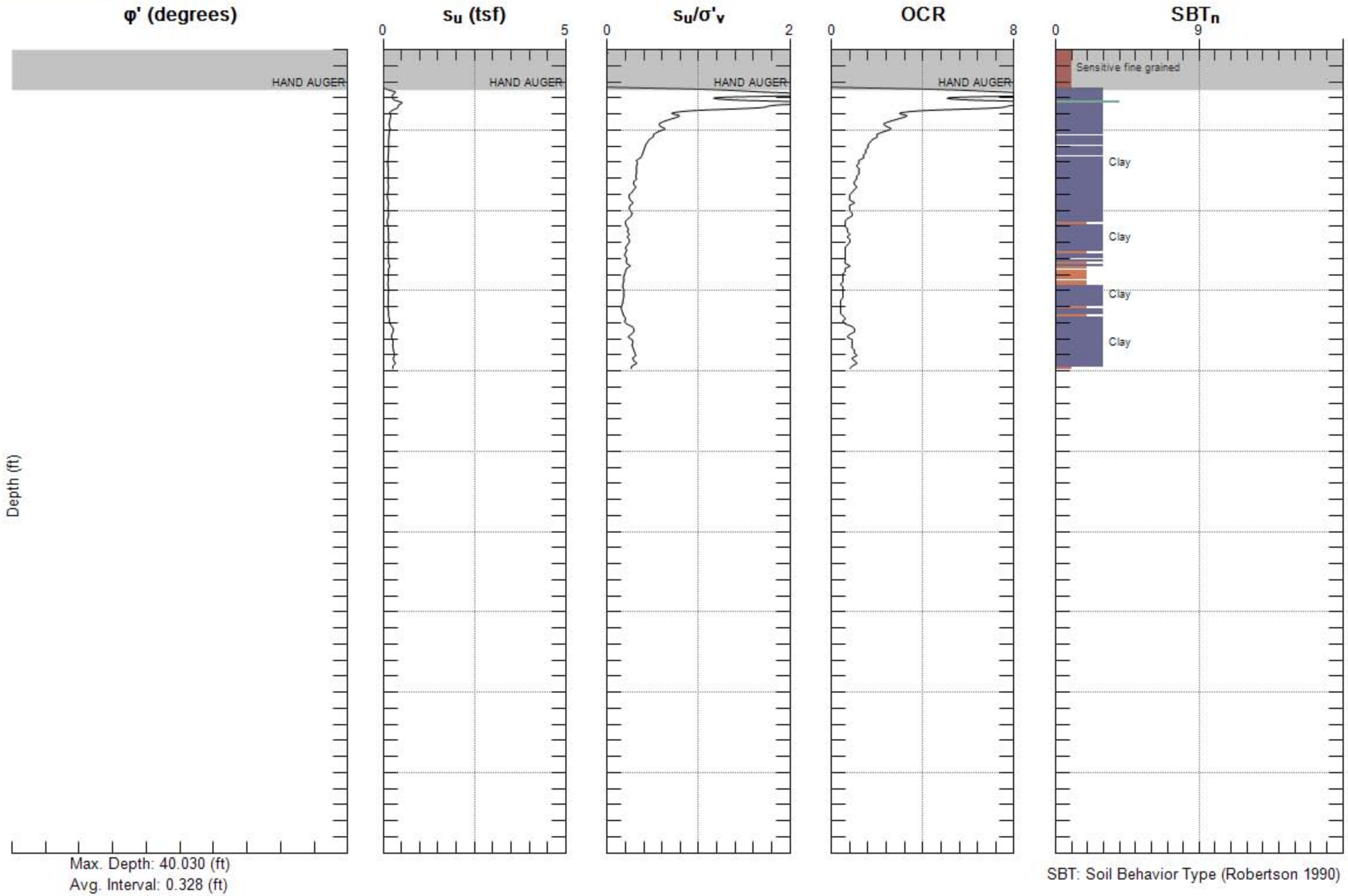


Max. Depth: 40.030 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

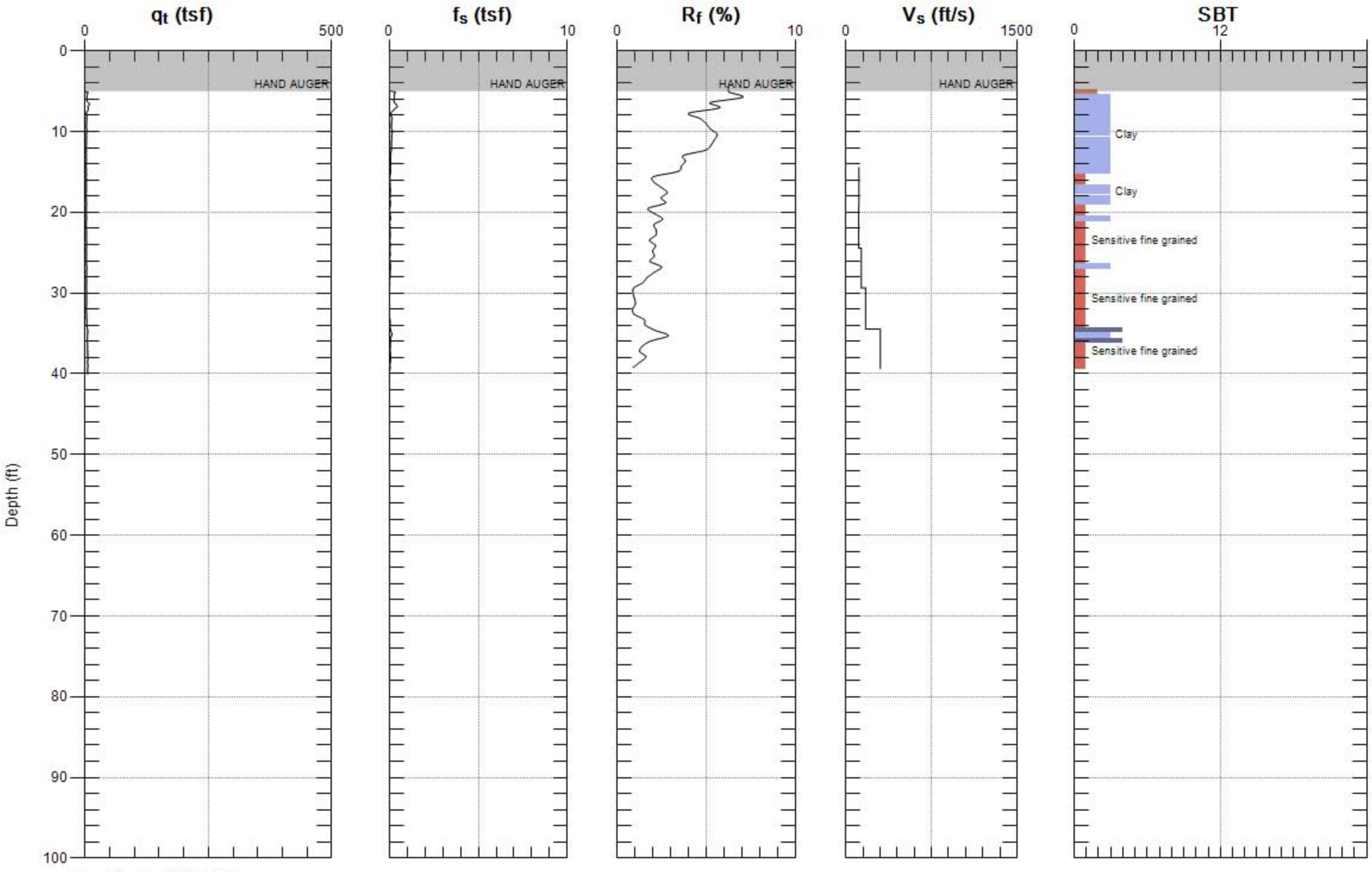
EARTH MECHANICS

Site: ANTIOCH BRIDGE
Sounding: CPT-28a Seis
Engineer: J.CASTLE
Date: 11/15/2006 05:34



EARTH MECHANICS

Site: ANTIOCH BRIDGE
Sounding: CPT-28a Seis
Engineer: J.CASTLE
Date: 11/15/2006 05:34

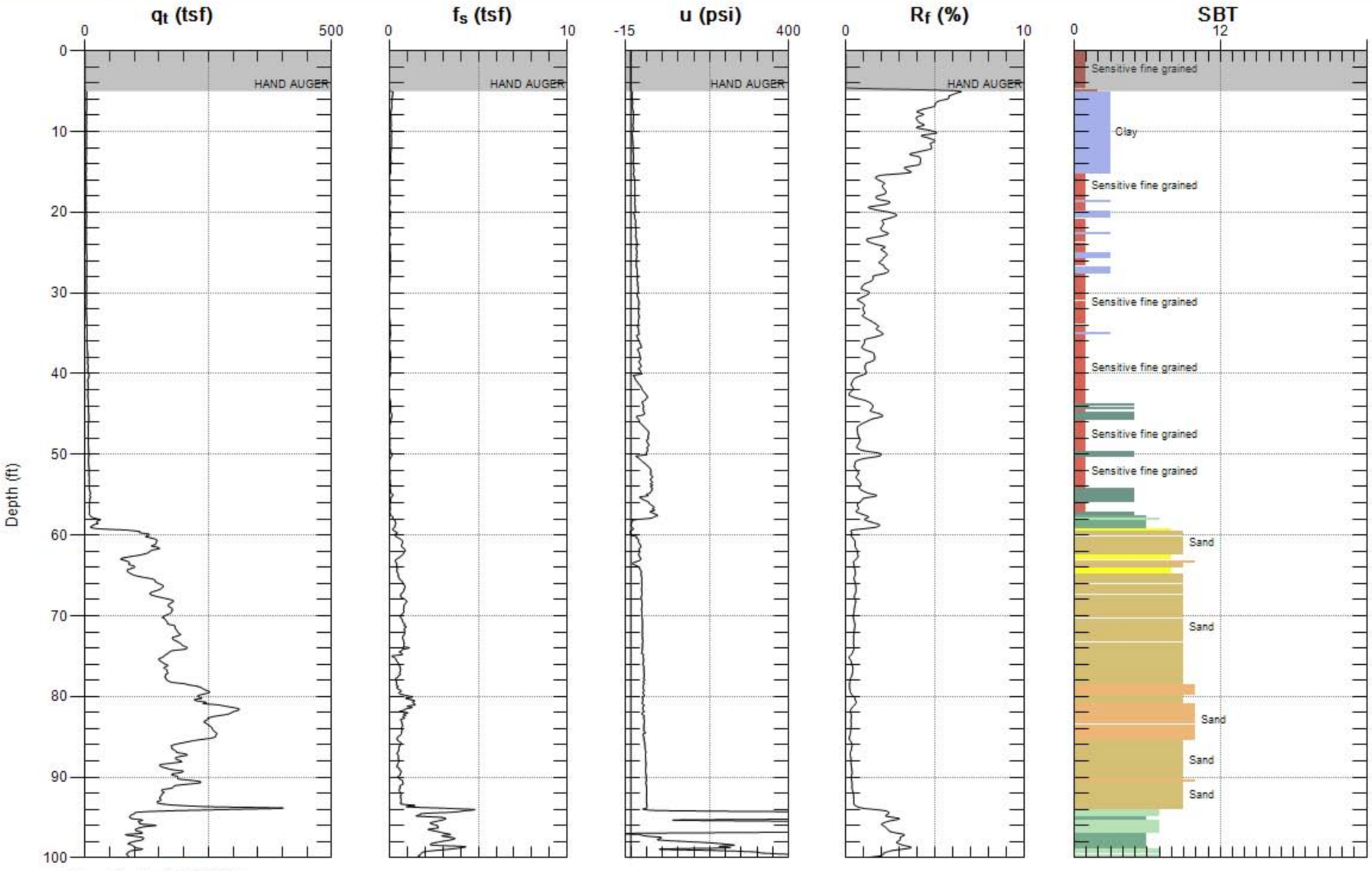


Max. Depth: 40.030 (ft)
Avg. Interval: 0.656 (ft)

SBT: Soil Behavior Type (Robertson 1990)

EARTH MECHANICS

Site: ANTIOCH BRIDGE
Sounding: CPT-28 Seis
Engineer: J.CASTLE
Date: 11/15/2006 02:59

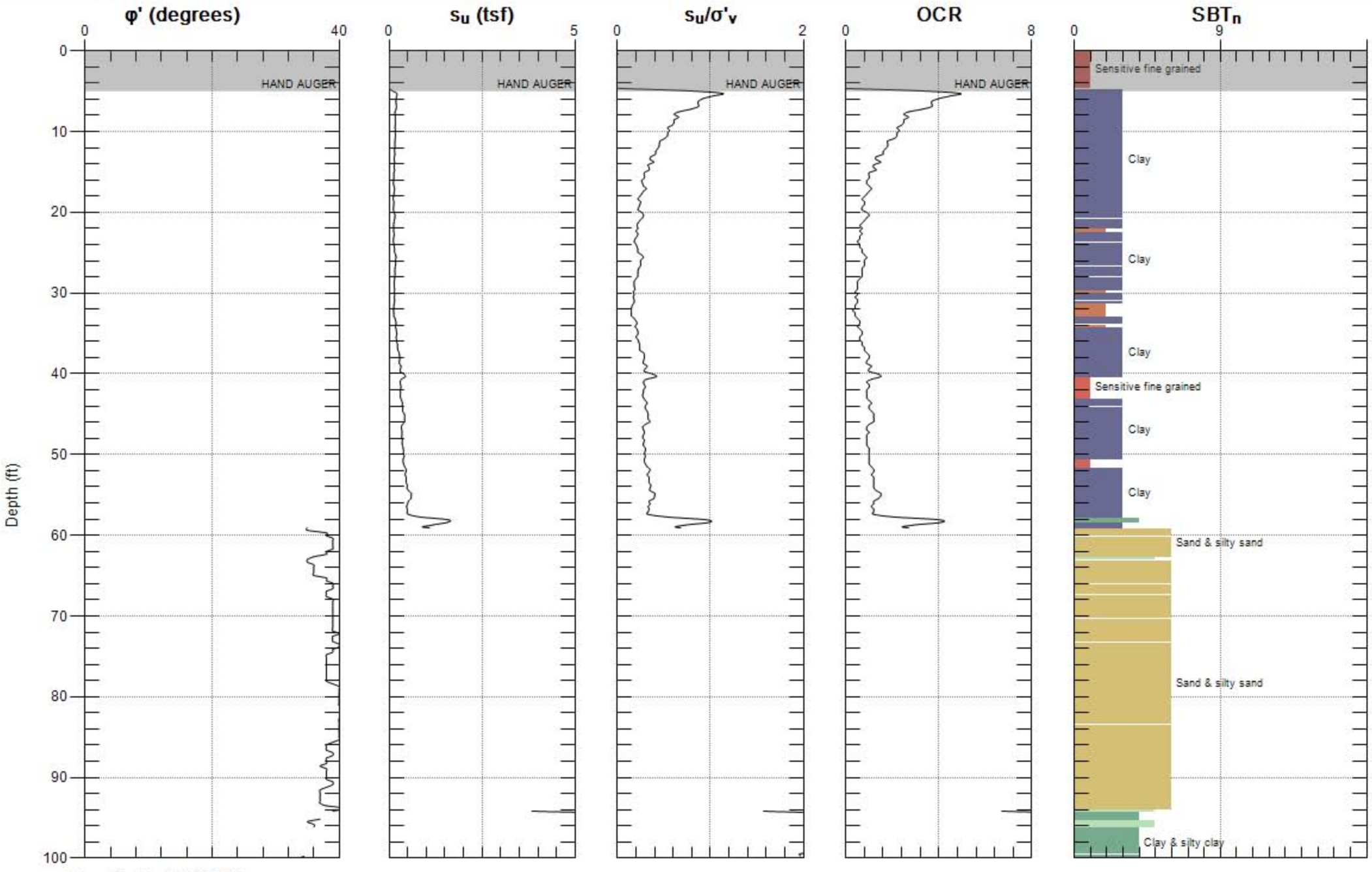


Max. Depth: 100.230 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

EARTH MECHANICS

Site: ANTIOCH BRIDGE
Sounding: CPT-28 Seis
Engineer: J.CASTLE
Date: 11/15/2006 02:59

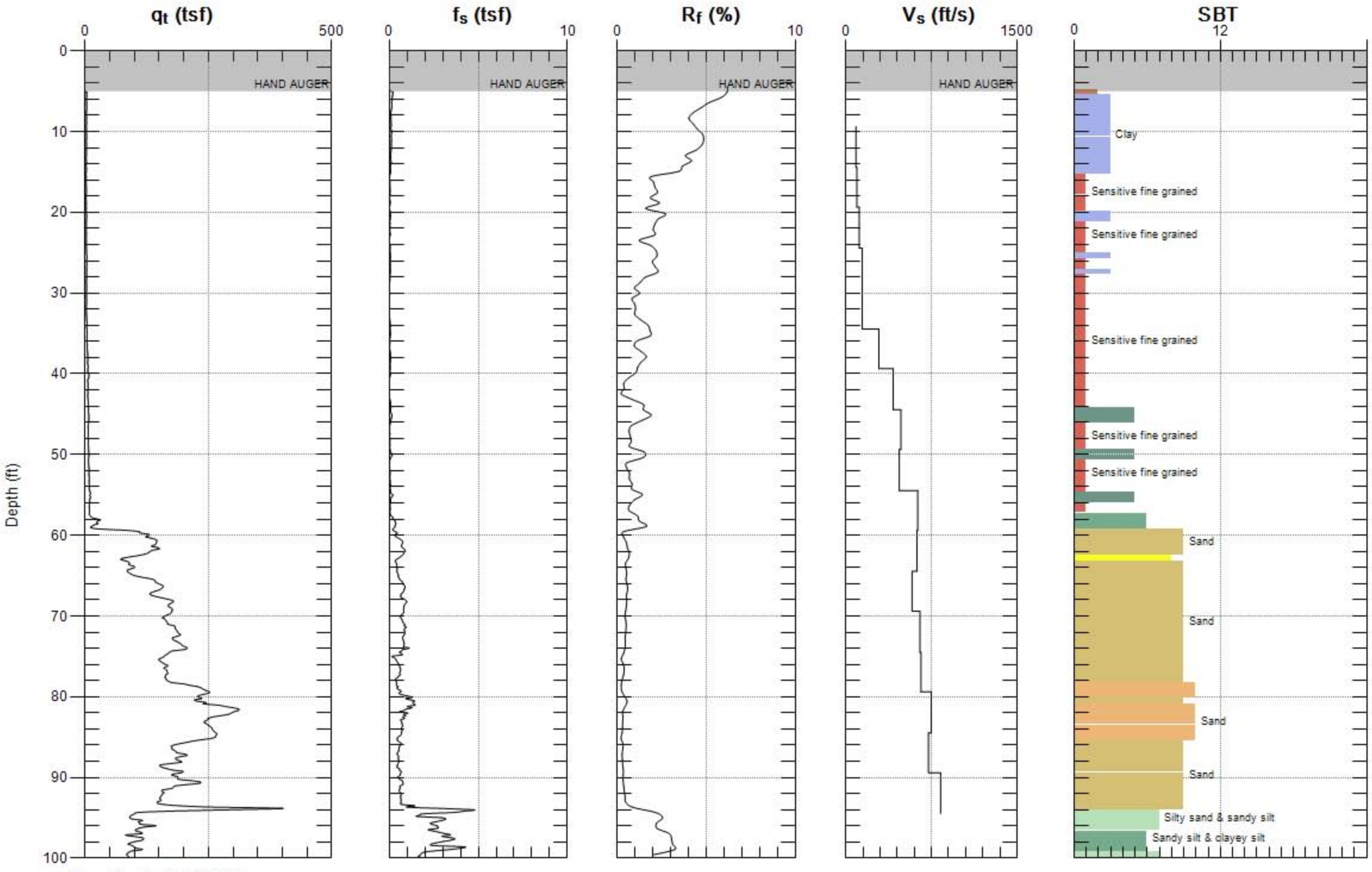


Max. Depth: 100.230 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

EARTH MECHANICS

Site: ANTIOCH BRIDGE
Sounding: CPT-28 Seis
Engineer: J.CASTLE
Date: 11/15/2006 02:59

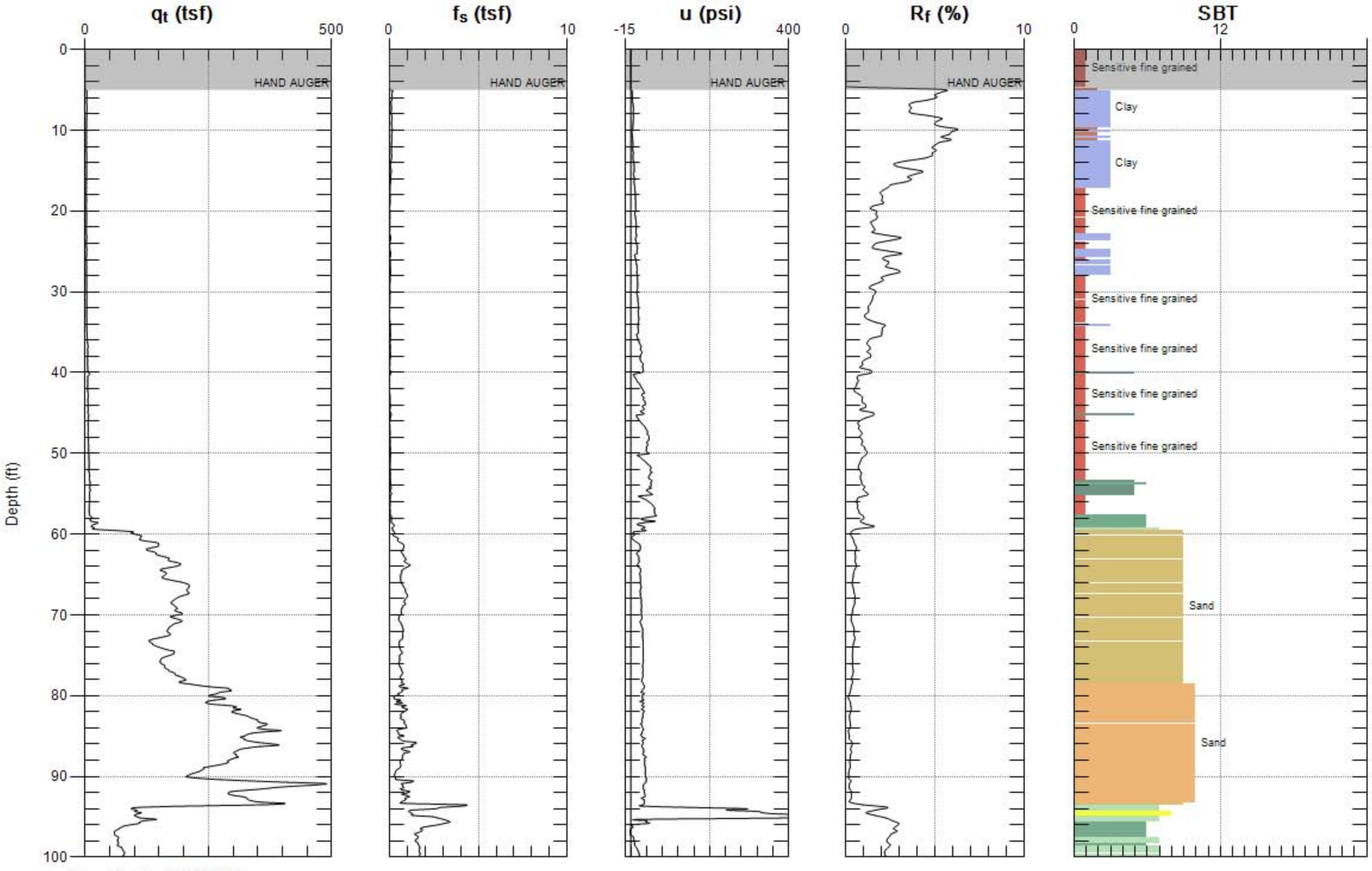


Max. Depth: 100.230 (ft)
Avg. Interval: 0.656 (ft)

SBT: Soil Behavior Type (Robertson 1990)

EARTH MECHANICS

Site: ANTIOCH BRIDGE
Sounding: CPT-29 Seis
Engineer: J.CASTLE
Date: 11/16/2006 03:02

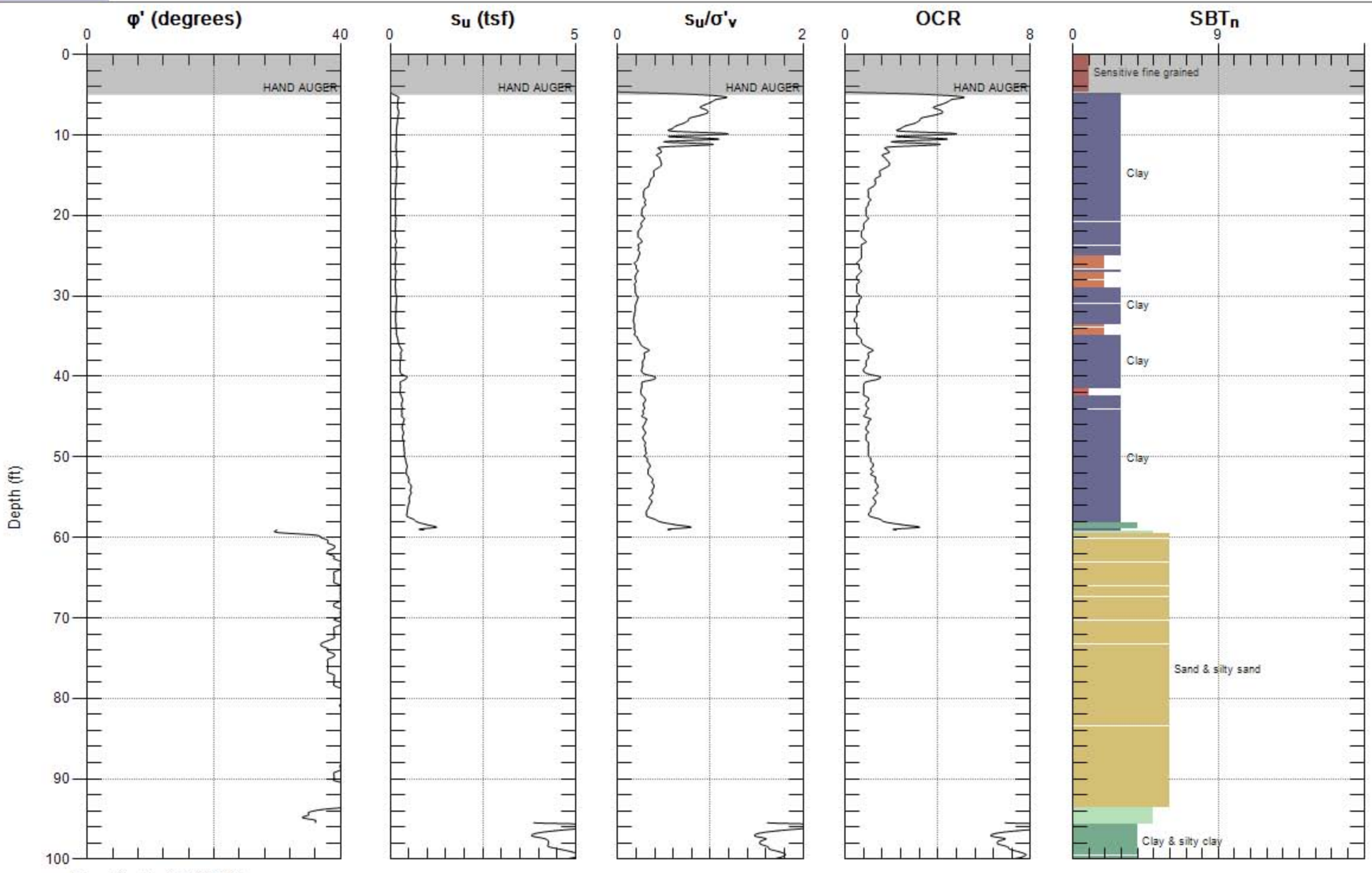


Max. Depth: 100.230 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

EARTH MECHANICS

Site: ANTIOCH BRIDGE
Sounding: CPT-29 Seis
Engineer: J.CASTLE
Date: 11/16/2006 03:02

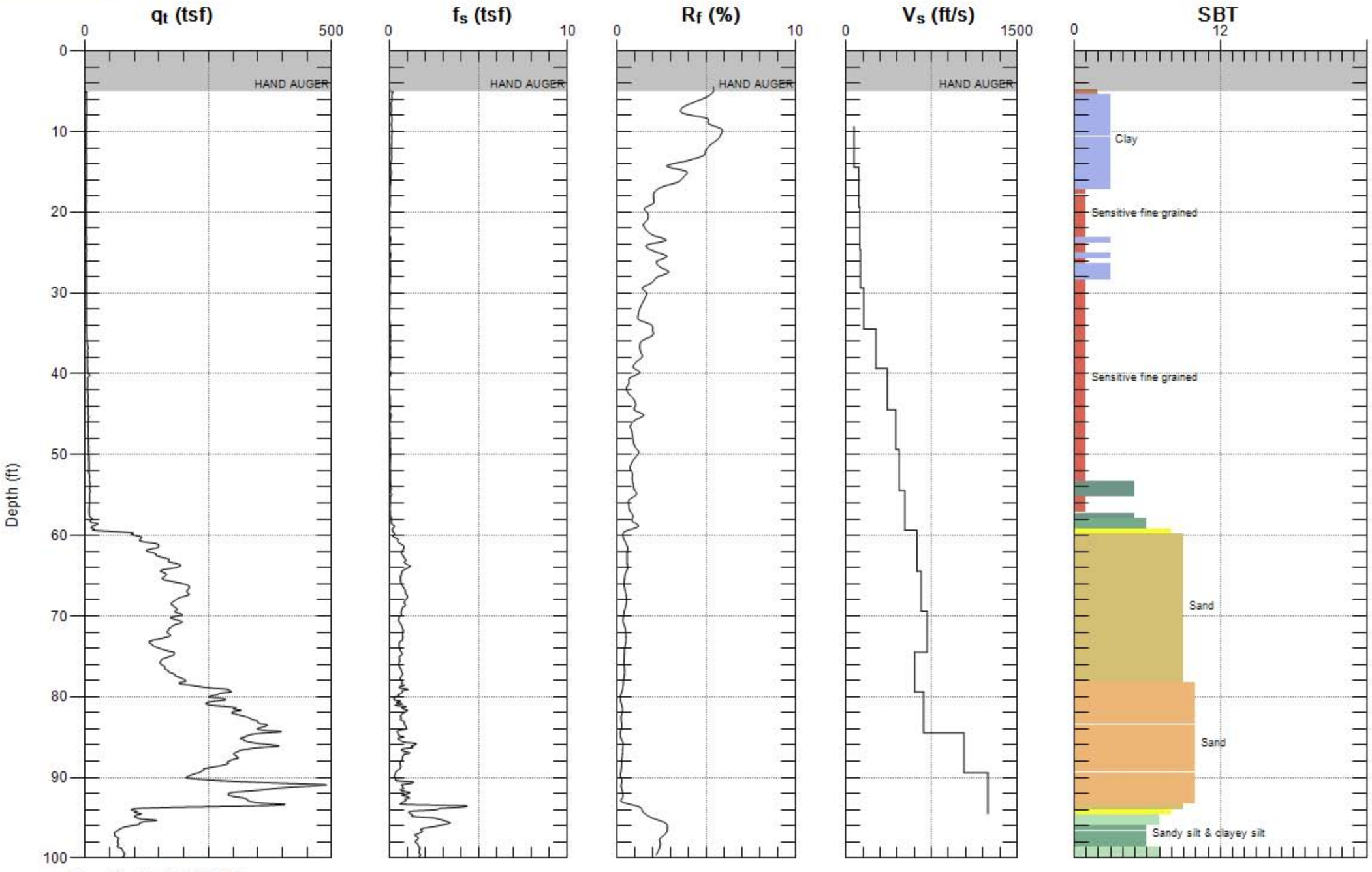


Max. Depth: 100.230 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

EARTH MECHANICS

Site: ANTIOCH BRIDGE
Sounding: CPT-29 Seis
Engineer: J.CASTLE
Date: 11/16/2006 03:02

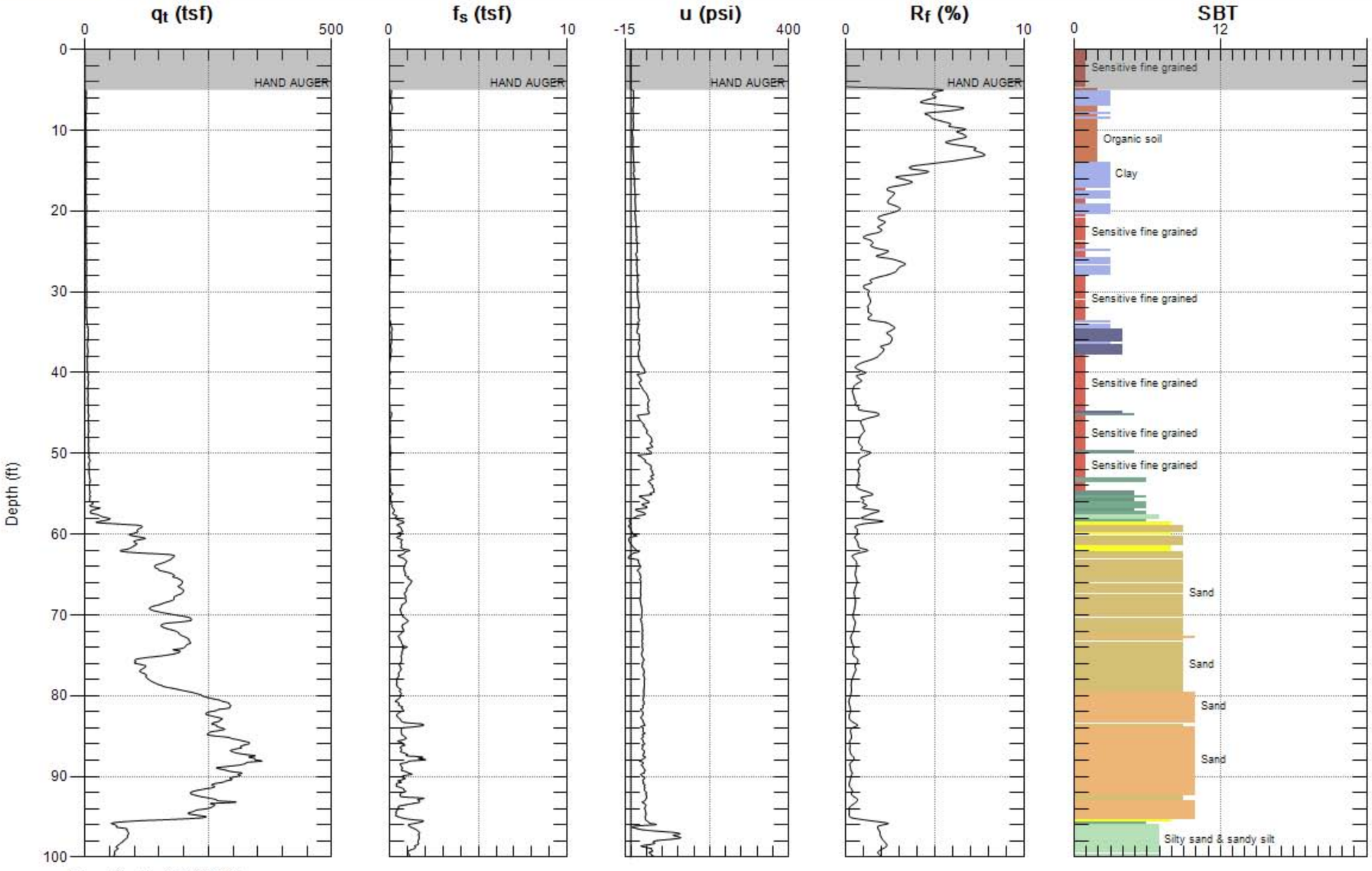


Max. Depth: 100.230 (ft)
Avg. Interval: 0.656 (ft)

SBT: Soil Behavior Type (Robertson 1990)

EARTH MECHANICS

Site: ANTIOCH BRIDGE
Sounding: CPT-30 Seis
Engineer: J.CASTLE
Date: 11/16/2006 11:37

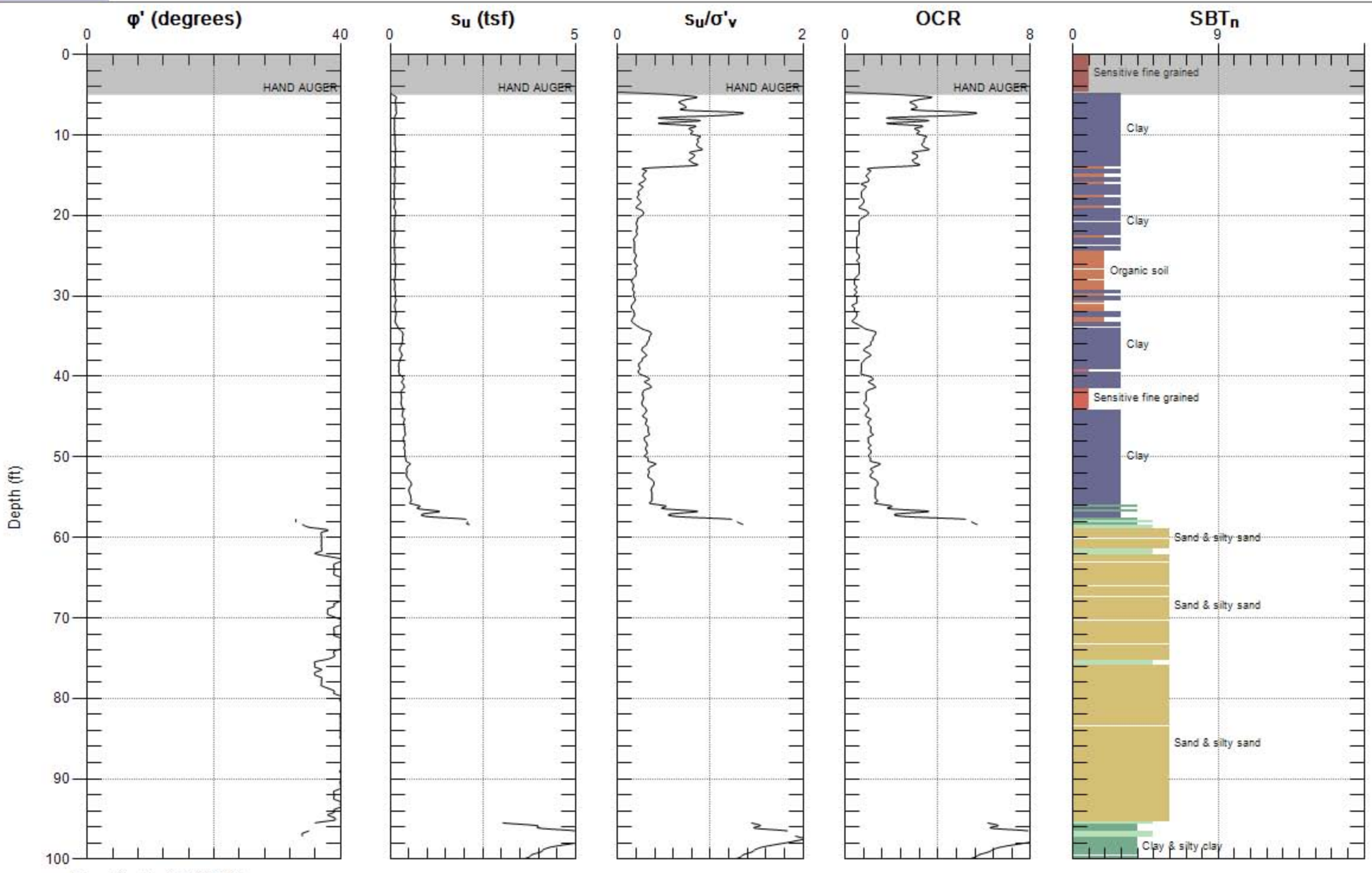


Max. Depth: 100.230 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

EARTH MECHANICS

Site: ANTIOCH BRIDGE
Sounding: CPT-30 Seis
Engineer: J.CASTLE
Date: 11/16/2006 11:37

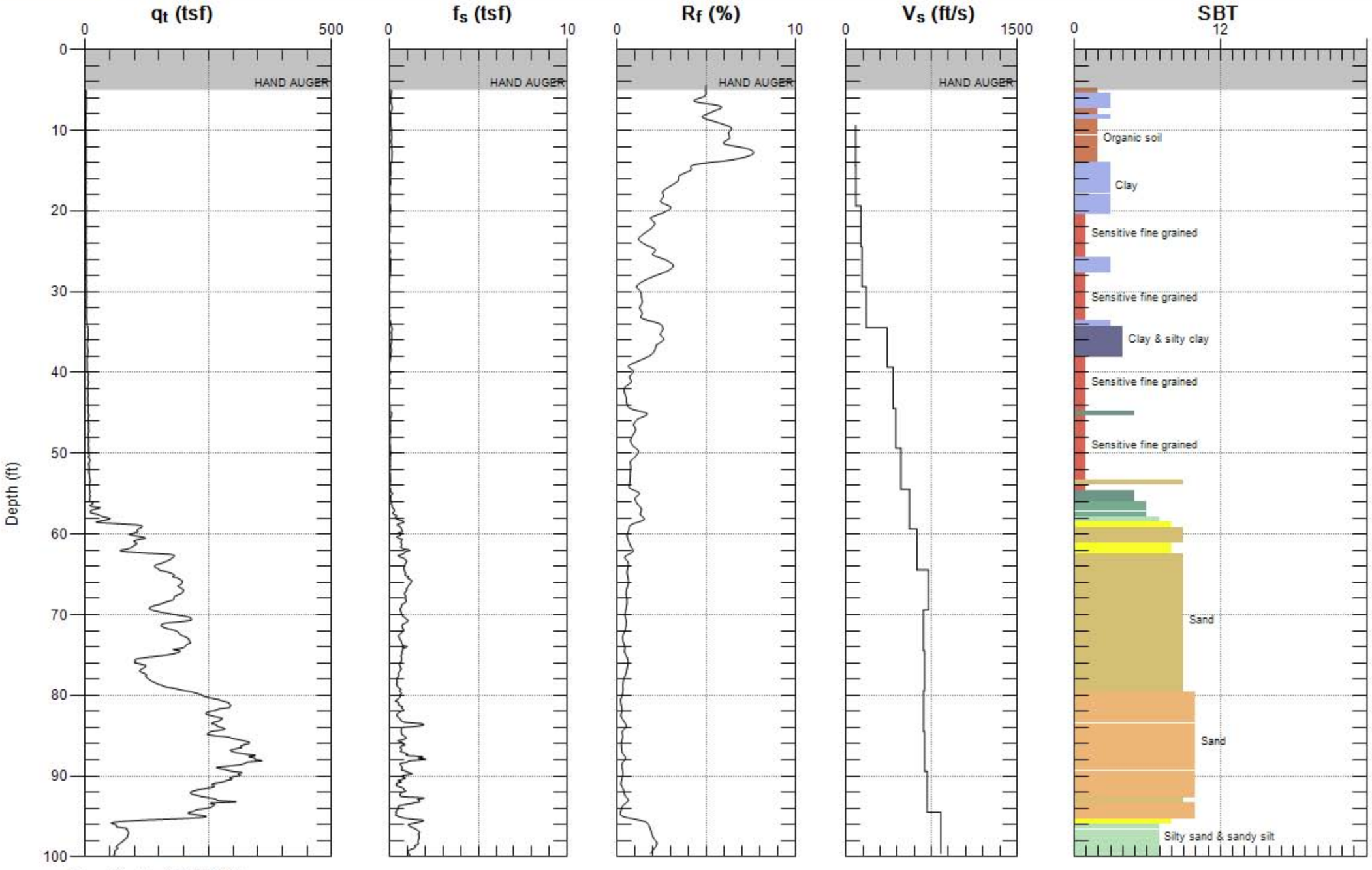


Max. Depth: 100.230 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

EARTH MECHANICS

Site: ANTIOCH BRIDGE
Sounding: CPT-30 Seis
Engineer: J.CASTLE
Date: 11/16/2006 11:37

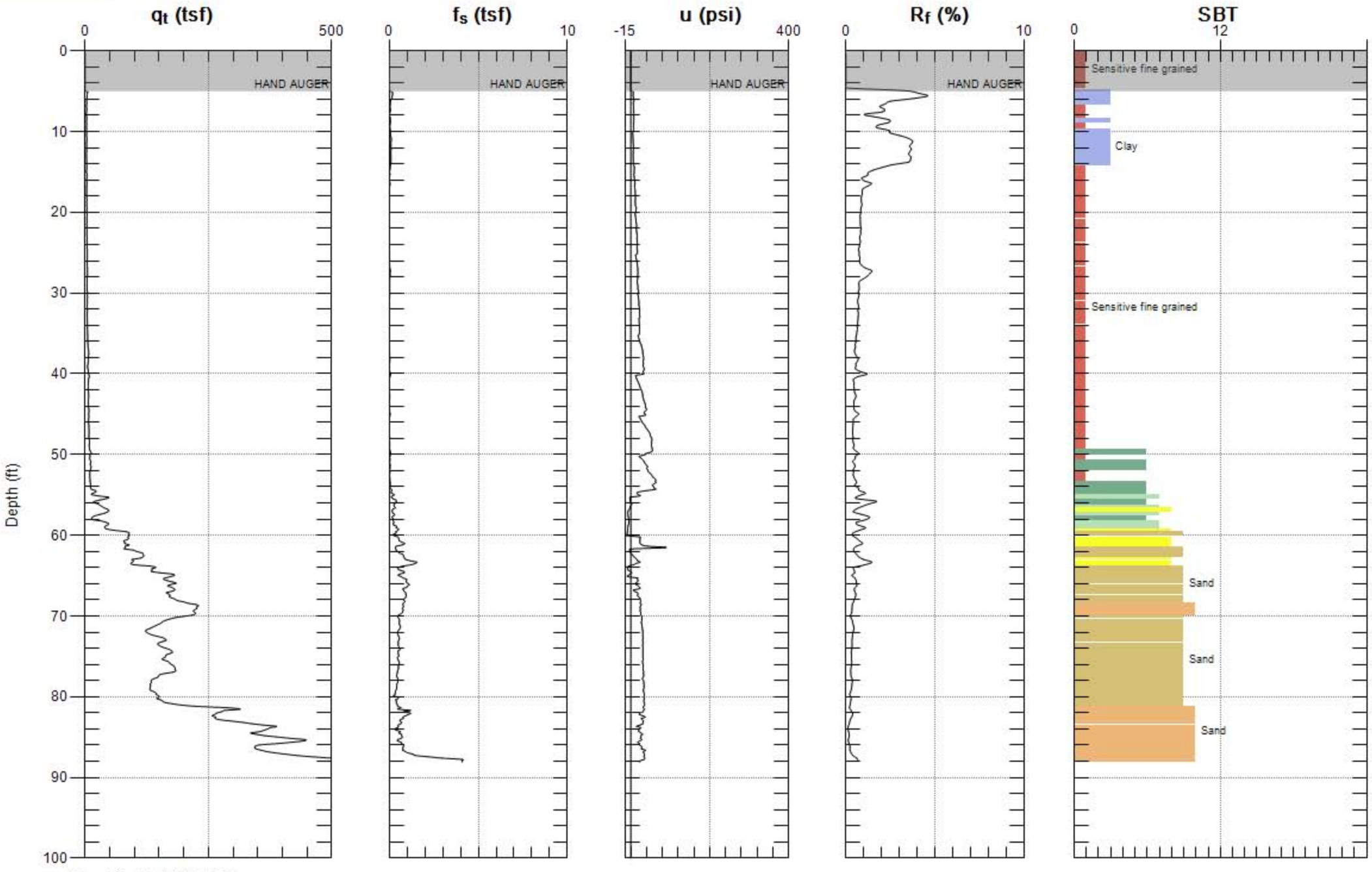


Max. Depth: 100.230 (ft)
Avg. Interval: 0.656 (ft)

SBT: Soil Behavior Type (Robertson 1990)

EARTH MECHANICS

Site: ANTIOCH BRIDGE
Sounding: CPT-31 Seis
Engineer: J.CASTLE
Date: 11/20/2006 08:11

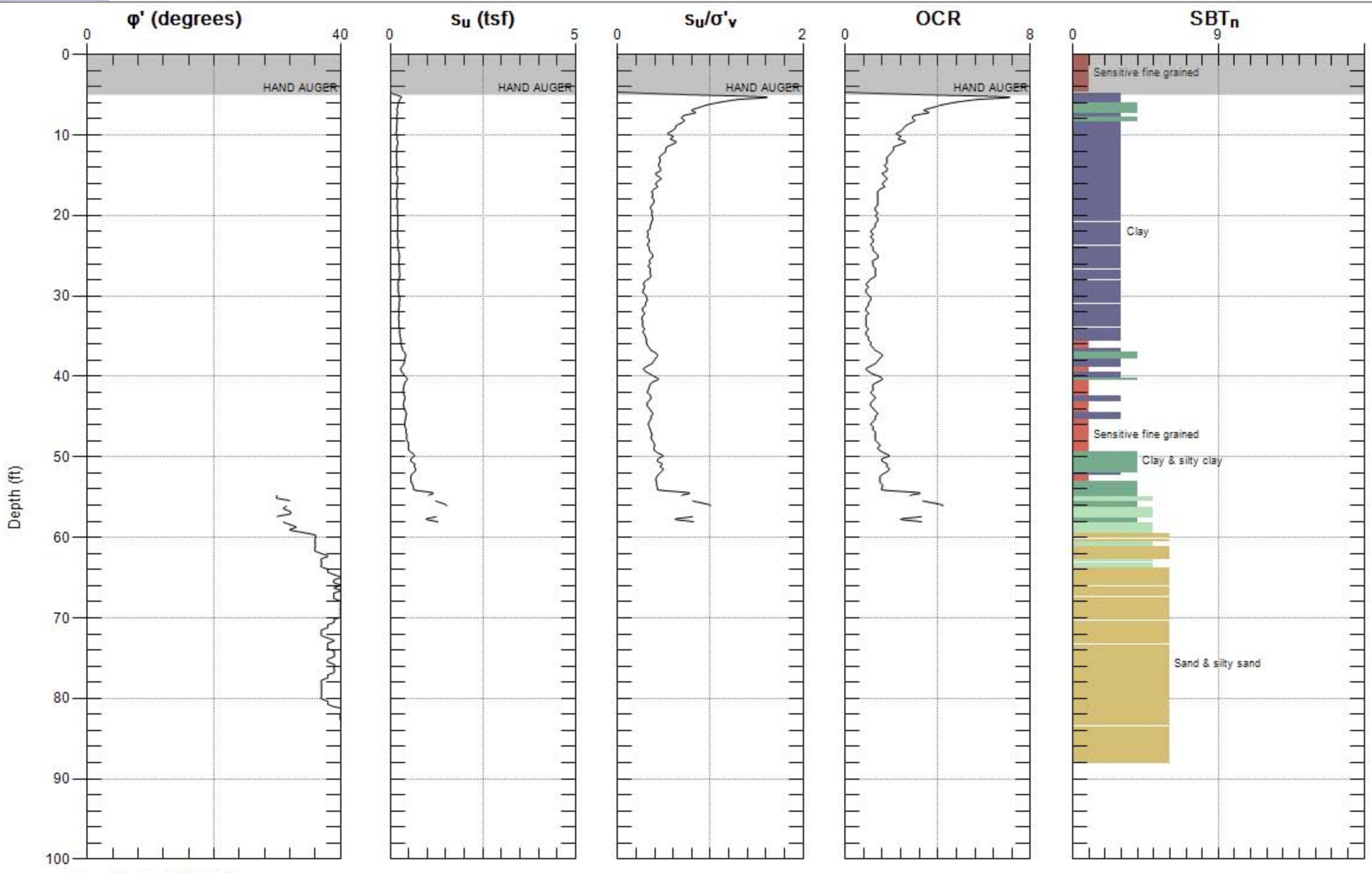


Max. Depth: 88.090 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

EARTH MECHANICS

Site: ANTIOCH BRIDGE
Sounding: CPT-31 Seis
Engineer: J.CASTLE
Date: 11/20/2006 08:11

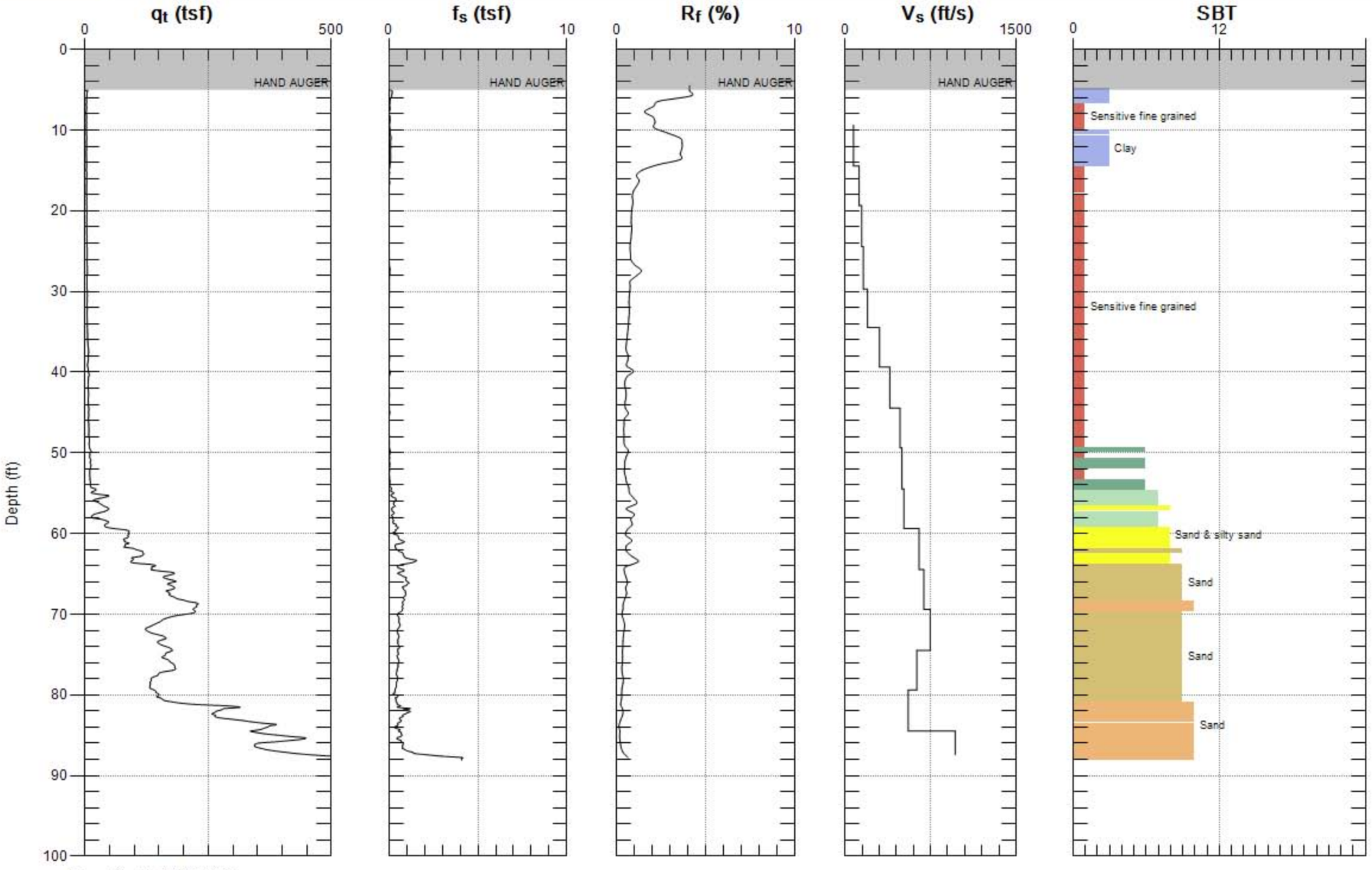


Max. Depth: 88.090 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

EARTH MECHANICS

Site: ANTIOCH BRIDGE
Sounding: CPT-31 Seis
Engineer: J.CASTLE
Date: 11/20/2006 08:11

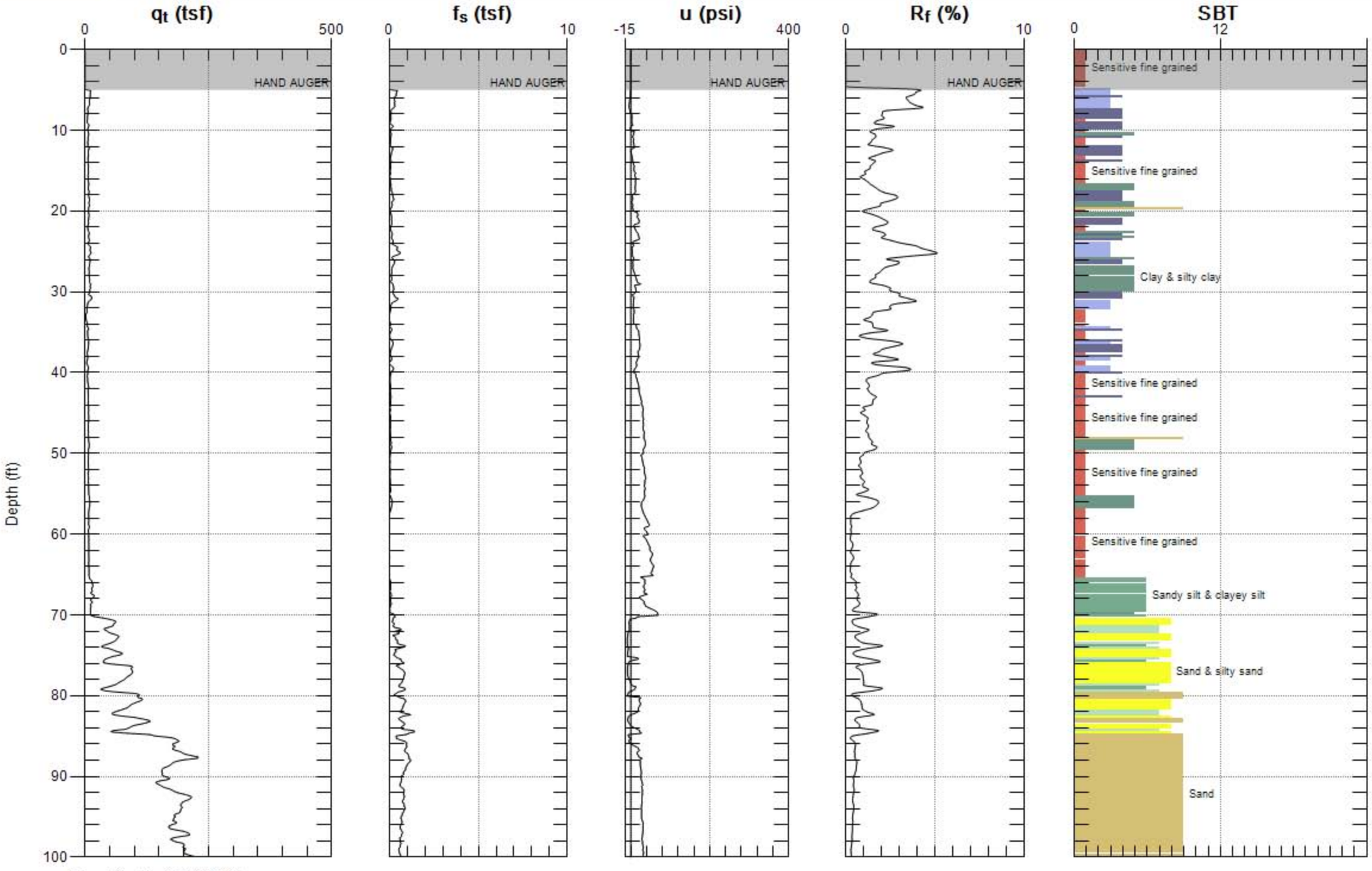


Max. Depth: 88.090 (ft)
Avg. Interval: 0.656 (ft)

SBT: Soil Behavior Type (Robertson 1990)

EARTH MECHANICS

Site: ANTIOCH BRIDGE
Sounding: CPT-32 Seis
Engineer: J.CASTLE
Date: 11/17/2006 08:54

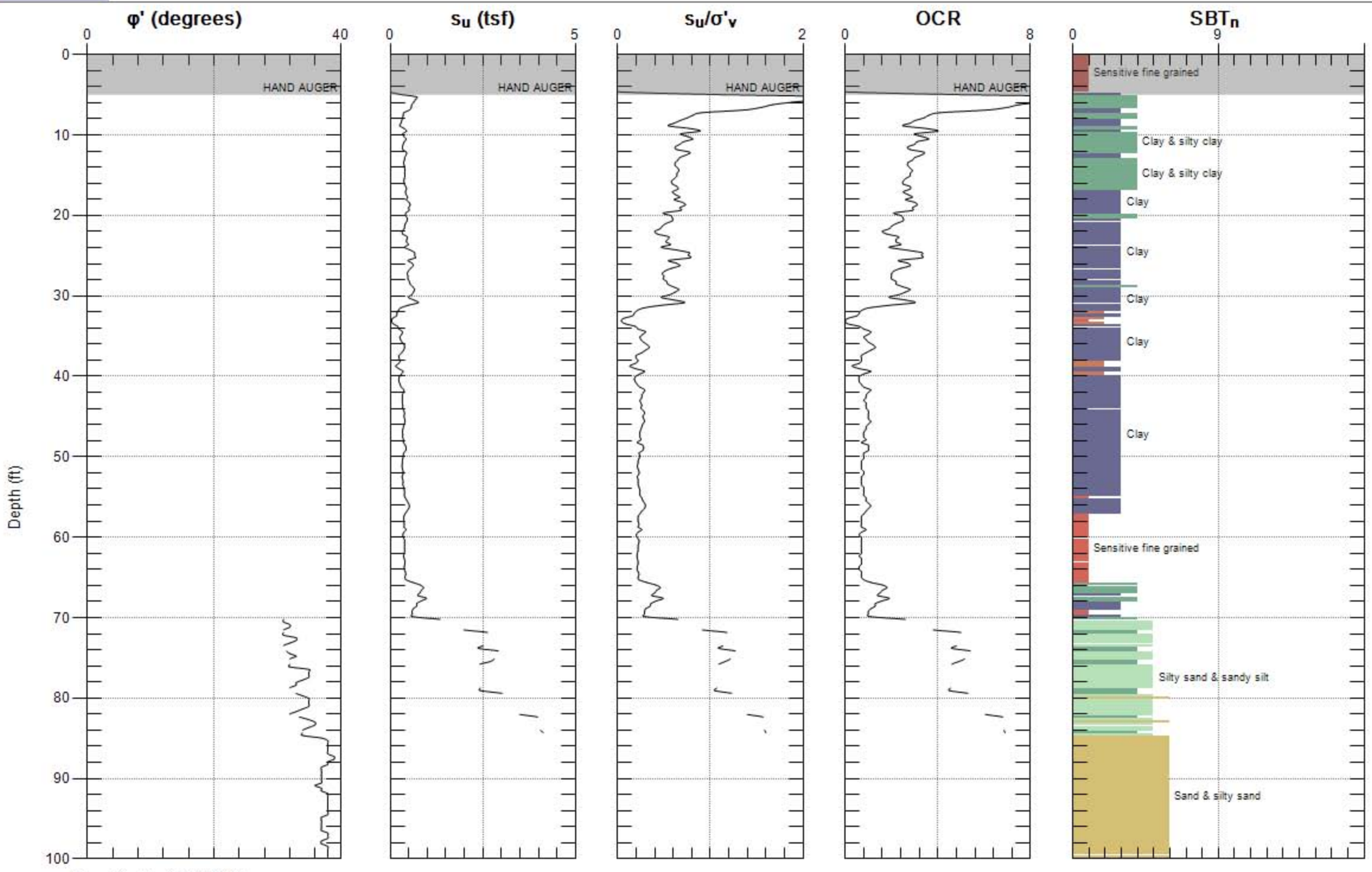


Max. Depth: 100.230 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

EARTH MECHANICS

Site: ANTIOCH BRIDGE
Sounding: CPT-32 Seis
Engineer: J.CASTLE
Date: 11/17/2006 08:54

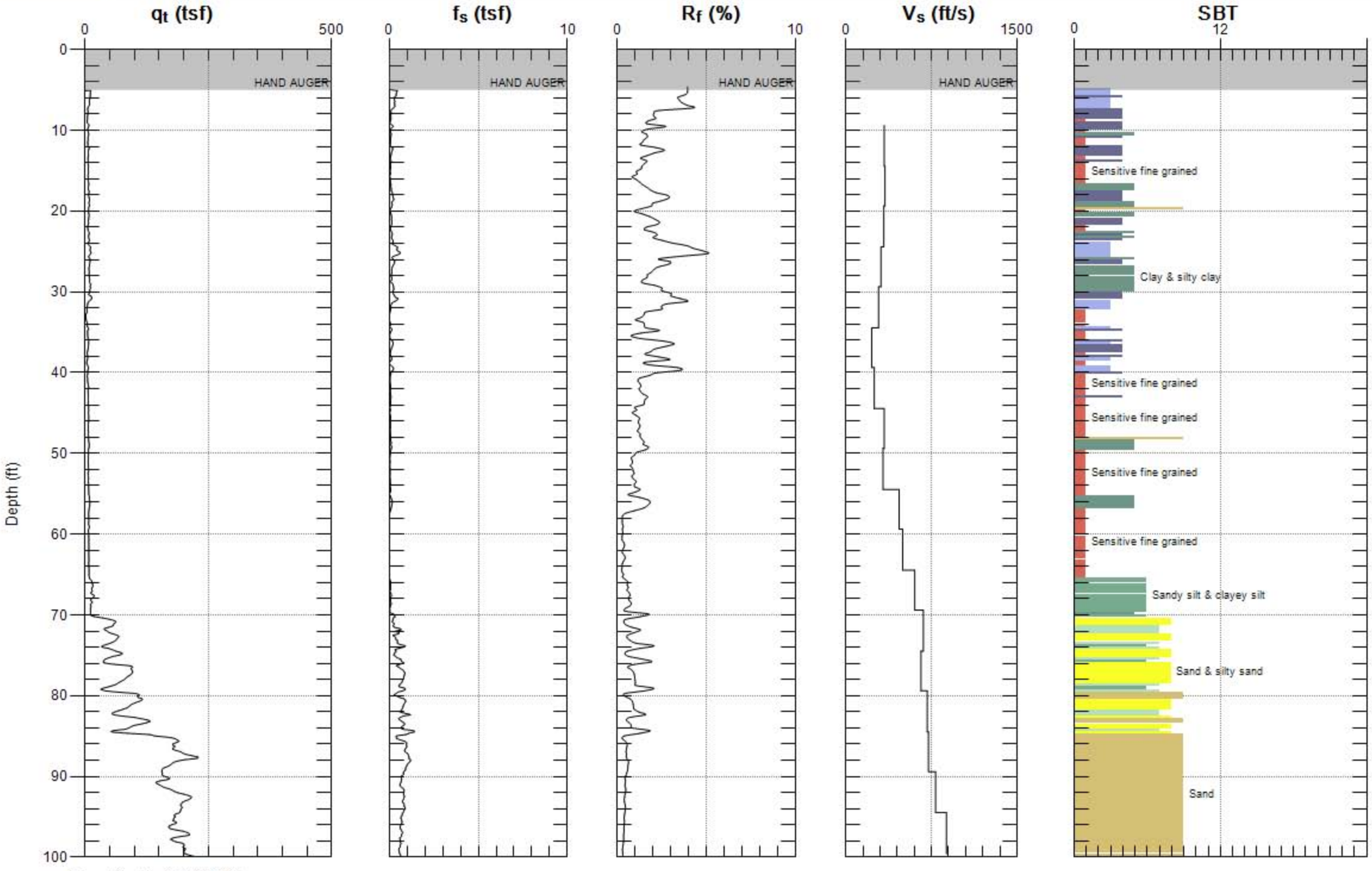


Max. Depth: 100.230 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

EARTH MECHANICS

Site: ANTIOCH BRIDGE
Sounding: CPT-32 Seis
Engineer: J.CASTLE
Date: 11/17/2006 08:54

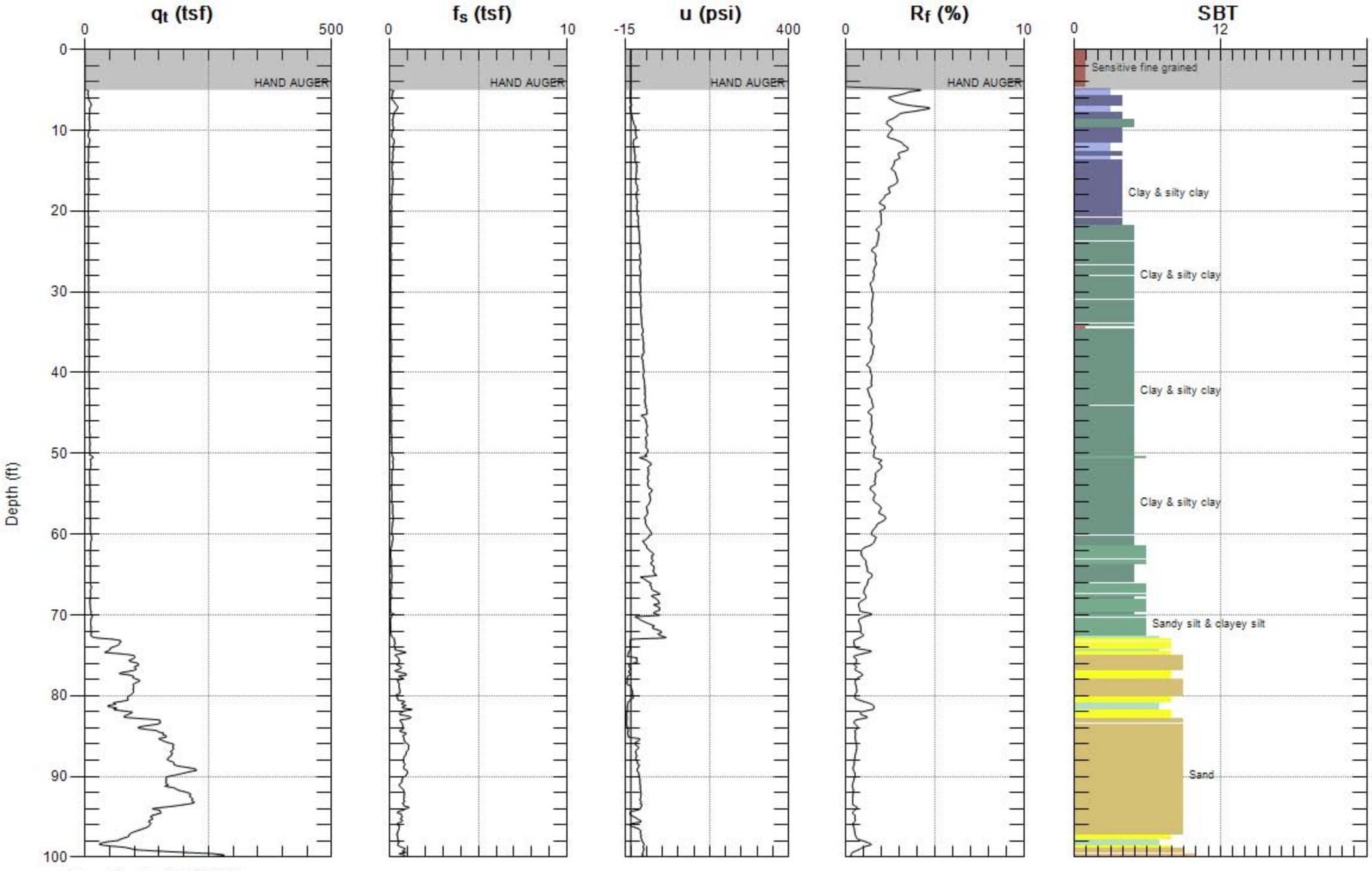


Max. Depth: 100.230 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

EARTH MECHANICS

Site: ANTIOCH BRIDGE
Sounding: CPT-33 Seis
Engineer: J.CASTLE
Date: 11/22/2006 08:10

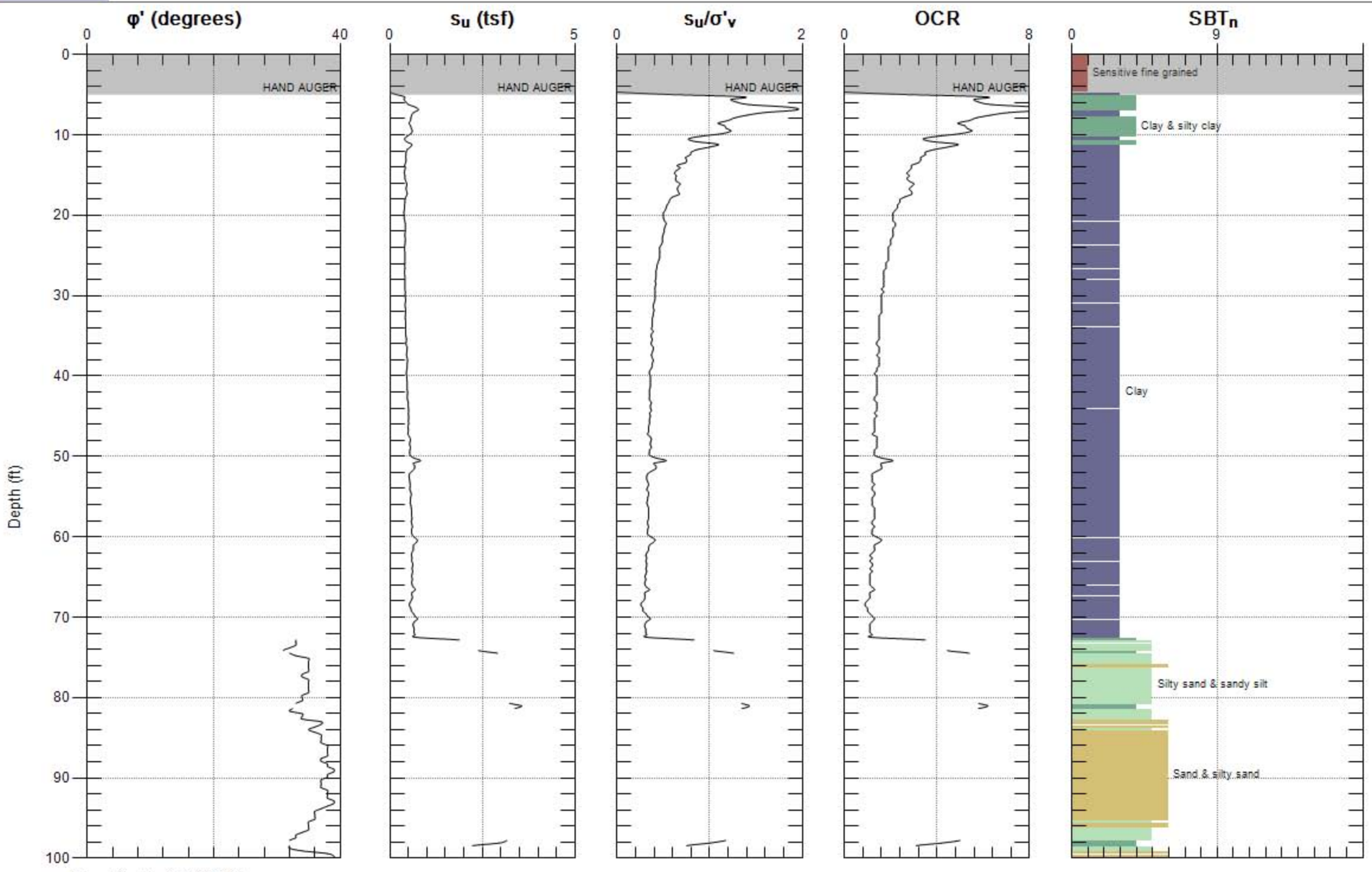


Max. Depth: 100.230 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

EARTH MECHANICS

Site: ANTIOCH BRIDGE
Sounding: CPT-33 Seis
Engineer: J.CASTLE
Date: 11/22/2006 08:10

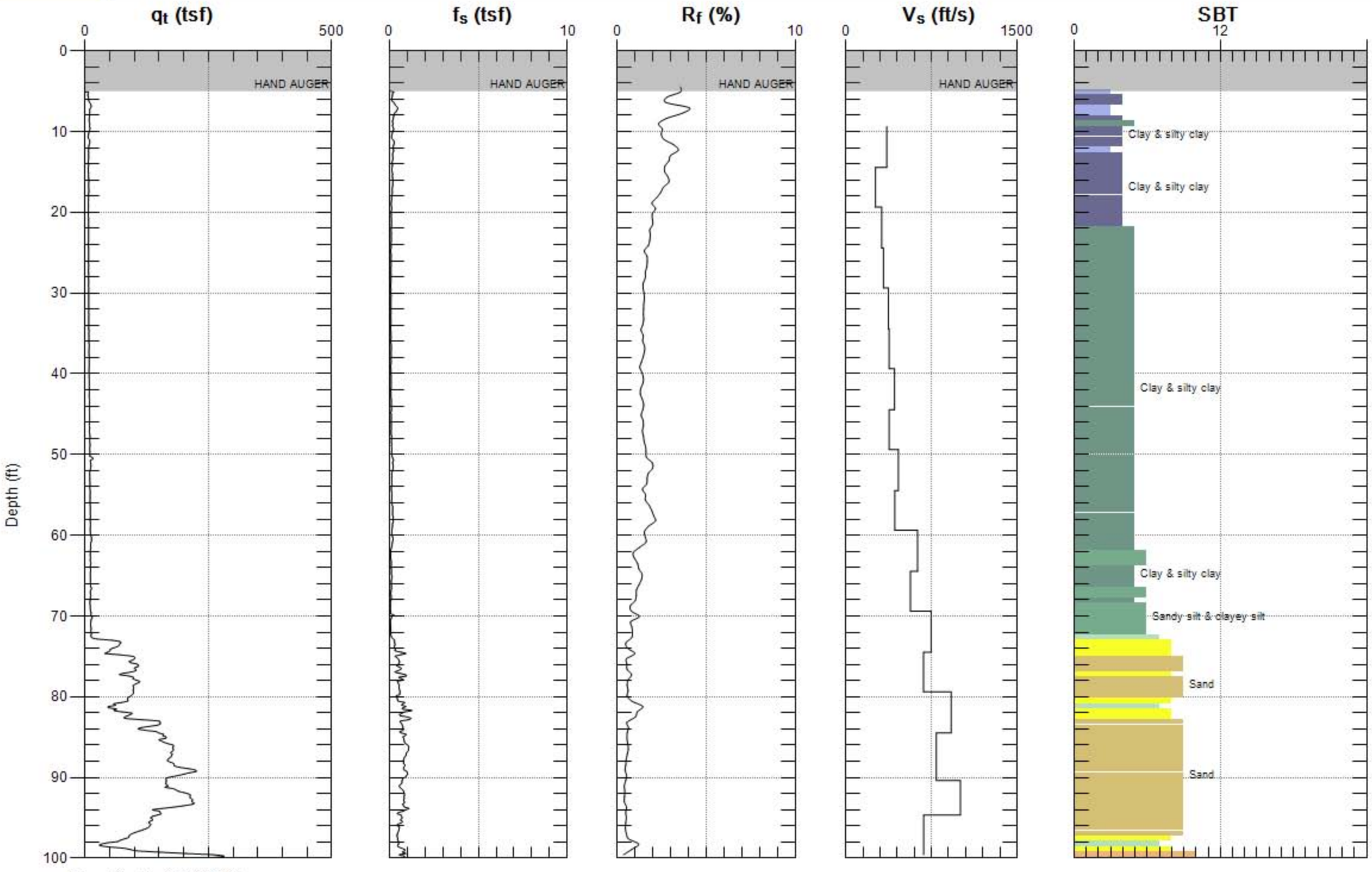


Max. Depth: 100.230 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

EARTH MECHANICS

Site: ANTIOCH BRIDGE
Sounding: CPT-33 Seis
Engineer: J.CASTLE
Date: 11/22/2006 08:10

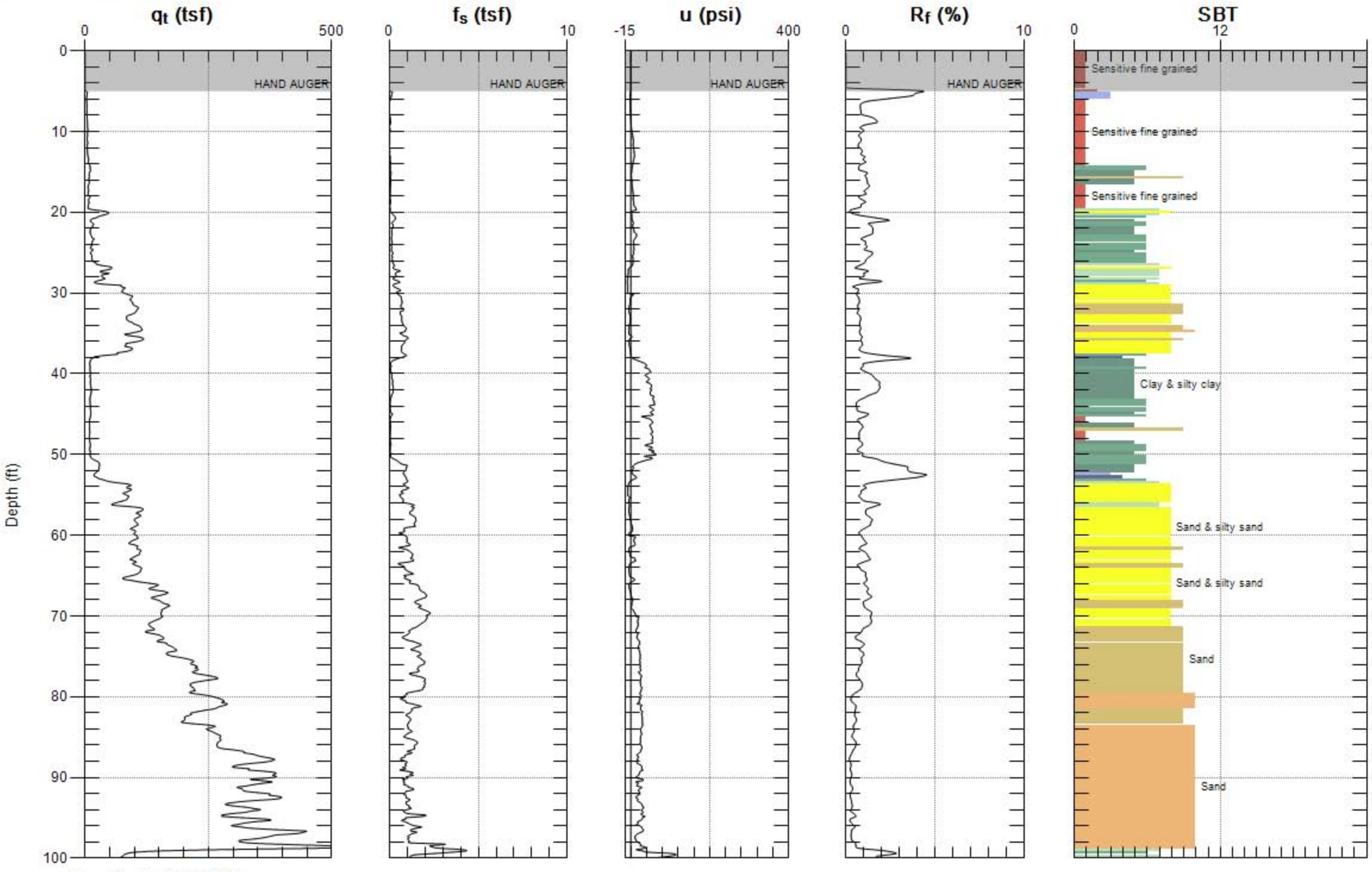


Max. Depth: 100.230 (ft)
Avg. Interval: 0.656 (ft)

SBT: Soil Behavior Type (Robertson 1990)

EARTH MECHANICS

Site: ANTIOCH BRIDGE
Sounding: CPT-34 Seis
Engineer: J.CASTLE
Date: 11/13/2006 09:46

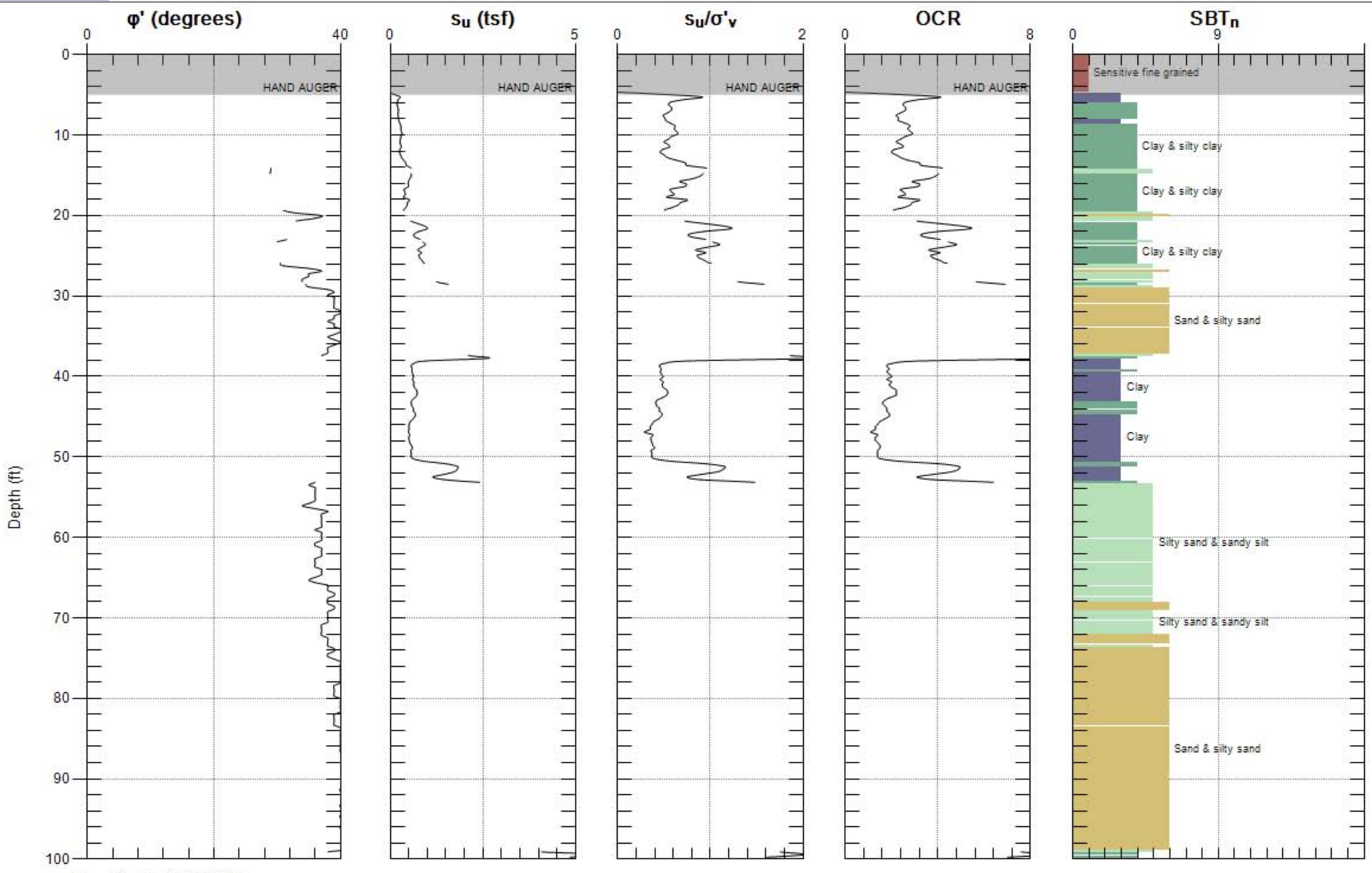


Max. Depth: 100.070 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

EARTH MECHANICS

Site: ANTIOCH BRIDGE
Sounding: CPT-34 Seis
Engineer: J.CASTLE
Date: 11/13/2006 09:46

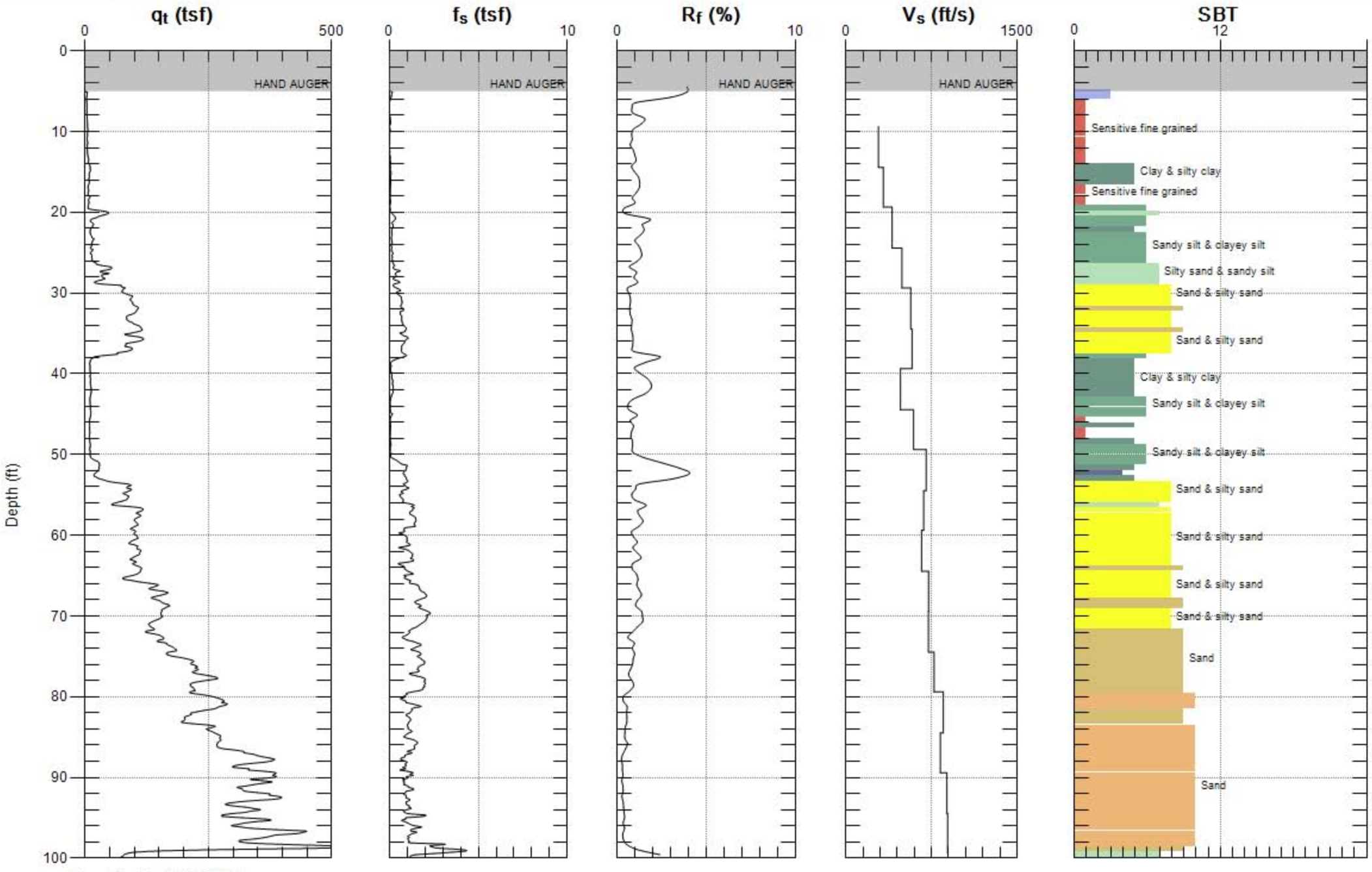


Max. Depth: 100.070 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

EARTH MECHANICS

Site: ANTIOCH BRIDGE
Sounding: CPT-34 Seis
Engineer: J.CASTLE
Date: 11/13/2006 09:46

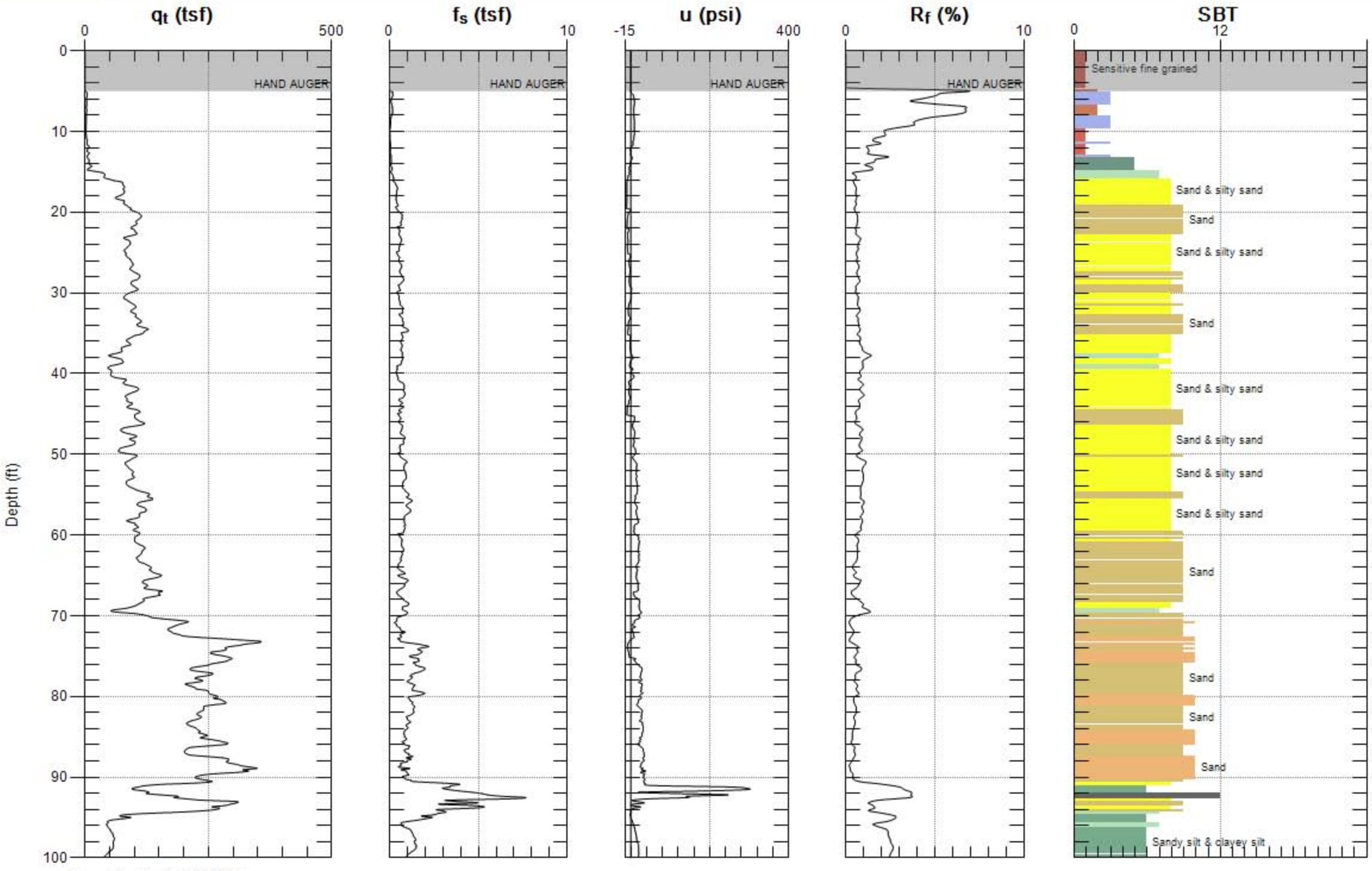


Max. Depth: 100.070 (ft)
Avg. Interval: 0.656 (ft)

SBT: Soil Behavior Type (Robertson 1990)

EARTH MECHANICS

Site: ANTIOCH BRIDGE
Sounding: CPT-35 Seis
Engineer: J.CASTLE
Date: 11/13/2006 12:26

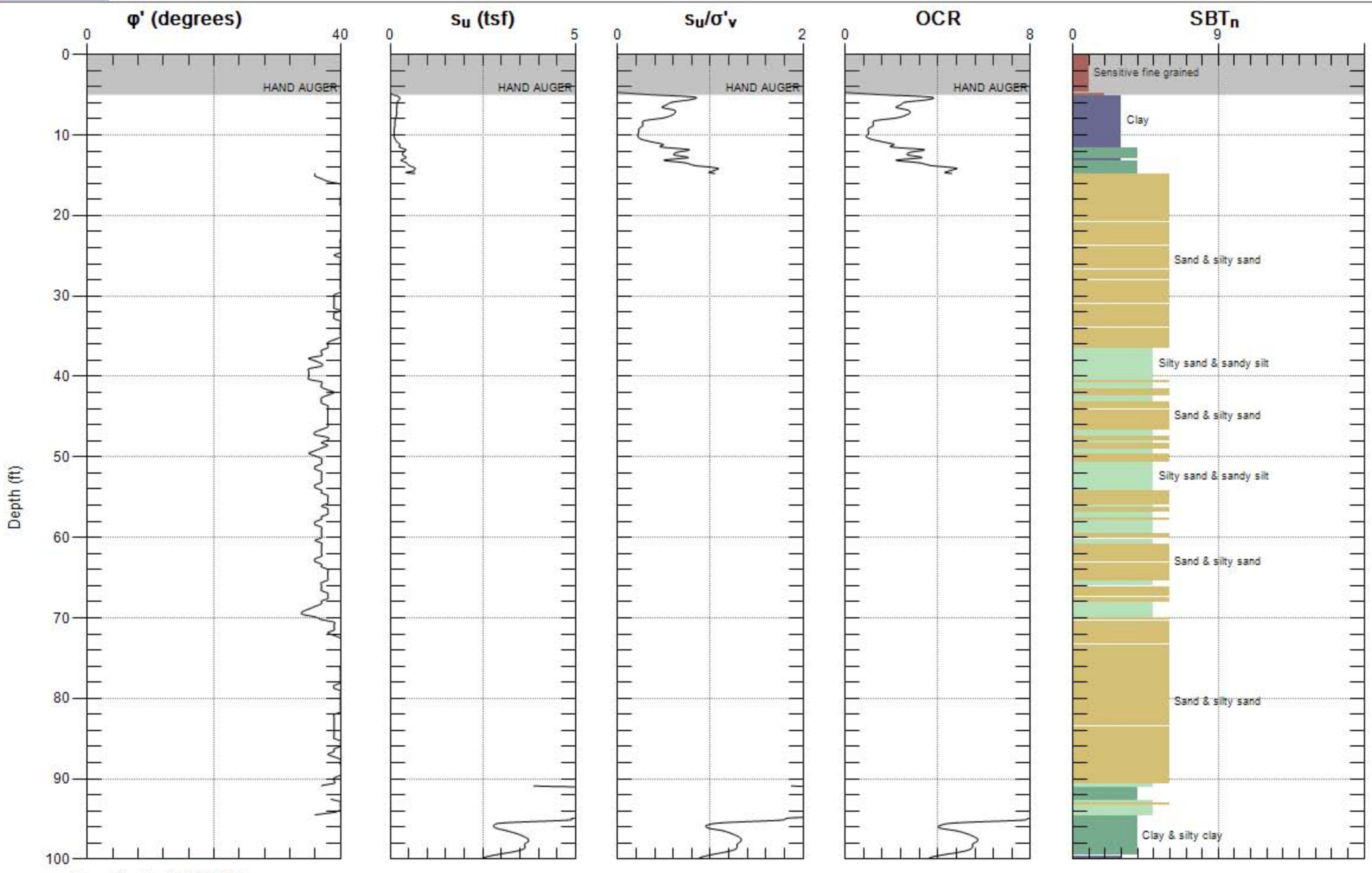


Max. Depth: 100.230 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

EARTH MECHANICS

Site: ANTIOCH BRIDGE
Sounding: CPT-35 Seis
Engineer: J.CASTLE
Date: 11/13/2006 12:26

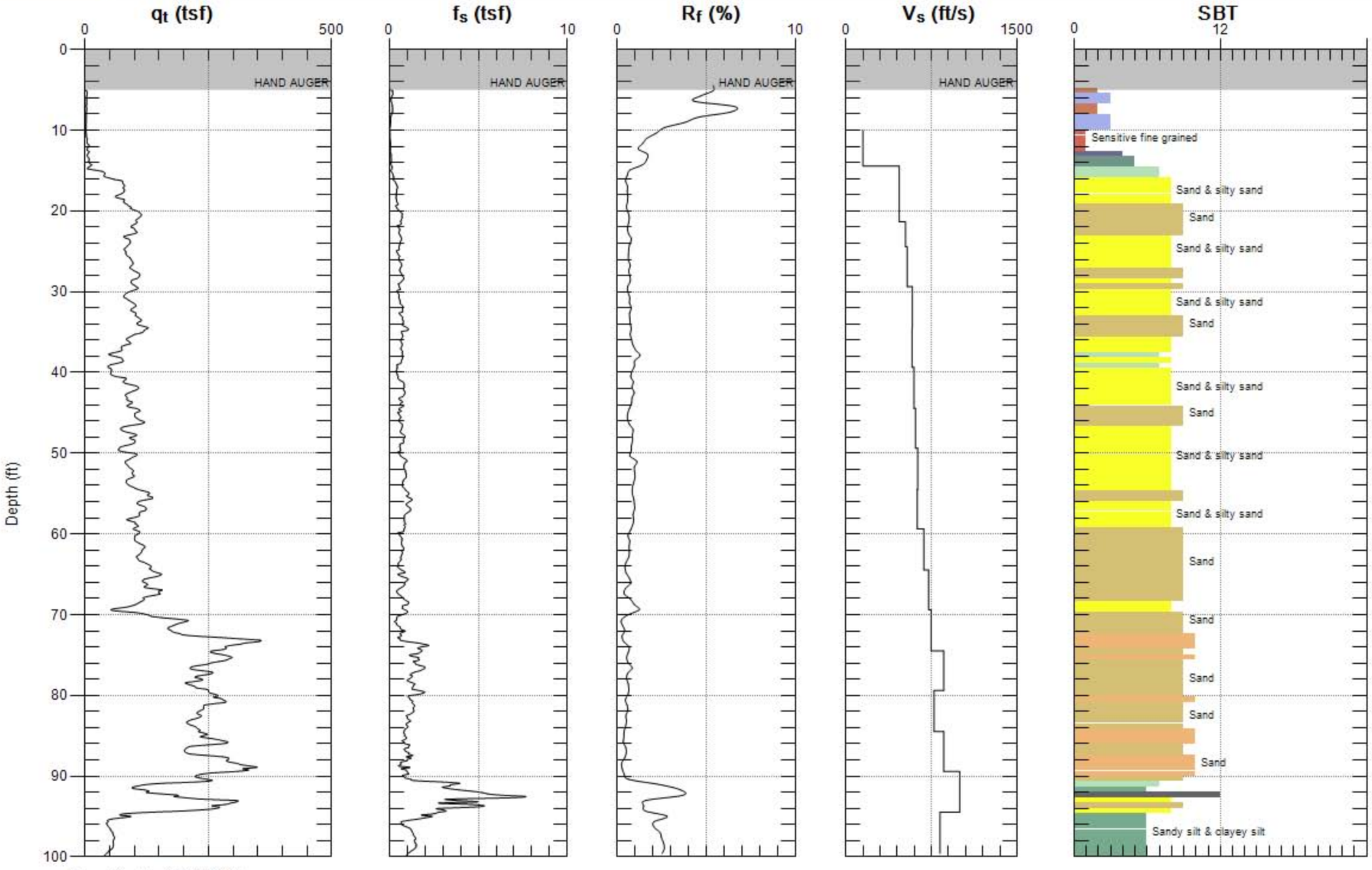


Max. Depth: 100.230 (ft)
Avg. Interval: 0.328 (ft)

SBT: Soil Behavior Type (Robertson 1990)

EARTH MECHANICS

Site: ANTIOCH BRIDGE
Sounding: CPT-35 Seis
Engineer: J.CASTLE
Date: 11/13/2006 12:26



Max. Depth: 100.230 (ft)
Avg. Interval: 0.656 (ft)

SBT: Soil Behavior Type (Robertson 1990)

FIGURE 1
SITE MAP
ANTIOCH AND
DUMBARTON BRIDGE
EMI/ANTIOCH & DUMBARTON GEOPHYS/CA

Source: USGS 250,000 Topographic Quadrangle Map, San Francisco, CA, 1956
Sacramento, CA, 1970, Santa Rosa, CA, San Jose, CA, 1962

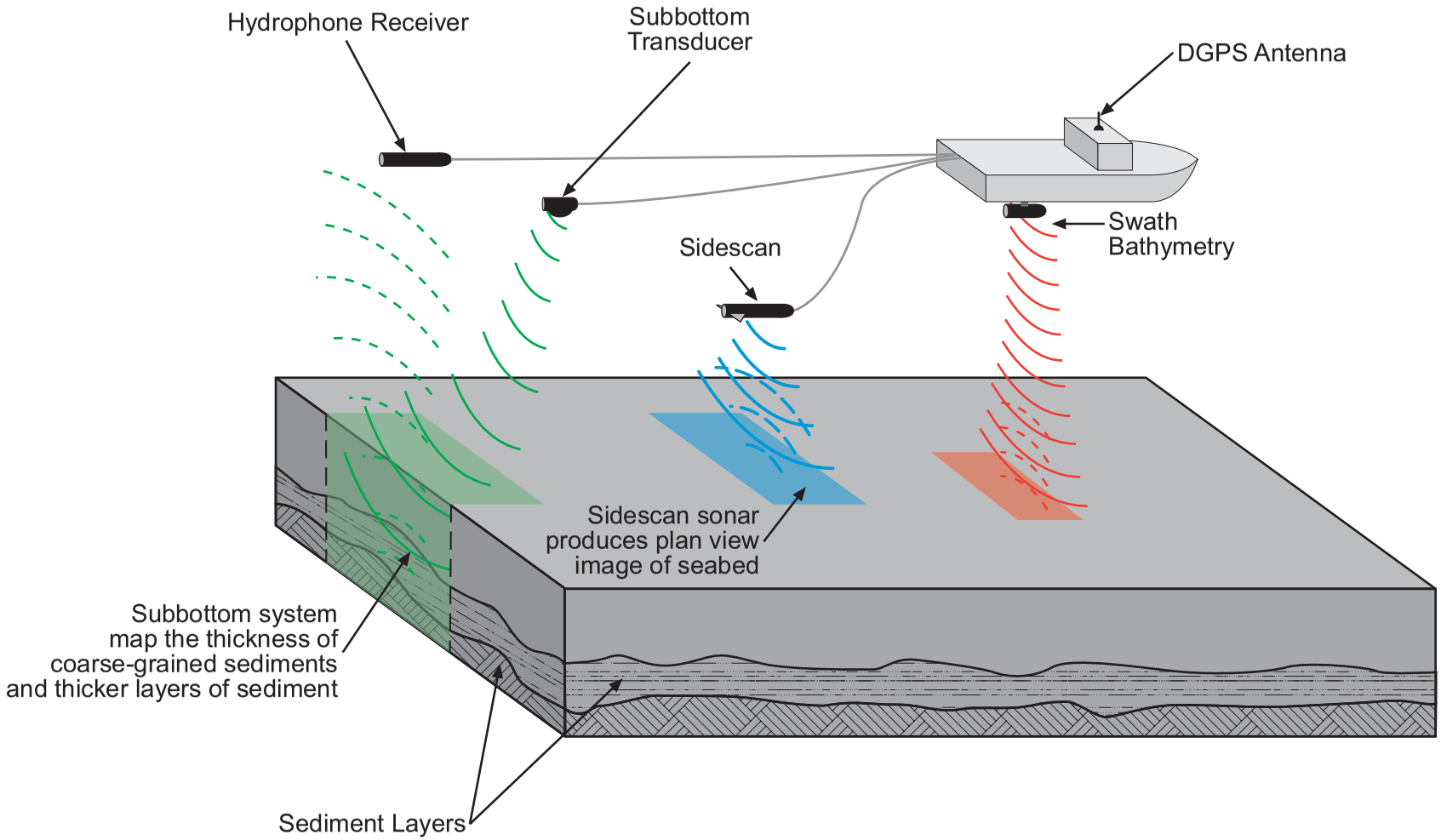
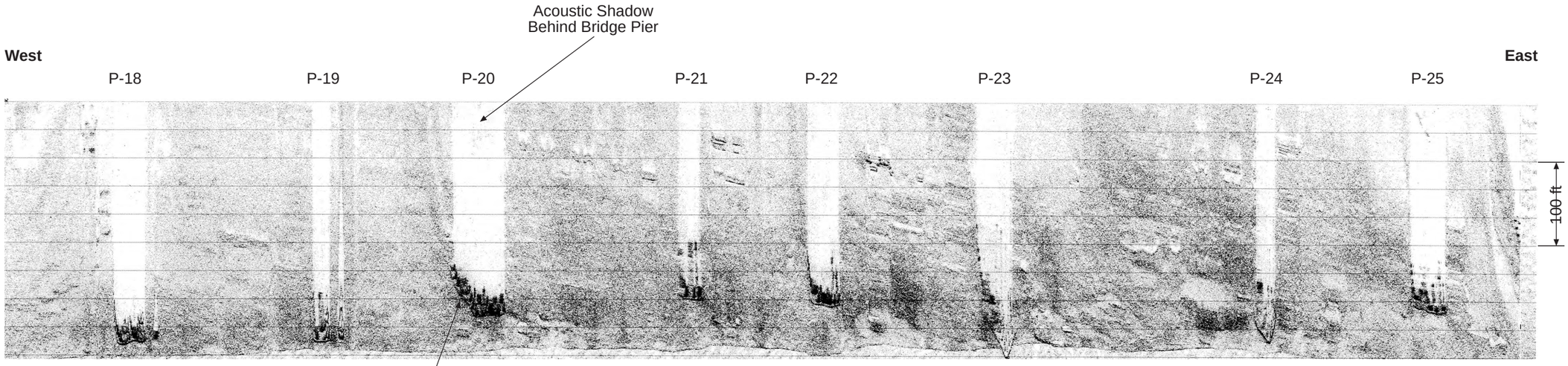


FIGURE **2**

SWATH BATHYMETRY, SIDESCAN SONAR, AND SUBBOTTOM PROFILING METHODS

EMI/ANTIOCH & DUMBARTON GEOPHYS/CA



Plan View Image
Made From South Side
of Bridge Looking North

FIGURE **3**
EXAMPLE OF SIDESCAN SONAR DATA FROM DUMBARTON BRIDGE
EMI/ANTIOCH & DUMBARTON GEOPHYS/CA

Plan View Image
Made Along West Side
of Bridge Looking East

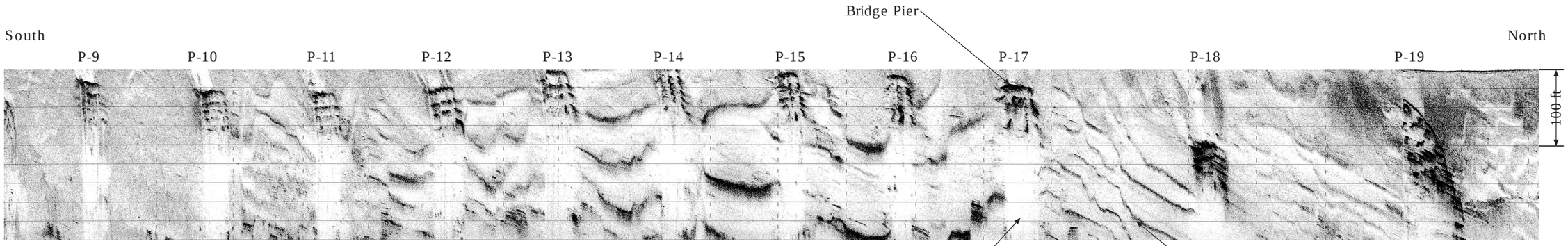
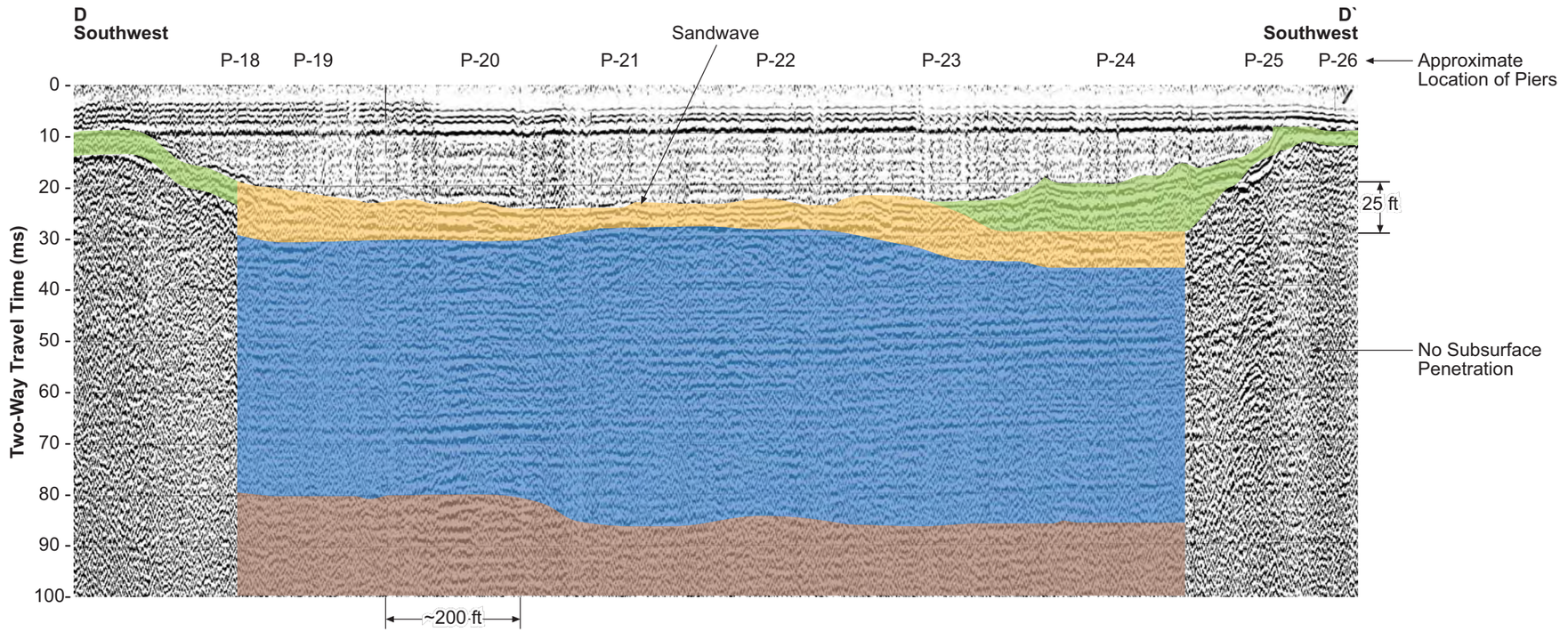
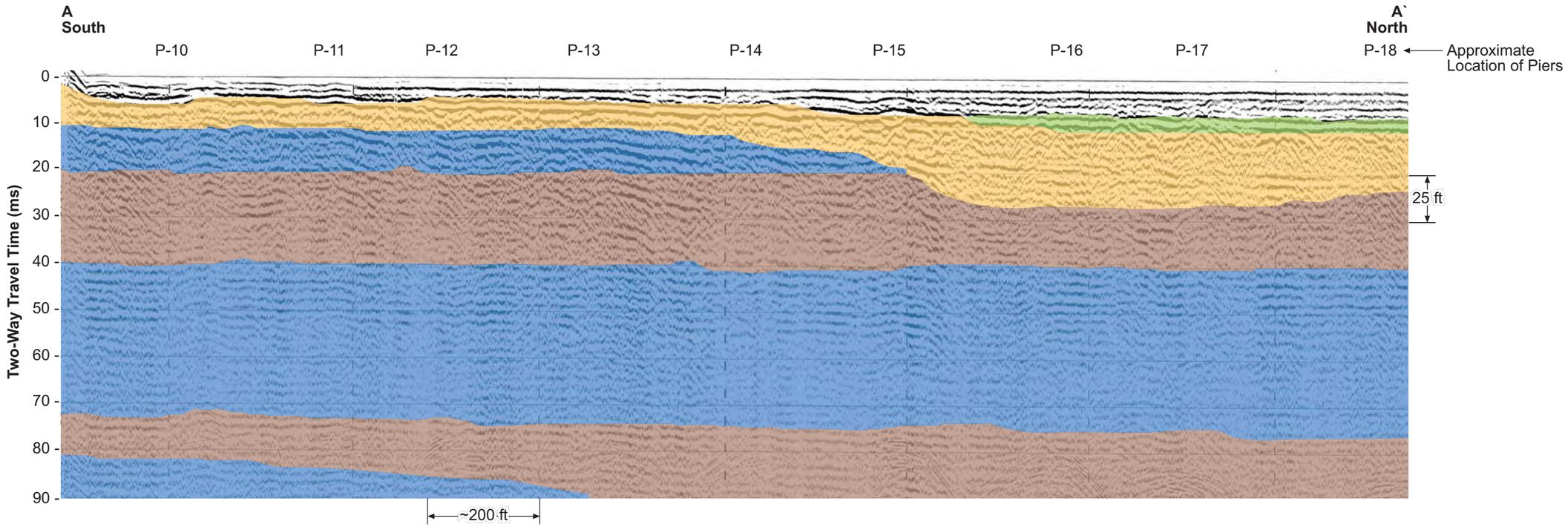


FIGURE 4
EXAMPLE OF SIDESCAN SONAR DATA
FROM ANTIOCH BRIDGE
EMI/ANTIOCH & DUMBARTON GEOPHYS/CA



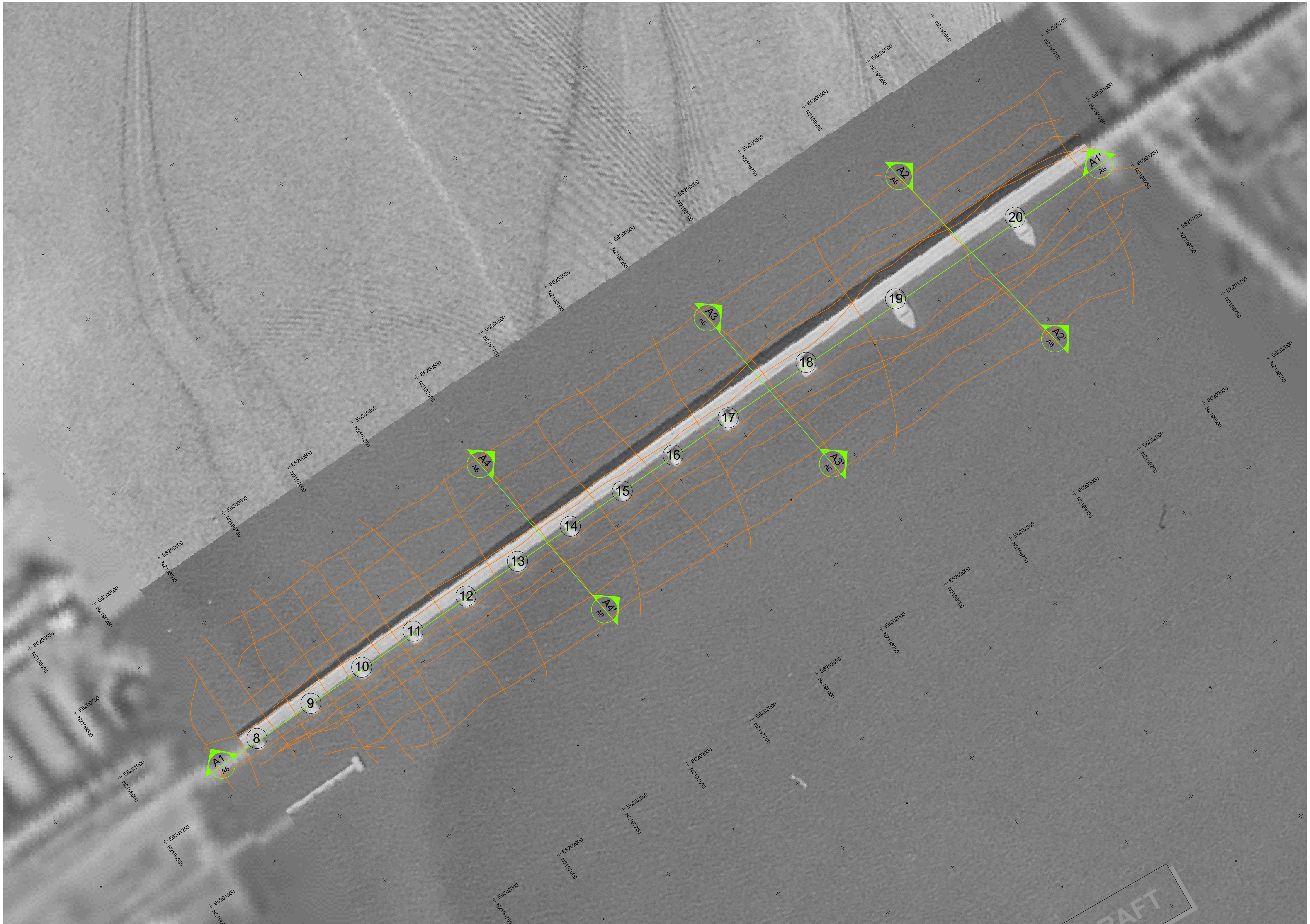
Note: Scale and location of piers for general reference only - not to exact scale.
See map D1 for location.

FIGURE **5**
EXAMPLE OF SUBBOTTOM DATA FROM DUMBARTON BRIDGE
EMI/ANTIOCH & DUMBARTON GEOPHYS/CA



Note: Scale and location of piers for general reference only - not to exact scale.
See map D1 for location.

FIGURE **6**
EXAMPLE OF SUBBOTTOM DATA FROM ANTIOCH BRIDGE
EMI/ANTIOCH & DUMBARTON GEOPHYS/CA



KEY MAP

ANTIOCH BRIDGE

SEE FIGURE 1 FOR LOCATION

LEGEND

GEOPHYSICAL SURVEY TRACKLINE

8 PIER NUMBER

A1 A1 CROSS SECTION LOCATION

SEE DRAWING A6 FOR PROFILES

N

0 150 300
SCALE IN FEET

INSTRUMENTATION

Navigation	- Trimble DGPS/HYPACK Software
Bathymetry	- Reson Model 2124
Subbottom	- Datasonic Bubble Pulser
Sidescan	- GeoAcoustic 100 KHz
Digital Acq.	- Chesapeake SonarWIZ
	- Sony 208 DAT

GEODETIC PARAMETERS

VERT. DATUM:	- NGVD 1929
HORIZ. DATUM:	- CA STATE PLANE ZONE III
PROJECTION:	- NAD 83

Golder Associates

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TEL: (425) 883-0777
FAX: (425) 882-5498

SUBMITTED TO:

Earth Mechanics Inc.
Geotechnical and Earthquake Engineering

PROJECT:
EMI/ANTIOCH AND DUMBARTON GEOPHYS/CA

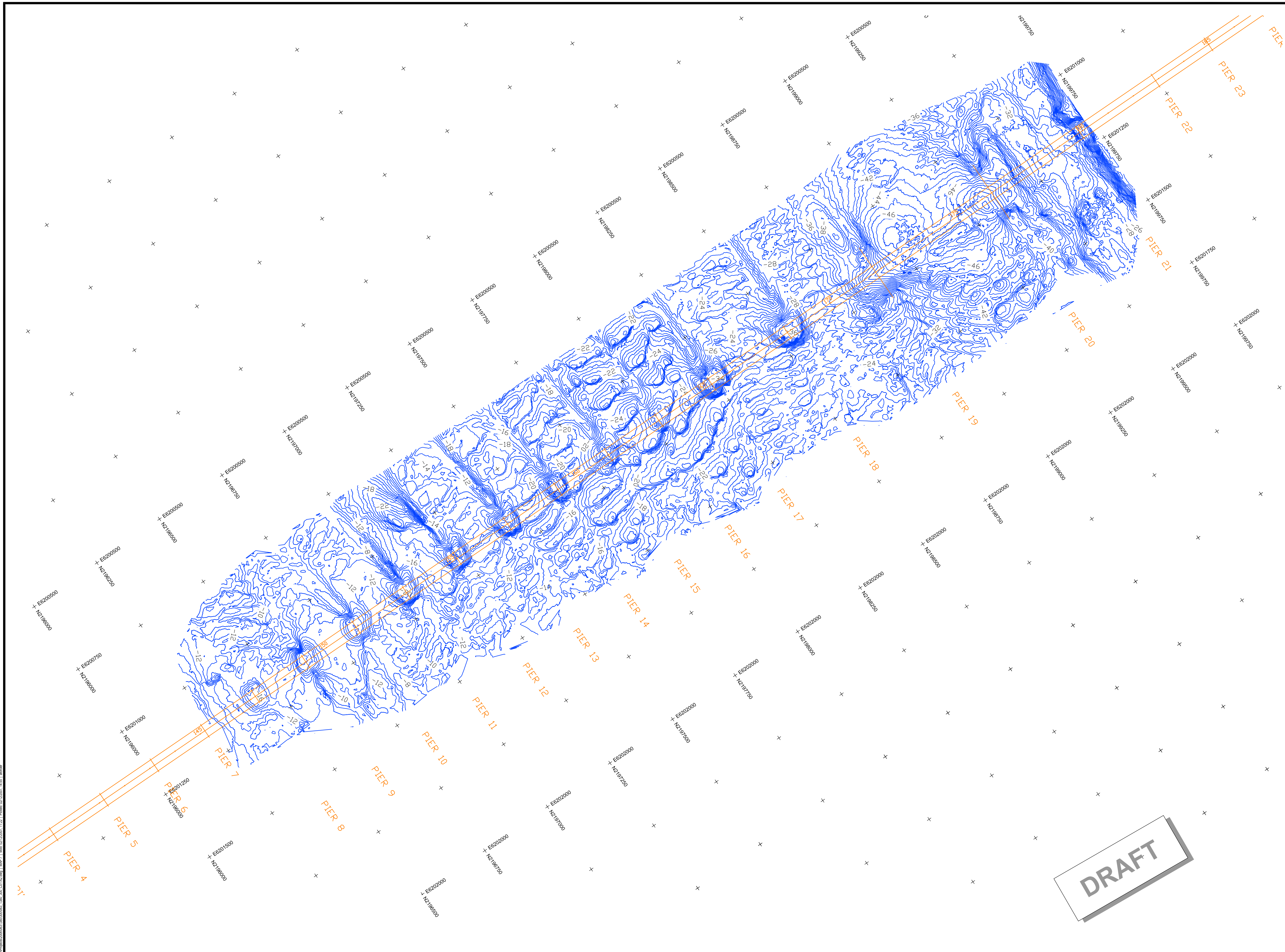
TITLE:

ANTIOCH TRACKLINE MAP

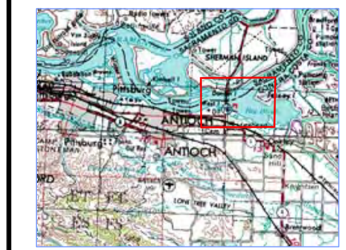
REV	DATE	REVISION DESCRIPTION	SIGNED
–	–	–	–

PROJECT No.	063–1380.300	
FILE No.	0631380300C01–A1.dwg	
REV. 0	SCALE	AS SHOWN
DESIGN	DS	12/18/06
CADD	ACF	1/12/07
CHECK	DS	1/12/07
REVIEW	–	–

A-1



KEY MAP



ANTIOCH BRIDGE

SEE FIGURE 1 FOR LOCATION

LEGEND

CONTOUR LINE
C.I. = 1 FT

0 150 300
SCALE IN FEET

INSTRUMENTATION

Navigation	- Trimble DGPS/HYPACK Software
Bathymetry	- Reson Model 2124
Subbottom	- Datasonic Bubble Pulser
Sidescan	- GeoAcoustic 100 KHz
Digital Acq.	- Chesapeake SonarWIZ
	- Sony 208 DAT

GEODETIC PARAMETERS

VERT. DATUM:	- NGVD 1929
HORIZ. DATUM:	- CA STATE PLANE ZONE III
PROJECTION:	- NAD 83

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Earth Mechanics Inc.
Geotechnical and Earthquake Engineering

PROJECT:
EMI/ANTIOCH AND DUMBARTON GEOPHYS/CA

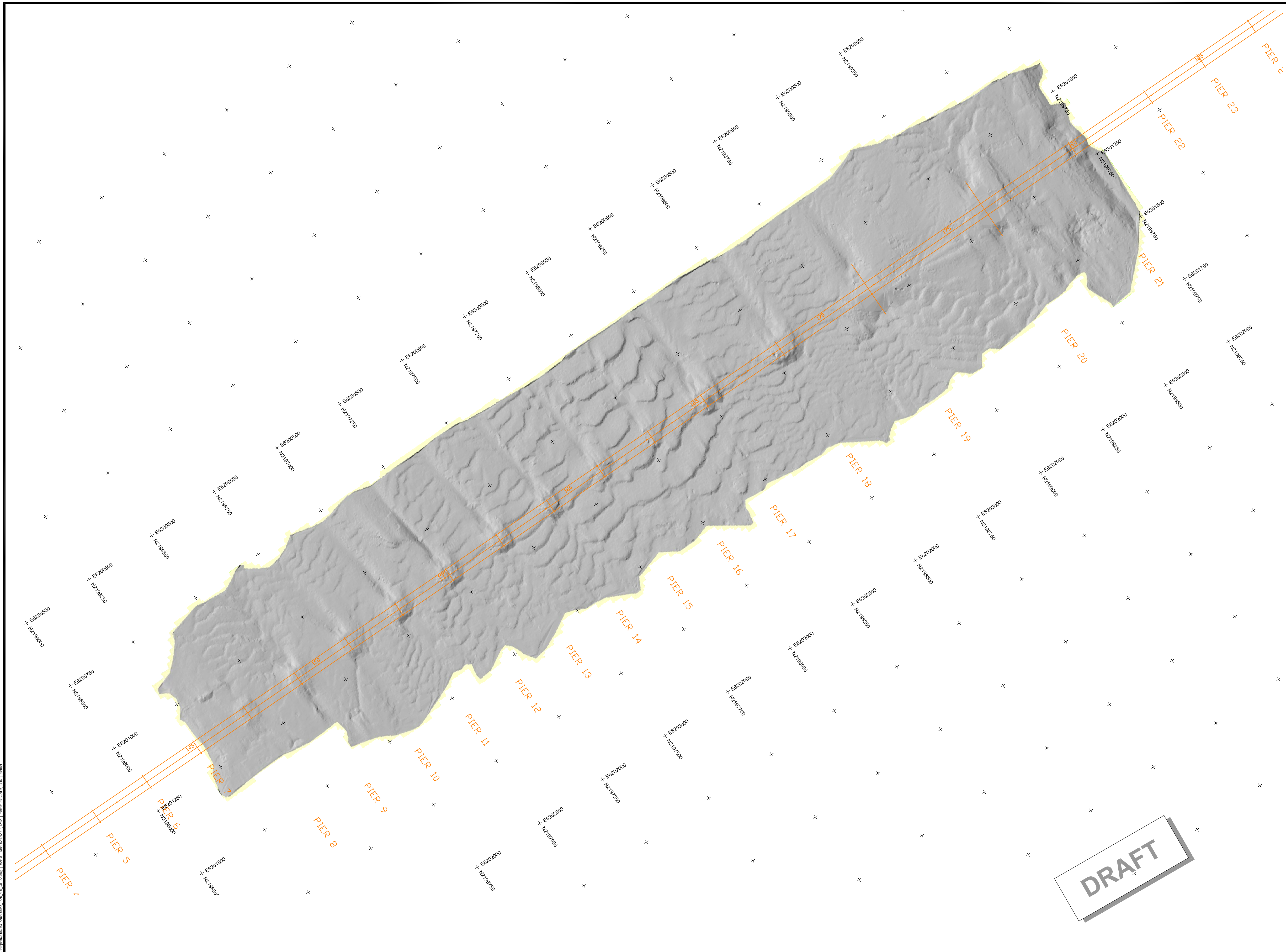
TITLE:

BATHYMETRIC CONTOUR MAP ANTIOCH BRIDGE

REV	DATE	REVISION DESCRIPTION	SIGNED
–	–	–	–

PROJECT No.	063–1380.300	
FILE No.	0631380300C01–A2.dwg	
REV. 0	SCALE	AS SHOWN
DESIGN	DS	12/18/06
CADD	ACF	1/12/07
CHECK	DS	1/12/07
REVIEW	–	–

A-2



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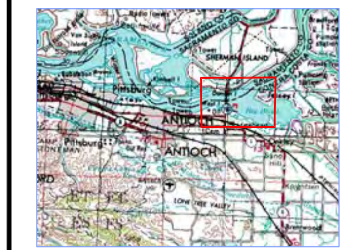
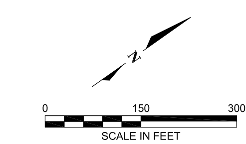


ANTIOCH BRIDGE

SEE FIGURE 1 FOR LOCATION

LEGEND



INSTRUMENTATION

Navigation	- Trimble DGPS/HYPACK Software
Bathymetry	- Reson Model 2124
Subbottom	- Datasonic Bubble Pulser
Sidescan	- GeoAcoustic 100 KHz
Digital Acq.	- Chesapeake SonarWIZ
	- Sony 208 DAT

GEODETIC PARAMETERS

VERT. DATUM:	- NGVD 1929
HORIZ. DATUM:	- CA STATE PLANE ZONE III
PROJECTION:	- NAD 83

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SUBMITTED TO:

Earth Mechanics Inc.
Geotechnical and Earthquake Engineering

PROJECT:
EMI/ANTIOCH AND DUMBARTON GEOPHYS/CA

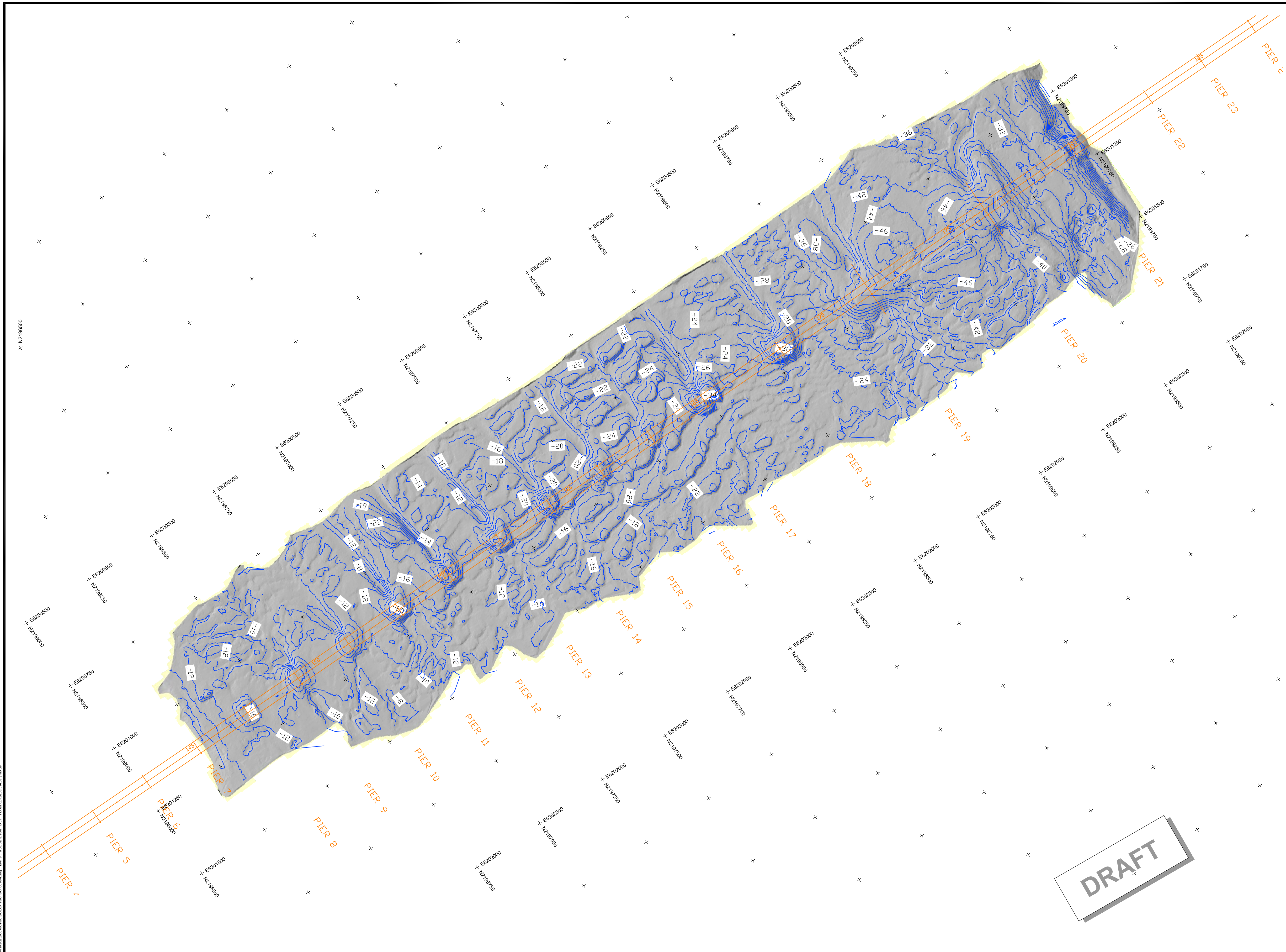
TITLE:

BATHYMETRIC SHADED RELIEF IMAGE ANTIOCH BRIDGE

REV	DATE	REVISION DESCRIPTION	SIGNED
–	–	–	–

PROJECT No.	063–1380.300	
FILE No.	0631380300C01–A3.dwg	
REV. 0	SCALE	AS SHOWN
DESIGN	DS	12/18/06
CADD	ACF	1/12/07
CHECK	DS	1/12/07
REVIEW	–	–

A-3



KEY MAP

ANTIOCH BRIDGE

SEE FIGURE 1 FOR LOCATION

LEGEND

CONTOUR LINE
C.I. = 1 FT

0 150 300
SCALE IN FEET

INSTRUMENTATION

Navigation	- Trimble DGPS/HYPACK Software
Bathymetry	- Reson Model 2124
Subbottom	- Datasonic Bubble Pulser
Sidescan	- GeoAcoustic 100 KHz
Digital Acq.	- Chesapeake SonarWIZ
	- Sony 208 DAT

GEODETIC PARAMETERS

VERT. DATUM:	- NGVD 1929
HORIZ. DATUM:	- CA STATE PLANE ZONE III
PROJECTION:	- NAD 83

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SUBMITTED TO:

Earth Mechanics Inc.
Geotechnical and Earthquake Engineering

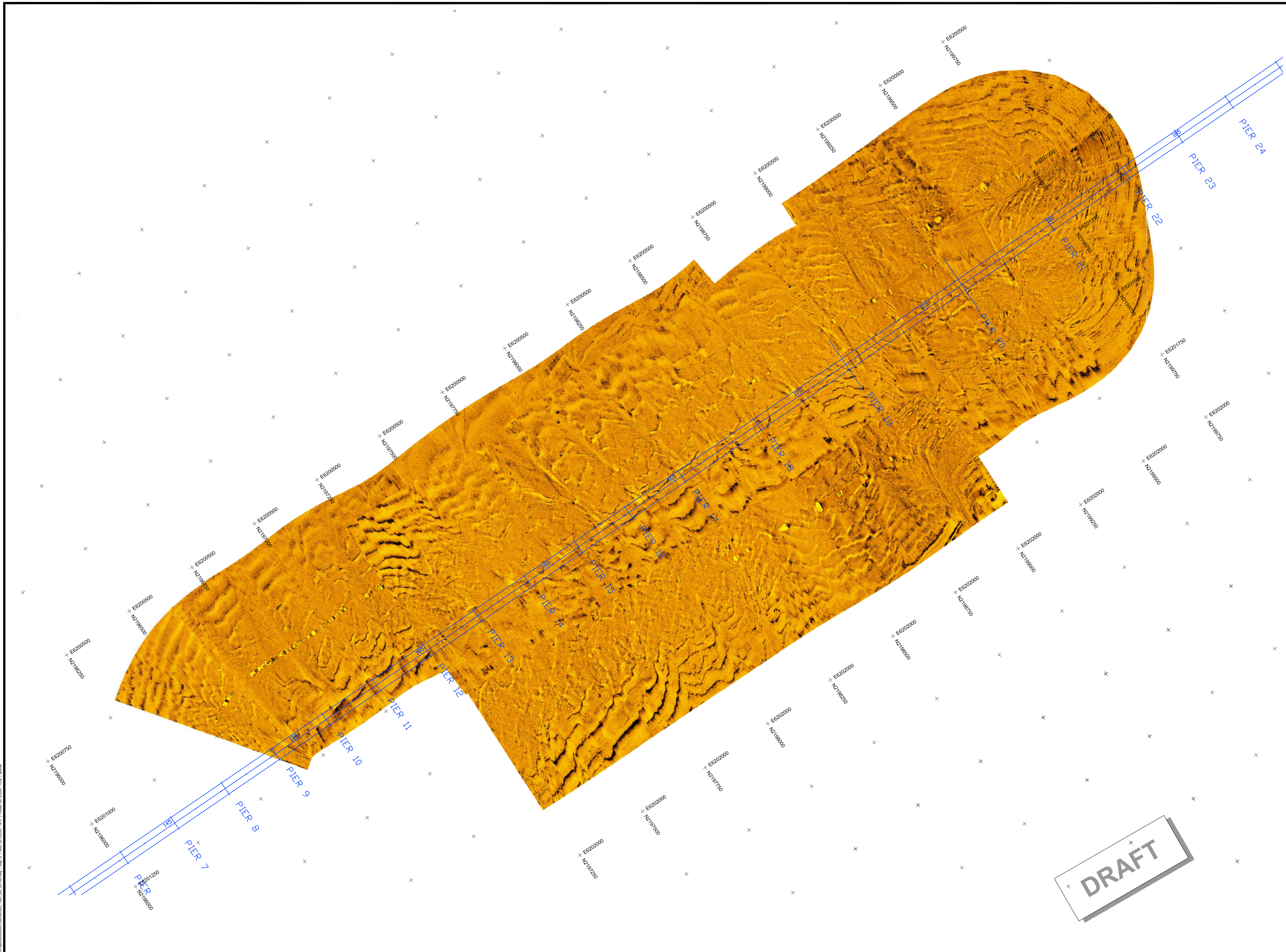
PROJECT:
EMI/ANTIOCH AND DUMBARTON GEOPHYS/CA

TITLE:
CONTOURS OVERLAIN ON BATHYMETRIC SHADED RELIEF IMAGE ANTIOCH BRIDGE

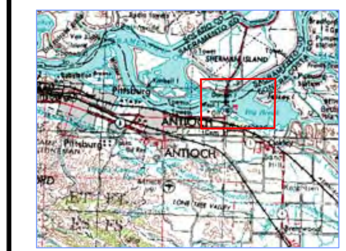
REV	DATE	REVISION DESCRIPTION	SIGNED
–	–	–	–

PROJECT No.		063-1380.300
FILE No.		0631380300C01-A4.dwg
REV. 0	SCALE	AS SHOWN
DESIGN	DS	12/18/06
CADD	ACF	1/12/07
CHECK	DS	1/12/07
REVIEW	–	–

A-4



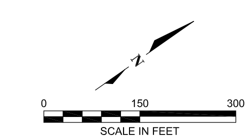
KEY MAP



ANTIOCH BRIDGE

SEE FIGURE 1 FOR LOCATION

LEGEND



INSTRUMENTATION

Navigation	- Trimble DGPS/HYPACK Software
Bathymetry	- Reson Model 2124
Subbottom	- Datasonic Bubble Pulser
Sidescan	- GeoAcoustic 100 KHz
Digital Acq.	- Chesapeake SonarWIZ
	- Sony 208 DAT

GEODETIC PARAMETERS

VERT. DATUM:	- NGVD 1929
HORIZ. DATUM:	- CA STATE PLANE ZONE III
PROJECTION:	- NAD 83

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SUBMITTED TO:

Earth Mechanics Inc.
Geotechnical and Earthquake Engineering

PROJECT:
EMI/ANTIOCH AND DUMBARTON GEOPHYS/CA

TITLE:

ANTIOCH SIDESCAN MOSAIC

REV	DATE	REVISION DESCRIPTION	SIGNED
–	–	–	–

PROJECT No.	063–1380.300	
FILE No.	0631380300C01–A5.dwg	
REV. 0	SCALE	AS SHOWN
DESIGN	DS	12/18/06
CADD	ACF	1/12/07
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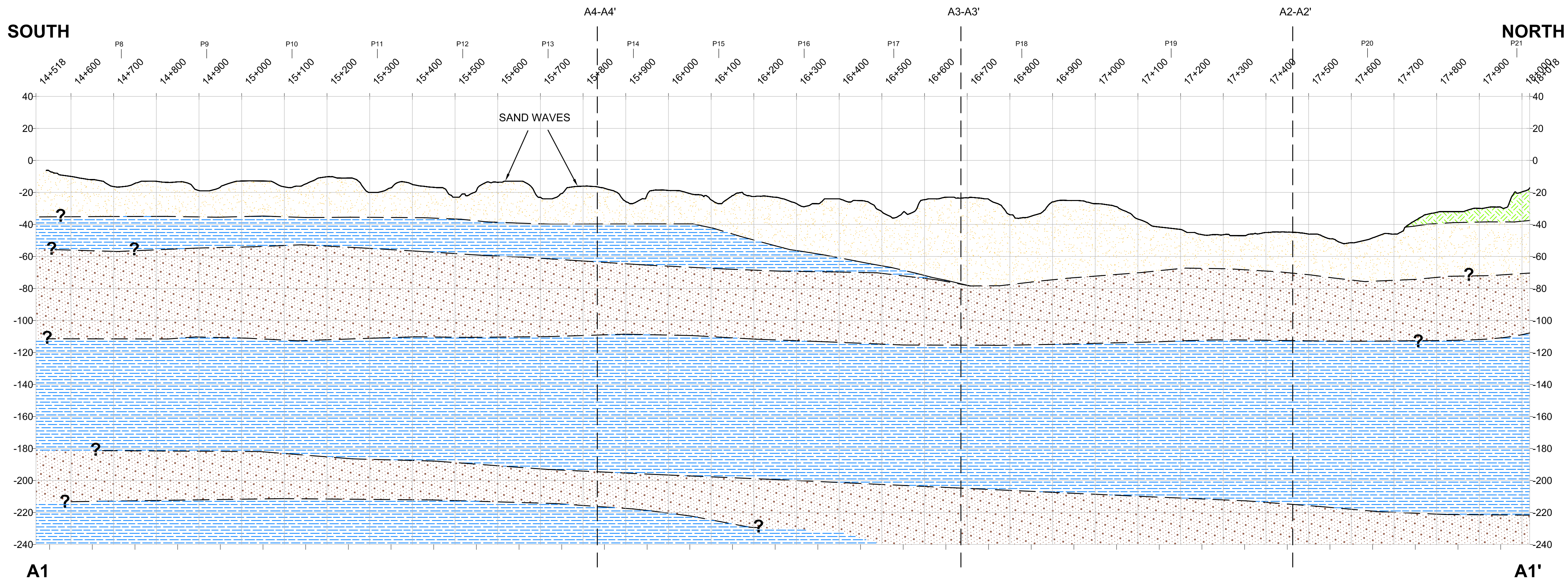
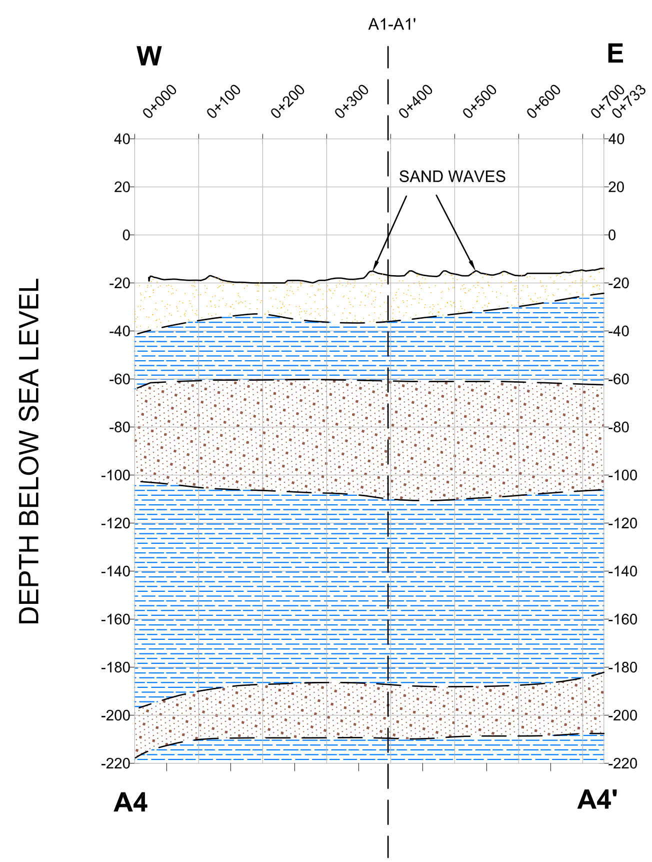
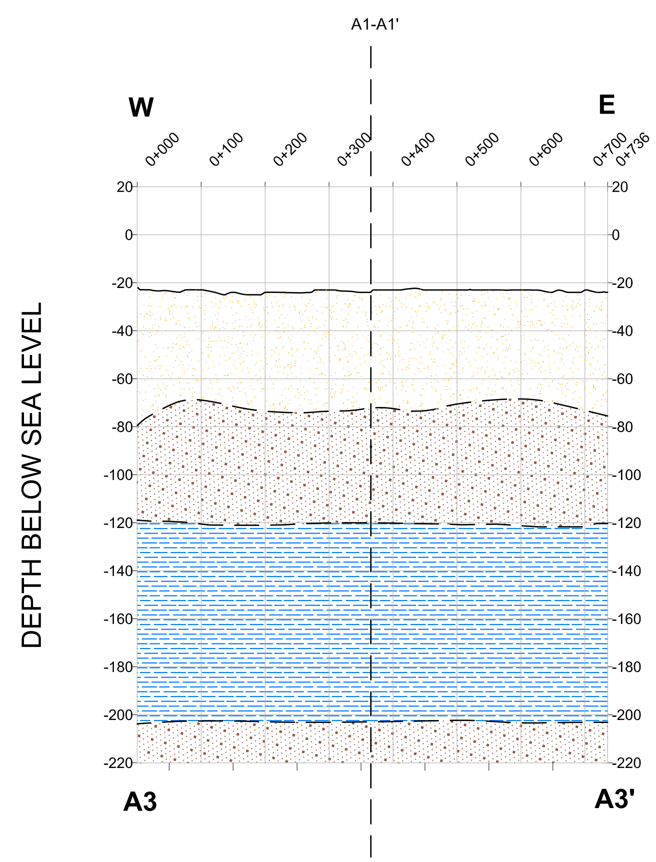
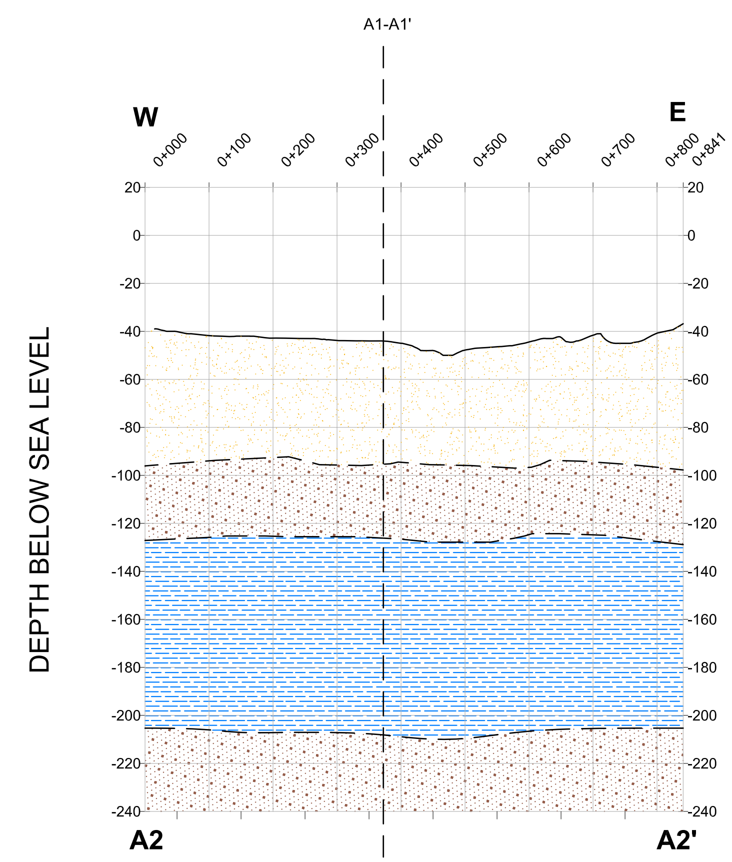
REVIEW	–	–

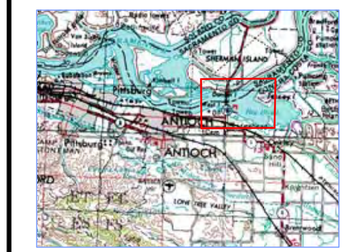
A-5











ANTIOCH BRIDGE

SEE FIGURE 1 FOR LOCATION

LEGEND

- YOUNG BAY MUD
- SAND
- HARD CLAY
- SAND AND GRAVEL

LITHOLOGY BASED ON GENERALIZED SOIL PROFILE FROM EMI

SEE DRAWING A1 FOR LOCATIONS

0 150 300
SCALE IN FEET
VERTICAL SCALE 1:40

INSTRUMENTATION

Navigation	- Trimble DGPS/HYPACK Software
Bathymetry	- Reson Model 2124
Subbottom	- Datasonic Bubble Pulser
Sidescan	- GeoAcoustic 100 KHz
Digital Acq.	- Chesapeake SonarWIZ
	- SONY 208 DAT

GEODETIC PARAMETERS

VERT. DATUM:	- NGVD 1929
HORIZ. DATUM:	- CA STATE PLANE ZONE III
PROJECTION:	- NAD 83

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SUBMITTED TO:

Earth Mechanics Inc.
Geotechnical and Earthquake Engineering

PROJECT:
EMI/ANTIOCH AND DUMBARTON GEOPHYS/CA

TITLE:

INTERPRETED PROFILES, ANTIOCH BRIDGE

REV	DATE	REVISION DESCRIPTION	SIGNED
–	–	–	–

PROJECT No.	063–1380.300	
FILE No.	0631380300C01–M10.dwg	
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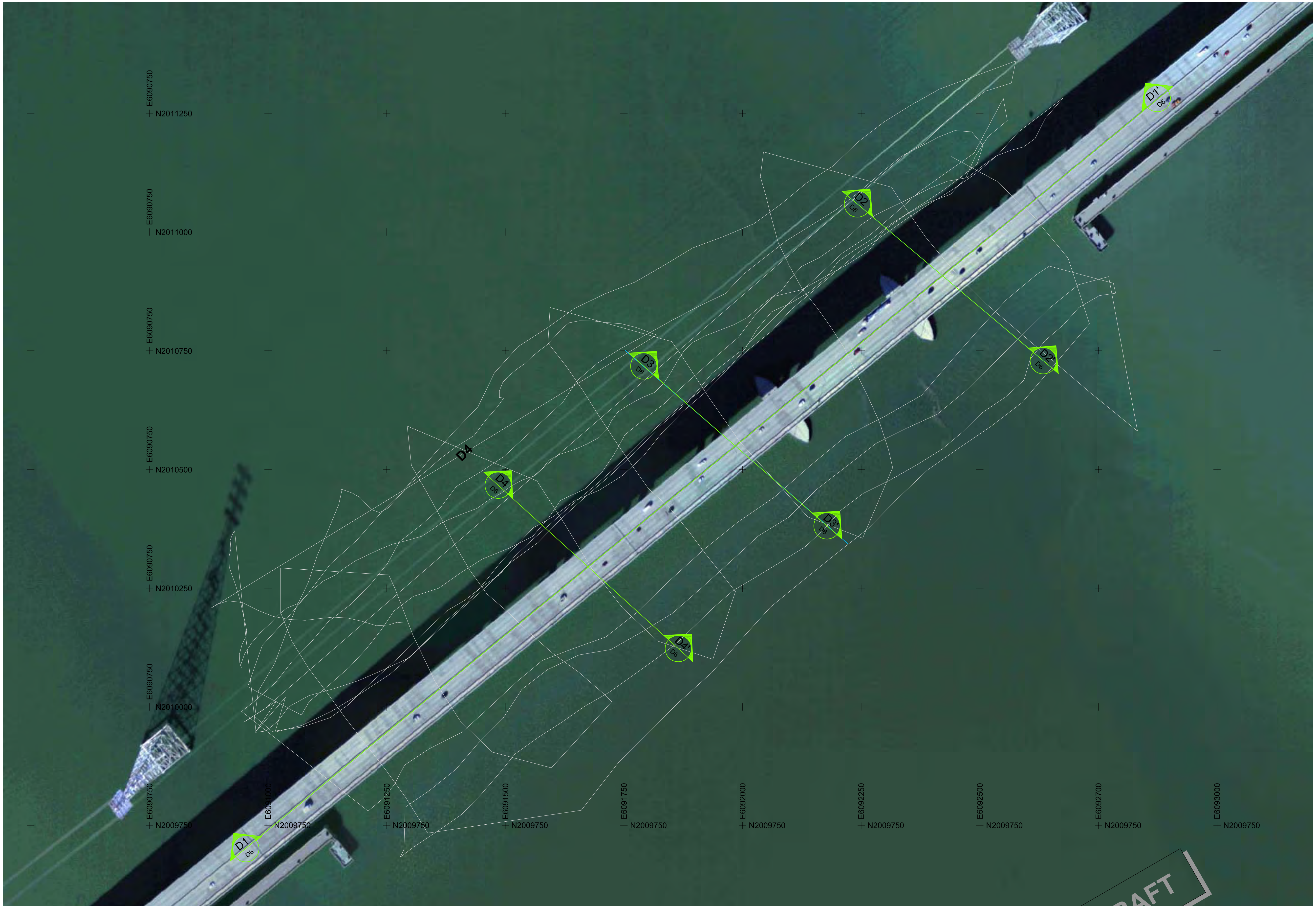
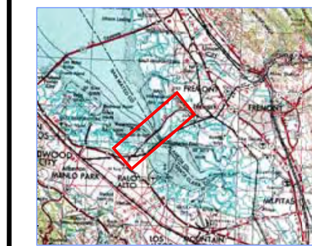
CADD	ACF	1/12/07
CHECK	DS	1/12/07
REVIEW	–	–

A-6



KEY MAP



DUMBARTON BRIDGE

SEE FIGURE 1 FOR LOCATION

LEGEND

GEOPHYSICAL SURVEY TRACKLINE

CROSS SECTION LOCATION

SEE DRAWING D6 FOR PROFILES

N

0 100 200

SCALE IN FEET

INSTRUMENTATION

Navigation	- Trimble DGPS/HYPACK Software
Bathymetry	- Reson Model 2124
Subbottom	- Datasonic Bubble Pulser
Sidescan	- GeoAcoustic 100 KHz
Digital Acq.	- Chesapeake SonarWIZ
	- Sony 208 DAT

GEODETIC PARAMETERS

VERT. DATUM: - NAVD 88
HORIZ. DATUM: - CA STATE PLANE ZONE III
PROJECTION: - NAD 83

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SUBMITTED TO:

Earth Mechanics Inc.
Geotechnical and Earthquake Engineering

PROJECT:
EMI/ANTIOCH AND DUMBARTON GEOPHYS/CA

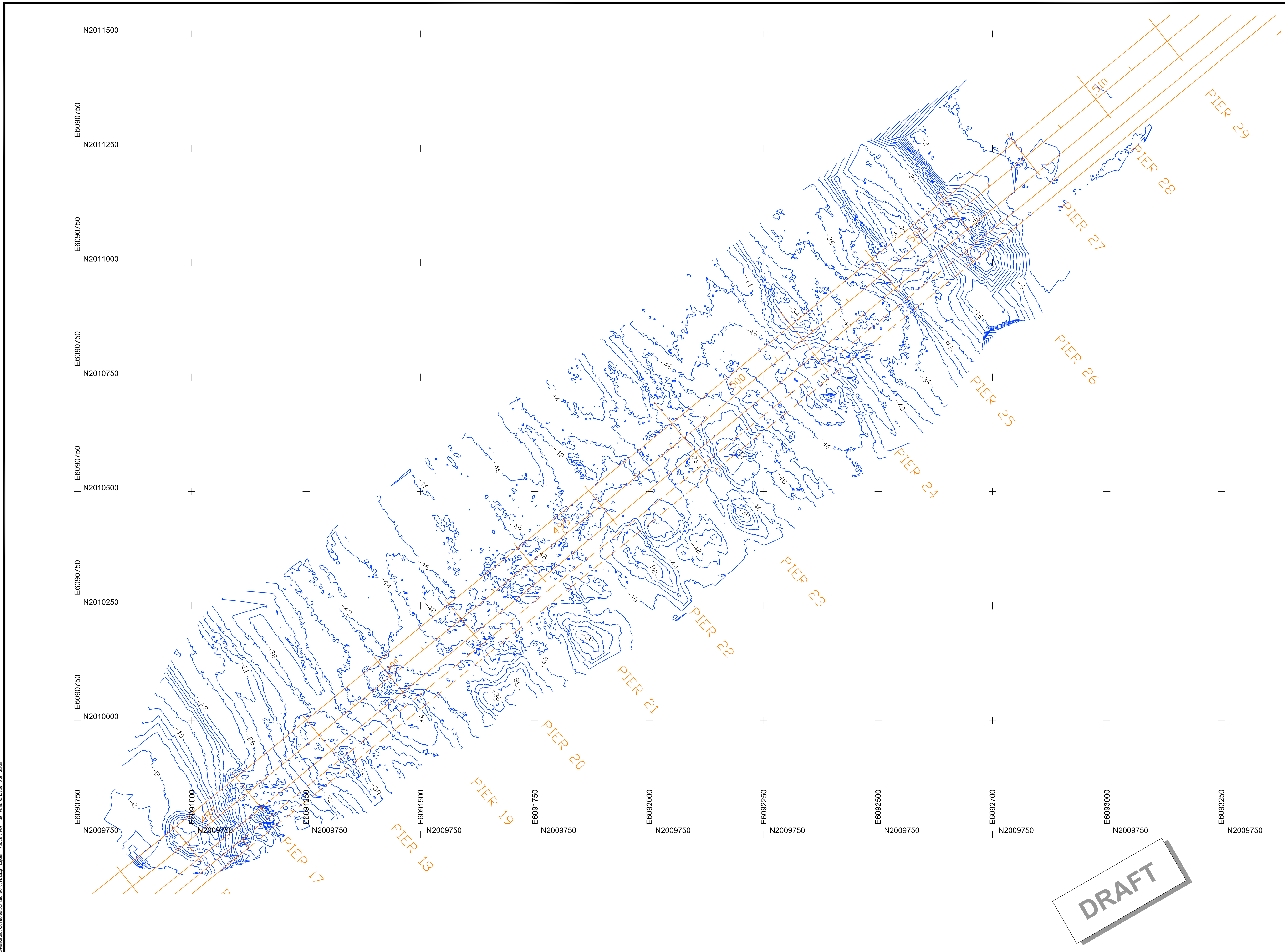
TITLE:

DUMBARTON TRACKLINE MAP

REV	DATE	REVISION DESCRIPTION	SIGNED
–	–	–	–

PROJECT No.		063–1380.300
FILE No.		0631380300C01–D1.dwg
REV. 0	SCALE	AS SHOWN
DESIGN	DS	12/18/06
CADD	ACF	1/12/07
CHECK	DS	1/12/07
REVIEW	–	–

D-1



KEY MAP

DUMBARTON BRIDGE

SEE FIGURE 1 FOR LOCATION

LEGEND

CONTOUR LINES
C.I.= 1 FT

N

0 100 200
SCALE IN FEET

INSTRUMENTATION

Navigation	- Trimble DGPS/HYPACK Software
Bathymetry	- Reson Model 2124
Subbottom	- Datasonic Bubble Pulser
Sidescan	- GeoAcoustic 100 KHz
Digital Acq.	- Chesapeake SonarWIZ
	- Sony 208 DAT

GEODETIC PARAMETERS

VERT. DATUM:	- NAVD 88
HORIZ. DATUM:	- CA STATE PLANE ZONE III
PROJECTION:	- NAD 83

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Earth Mechanics Inc.
Geotechnical and Earthquake Engineering

PROJECT:
EM/ANTIOCH AND DUMBARTON
GEOPHYS/CA

TITLE:

BATHYMETRIC CONTOURS DUMBARTON BRIDGE

REV	DATE	REVISION DESCRIPTION	SIGNED
–	–	–	–

PROJECT No.		063–1380.300
FILE No.		0631380300C01–D2.dwg
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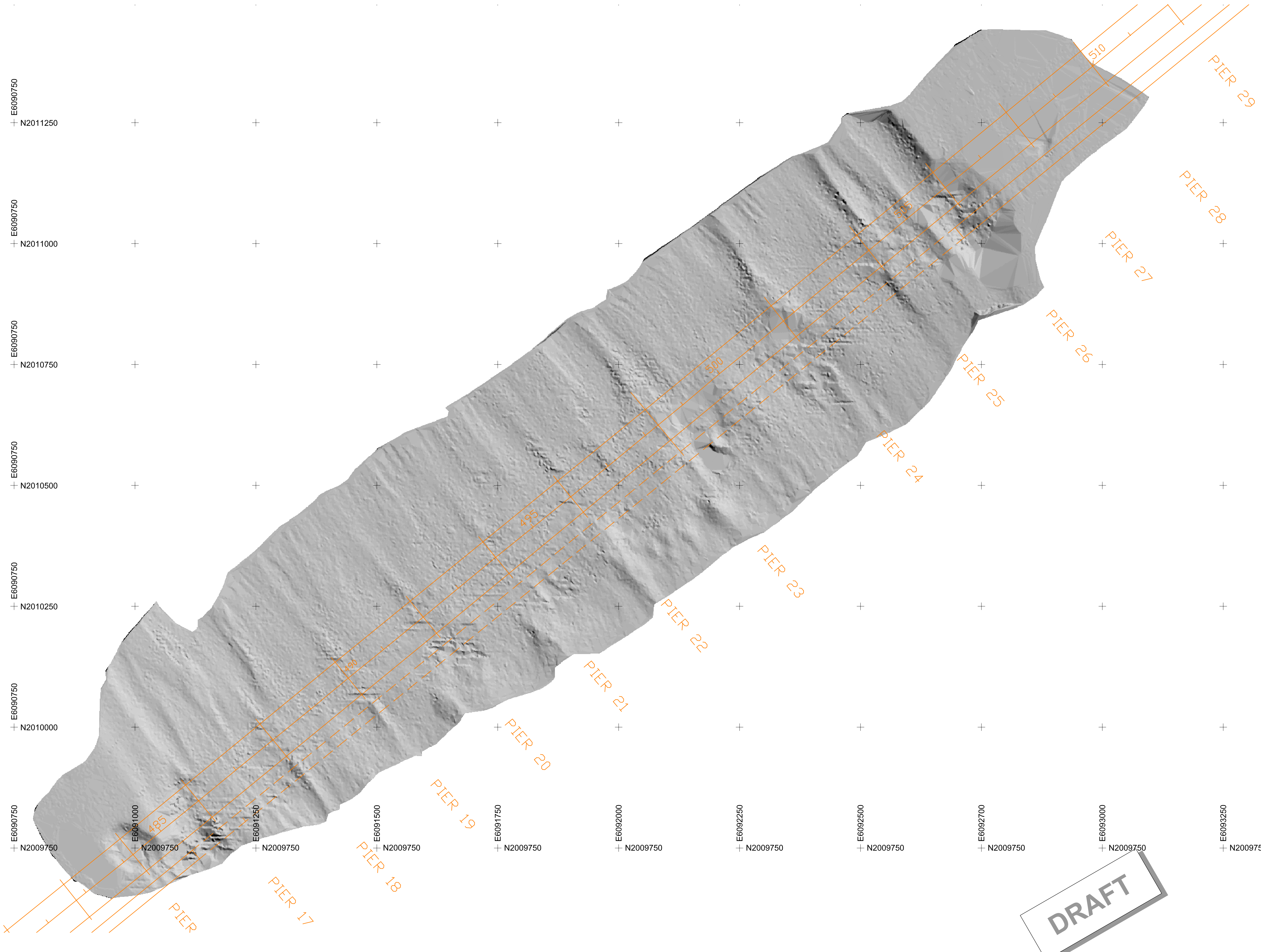
CADD	ACF	1/12/07
CHECK	DS	1/12/07
REVIEW	–	–

D-2

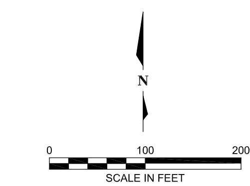


KEY MAP

DUMBARTON BRIDGE

SEE FIGURE 1 FOR LOCATION

LEGEND



INSTRUMENTATION

Navigation - Trimble DGPS/HYPACK Software
Bathymetry - Reson Model 2124
Subbottom - Datasonic Bubble Pulser
Sidescan - GeoAcoustic 100 KHz
Digital Acq. - Chesapeake SonarWIZ
- Sony 208 DAT

GEODETIC PARAMETERS

VERT. DATUM: - NSVD 88
HORIZ. DATUM: - CA STATE PLANE ZONE III
PROJECTION: - NAD 83

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SUBMITTED TO:

Earth Mechanics Inc.
Geotechnical and Earthquake Engineering

PROJECT:
EMI/ANTIOCH AND DUMBARTON GEOPHYS/CA

TITLE:
BATHYMETRIC SHADED RELIEF IMAGE DUMBARTON BRIDGE

REV	DATE	REVISION DESCRIPTION	SIGNED
–	–	–	–

PROJECT No.	063–1380.300	
FILE No.	0631380300C01–D3.dwg	
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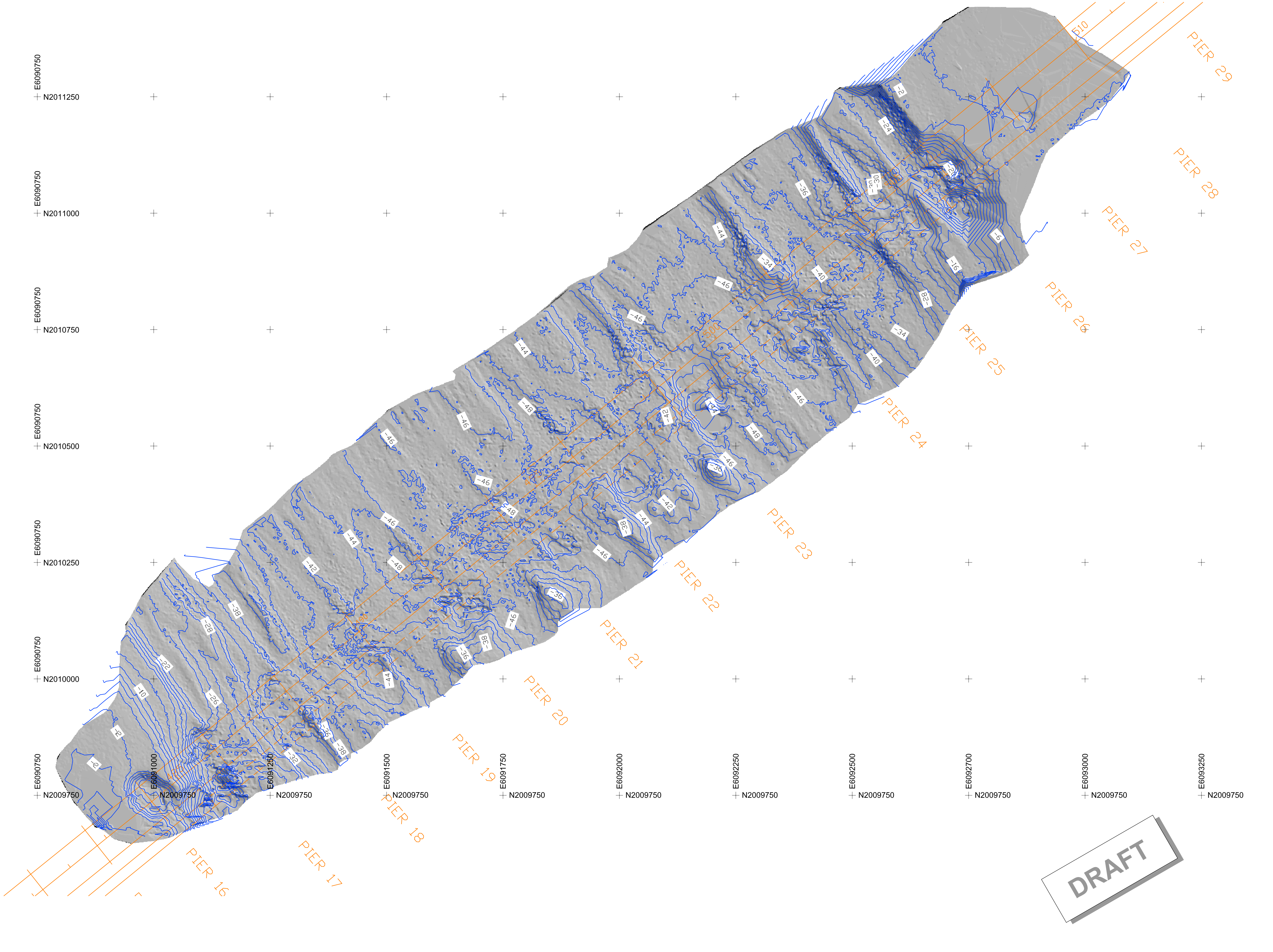
REVIEW	–	–

D-3



KEY MAP

DUMBARTON BRIDGE

SEE FIGURE 1 FOR LOCATION

LEGEND

CONTOURS
C.I. = 1 FT

N

0 100 200
SCALE IN FEET

INSTRUMENTATION

Navigation	- Trimble DGPS/HYPACK Software
Bathymetry	- Reson Model 2124
Subbottom	- Datasonic Bubble Pulser
Sidescan	- GeoAcoustic 100 KHz
Digital Acq.	- Chesapeake SonarWIZ
	- Sony 208 DAT

GEODETIC PARAMETERS

VERT. DATUM:	- NAVD 88
HORIZ. DATUM:	- CA STATE PLANE ZONE III
PROJECTION:	- NAD 83

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SUBMITTED TO:

Earth Mechanics Inc.
Geotechnical and Earthquake Engineering

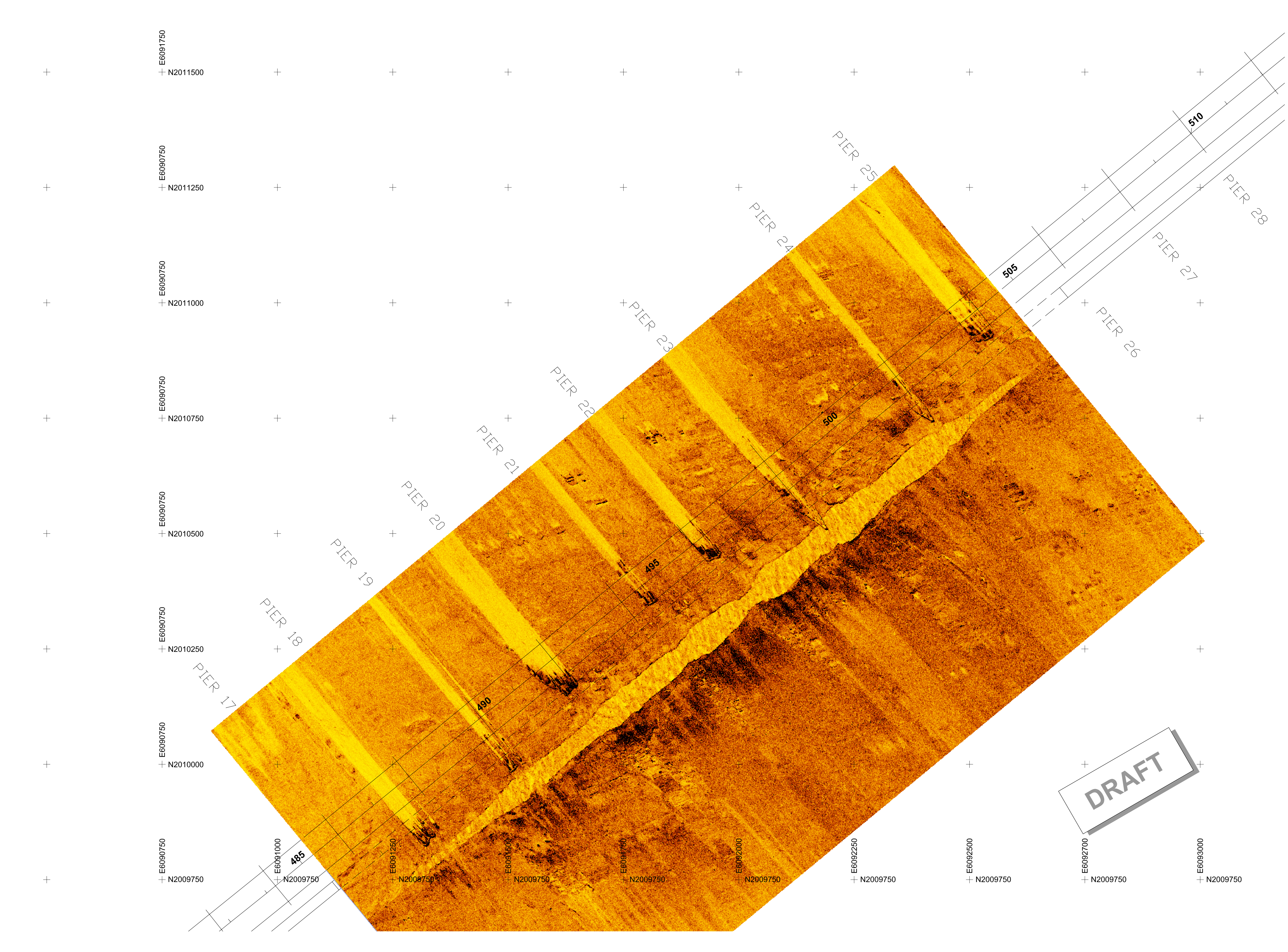
PROJECT:
EMI/ANTIOCH AND DUMBARTON GEOPHYS/CA

TITLE:
CONTOURS OVERLAIN ON BATHYMETRIC SHADED RELIEF IMAGE DUMBARTON BRIDGE

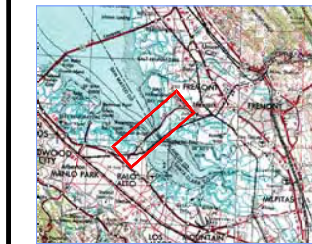
REV	DATE	REVISION DESCRIPTION	SIGNED
–	–	–	–

PROJECT No.	063–1380.300	
FILE No.	0631380300C01–D4.dwg	
REV. 0	SCALE	AS SHOWN
DESIGN	DS	12/18/06
CADD	ACF	1/12/07
CHECK	DS	1/12/07
REVIEW	–	–

D-4



KEY MAP



DUMBARTON BRIDGE

SEE FIGURE 1 FOR LOCATION

LEGEND

N

0 100 200

SCALE IN FEET

INSTRUMENTATION

Navigation	- Trimble DGPS/HYPACK Software
Bathymetry	- Reson Model 2124
Subbottom	- Datasonic Bubble Pulser
Sidescan	- GeoAcoustic 100 KHz
Digital Acq.	- Chesapeake SonarWIZ
	- Sony 208 DAT

GEODETIC PARAMETERS

VERT. DATUM:	- NAVD 88
HORIZ. DATUM:	- CA STATE PLANE ZONE III
PROJECTION:	- NAD 83

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SUBMITTED TO:

Earth Mechanics Inc.
Geotechnical and Earthquake Engineering

PROJECT:
EMI/ANTIOCH AND DUMBARTON GEOPHYS/CA

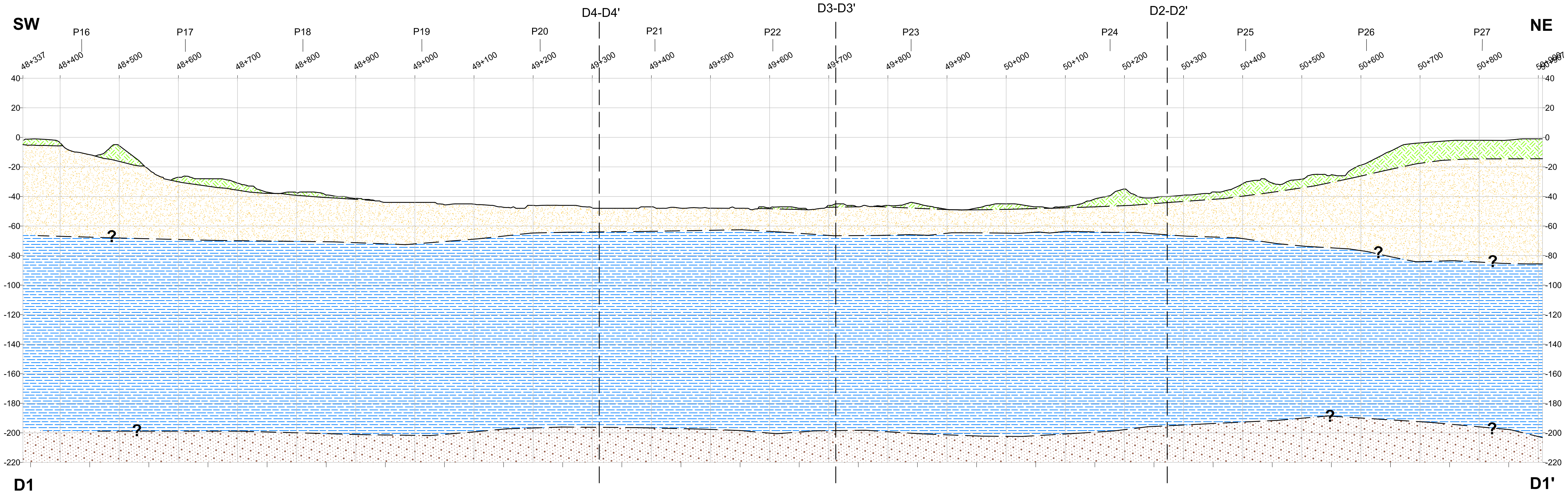
TITLE:

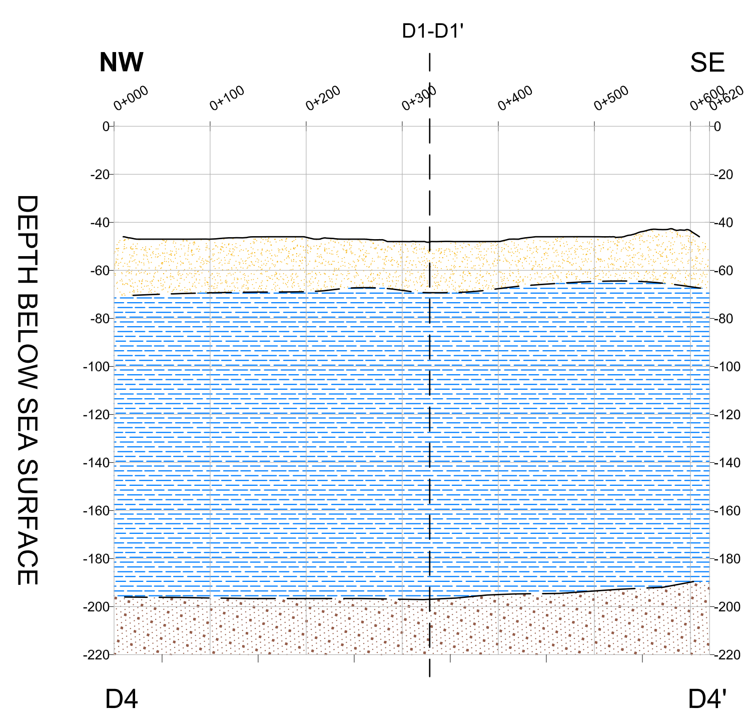
DUMBARTON SIDESCAN MOSAIC

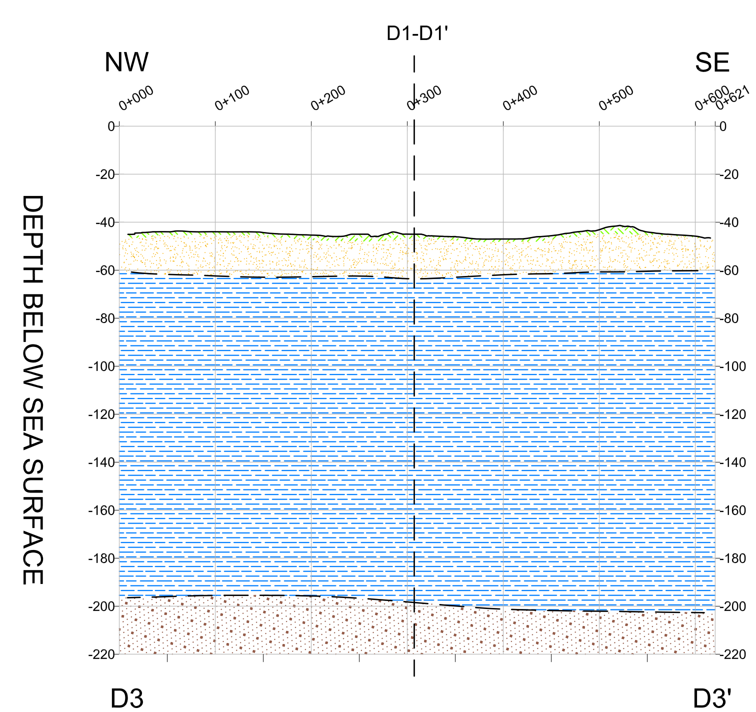
REV	DATE	REVISION DESCRIPTION	SIGNED
–	–	–	–

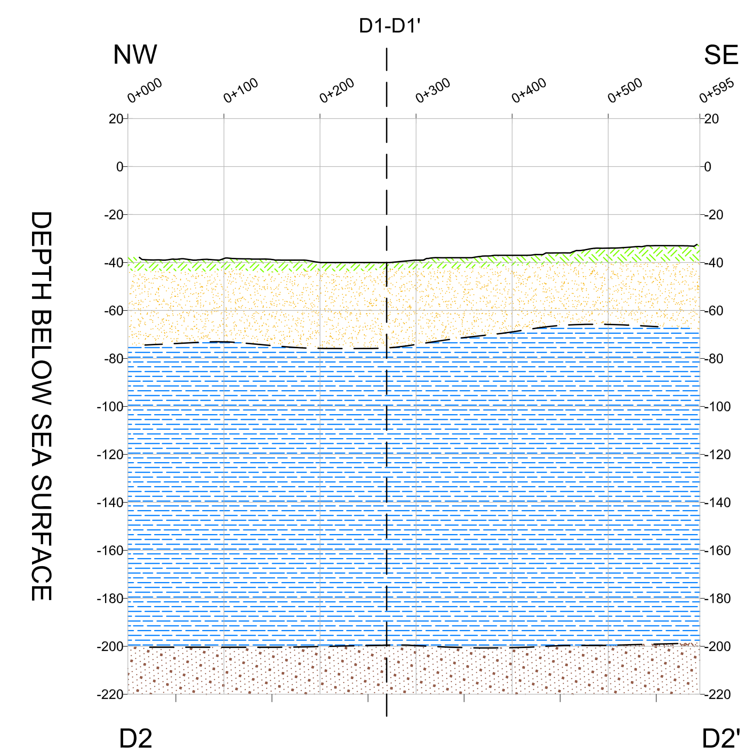
PROJECT No.		063–1380.300
FILE No.		0631380300C01–D5.dwg
REV. 0	SCALE	AS SHOWN
DESIGN	DS	12/18/06
CADD	ACF	1/12/07
CHECK	DS	1/12/07
REVIEW	–	–

D5

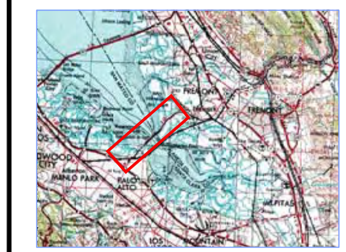








KEY MAP



DUMBARTON BRIDGE

SEE FIGURE 1 FOR LOCATION

LEGEND

- YOUNG BAY MUD
- SAND
- HARD CLAY
- SAND AND GRAVEL

LITHOLOGY BASED ON GENERALIZED SOIL PROFILE FROM EMI

SEE DRAWING D1 FOR LOCATIONS

0 100 200
SCALE IN FEET
VERICAL SCALE 1:40

INSTRUMENTATION

Navigation	- Trimble DGPS/HYPACK Software
Bathymetry	- Reson Model 2124
Subbottom	- Datasonic Bubble Pulser
Sidescan	- GeoAcoustic 100 KHz
Digital Acq.	- Chesapeake SonarWIZ
	- Sony 208 DAT

GEODETIC PARAMETERS

VERT. DATUM:	- NAVD 88
HORIZ. DATUM:	- CA STATE PLANE ZONE III
PROJECTION:	- NAD 83

Golder Associates

GOLDER ASSOCIATES INC.
18300 NE UNION HILL ROAD, SUITE 200
REDMOND, WA USA 98052-3333
TEL: (425) 883-0777
FAX: (425) 882-5498

SUBMITTED TO:

Earth Mechanics Inc.
Geotechnical and Earthquake Engineering

PROJECT:
EMI/ANTIOCH AND DUMBARTON GEOPHYS/CA

TITLE:

INTERPRETED PROFILES, DUMBARTON BRIDGE

REV	DATE	REVISION DESCRIPTION	SIGNED
–	–	–	–

PROJECT No.		063–1380.300
FILE No.		0631380300C01–D6.dwg
REV. 0	SCALE	AS SHOWN
DESIGN	DS	12/18/06
CADD	ACF	1/12/07
CHECK	DS	1/12/07
REVIEW	–	–

D-6

Amount of Material in Soil Finer Than No. 200 Sieve
(ASTM D-1140-97)

Project No. : 06-155 **Project Name** : BATA/ Antioch Bridge

Boring No.	: 06-1		Prepared By : M.T.	Date : 03/15/07	Percentage of			Maximum Size		
Sample No.	: S-2		Washed By : ~~M.T.~~ RJ	Date : 3-18-07	Gravel	Sand	Fine			
Depth (ft)	:	10.0	Tested By : M.T.	Date : 3-19-07	5	45	50	3/4"		
Depth (m)	:		Checked By : R.J.	Date : 3-19-07						
Description	: Olive, ~~CLAYEY SAND w/ GVL (SC)~~				Sample		Retained On			
Method (A) - Soaked by Water			CLAYEY SAND / SANDY CLAY (CL/SC)				No. 200	No. 4		
Method (B) - Soaked by Deflocculating Agent (Minimum 2 Hours)					Tested	Moisture	Sieve			
Container Number					S-2 →	→	→			
Wet Weight of Soil + Container (gm)					473.22 →					
Dry Weight of Soil + Container (gm)						388.67	252.05			
Weight of Container (gm)					116.86 →	→	→			
Weight of Dry Soil (gm)						271.81	135.19	12.68		
Moisture Content (%)										
(%) of Soil Passing No. 200 Sieve and Retained on No. 4 Sieve							50.26	4.67		
Remark :										

Boring No.	: 06-1		Prepared By : M.T.	Date : 03/16/07	Percentage of			Maximum Size		
Sample No.	: S-5		Washed By : ~~M.T.~~ RJ	Date : 3-18-07	Gravel	Sand	Fine			
Depth (ft)	:	25.0	Tested By : M.T.	Date : 3-19-07	0	69	31	1/4"		
Depth (m)	:		Checked By : R.J.	Date : 3-19-07						
Description	: BLUISH BLACK, SILTY SAND (SM)				Sample		Retained On			
Method (A) - Soaked by Water							No. 200	No. 4		
Method (B) - Soaked by Deflocculating Agent (Minimum 2 Hours)					Tested	Moisture	Sieve			
Container Number					S-3 →	→	→			
Wet Weight of Soil + Container (gm)					545.98 →					
Dry Weight of Soil + Container (gm)						489.46	374.52			
Weight of Container (gm)					118.19 →	→	→			
Weight of Dry Soil (gm)						371.27	256.33	0.69		
Moisture Content (%)										
(%) of Soil Passing No. 200 Sieve and Retained on No. 4 Sieve							30.96	0.19		
Remark :										

Boring No.	: 06-1		Prepared By : M.T.	Date : 03/16/07	Percentage of			Maximum Size		
Sample No.	: D-8		Washed By : ~~M.T.~~ RJ	Date : 3-18-07	Gravel	Sand	Fine			
Depth (ft)	:	40.0	Tested By : M.T.	Date : 3-19-07	0	8	92	#8		
Depth (m)	:		Checked By : R.J.	Date : 3-19-07						
Description	: Olive Brown, ~~CLAY w/ SAND (CL)~~				Sample		Retained On			
Method (A) - Soaked by Water			LEAN CLAY (CL)				No. 200	No. 4		
Method (B) - Soaked by Deflocculating Agent (Minimum 2 Hours)					Tested	Moisture	Sieve			
Container Number					S-5 →	→	→			
Wet Weight of Soil + Container (gm)					419.66 →					
Dry Weight of Soil + Container (gm)						356.17	136.41			
Weight of Container (gm)					117.79 →	→	→			
Weight of Dry Soil (gm)						238.38	18.62	0		
Moisture Content (%)										
(%) of Soil Passing No. 200 Sieve and Retained on No. 4 Sieve							92.19	0		
Remark :										

Amount of Material in Soil Finer Than No. 200 Sieve
(ASTM D-1140-97)

Project No. : 06-155 **Project Name** : BATA/ Antioch Bridge

Boring No.	: 06-1		Prepared By : M.T.	Date : 03/16/07	Percentage of			Maximum Size
Sample No.	: S-11		Washed By : ~~M.T.~~ R.J.	Date : 3-18-07	Gravel	Sand	Fine	
Depth (ft)	:	55.0	Tested By : M.T.	Date : 3-19-07	0	93	7	#50
Depth (m)	:		Checked By : R.J.	Date : 3-19-07				
Description	: DK Brown, ~~P/G SAND (SP)~~				Sample		Retained On	
Method (A) - Soaked by Water			P/G SAND w/ SILT				No. 200	No. 4
Method (B) - Soaked by Deflocculating Agent (Minimum 2 Hours)			(SP-SM)		Tested	Moisture	Sieve	
Container Number					S-8	→	→	
Wet Weight of Soil + Container (gm)					487.03	→		
Dry Weight of Soil + Container (gm)						496.79	387.99	
Weight of Container (gm)					118.29	→	→	
Weight of Dry Soil (gm)						288.50	269.70	0
Moisture Content (%)								
(%) of Soil Passing No. 200 Sieve and Retained on No. 4 Sieve							6.52	0
Remark :								

Boring No.	: 06-2		Prepared By : M.T. R.J.	Date : 4-6-07	Percentage of			Maximum Size
Sample No.	: D-2		Washed By : M.T.	Date : 4-7-07	Gravel	Sand	Fine	
Depth (ft)	:	10.0	Tested By : M.T.	Date : 4-8-07	2	67	31	1/2"
Depth (m)	:		Checked By : R.J.	Date : 4-8-07				
Description	: V. DK. Grey, SILTY SAND (SM)				Sample		Retained On	
Method (A) - Soaked by Water							No. 200	No. 4
Method (B) - Soaked by Deflocculating Agent (Minimum 2 Hours)					Tested	Moisture	Sieve	
Container Number					S-6	→	→	→
Wet Weight of Soil + Container (gm)								
Dry Weight of Soil + Container (gm)						484.59	370.18	
Weight of Container (gm)					116.77	→	→	
Weight of Dry Soil (gm)								8.11
Moisture Content (%)								
(%) of Soil Passing No. 200 Sieve and Retained on No. 4 Sieve							31.1	2.2
Remark : lots of organic, >4 mud balls were Cemented mud,								

Boring No.	: 06-2		Prepared By : M.T.	Date : 03/20/07	Percentage of			Maximum Size
Sample No.	: S-7		Washed By : M.T.	Date : 03/21/07	Gravel	Sand	Fine	
Depth (ft)	:	35.0	Tested By : M.T.	Date : 03/23/07	1	93	6	1/4"
Depth (m)	:		Checked By : R.J.	Date : 3-23-07				
Description	: DK Bluish Gray, ~~P/G SAND (SP)~~				Sample		Retained On	
Method (A) - Soaked by Water			P/G SAND w/ SILT (SP-SM)				No. 200	No. 4
Method (B) - Soaked by Deflocculating Agent (Minimum 2 Hours)					Tested	Moisture	Sieve	
Container Number					S-21	→	→	
Wet Weight of Soil + Container (gm)					498.36	→		
Dry Weight of Soil + Container (gm)						408.36	390.28	
Weight of Container (gm)					114.66	→	→	
Weight of Dry Soil (gm)						293.70	275.62	2.24
Moisture Content (%)								
(%) of Soil Passing No. 200 Sieve and Retained on No. 4 Sieve							6.16	0.76
Remark :								

Amount of Material in Soil Finer Than No. 200 Sieve
(ASTM D-1140-97)

Project No. : 06-155 **Project Name** : BATA/ Antioch Bridge

Boring No.	:	06-2	Prepared By : M.T.	Date : 03/20/07	Percentage of			Maximum Size			
Sample No.	:	S-11	Washed By : M.T.	Date : 03/21/07	Gravel	Sand	Fine				
Depth (ft)	:	55.0	Tested By : M.T.	Date : 03/23/07	0	90	10	#8			
Depth (m)	:		Checked By : R.J.	Date : 3-26-07							
Description	:	olive, P/G SAND w/ SILT, w/ clay (SP-SM)			Sample		Retained On				
	Method (A) - Soaked by Water						No. 200	No. 4			
	Method (B) - Soaked by Deflocculating Agent (Minimum 2 Hours)				Tested	Moisture	Sieve				
Container Number					S-24	→	→				
Wet Weight of Soil + Container (gm)					417.64	→					
Dry Weight of Soil + Container (gm)						351.45	328.00				
Weight of Container (gm)					113.12	→	→				
Weight of Dry Soil (gm)						238.33	214.88	0			
Moisture Content (%)											
(%) of Soil Passing No. 200 Sieve and Retained on No. 4 Sieve							9.84	0			
Remark :											

Boring No.	:	06-2	Prepared By : M.T.	Date : 03/20/07	Percentage of			Maximum Size			
Sample No.	:	S-13	Washed By : M.T.	Date : 03/21/07	Gravel	Sand	Fine				
Depth (ft)	:	65.0	Tested By : M.T.	Date : 03/23/07	0	91	9	#8			
Depth (m)	:		Checked By : R.J.	Date : 3-26-07							
Description	:	Olive Yellow, P/G SAND w/ SILT (SP-SM)			Sample		Retained On				
	Method (A) - Soaked by Water						No. 200	No. 4			
	Method (B) - Soaked by Deflocculating Agent (Minimum 2 Hours)				Tested	Moisture	Sieve				
Container Number					S-25	→	→				
Wet Weight of Soil + Container (gm)					386.18	→					
Dry Weight of Soil + Container (gm)						343.07	323.31				
Weight of Container (gm)					112.92	→	→				
Weight of Dry Soil (gm)						230.15	210.39	0			
Moisture Content (%)											
(%) of Soil Passing No. 200 Sieve and Retained on No. 4 Sieve							8.59	0			
Remark :											

Boring No.	:	06-6	Prepared By : M.T.	Date : 03/21/07	Percentage of			Maximum Size			
Sample No.	:	D-14	Washed By : M.T.	Date : 03/23/07	Gravel	Sand	Fine				
Depth (ft)	:	61.0	Tested By : M.T.	Date : 03/26/07	0	95	5	#50			
Depth (m)	:		Checked By : R.J.	Date : 3-26-07							
Description	:	Bluish Gray, P/G SAND (SP)			Sample		Retained On				
	Method (A) - Soaked by Water	P/G SAND w/ SILT (SP-SM)					No. 200	No. 4			
	Method (B) - Soaked by Deflocculating Agent (Minimum 2 Hours)				Tested	Moisture	Sieve				
Container Number					S-3	→	→				
Wet Weight of Soil + Container (gm)					415.42	→					
Dry Weight of Soil + Container (gm)						354.06	343.14				
Weight of Container (gm)					118.18	→	→				
Weight of Dry Soil (gm)						235.88	224.96	0			
Moisture Content (%)											
(%) of Soil Passing No. 200 Sieve and Retained on No. 4 Sieve							4.63	0			
Remark :	In Mica										

Amount of Material in Soil Finer Than No. 200 Sieve
(ASTM D-1140-97)

Project No. : 06-155 **Project Name** : BATA/ Antioch Bridge

Boring No.	: 06 – 6		Prepared By : M.T.	Date : 03/21/07	Percentage of			Maximum Size			
Sample No.	: S-19		Washed By : M.T.	Date : 03/24/07	Gravel	Sand	Fine				
Depth (ft)	:	86.0	Tested By : M.T.	Date : 03/26/07	0	93	7	# 50			
Depth (m)	:		Checked By : R.J.	Date : 3-27-07							
Description	: DK olive, ~~P/G SAND (SP)~~				Sample		Retained On				
Method (A) - Soaked by Water			P/G SAND w/ SILT (SP-SM)				No. 200	No. 4			
Method (B) - Soaked by Deflocculating Agent (Minimum 2 Hours)					Tested	Moisture	Sieve				
Container Number					S-8	→	→				
Wet Weight of Soil + Container (gm)					469.88	→					
Dry Weight of Soil + Container (gm)						397.54	377.24				
Weight of Container (gm)					118.29	→	→				
Weight of Dry Soil (gm)						279.25	258.95	0			
Moisture Content (%)											
(%) of Soil Passing No. 200 Sieve and Retained on No. 4 Sieve							7.27	0			
Remark :											

Boring No.	: 06-7		Prepared By : M.T.	Date : 03/27/07	Percentage of			Maximum Size			
Sample No.	: D-12		Washed By : ~~M.T.~~ R.J.	Date : 04/1/07	Gravel	Sand	Fine				
Depth (ft)	:	60.0	Tested By : M.T.	Date : 04/2/07	0	9	91	# 100			
Depth (m)	:		Checked By : R.J.	Date :							
Description	: DK Bluish Gray, ~~SANDY SILT (ML)~~				Sample		Retained On				
Method (A) - Soaked by Water			SILT (ML)				No. 200	No. 4			
Method (B) - Soaked by Deflocculating Agent (Minimum 2 Hours)					Tested	Moisture	Sieve				
Container Number					S-6	→	→				
Wet Weight of Soil + Container (gm)					387.33	→					
Dry Weight of Soil + Container (gm)						311.05	134.29				
Weight of Container (gm)					116.76	→	→				
Weight of Dry Soil (gm)						194.29	17.53	0			
Moisture Content (%)											
(%) of Soil Passing No. 200 Sieve and Retained on No. 4 Sieve							90.98	0			
Remark : tr Peat, mica											

Boring No.	: 06-7		Prepared By : M.T.	Date : 03/27/07	Percentage of			Maximum Size			
Sample No.	: S-13		Washed By : ~~M.T.~~ R.J.	Date : 04/01/07	Gravel	Sand	Fine				
Depth (ft)	:	64.0	Tested By : M.T.	Date : 04/02/07	0	88	12	# 30			
Depth (m)	:		Checked By : R.J.	Date :							
Description	: DK Bluish Gray, ~~SILTY SAND (SM)~~				Sample		Retained On				
Method (A) - Soaked by Water			P/G SAND w/ SILT (SP-SM)				No. 200	No. 4			
Method (B) - Soaked by Deflocculating Agent (Minimum 2 Hours)					Tested	Moisture	Sieve				
Container Number					S-1	→	→				
Wet Weight of Soil + Container (gm)					481.97	→					
Dry Weight of Soil + Container (gm)						400.21	366.08				
Weight of Container (gm)					118.80	→	→				
Weight of Dry Soil (gm)						281.41	247.28	0			
Moisture Content (%)											
(%) of Soil Passing No. 200 Sieve and Retained on No. 4 Sieve							12.13	0			
Remark : tr mica, organic											

Amount of Material in Soil Finer Than No. 200 Sieve
(ASTM D-1140-97)

Project No. : 06-155 **Project Name** : BATA/ Antioch Bridge

Boring No.	06-8	Prepared By : M.T.	Date : 03/30/07	Percentage of			Maximum Size			
Sample No.	S-16	Washed By : ~~M.T.~~ R.J.	Date : 04/01/07	Gravel	Sand	Fine				
Depth (ft)	71.0	Tested By : M.T.	Date : 04/02/07	0	92	8	# 16			
Depth (m)		Checked By : R.J.	Date : "							
Description	: DK Gray, P/G SAND w/ SILT (SP-SM)			Sample		Retained On				
	Method (A) - Soaked by Water					No. 200	No. 4			
	Method (B) - Soaked by Deflocculating Agent (Minimum 2 Hours)			Tested	Moisture	Sieve				
Container Number				S-3	→	→				
Wet Weight of Soil + Container (gm)				433.18	→					
Dry Weight of Soil + Container (gm)					368.09	348.05				
Weight of Container (gm)				118.18	→	→				
Weight of Dry Soil (gm)					249.91	229.87	0			
Moisture Content (%)										
(%) of Soil Passing No. 200 Sieve and Retained on No. 4 Sieve						8.02	0			
Remark :	tr mica, organic									

Boring No.	06-9	Prepared By : M.T.	Date : 03/30/07	Percentage of			Maximum Size			
Sample No.	S-4	Washed By : ~~M.T.~~ R.J.	Date : 04/01/07	Gravel	Sand	Fine				
Depth (ft)	20.0	Tested By : M.T.	Date : 04/02/07	0	92	8	#8			
Depth (m)		Checked By : R.J.	Date : "							
Description	: DK Gray, ~~P/G SAND (SP)~~ P/G SAND w/ SILT (SP-SM)			Sample		Retained On				
	Method (A) - Soaked by Water					No. 200	No. 4			
	Method (B) - Soaked by Deflocculating Agent (Minimum 2 Hours)			Tested	Moisture	Sieve				
Container Number				S-11	→	→				
Wet Weight of Soil + Container (gm)				475.72	→					
Dry Weight of Soil + Container (gm)					403.19	379.61				
Weight of Container (gm)				119.90	→	→				
Weight of Dry Soil (gm)					283.29	259.71	0			
Moisture Content (%)										
(%) of Soil Passing No. 200 Sieve and Retained on No. 4 Sieve						8.32	0			
Remark :	tr mica, organic									

Boring No.	06-9	Prepared By : M.T.	Date : 03/03/07	Percentage of			Maximum Size			
Sample No.	S-6	Washed By : ~~M.T.~~ R.J.	Date : 04/01/07	Gravel	Sand	Fine				
Depth (ft)	30.0	Tested By : M.T.	Date : 04/02/07	0	93	7	# 16			
Depth (m)		Checked By : R.J.	Date :							
Description	: DK Gray, ~~P/G SAND (SP)~~ P/G SAND w/ SILT (SP-SM)			Sample		Retained On				
	Method (A) - Soaked by Water					No. 200	No. 4			
	Method (B) - Soaked by Deflocculating Agent (Minimum 2 Hours)			Tested	Moisture	Sieve				
Container Number				S-12	→	→				
Wet Weight of Soil + Container (gm)				475.01	→					
Dry Weight of Soil + Container (gm)					391.65	373.77				
Weight of Container (gm)				114.29	→	→				
Weight of Dry Soil (gm)					277.36	259.48	0			
Moisture Content (%)										
(%) of Soil Passing No. 200 Sieve and Retained on No. 4 Sieve						6.45	0			
Remark :	tr mica, organic									

Amount of Material in Soil Finer Than No. 200 Sieve
(ASTM D-1140-97)

Project No. : 06-155 **Project Name** : BATA/ Antioch Bridge

Boring No.	: 06-9	Prepared By : M.T.	Date : 03/30/07	Percentage of			Maximum				
Sample No.	: S-10	Washed By : M.T.R.J.	Date : 04/01/07	Gravel	Sand	Fine	Size				
Depth (ft)	: 50.0	Tested By : M.T.	Date : 04/02/07	0	96	4	1/4"				
Depth (m)	:	Checked By : R.J.	Date : 4-6-07								
Description	: DK Gray, P/G SAND (SP)			Sample		Retained On					
Method (A) - Soaked by Water						No. 200	No. 4				
Method (B) - Soaked by Deflocculating Agent (Minimum 2 Hours)				Tested	Moisture	Sieve					
Container Number				S-14	→	→					
Wet Weight of Soil + Container (gm)				451.85	→						
Dry Weight of Soil + Container (gm)					372.63	361.41					
Weight of Container (gm)				115.82	→	→					
Weight of Dry Soil (gm)					256.81	245.59	0.45				
Moisture Content (%)											
(%) of Soil Passing No. 200 Sieve and Retained on No. 4 Sieve						4.37	0.18				
Remark : tr mica, organic											

Boring No.	: 06-9	Prepared By : M.T.	Date : 04/02/07	Percentage of			Maximum				
Sample No.	: S-14	Washed By : M.T.	Date : 04/05/07	Gravel	Sand	Fine	Size				
Depth (ft)	: 70.0	Tested By : M.T.	Date : 04/06/07	0	92	8	#8				
Depth (m)	:	Checked By : R.J.	Date : 4-6-07								
Description	: DK Gray, P/G SAND w/ SILT (SP-SM)			Sample		Retained On					
Method (A) - Soaked by Water						No. 200	No. 4				
Method (B) - Soaked by Deflocculating Agent (Minimum 2 Hours)				Tested	Moisture	Sieve					
Container Number				S-16	→	→					
Wet Weight of Soil + Container (gm)				470.81	→						
Dry Weight of Soil + Container (gm)					393.12	370.22					
Weight of Container (gm)				114.19	→	→					
Weight of Dry Soil (gm)					278.93	256.03	0				
Moisture Content (%)											
(%) of Soil Passing No. 200 Sieve and Retained on No. 4 Sieve						8.21	0				
Remark : tr organic											

Boring No.	: 06-9	Prepared By : M.T.	Date : 04/02/07	Percentage of			Maximum				
Sample No.	: S-16	Washed By : M.T.	Date : 04/05/07	Gravel	Sand	Fine	Size				
Depth (ft)	: 80.0	Tested By : M.T.	Date : 04/06/07	6	89	5	1/4"				
Depth (m)	:	Checked By : R.J.	Date : 4-6-07								
Description	: DK Gray, ~~P/G SAND, (SP)~~ P/G SAND w/ SILT (SP-SM)			Sample		Retained On					
Method (A) - Soaked by Water						No. 200	No. 4				
Method (B) - Soaked by Deflocculating Agent (Minimum 2 Hours)				Tested	Moisture	Sieve					
Container Number				S-18	→	→					
Wet Weight of Soil + Container (gm)				469.00	→						
Dry Weight of Soil + Container (gm)					400.78	386.36					
Weight of Container (gm)				115.61	→	→					
Weight of Dry Soil (gm)					285.17	270.75	16.43				
Moisture Content (%)											
(%) of Soil Passing No. 200 Sieve and Retained on No. 4 Sieve						5.06	5.76				
Remark :											

Amount of Material in Soil Finer Than No. 200 Sieve
(ASTM D-1140-97)

Project No. : 06-155 **Project Name** : BATA/ Antioch Bridge

Boring No.	: 06-10		Prepared By : M.T.	Date : 04/02/07	Percentage of			Maximum Size			
Sample No.	: S-1		Washed By : M.T.	Date : 04/05/07	Gravel	Sand	Fine				
Depth (ft)	:	5.5	Tested By : M.T.	Date : 04/06/07	12	65	23	3/4"			
Depth (m)	:		Checked By : R.J.	Date : 4-6-07							
Description	: Olive Brown w/ Black, SILTY SAND (SM)				Sample		Retained On				
Method (A) - Soaked by Water							No. 200	No. 4			
Method (B) - Soaked by Deflocculating Agent (Minimum 2 Hours)					Tested	Moisture	Sieve				
Container Number					S-19	→	→				
Wet Weight of Soil + Container (gm)					355.99	→					
Dry Weight of Soil + Container (gm)						310.63	266.72				
Weight of Container (gm)					116.60	→	→				
Weight of Dry Soil (gm)						194.03	150.12	22.55			
Moisture Content (%)											
(%) of Soil Passing No. 200 Sieve and Retained on No. 4 Sieve							22.63	11.62			
Remark : tr wood											

Boring No.	: 06-10		Prepared By : M.T.	Date : 04/02/07	Percentage of			Maximum Size			
Sample No.	: S-4		Washed By : M.T.	Date : 04/05/07	Gravel	Sand	Fine				
Depth (ft)	:	20.5	Tested By : M.T.	Date : 04/06/07	0	93	7	#30			
Depth (m)	:		Checked By : R.J.	Date : 4-6-07							
Description	: DK Olive Gray, P/G SAND w/ SILT (SP-SM)				Sample		Retained On				
Method (A) - Soaked by Water							No. 200	No. 4			
Method (B) - Soaked by Deflocculating Agent (Minimum 2 Hours)					Tested	Moisture	Sieve				
Container Number					S-4	→	→				
Wet Weight of Soil + Container (gm)					407.06	→					
Dry Weight of Soil + Container (gm)						343.11	327.63				
Weight of Container (gm)					118.06	→	→				
Weight of Dry Soil (gm)						225.05	209.57	0			
Moisture Content (%)											
(%) of Soil Passing No. 200 Sieve and Retained on No. 4 Sieve							6.88	0			
Remark : tr mica											

Boring No.	: 06-10		Prepared By : M.T.	Date : 04/02/07	Percentage of			Maximum Size			
Sample No.	: S-8		Washed By : M.T.	Date : 04/05/07	Gravel	Sand	Fine				
Depth (ft)	:	41.0	Tested By : M.T.	Date : 04/06/07	0	96	4	#30			
Depth (m)	:		Checked By : R.J.	Date : 4-6-07							
Description	: DK Olive Gray, P/G SAND (SP)				Sample		Retained On				
Method (A) - Soaked by Water							No. 200	No. 4			
Method (B) - Soaked by Deflocculating Agent (Minimum 2 Hours)					Tested	Moisture	Sieve				
Container Number					S-9	→	→				
Wet Weight of Soil + Container (gm)					463.74	→					
Dry Weight of Soil + Container (gm)						384.50	372.68				
Weight of Container (gm)					115.78	→	→				
Weight of Dry Soil (gm)						268.72	256.90	0			
Moisture Content (%)											
(%) of Soil Passing No. 200 Sieve and Retained on No. 4 Sieve							4.40	0			
Remark : tr mica											

Amount of Material in Soil Finer Than No. 200 Sieve
(ASTM D-1140-97)

Project No. : 06-155 **Project Name** : BATA/ Antioch Bridge

Boring No.	: 06-10		Prepared By : M.T.	Date : 04/03/07	Percentage of			Maximum Size		
Sample No.	: S-12		Washed By : M.T.	Date : 04/05/07	Gravel	Sand	Fine			
Depth (ft)	:	61.0	Tested By : M.T.	Date : 04/06/07	0	93	7	1/4"		
Depth (m)	:		Checked By : R.J.	Date : 4/6-07						
Description	: DK Bluish Gray, P/G SAND w/ SILT (SP-SM)				Sample		Retained On			
Method (A) - Soaked by Water							No. 200	No. 4		
Method (B) - Soaked by Deflocculating Agent (Minimum 2 Hours)					Tested	Moisture	Sieve			
Container Number					S-15					
Wet Weight of Soil + Container (gm)					484.08					
Dry Weight of Soil + Container (gm)						397.63	376.96			
Weight of Container (gm)					114.75					
Weight of Dry Soil (gm)						282.88	262.21	0.27		
Moisture Content (%)										
(%) of Soil Passing No. 200 Sieve and Retained on No. 4 Sieve							7.31	0.10		
Remark :										

Boring No.	:		Prepared By : M.T.	Date :	Percentage of			Maximum Size		
Sample No.	:		Washed By : M.T.	Date :	Gravel	Sand	Fine			
Depth (ft)	:		Tested By : M.T.	Date :						
Depth (m)	:		Checked By : R.J.	Date :						
Description	:				Sample		Retained On			
Method (A) - Soaked by Water							No. 200	No. 4		
Method (B) - Soaked by Deflocculating Agent (Minimum 2 Hours)					Tested	Moisture	Sieve			
Container Number										
Wet Weight of Soil + Container (gm)										
Dry Weight of Soil + Container (gm)										
Weight of Container (gm)										
Weight of Dry Soil (gm)										
Moisture Content (%)										
(%) of Soil Passing No. 200 Sieve and Retained on No. 4 Sieve										
Remark :										

Boring No.	:		Prepared By : M.T.	Date :	Percentage of			Maximum Size		
Sample No.	:		Washed By : M.T.	Date :	Gravel	Sand	Fine			
Depth (ft)	:		Tested By : M.T.	Date :						
Depth (m)	:		Checked By : R.J.	Date :						
Description	:				Sample		Retained On			
Method (A) - Soaked by Water							No. 200	No. 4		
Method (B) - Soaked by Deflocculating Agent (Minimum 2 Hours)					Tested	Moisture	Sieve			
Container Number										
Wet Weight of Soil + Container (gm)										
Dry Weight of Soil + Container (gm)										
Weight of Container (gm)										
Weight of Dry Soil (gm)										
Moisture Content (%)										
(%) of Soil Passing No. 200 Sieve and Retained on No. 4 Sieve										
Remark :										

PARTICLE SIZE ANALYSIS OF SOIL

ASTM D-422-63 (Rev. 1990) / CT - 202, 203

Project No : 06-155	Project Name : BATA / Antioch Bridge
Standard : ☑ CAL. TRAN. ☐ ASTM ☐ OTHER	

Prepared By : R.J.	Date : 04/06/07	Tested By : M.T.	Date : 04/08/07	Checked By : R.J.
Washed By : M.T.	Date : 04/07/07	Computed By : C.Y.	Date : 05/29/07	Date : 05/29/07

Boring No. : 06-1	Depth : (ft) :	20.0	21.5
Sample No. : D-4	(m) :	6.10	6.56

Description : Olive, Silty Sand (SM)

	Before Washing Sample		After Wet Sieve
	Tested	Moisture	
Container Number	S-11	S-11	S-11
Wet Wt. of Soil + Cont. (gm)	430.41	430.41	
Dry Wt. of Soil + Cont. (gm)		430.41	292.21
Weight of Container (gm)	119.91	119.91	119.91
Weight of Dry Soil (gm)	310.50	310.5	172.3
Moisture Content (%)		0.00	

Remark : 1

Sieve	Cimulative Weight	(%)
5"		
4"		
3"		
2.5"		
2.0"		
1.5"		
1.0"		
3/4"		
1/2"		
3/8"	0.00	100.00
No. 4	2.26	99.27
Cu :		
Cc :		

Sieve	Cimulative Weight	(%)
No. 8	3.11	99.00
No. 10		
No. 16	4.18	98.65
No. 20		
No. 30	5.63	98.19
No. 40		
No. 50	13.94	95.51
No. 60		
No. 100	90.39	70.89
No. 200	169.70	45.35
Pan	172.44	
Gravel	Sand	Fine
1	54	45

Prepared By : M.T.	Date : 03/16/07	Tested By : M.T.	Date : 03/21/07	Checked By : R.J.
Washed By : R.J.	Date : 03/18/07	Computed By : C.Y.	Date : 05/29/07	Date : 05/29/07

Boring No. : 06-1	Depth : (ft) :	35.0	36.5
Sample No. : S-7	(m) :	10.68	11.13

Description : Olive Brown, Lean Clay (CL)

	Before Washing Sample		After Wet Sieve
	Tested	Moisture	
Container Number	S-4	S-4	S-4
Wet Wt. of Soil + Cont. (gm)	501.91	501.91	
Dry Wt. of Soil + Cont. (gm)		413.22	128.86
Weight of Container (gm)	118.10	118.10	118.10
Weight of Dry Soil (gm)	295.12	295.12	10.76
Moisture Content (%)		30.05	

Remark : 2

Sieve	Cimulative Weight	(%)
5"		
4"		
3"		
2.5"		
2.0"		
1.5"		
1.0"		
3/4"		
1/2"		
3/8"		
No. 4	0.00	100.00
Cu :		
Cc :		

Sieve	Cimulative Weight	(%)
No. 8	0.02	99.99
No. 10		
No. 16	0.49	99.83
No. 20		
No. 30	1.66	99.44
No. 40		
No. 50	3.94	98.66
No. 60		
No. 100	7.05	97.61
No. 200	10.75	96.36
Pan	10.95	
Gravel	Sand	Fine
0	4	96

Prepared By : M.T.	Date : 03/16/07	Tested By : M.T.	Date : 03/22/07	Checked By : R.J.
Washed By : R.J.	Date : 03/18/07	Computed By : C.Y.	Date : 05/29/07	Date : 05/29/07

Boring No. : 06-1	Depth : (ft) :	50.0	51.5
Sample No. : D-10	(m) :	15.25	15.71

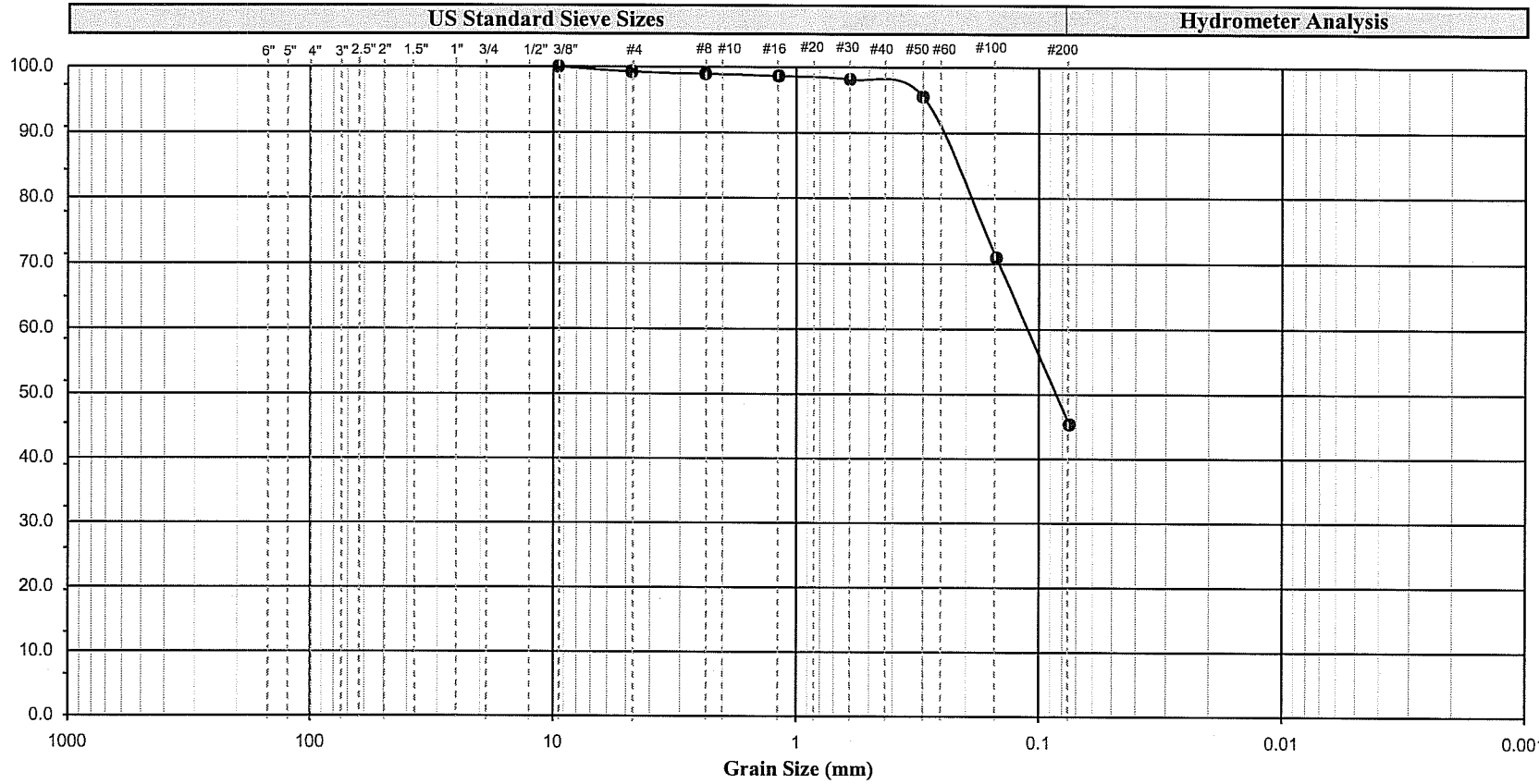
Description : Dark Brown, Poorly Graded Sand with Silt (SP-SM)

	Before Washing Sample		After Wet Sieve
	Tested	Moisture	
Container Number	S-6	S-6	S-6
Wet Wt. of Soil + Cont. (gm)	429.50	429.50	
Dry Wt. of Soil + Cont. (gm)		373.74	359.23
Weight of Container (gm)	116.81	116.81	116.81
Weight of Dry Soil (gm)	256.93	256.93	242.42
Moisture Content (%)		21.70	

Remark : 3

Sieve	Cimulative Weight	(%)
5"		
4"		
3"		
2.5"		
2.0"		
1.5"		
1.0"		
3/4"		
1/2"		
3/8"		
No. 4	0.00	100.00
Cu :	2.5	
Cc :	1.2	

Sieve	Cimulative Weight	(%)
No. 8	0.00	100.00
No. 10		
No. 16	0.00	100.00
No. 20		
No. 30	0.37	99.86
No. 40		
No. 50	68.94	73.17
No. 60		
No. 100	217.05	15.52
No. 200	241.27	6.10
Pan	242.41	
Gravel	Sand	Fine
0	94	6



Cobbles	Gravel		Sand			Silt or Clay
	Coarse	Fine	Coarse	Medium	Fine	

Symbol	Boring Number	Sample Number	Depth (ft)		Depth (m)		Soil Color	Soil Description	U.S.C.S.
●	06-1	D-4	20.0	21.5	6.10	6.56	Olive	Silty sand	SM
Remark									

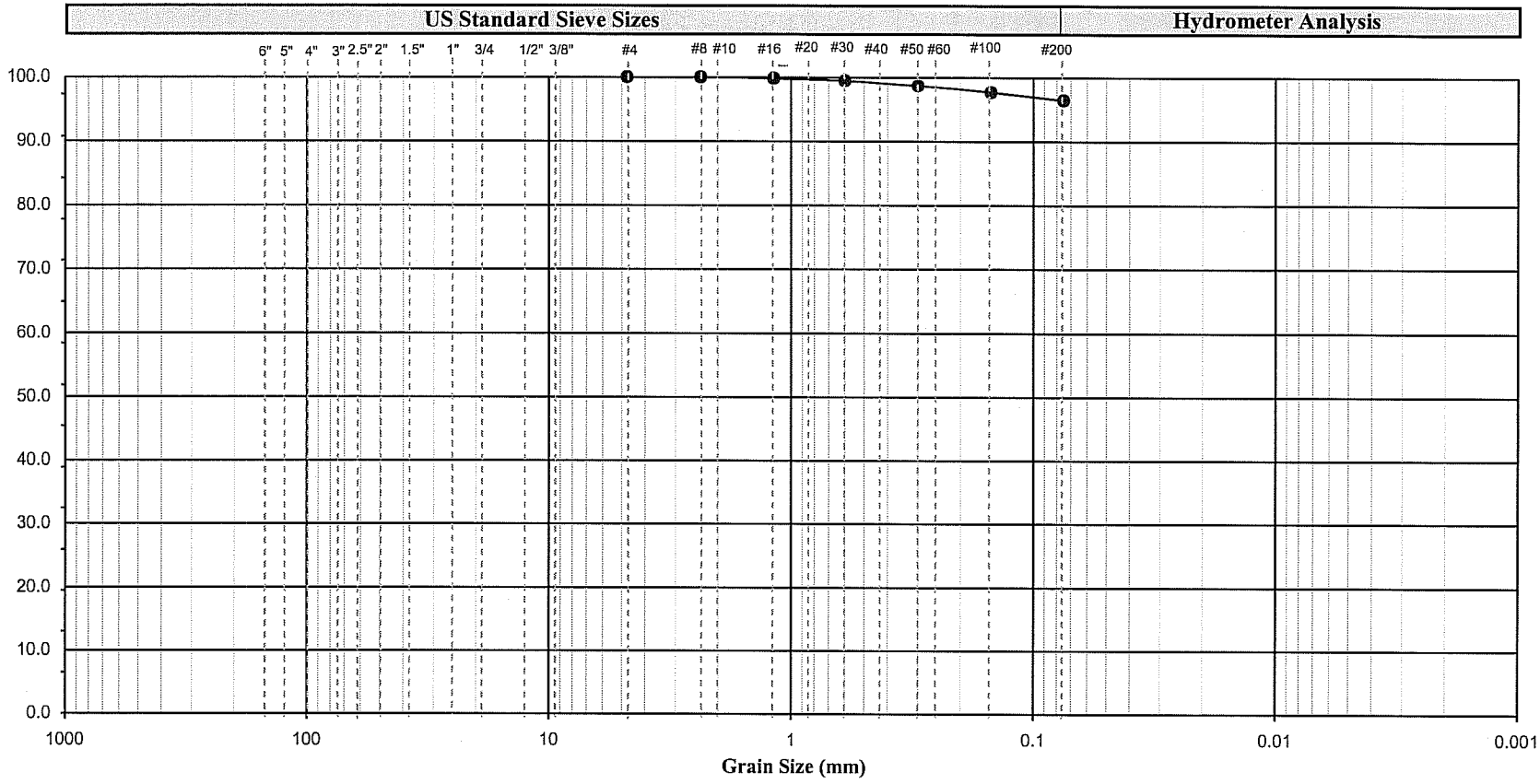
Earth Mechanics, Inc.
Geotechnical and Earthquake Engineering

BATA / Antioch Bridge

Project No. : *06-155* **Date :** *04/08/07*

GRAIN SIZE ANALYSIS
(ASTM D-422-63)

Figure No. :



Cobbles	Gravel		Sand			Silt or Clay
	Coarse	Fine	Coarse	Medium	Fine	

Symbol	Boring Number	Sample Number	Depth (ft)		Depth (m)		Soil Color	Soil Description	U.S.C.S.
●	06-1	S-7	35.0	36.5	10.68	11.13	Olive Brown	Lean clay	CL
Remark									

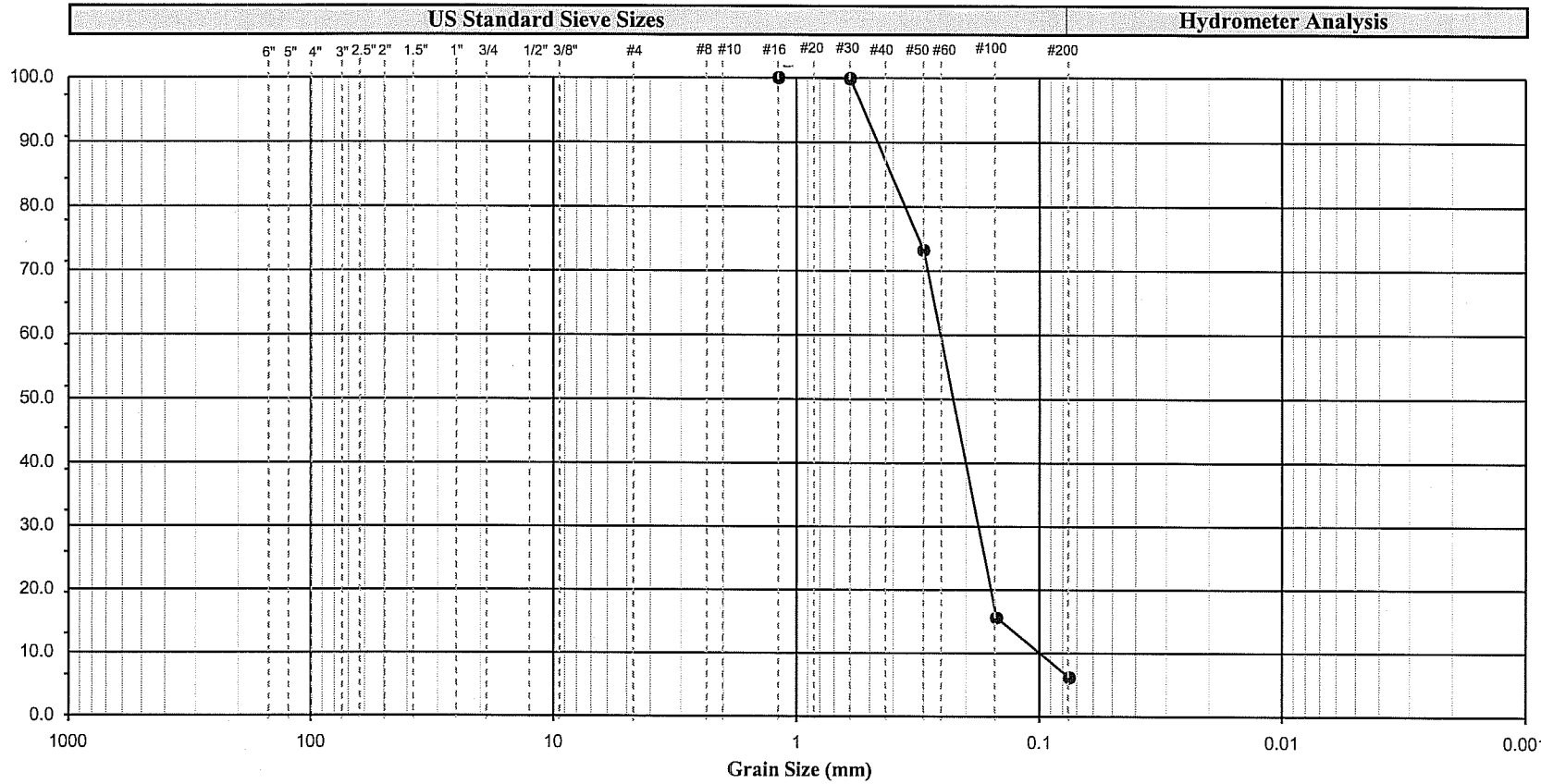
Earth Mechanics, Inc.
Geotechnical and Earthquake Engineering

BATA / Antioch Bridge

Project No. : *06-155* **Date :** *04/08/07*

GRAIN SIZE ANALYSIS
(ASTM D-422-63)

Figure No. :



Cobbles	Gravel		Sand			Silt or Clay
	Coarse	Fine	Coarse	Medium	Fine	

Symbol	Boring Number	Sample Number	Depth (ft)		Depth (m)		Soil Color	Soil Description	U.S.C.S.
●	06-1	D-10	50.0	51.5	15.25	15.71	Dark Brown	Poorly graded sand with silt	SP-SM
Remark									

Earth Mechanics, Inc.
Geotechnical and Earthquake Engineering

BATA / Antioch Bridge

Project No. : 06-155 Date : 04/08/07

GRAIN SIZE ANALYSIS
(ASTM D-422-63)

Figure No. :

PARTICLE SIZE ANALYSIS OF SOIL

ASTM D-422-63 (Rev. 1990) / CT - 202, 203

Project No : 06-155	Project Name : BATA / Antioch Bridge
Standard : ☑ CAL. TRAN. ☐ ASTM ☐ OTHER	

Prepared By : M.T.	Date : 03/16/07	Tested By : M.T.	Date : 03/22/07	Checked By : R.J.	
Washed By : R.J.	Date : 03/18/07	Computed By : C.Y.	Date : 05/29/07	Date :	05/29/07

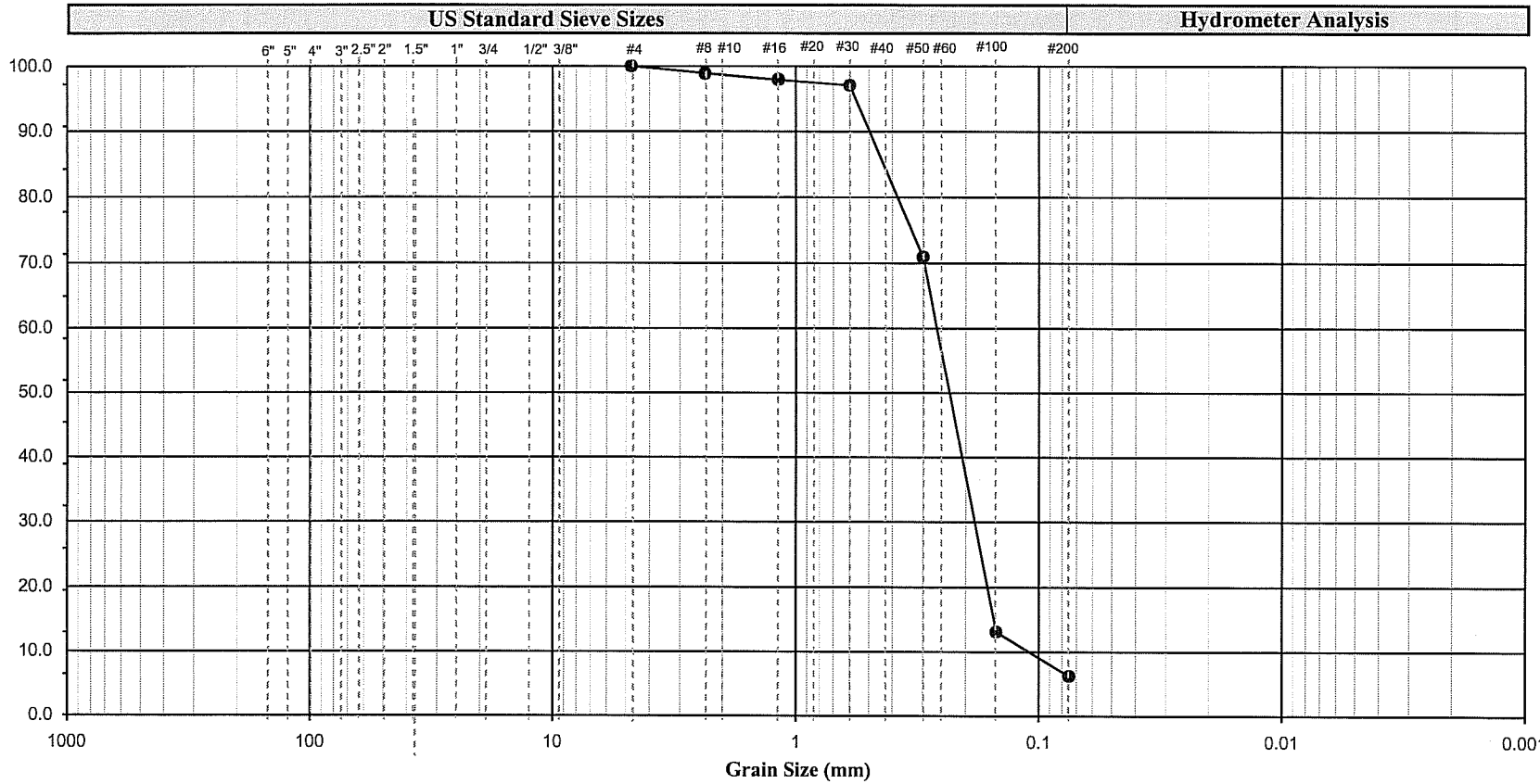
Boring No.	: 06-1	Depth :	(ft) :	75.0	76.5	Sieve	Cimulative Weight	(%)	Sieve	Cimulative Weight	(%)
Sample No.	: S-15		(m) :	22.88	23.33						
Description	: Dark Olive Brown, Poorly Graded Sand with Silt (SP-SM)					5"			No. 8	0.07	99.97
						4"			No. 10		
		Before Washing Sample		After Wet Sieve		3"			No. 16	0.25	99.90
		Tested	Moisture			2.5"			No. 20		
Container Number		S-9	S-9	S-9		2.0"			No. 30	1.77	99.28
Wet Wt. of Soil + Cont. (gm)		431.85	431.85			1.5"			No. 40		
Dry Wt. of Soil + Cont. (gm)			362.42	345.80		1.0"			No. 50	70.09	71.58
Weight of Container (gm)		115.79	115.79	115.79		3/4"			No. 60		
Weight of Dry Soil (gm)		246.63	246.63	230.01		1/2"			No. 100	216.59	12.18
Moisture Content (%)			28.15			3/8"			No. 200	229.55	6.93
						No. 4	0.00	100.00	Pan	230.15	
Remark :						Cu :	2.3		Gravel	Sand	Fine
4						Cc :	1.2		0	93	7

Prepared By : M.T.	Date : 03/16/07	Tested By : M.T.	Date : 03/22/07	Checked By : R.J.	
Washed By : R.J.	Date : 03/18/07	Computed By : C.Y.	Date : 05/29/07	Date :	05/29/07

Boring No.	: 06-1	Depth :	(ft) :	120.0	121.5	Sieve	Cimulative Weight	(%)	Sieve	Cimulative Weight	(%)
Sample No.	: D-22		(m) :	36.60	37.06						
Description	: Gray, Well Gravel with Sand and Silt (GW-GM)					5"			No. 8	198.75	41.66
						4"			No. 10		
		Before Washing Sample		After Wet Sieve		3"			No. 16	220.54	35.26
		Tested	Moisture			2.5"			No. 20		
Container Number		S-10	S-10	S-10		2.0"			No. 30	254.33	25.34
Wet Wt. of Soil + Cont. (gm)		490.76	490.76			1.5"			No. 40		
Dry Wt. of Soil + Cont. (gm)			459.79	442.72		1.0"			No. 50	291.45	14.45
Weight of Container (gm)		119.12	119.12	119.12		3/4"	0.00	100.00	No. 60		
Weight of Dry Soil (gm)		340.67	340.67	323.6		1/2"	70.21	79.39	No. 100	313.43	8.00
Moisture Content (%)			9.09			3/8"	116.17	65.90	No. 200	323.07	5.17
						No. 4	167.84	50.73	Pan	323.63	
Remark :						Cu :	38.9		Gravel	Sand	Fine
5						Cc :	0.5		49	46	5

Prepared By : M.T.	Date : 03/20/07	Tested By : M.T.	Date : 03/22/07	Checked By : R.J.	
Washed By : M.T.	Date : 03/21/07	Computed By : C.Y.	Date : 05/29/07	Date :	05/29/07

Boring No.	: 06-2	Depth :	(ft) :	5.0	6.5	Sieve	Cimulative Weight	(%)	Sieve	Cimulative Weight	(%)
Sample No.	: S-1		(m) :	1.53	1.98						
Description	: Bluish Gray to Gray, Clayey Sand (SC)					5"			No. 8	17.34	93.50
						4"			No. 10		
		Before Washing Sample		After Wet Sieve		3"			No. 16	20.77	92.21
		Tested	Moisture			2.5"			No. 20		
Container Number		S-19	S-19	S-19		2.0"			No. 30	28.73	89.23
Wet Wt. of Soil + Cont. (gm)		439.27	439.27			1.5"			No. 40		
Dry Wt. of Soil + Cont. (gm)			383.35	270.46		1.0"			No. 50	49.63	81.39
Weight of Container (gm)		116.61	116.61	116.61		3/4"			No. 60		
Weight of Dry Soil (gm)		266.74	266.74	153.85		1/2"	0.00	100.00	No. 100	112.22	57.93
Moisture Content (%)			20.96			3/8"	1.90	99.29	No. 200	152.63	42.78
						No. 4	11.95	95.52	Pan	153.99	
Remark :						Cu :			Gravel	Sand	Fine
6						Cc :			4	53	43



Cobbles	Gravel		Sand			Silt or Clay
	Coarse	Fine	Coarse	Medium	Fine	

Symbol	Boring Number	Sample Number	Depth (ft)		Depth (m)		Soil Color	Soil Description	U.S.C.S.
●	06-1	S-15	75.0	76.5	22.88	23.33	Dark Olive Brown	Poorly graded sand with silt	SP-SM
Remark									

Earth Mechanics, Inc.
Geotechnical and Earthquake Engineering

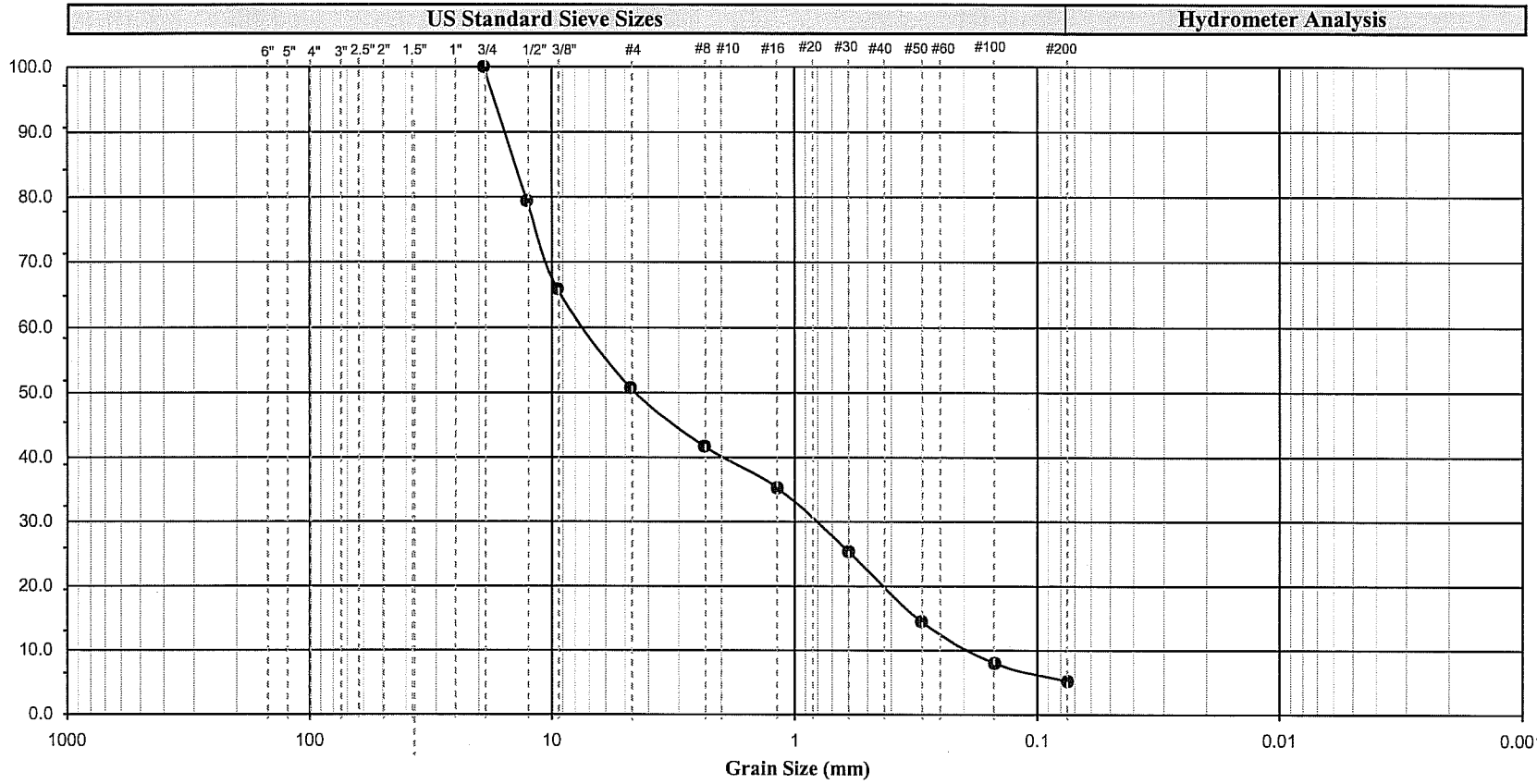
BATA / Antioch Bridge

Project No. : 06-155

Date : 04/08/07

GRAIN SIZE ANALYSIS
(ASTM D-422-63)

Figure No. :



Cobbles	Gravel		Sand			Silt or Clay
	Coarse	Fine	Coarse	Medium	Fine	

Symbol	Boring Number	Sample Number	Depth (ft)		Depth (m)		Soil Color	Soil Description	U.S.C.S.
●	06-1	D-22	120.0	121.5	36.60	37.06	Gary	Poorly graded gravel with silt and sand	GP-GM
Remark									

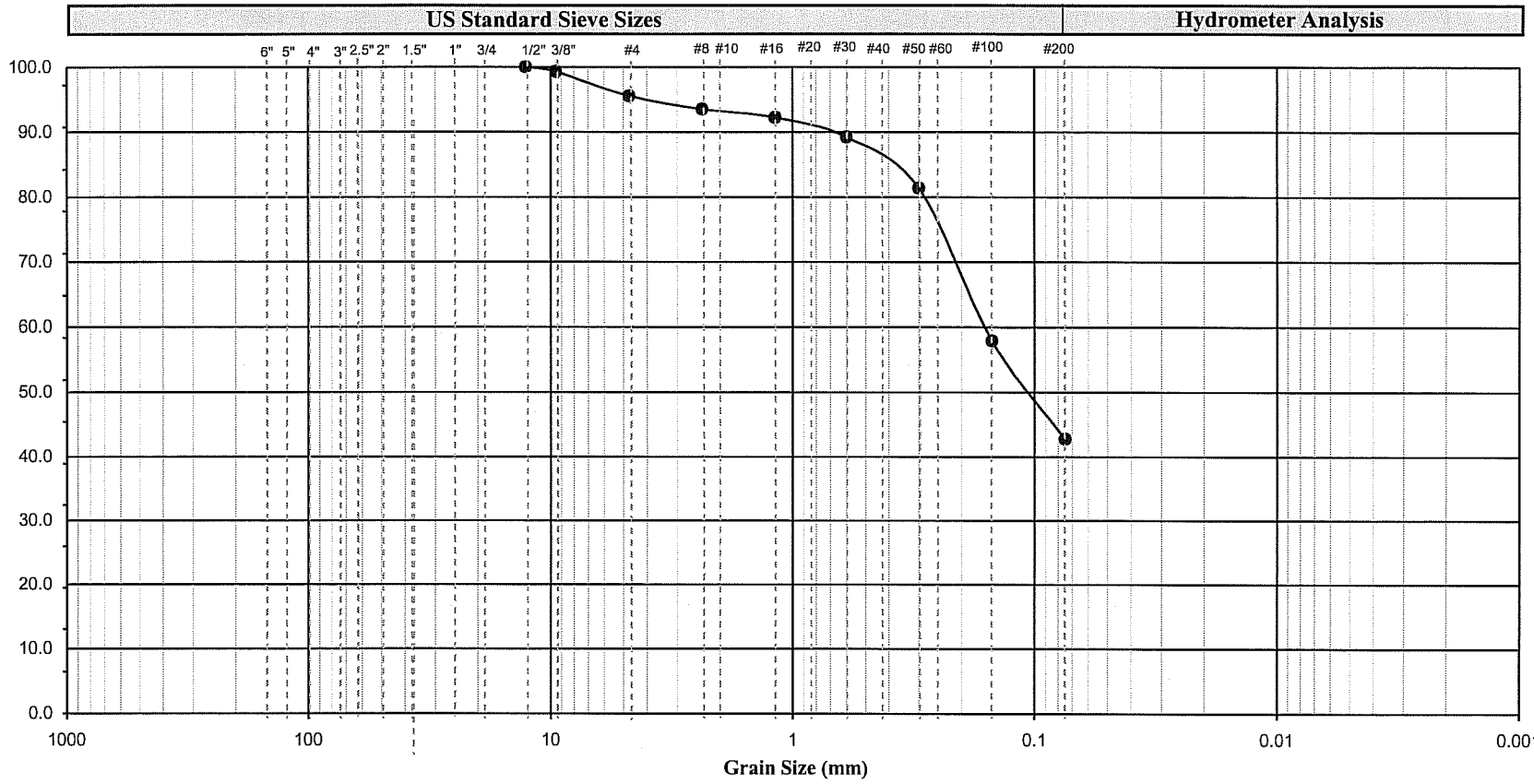
Earth Mechanics, Inc.
Geotechnical and Earthquake Engineering

BATA / Antioch Bridge

Project No. : 06-155 Date : 04/08/07

GRAIN SIZE ANALYSIS
(ASTM D-422-63)

Figure No. :



Cobbles	Gravel		Sand			Silt or Clay
	Coarse	Fine	Coarse	Medium	Fine	

Symbol	Boring Number	Sample Number	Depth (ft)		Depth (m)		Soil Color	Soil Description	U.S.C.S.
●	06-2	S-1	5.0	6.5	1.53	1.98	Bluish Gray to Gray	Clayey sand	SC
Remark									

Earth Mechanics, Inc.
Geotechnical and Earthquake Engineering

BATA / Antioch Bridge

Project No. : *06-155* **Date :** *04/08/07*

GRAIN SIZE ANALYSIS
(ASTM D-422-63)

Figure No. :

PARTICLE SIZE ANALYSIS OF SOIL

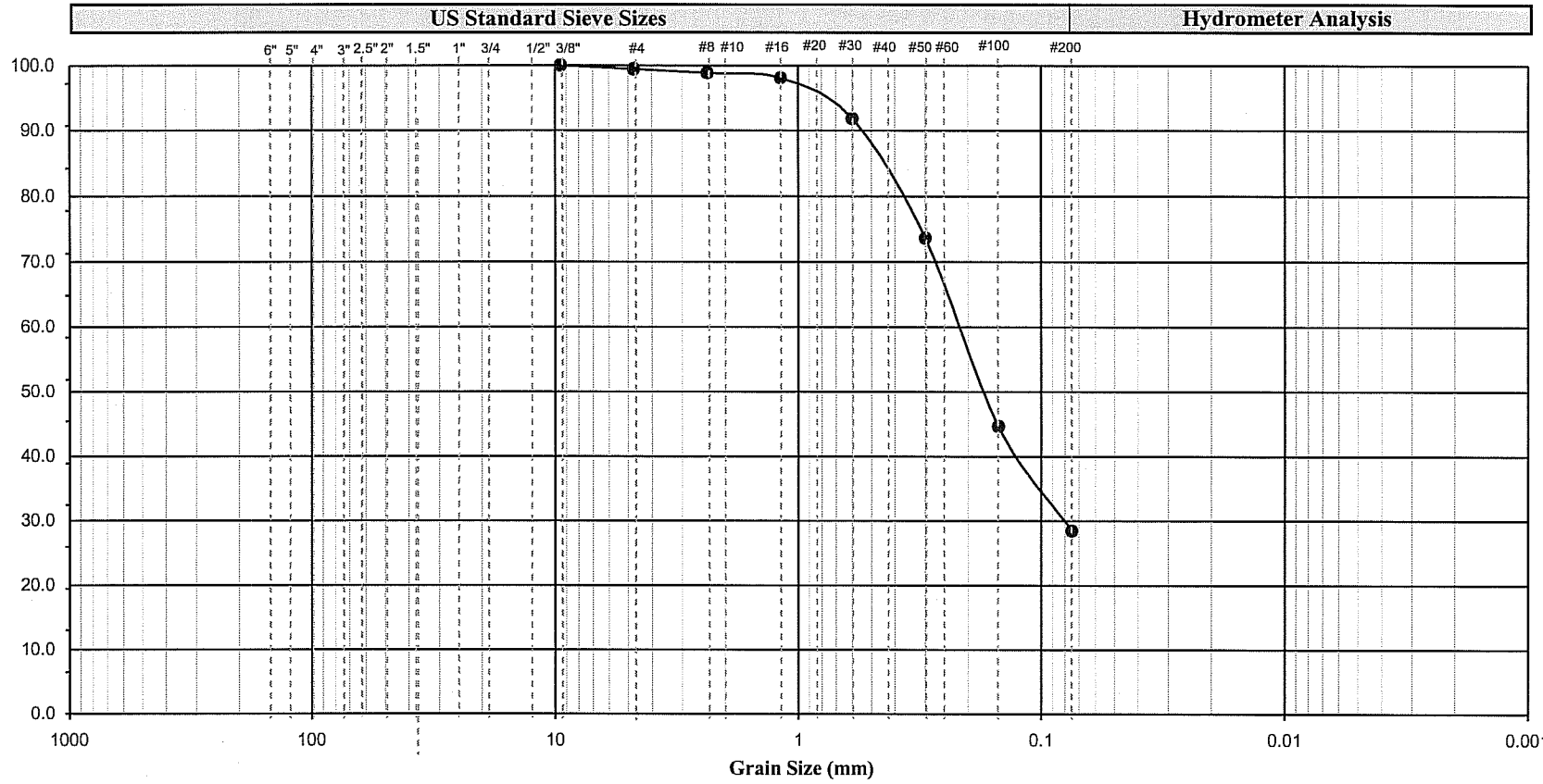
ASTM D-422-63 (Rev. 1990) / CT - 202, 203

Project No : 06-155	Project Name : BATA / Antioch Bridge
Standard : ☑ CAL. TRAN. ☐ ASTM ☐ OTHER	

Prepared By : M.T.	Date : 03/20/07	Tested By : M.T.	Date : 03/26/07	Checked By : R.J.						
Washed By : M.T.	Date : 03/21/07	Computed By : C.Y.	Date : 05/29/07	Date : 05/29/07						
Boring No. : 06-2	Depth : (ft) : 25.0	26.5	Sieve	Cimulative Weight	(%)	Sieve	Cimulative Weight	(%)		
Sample No. : S-5	(m) : 7.63	8.08								
Description : Dark Bluish Gray, Silty Sand (SM)			5"			No. 8	3.23	98.89		
			4"			No. 10				
	Before Washing Sample		After Wet Sieve	3"			No. 16	5.43	98.13	
	Tested	Moisture		2.5"			No. 20			
Container Number	S-20	S-20	S-20	2.0"			No. 30	23.89	91.79	
Wet Wt. of Soil + Cont. (gm)	460.42	460.42		1.5"			No. 40			
Dry Wt. of Soil + Cont. (gm)		406.14	324.17	1.0"			No. 50	76.72	73.63	
Weight of Container (gm)	115.17	115.17	115.17	3/4"			No. 60			
Weight of Dry Soil (gm)	290.97	290.97	209	1/2"			No. 100	161.17	44.61	
Moisture Content (%)		18.65		3/8"	0.00	100.00	No. 200	208.30	28.41	
Remark :				No. 4	1.66	99.43	Pan	209.23		
				Cu :			Gravel	Sand	Fine	
7				Cc :			1	71	28	

Prepared By : M.T.	Date : 03/20/07	Tested By : M.T.	Date : 03/26/07	Checked By : R.J.						
Washed By : M.T.	Date : 03/21/07	Computed By : C.Y.	Date : 05/29/07	Date : 05/29/07						
Boring No. : 06-2	Depth : (ft) : 45.0	46.5	Sieve	Cimulative Weight	(%)	Sieve	Cimulative Weight	(%)		
Sample No. : S-9	(m) : 13.73	14.18								
Description : Gray, Silty Sand (SM)			5"			No. 8	0.00	100.00		
			4"			No. 10				
	Before Washing Sample		After Wet Sieve	3"			No. 16	0.27	99.89	
	Tested	Moisture		2.5"			No. 20			
Container Number	S-23	S-23	S-23	2.0"			No. 30	1.12	99.52	
Wet Wt. of Soil + Cont. (gm)	440.40	440.40		1.5"			No. 40			
Dry Wt. of Soil + Cont. (gm)		348.66	2888.16	1.0"			No. 50	10.78	95.41	
Weight of Container (gm)	113.82	113.82	113.82	3/4"			No. 60			
Weight of Dry Soil (gm)	234.84	234.84	2774.34	1/2"			No. 100	152.49	35.07	
Moisture Content (%)		39.06		3/8"			No. 200	174.42	25.73	
Remark :				No. 4	0	100.00	Pan	174.61		
				Cu :			Gravel	Sand	Fine	
8				Cc :			0	74	26	

Prepared By : M.T.	Date : 04/06/07	Tested By : M.T.	Date : 04/08/07	Checked By : R.J.						
Washed By : M.T.	Date : 04/07/07	Computed By : C.Y.	Date : 05/29/07	Date : 05/29/07						
Boring No. : 06-6	Depth : (ft) : 71.0	72.5	Sieve	Cimulative Weight	(%)	(%)	Cimulative Weight	(%)		
Sample No. : D-16	(m) : 21.66	22.11								
Description : Very Dark Gray, Poorly Graded Sand with Silt (SP-SM)			5"			No. 8	0.21	99.94		
			4"			No. 10				
	Before Washing Sample		After Wet Sieve	3"			No. 16	0.48	99.86	
	Tested	Moisture		2.5"			No. 20			
Container Number	S-12	S-12	S-12	2.0"			No. 30	1.72	99.49	
Wet Wt. of Soil + Cont. (gm)	451.85	451.85		1.5"			No. 40			
Dry Wt. of Soil + Cont. (gm)		451.85	434.50	1.0"			No. 50	19.32	94.28	
Weight of Container (gm)	114.28	114.28	114.28	3/4"			No. 60			
Weight of Dry Soil (gm)	337.57	337.57	320.22	1/2"			No. 100	232.18	31.22	
Moisture Content (%)		0.00		3/8"			No. 200	318.07	5.78	
Remark :				No. 4	0	100.00	Pan	320.32		
				Cu :	2.5		Gravel	Sand	Fine	
9				Cc :	1.1		0	94	6	



Cobbles	Gravel		Sand			Silt or Clay
	Coarse	Fine	Coarse	Medium	Fine	

Symbol	Boring Number	Sample Number	Depth (ft)		Depth (m)		Soil Color	Soil Description	U.S.C.S.
●	06-2	S-5	25.0	26.5	7.63	8.08	Dark Bluish Gray	Silty sand	SM
Remark									

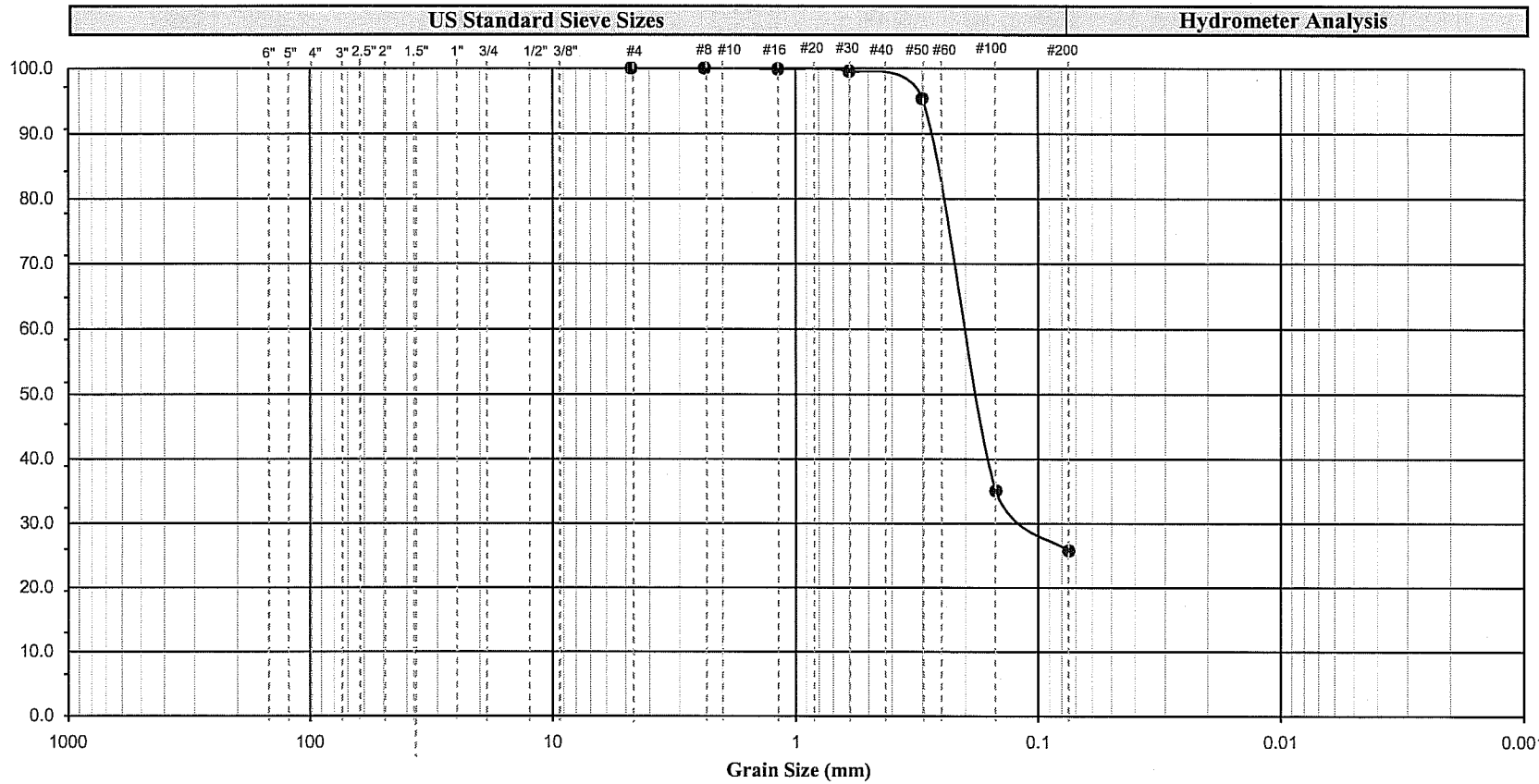
Earth Mechanics, Inc.
Geotechnical and Earthquake Engineering

BATA / Antioch Bridge

Project No. : *06-155* **Date :** *04/08/07*

GRAIN SIZE ANALYSIS
(ASTM D-422-63)

Figure No. :



Cobbles	Gravel		Sand			Silt or Clay
	Coarse	Fine	Coarse	Medium	Fine	

Symbol	Boring Number	Sample Number	Depth (ft)		Depth (m)		Soil Color	Soil Description	U.S.C.S.
●	06-2	S-9	45.0	46.5	13.73	14.18	Gray	Silty sand	SM
Remark									

Earth Mechanics, Inc.
Geotechnical and Earthquake Engineering

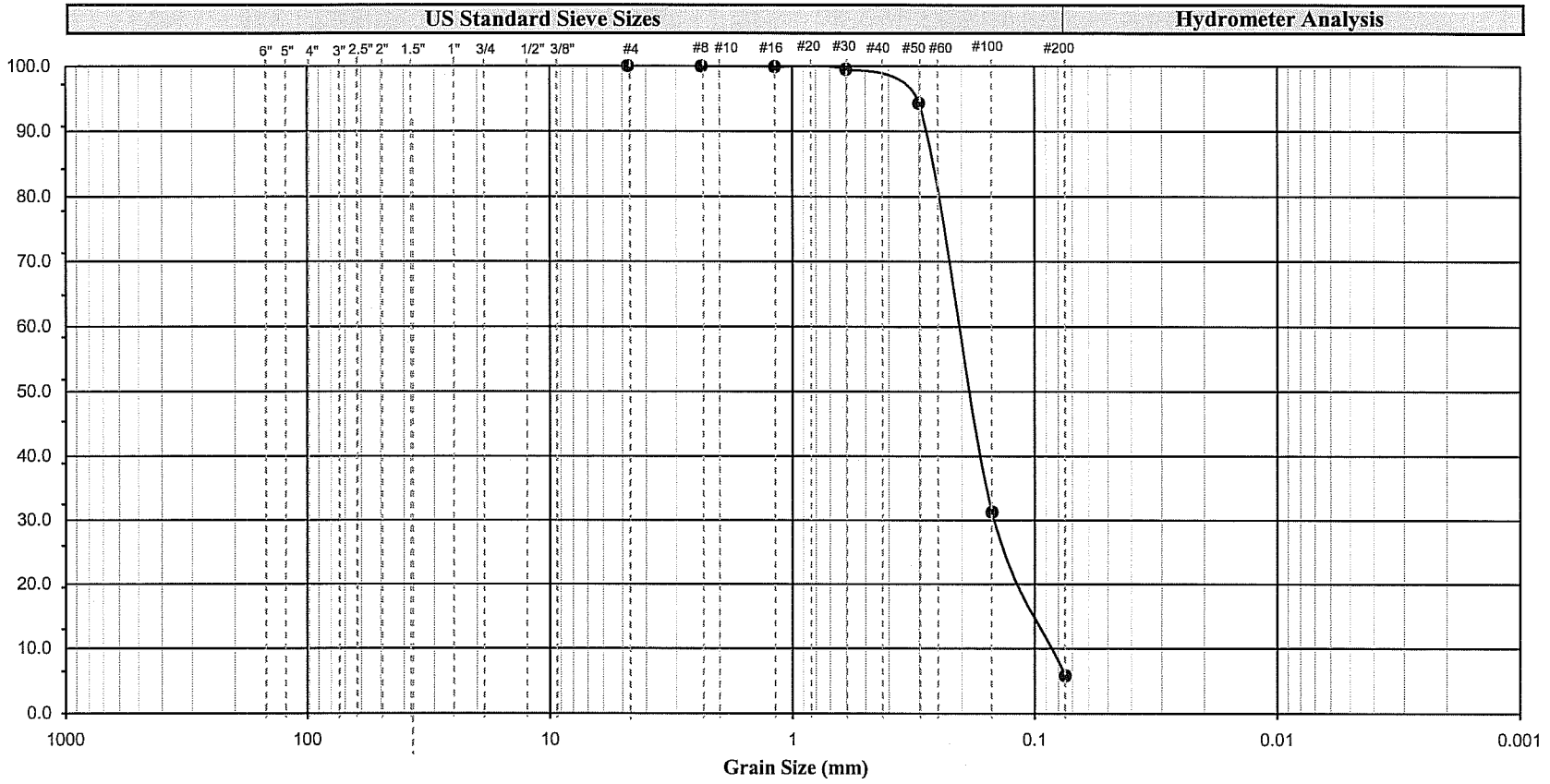
BATA / Antioch Bridge

Project No. : *06-155*

Date : *04/08/07*

GRAIN SIZE ANALYSIS
(ASTM D-422-63)

Figure No. :



Cobbles	Gravel		Sand			Silt or Clay
	Coarse	Fine	Coarse	Medium	Fine	

Symbol	Boring Number	Sample Number	Depth (ft)		Depth (m)		Soil Color	Soil Description	U.S.C.S.
●	06-6	D-16	71.0	72.5	21.66	22.11	Very Dark Gray	Poorly graded sand with silt	SP-SM
Remark									

Earth Mechanics, Inc.
Geotechnical and Earthquake Engineering

BATA / Antioch Bridge

Project No. : 06-155 Date : 04/08/07

GRAIN SIZE ANALYSIS
(ASTM D-422-63)

Figure No. :

PARTICLE SIZE ANALYSIS OF SOIL

ASTM D-422-63 (Rev. 1990) / CT - 202, 203

Project No : 06-155	Project Name : BATA / Antioch Bridge
Standard : ☑ CAL. TRAN. ☐ ASTM ☐ OTHER	

Prepared By : M.T.	Date : 03/21/07	Tested By : M.T.	Date : 03/26/07	Checked By : R.J.
Washed By : M.T.	Date : 03/25/07	Computed By : C.Y.	Date : 05/30/07	Date : 05/30/07

Boring No. : 06-6	Depth :	(ft) : 81.0	82.5
Sample No. : D-18		(m) : 24.71	25.16

Description : Dark Gray, Poorly Graded Sand with Silt (SP-SM)

	Before Washing Sample		After Wet Sieve
	Tested	Moisture	
Container Number	S-5	S-5	S-5
Wet Wt. of Soil + Cont. (gm)	421.35	421.35	
Dry Wt. of Soil + Cont. (gm)		358.66	345.30
Weight of Container (gm)	117.77	117.77	117.77
Weight of Dry Soil (gm)	240.89	240.89	227.53
Moisture Content (%)		26.02	

Sieve	Cimulative Weight	(%)	Sieve	Cimulative Weight	(%)
5"			No. 8	0.00	100.00
4"			No. 10		
3"			No. 16	0.01	100.00
2.5"			No. 20		
2.0"			No. 30	0.31	99.87
1.5"			No. 40		
1.0"			No. 50	35.14	85.41
3/4"			No. 60		
1/2"			No. 100	198.29	17.68
3/8"			No. 200	226.91	5.80
No. 4	0.00	100.00	Pan	227.57	
Cu :	2.4		Gravel	Sand	Fine
Cc :	1.3		0	94	6

Remark : 1

Prepared By : M.T.	Date : 03/27/07	Tested By : M.T.	Date : 03/26/07	Checked By : R.J.
Washed By : R.J.	Date : 04/01/07	Computed By : C.Y.	Date : 05/30/07	Date : 05/30/07

Boring No. : 06-7	Depth :	(ft) : 54.0	55.5
Sample No. : S-11		(m) : 16.47	16.93

Description : Dark Bluish Gray, Silty Sand (SM)

	Before Washing Sample		After Wet Sieve
	Tested	Moisture	
Container Number	S-5	S-5	S-5
Wet Wt. of Soil + Cont. (gm)	480.03	480.03	
Dry Wt. of Soil + Cont. (gm)		393.16	320.41
Weight of Container (gm)	117.78	117.78	117.78
Weight of Dry Soil (gm)	275.38	275.38	202.63
Moisture Content (%)		31.55	

Sieve	Cimulative Weight	(%)	Sieve	Cimulative Weight	(%)
5"			No. 8	0.00	100.00
4"			No. 10		
3"			No. 16	0.07	99.97
2.5"			No. 20		
2.0"			No. 30	0.33	99.88
1.5"			No. 40		
1.0"			No. 50	3.34	98.79
3/4"			No. 60		
1/2"			No. 100	79.71	71.05
3/8"			No. 200	195.99	28.83
No. 4	0.00	100.00	Pan	202.91	
Cu :	1.7		Gravel	Sand	Fine
Cc :	0.6		0	71	29

Remark : 2

Prepared By : M.T.	Date : 03/27/07	Tested By : M.T.	Date : 03/22/07	Checked By : R.J.
Washed By : R.J.	Date : 04/01/07	Computed By : C.Y.	Date : 05/29/07	Date : 05/29/07

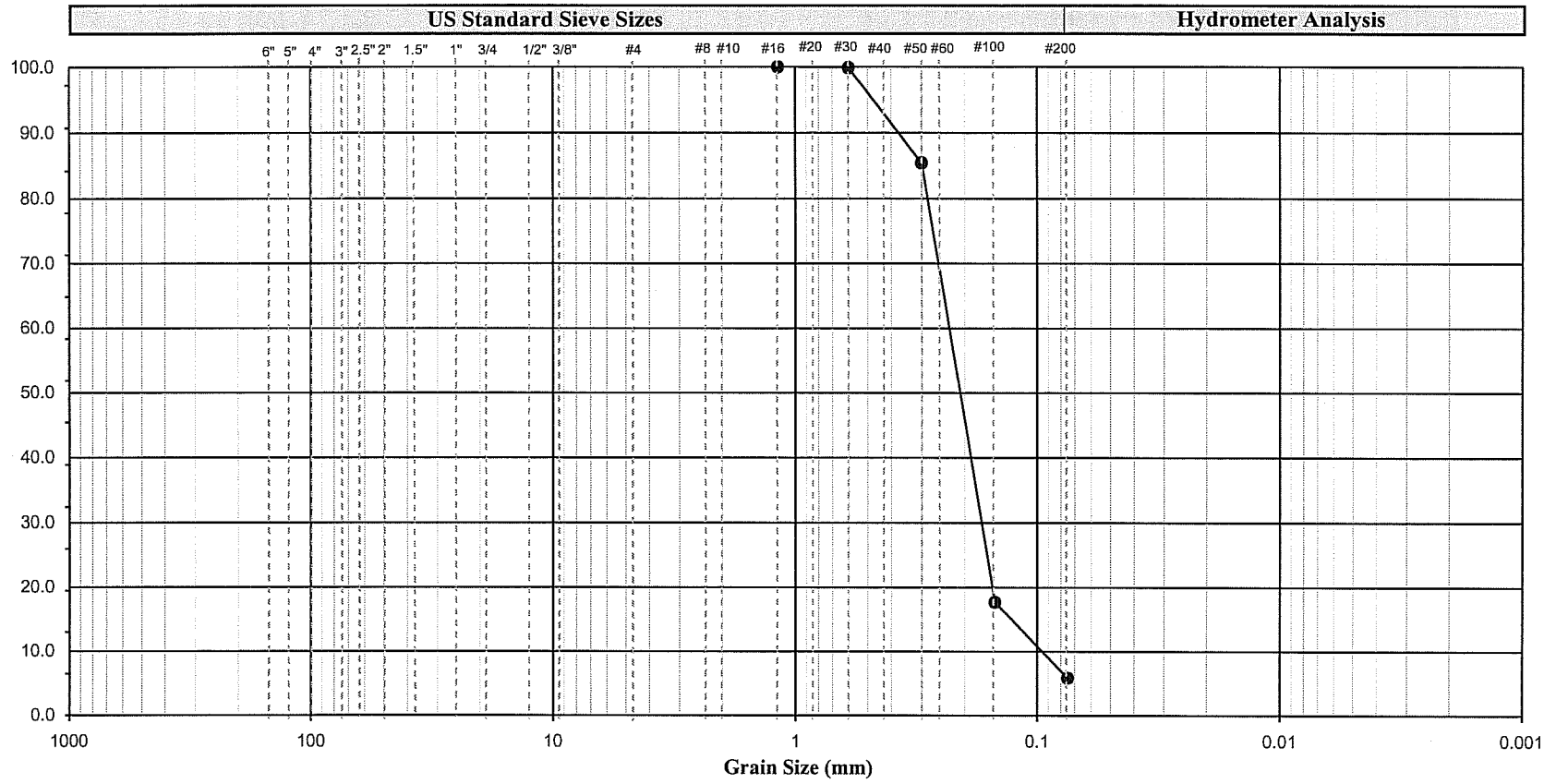
Boring No. : 06-7	Depth :	(ft) : 74.0	75.5
Sample No. : S-15		(m) : 22.57	23.03

Description : Dark Bluish Gray, Poorly Graded Sand with Silt (SP-SM)

	Before Washing Sample		After Wet Sieve
	Tested	Moisture	
Container Number	S-2	S-2	S-2
Wet Wt. of Soil + Cont. (gm)	498.17	498.17	
Dry Wt. of Soil + Cont. (gm)		419.20	404.32
Weight of Container (gm)	116.85	116.85	116.85
Weight of Dry Soil (gm)	302.35	302.35	287.47
Moisture Content (%)		26.12	

Sieve	Cimulative Weight	(%)	Sieve	Cimulative Weight	(%)
5"			No. 8	2.89	99.04
4"			No. 10		
3"			No. 16	4.23	98.60
2.5"			No. 20		
2.0"			No. 30	14.84	95.09
1.5"			No. 40		
1.0"			No. 50	117.30	61.20
3/4"			No. 60		
1/2"			No. 100	275.28	8.95
3/8"	0.00	100.00	No. 200	286.81	5.14
No. 4	1.50	99.50	Pan	287.10	
Cu :	1.9		Gravel	Sand	Fine
Cc :	1.0		0	95	5

Remark : 3



Cobbles	Gravel		Sand			Silt or Clay
	Coarse	Fine	Coarse	Medium	Fine	

Symbol	Boring Number	Sample Number	Depth (ft)		Depth (m)		Soil Color	Soil Description	U.S.C.S.
●	06-6	D-18	81.0	82.5	24.71	25.16	Dark Gray	Poorly graded sand with silt	SP-SM
Remark									

Earth Mechanics, Inc.
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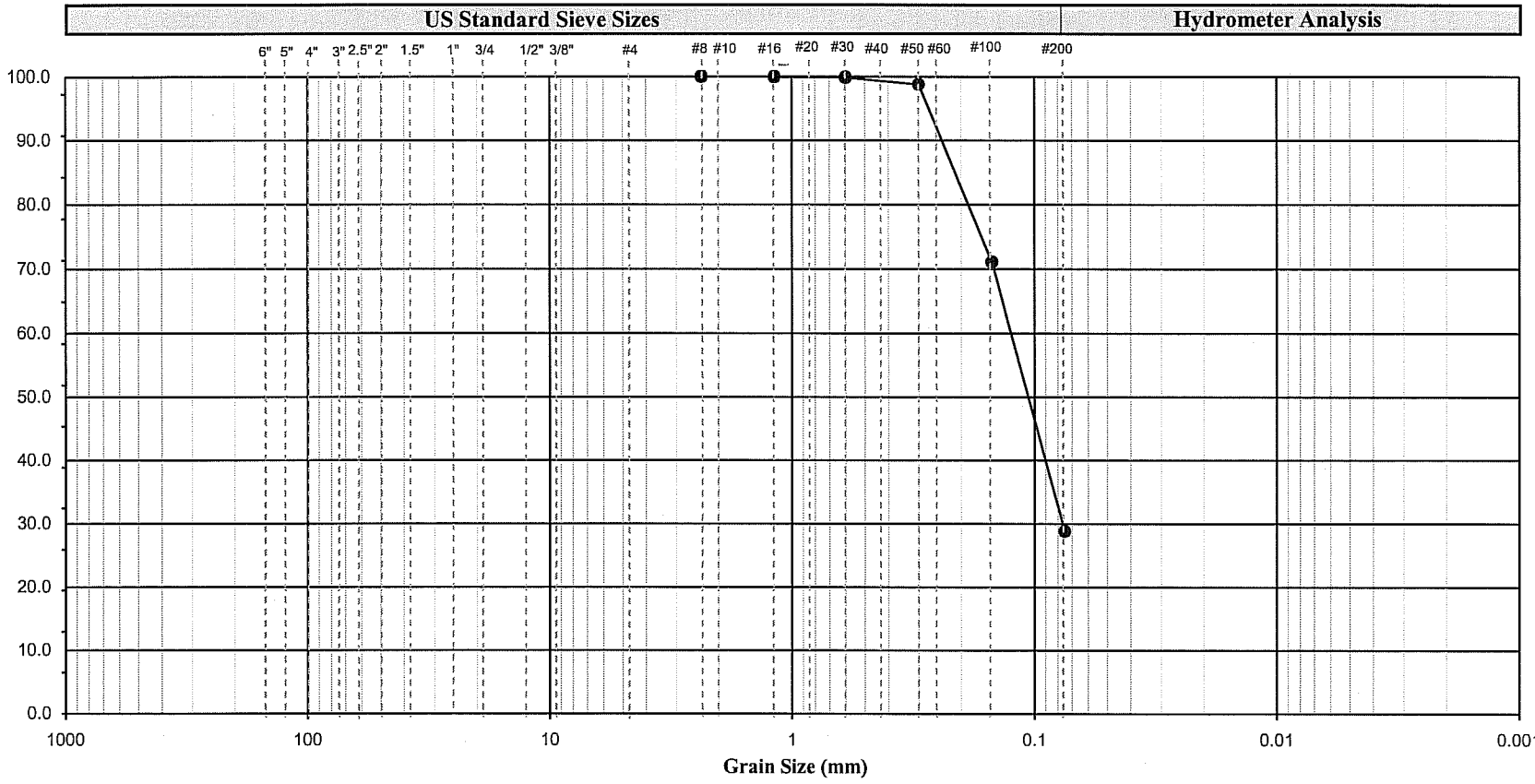
BATA / Antioch Bridge

Project No. : *06-155* **Date :** *03/26/07*

GRAIN SIZE ANALYSIS
(ASTM D-422-63)

Figure No. :



Cobbles	Gravel		Sand			Silt or Clay
	Coarse	Fine	Coarse	Medium	Fine	

Symbol	Boring Number	Sample Number	Depth (ft)		Depth (m)		Soil Color	Soil Description	U.S.C.S.
●	06-7	S-11	54.0	55.5	16.47	16.93	Dark Bluish Gray	Silty sand	SM
Remark									

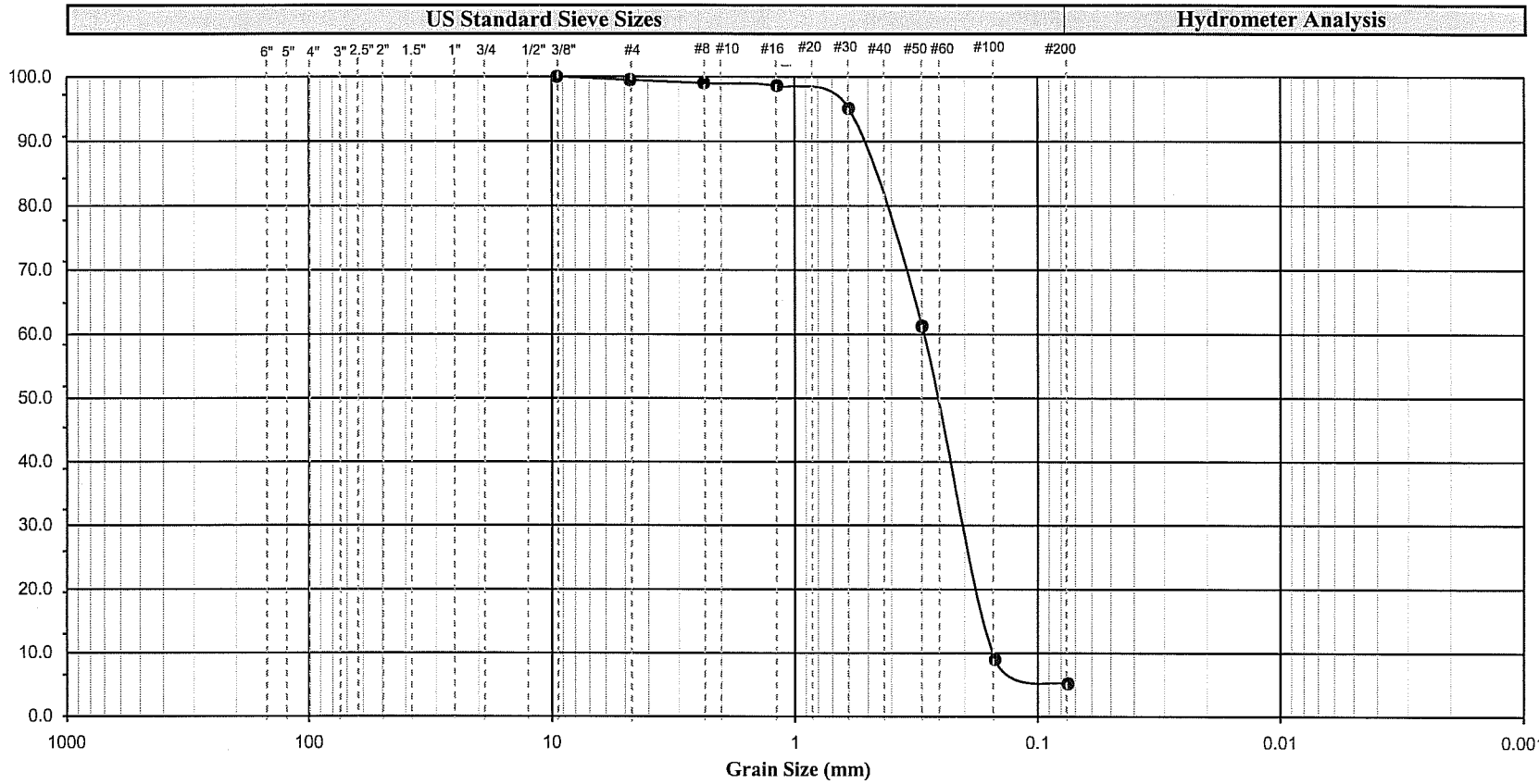
Earth Mechanics, Inc.
Geotechnical and Earthquake Engineering

BATA / Antioch Bridge

Project No. : *06-155* **Date :** *03/26/07*

GRAIN SIZE ANALYSIS
(ASTM D-422-63)

Figure No. :



Cobbles	Gravel		Sand			Silt or Clay
	Coarse	Fine	Coarse	Medium	Fine	

Symbol	Boring Number	Sample Number	Depth (ft)		Depth (m)		Soil Color	Soil Description	U.S.C.S.
●	06-7	S-15	74.0	75.5	22.57	23.03	Dark Bluish Gray	Poorly graded sand with silt	SP-SM
Remark									

Earth Mechanics, Inc.
Geotechnical and Earthquake Engineering

BATA / Antioch Bridge

Project No. : *06-155* **Date :** *03/26/07*

GRAIN SIZE ANALYSIS
(ASTM D-422-63)

Figure No. :

PARTICLE SIZE ANALYSIS OF SOIL

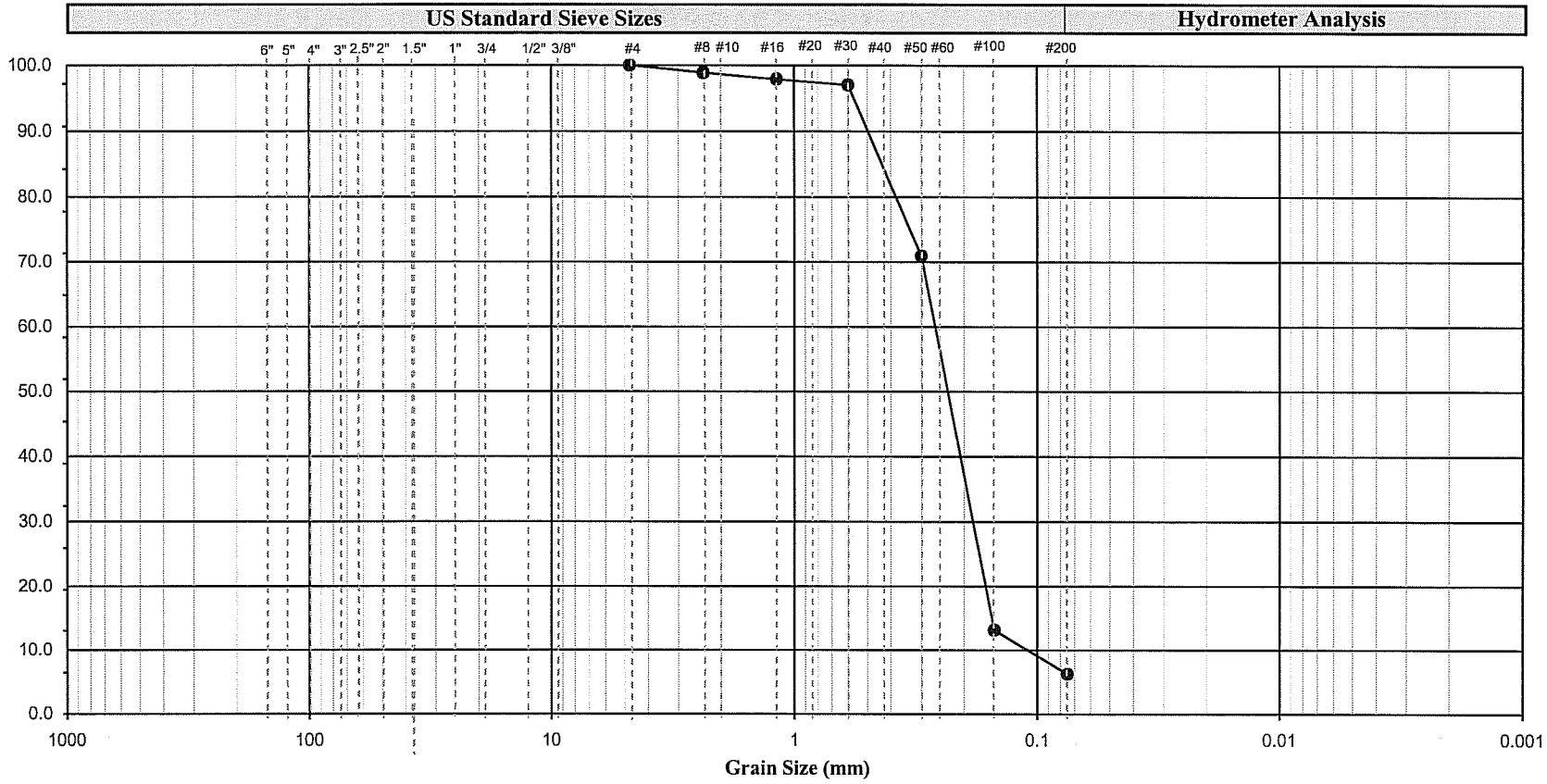
ASTM D-422-63 (Rev. 1990) / CT - 202, 203

Project No : 06-155	Project Name : BATA / Antioch Bridge
Standard : ☑ CAL. TRAN. ☐ ASTM ☐ OTHER	

Prepared By : M.T.	Date : 03/27/07	Tested By : M.T.	Date : 03/26/07	Checked By : R.J.							
Washed By : R.J.	Date : 04/01/07	Computed By : C.Y.	Date : 05/30/07	Date : 05/30/07							
Boring No. : 06-8	Depth : (ft) : 60.5	62.0		Sieve	Cimulative Weight	(%)	Sieve	Cimulative Weight	(%)		
Sample No. : S-14	(m) : 18.45	18.91									
Description : Dark Bluish Gray, Poorly Graded Sand with Silt (SP-SM)				5"			No. 8	0.00	100.00		
				4"			No. 10				
	Before Washing Sample		After Wet Sieve	3"			No. 16	0.06	99.98		
	Tested	Moisture		2.5"			No. 20				
Container Number	S-4	S-4	S-4	2.0"			No. 30	0.52	99.82		
Wet Wt. of Soil + Cont. (gm)	498.26	498.26		1.5"			No. 40				
Dry Wt. of Soil + Cont. (gm)		406.87	378.28	1.0"			No. 50	4.78	98.34		
Weight of Container (gm)	118.06	118.06	118.06	3/4"			No. 60				
Weight of Dry Soil (gm)	288.81	288.81	260.22	1/2"			No. 100	155.33	46.22		
Moisture Content (%)		31.64		3/8"			No. 200	255.45	11.55		
Remark :				No. 4	0.00	100.00	Pan	260.30			
				Cu :			Gravel	Sand	Fine		
4				Cc :			0	88	12		

Prepared By : M.T.	Date : 03/27/07	Tested By : M.T.	Date : 03/22/07	Checked By : R.J.							
Washed By : R.J.	Date : 04/01/07	Computed By : C.Y.	Date : 05/29/07	Date : 05/29/07							
Boring No. : 06-8	Depth : (ft) : 81.0	82.5		Sieve	Cimulative Weight	(%)	Sieve	Cimulative Weight	(%)		
Sample No. : S-18	(m) : 24.71	25.16									
Description : Dark Gray, Poorly Graded Sand with Silt (SP-SM)				5"			No. 8	100.99	70.26		
				4"			No. 10				
	Before Washing Sample		After Wet Sieve	3"			No. 16	128.05	62.29		
	Tested	Moisture		2.5"			No. 20				
Container Number	S-4	S-4	S-4	2.0"			No. 30	176.39	48.05		
Wet Wt. of Soil + Cont. (gm)	505.08	505.08		1.5"			No. 40				
Dry Wt. of Soil + Cont. (gm)		455.33	437.30	1.0"			No. 50	271.03	20.18		
Weight of Container (gm)	115.77	115.77	115.77	3/4"			No. 60				
Weight of Dry Soil (gm)	339.56	339.56	321.53	1/2"	0.00	100.00	No. 100	310.99	8.41		
Moisture Content (%)		14.65		3/8"	10.49	96.91	No. 200	321.30	5.38		
Remark :				No. 4	62.93	81.47	Pan	321.52			
				Cu :	6.4		Gravel	Sand	Fine		
5				Cc :	0.9		19	76	5		

Prepared By : M.T.	Date : 03/27/07	Tested By : M.T.	Date : 03/26/07	Checked By : R.J.							
Washed By : R.J.	Date : 04/01/07	Computed By : C.Y.	Date : 05/30/07	Date : 05/30/07							
Boring No. : 06-8	Depth : (ft) : 91.0	92.5		Sieve	Cimulative Weight	(%)	Sieve	Cimulative Weight	(%)		
Sample No. : S-20	(m) : 27.76	28.21									
Description : Dark Gray, Poorly Graded Sand with Silt (SP-SM)				5"			No. 8	54.11	82.38		
				4"			No. 10				
	Before Washing Sample		After Wet Sieve	3"			No. 16	67.63	77.98		
	Tested	Moisture		2.5"			No. 20				
Container Number	S-8	S-8	S-8	2.0"			No. 30	95.95	68.75		
Wet Wt. of Soil + Cont. (gm)	484.99	484.99		1.5"			No. 40				
Dry Wt. of Soil + Cont. (gm)		425.36	408.15	1.0"			No. 50	239.82	21.90		
Weight of Container (gm)	118.29	118.29	118.29	3/4"	0.00	100.00	No. 60				
Weight of Dry Soil (gm)	307.07	307.07	289.86	1/2"	12.98	95.77	No. 100	280.11	8.78		
Moisture Content (%)		19.42		3/8"	18.56	93.96	No. 200	289.30	5.79		
Remark :				No. 4	34.34	88.82	Pan	289.78			
				Cu :	3.3		Gravel	Sand	Fine		
6				Cc :	1.4		11	83	6		



Cobbles	Gravel		Sand			Silt or Clay
	Coarse	Fine	Coarse	Medium	Fine	

Symbol	Boring Number	Sample Number	Depth (ft)		Depth (m)		Soil Color	Soil Description	U.S.C.S.
●	06-8	S-14	60.5	62.0	18.45	18.91	Dark Bluish Gray	Poorly graded sand with silt	SP-SM
Remark									

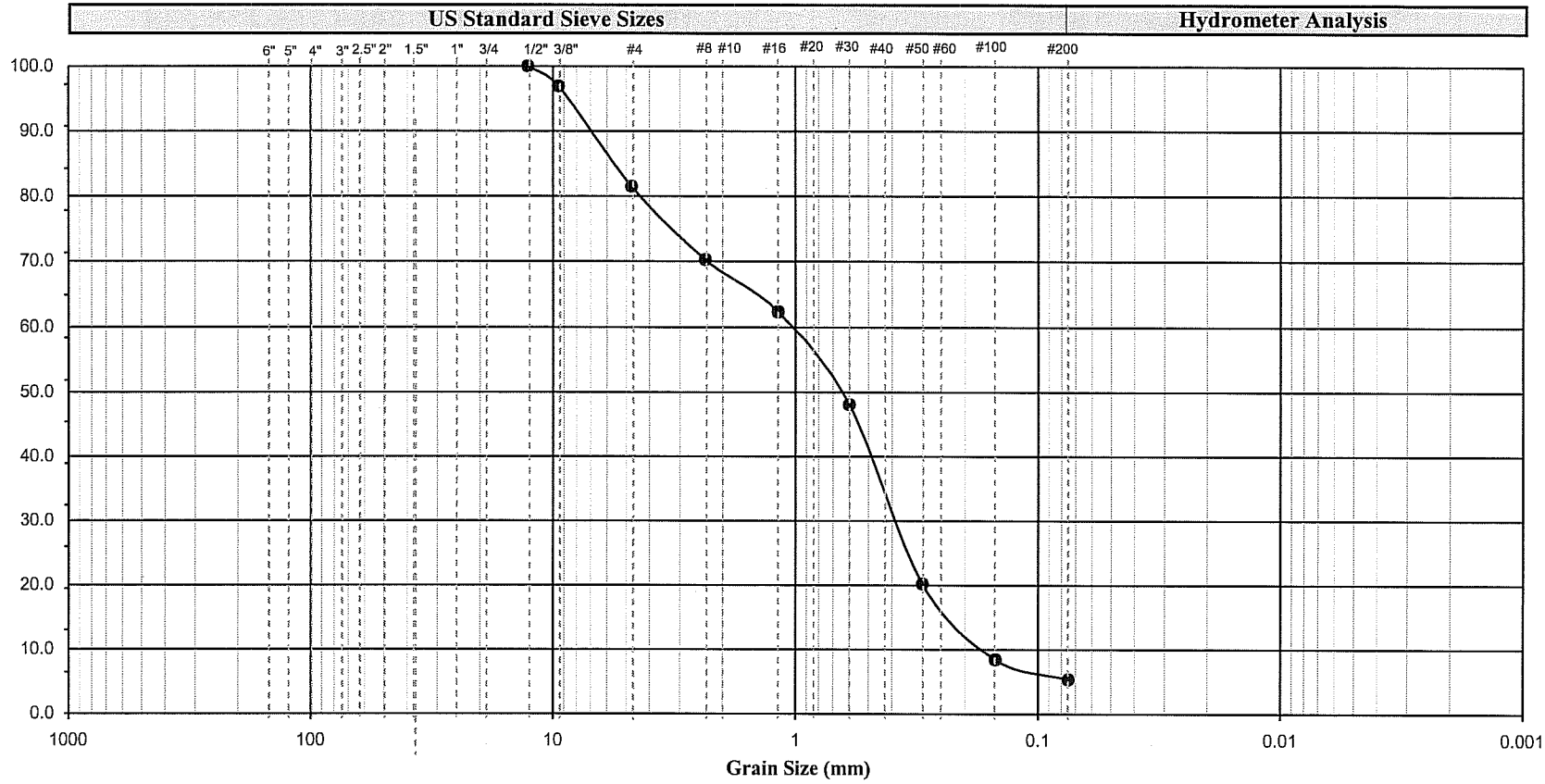
Earth Mechanics, Inc.
Geotechnical and Earthquake Engineering

BATA / Antioch Bridge

Project No. : *06-155* **Date :** *03/26/07*

GRAIN SIZE ANALYSIS
(ASTM D-422-63)

Figure No. :



Cobbles	Gravel		Sand			Silt or Clay
	Coarse	Fine	Coarse	Medium	Fine	

Symbol	Boring Number	Sample Number	Depth (ft)		Depth (m)		Soil Color	Soil Description	U.S.C.S.
●	06-8	S-18	81.0	82.5	24.71	25.16	Dark Gray	Poorly graded sand with silt with gravel	SP-SM
Remark									

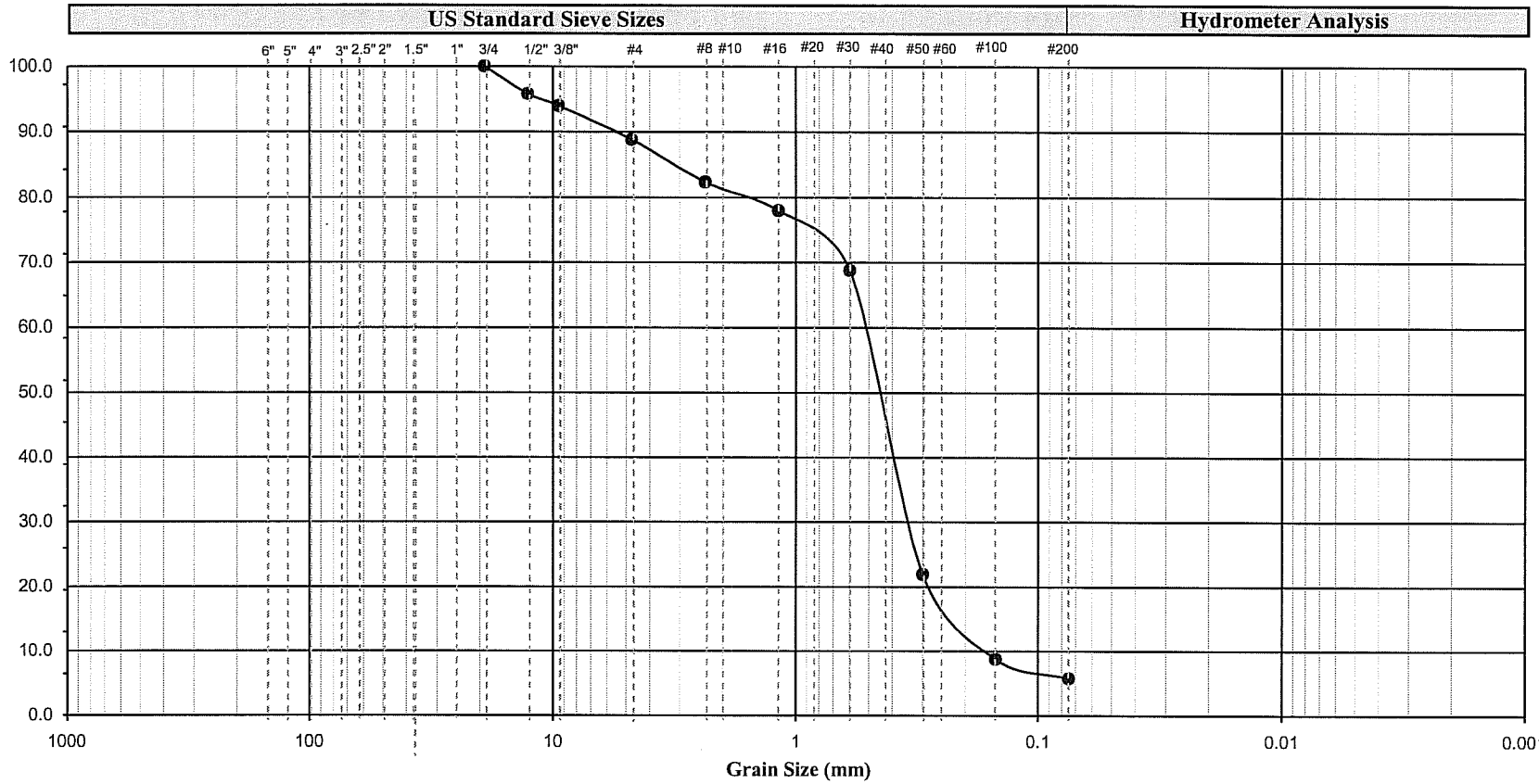
Earth Mechanics, Inc.
Geotechnical and Earthquake Engineering

BATA / Antioch Bridge

Project No. : *06-155* **Date :** *03/26/07*

GRAIN SIZE ANALYSIS
(ASTM D-422-63)

Figure No. :



Cobbles	Gravel		Sand			Silt or Clay
	Coarse	Fine	Coarse	Medium	Fine	

Symbol	Boring Number	Sample Number	Depth (ft)		Depth (m)		Soil Color	Soil Description	U.S.C.S.
●	06-8	S-20	91.0	92.5	27.76	28.21	Dark Gray	Poorly graded sand with silt	SP-SM
Remark									

Earth Mechanics, Inc.
Geotechnical and Earthquake Engineering

BATA / Antioch Bridge

Project No. : *06-155* **Date :** *03/26/07*

GRAIN SIZE ANALYSIS
(ASTM D-422-63)

Figure No. :

PARTICLE SIZE ANALYSIS OF SOIL

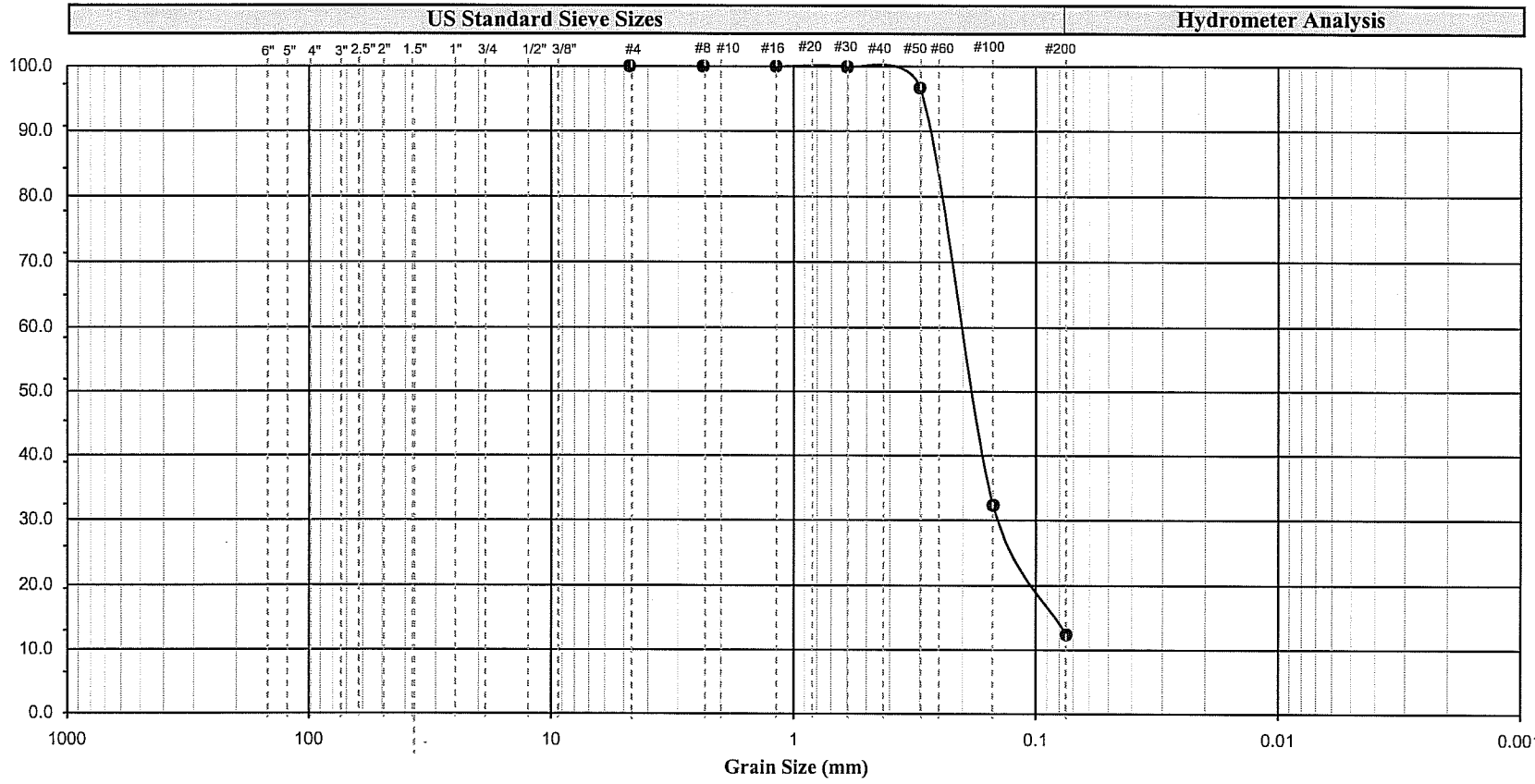
ASTM D-422-63 (Rev. 1990) / CT - 202, 203

Project No : 06-155	Project Name : BATA / Antioch Bridge
Standard : ☑ CAL. TRAN. ☐ ASTM ☐ OTHER	

Prepared By : M.T.	Date : 03/27/07	Tested By : M.T.	Date : 03/26/07	Checked By : R.J.							
Washed By : R.J.	Date : 04/01/07	Computed By : C.Y.	Date : 05/30/07	Date : 05/30/07							
Boring No. : 06-9	Depth : (ft) : 15.0	16.5		Sieve	Cimulative Weight	(%)	Sieve	Cimulative Weight	(%)		
Sample No. : D-3	(m) : 4.58	5.03									
Description : Dark Bluish Gray, Poorly Graded Sand with Silt (SP-SM)				5"			No. 8	0.02	99.99		
				4"			No. 10				
	Before Washing Sample		After Wet Sieve	3"			No. 16	0.05	99.98		
	Tested	Moisture		2.5"			No. 20				
Container Number	S-10	S-10	S-10	2.0"			No. 30	0.19	99.92		
Wet Wt. of Soil + Cont. (gm)	413.05	413.05		1.5"			No. 40				
Dry Wt. of Soil + Cont. (gm)		348.63	322.09	1.0"			No. 50	7.65	96.67		
Weight of Container (gm)	119.13	119.13	119.13	3/4"			No. 60				
Weight of Dry Soil (gm)	229.50	229.5	202.96	1/2"			No. 100	155.37	32.30		
Moisture Content (%)		28.07		3/8"			No. 200	201.05	12.40		
Remark :				No. 4	0	100.00	Pan	202.94			
				Cu :			Gravel	Sand	Fine		
7				Cc :			0	88	12		

Prepared By : M.T.	Date : 03/27/07	Tested By : M.T.	Date : 03/26/07	Checked By : R.J.							
Washed By : R.J.	Date : 04/01/07	Computed By : C.Y.	Date : 05/30/07	Date : 05/30/07							
Boring No. : 06-9	Depth : (ft) : 40.0	41.5		Sieve	Cimulative Weight	(%)	Sieve	Cimulative Weight	(%)		
Sample No. : S-8	(m) : 12.20	12.66									
Description : Dark Gray, Poorly Graded Sand with Silt (SP-SM)				5"			No. 8	1.27	99.51		
				4"			No. 10				
	Before Washing Sample		After Wet Sieve	3"			No. 16	1.42	99.45		
	Tested	Moisture		2.5"			No. 20				
Container Number	S-13	S-13	S-13	2.0"			No. 30	3.39	98.68		
Wet Wt. of Soil + Cont. (gm)	451.01	451.01		1.5"			No. 40				
Dry Wt. of Soil + Cont. (gm)		370.96	359.31	1.0"			No. 50	69.07	73.16		
Weight of Container (gm)	113.64	113.64	113.64	3/4"			No. 60				
Weight of Dry Soil (gm)	257.32	257.32	245.67	1/2"			No. 100	231.52	10.03		
Moisture Content (%)		31.11		3/8"	0.00	100.00	No. 200	245.49	4.60		
Remark :				No. 4	0.79	99.69	Pan	245.79			
				Cu :	1.8		Gravel	Sand	Fine		
8				Cc :	1.0		0	95	5		

Prepared By : M.T.	Date : 03/27/07	Tested By : M.T.	Date : 03/26/07	Checked By : R.J.							
Washed By : R.J.	Date : 04/01/07	Computed By : C.Y.	Date : 05/30/07	Date : 05/30/07							
Boring No. : 06-9	Depth : (ft) : 60.0	61.5		Sieve	Cimulative Weight	(%)	(%)	Cimulative Weight	(%)		
Sample No. : S-12	(m) : 18.30	18.76									
Description : Dark Gray, Poorly Graded Sand with Silt (SP-SM)				5"			No. 8	12.74	95.40		
				4"			No. 10				
	Before Washing Sample		After Wet Sieve	3"			No. 16	19.26	93.05		
	Tested	Moisture		2.5"			No. 20				
Container Number	S-15	S-15	S-15	2.0"			No. 30	47.44	82.89		
Wet Wt. of Soil + Cont. (gm)	454.42	454.42		1.5"			No. 40				
Dry Wt. of Soil + Cont. (gm)		391.93	377.79	1.0"			No. 50	152.25	45.07		
Weight of Container (gm)	114.74	114.74	114.74	3/4"			No. 60				
Weight of Dry Soil (gm)	277.19	277.19	263.05	1/2"			No. 100	249.60	9.95		
Moisture Content (%)		22.54		3/8"	0.00	100.00	No. 200	262.53	5.29		
Remark :				No. 4	7.47	97.31	Pan	263.00			
				Cu :	2.8		Gravel	Sand	Fine		
9				Cc :	0.9		3	92	5		



Cobbles	Gravel		Sand			Silt or Clay
	Coarse	Fine	Coarse	Medium	Fine	

Symbol	Boring Number	Sample Number	Depth (ft)		Depth (m)		Soil Color	Soil Description	U.S.C.S.
●	06-9	D-3	15.0	16.5	4.58	5.03	Dark Bluish Gray	Poorly graded sand with silt	SP-SM
Remark									

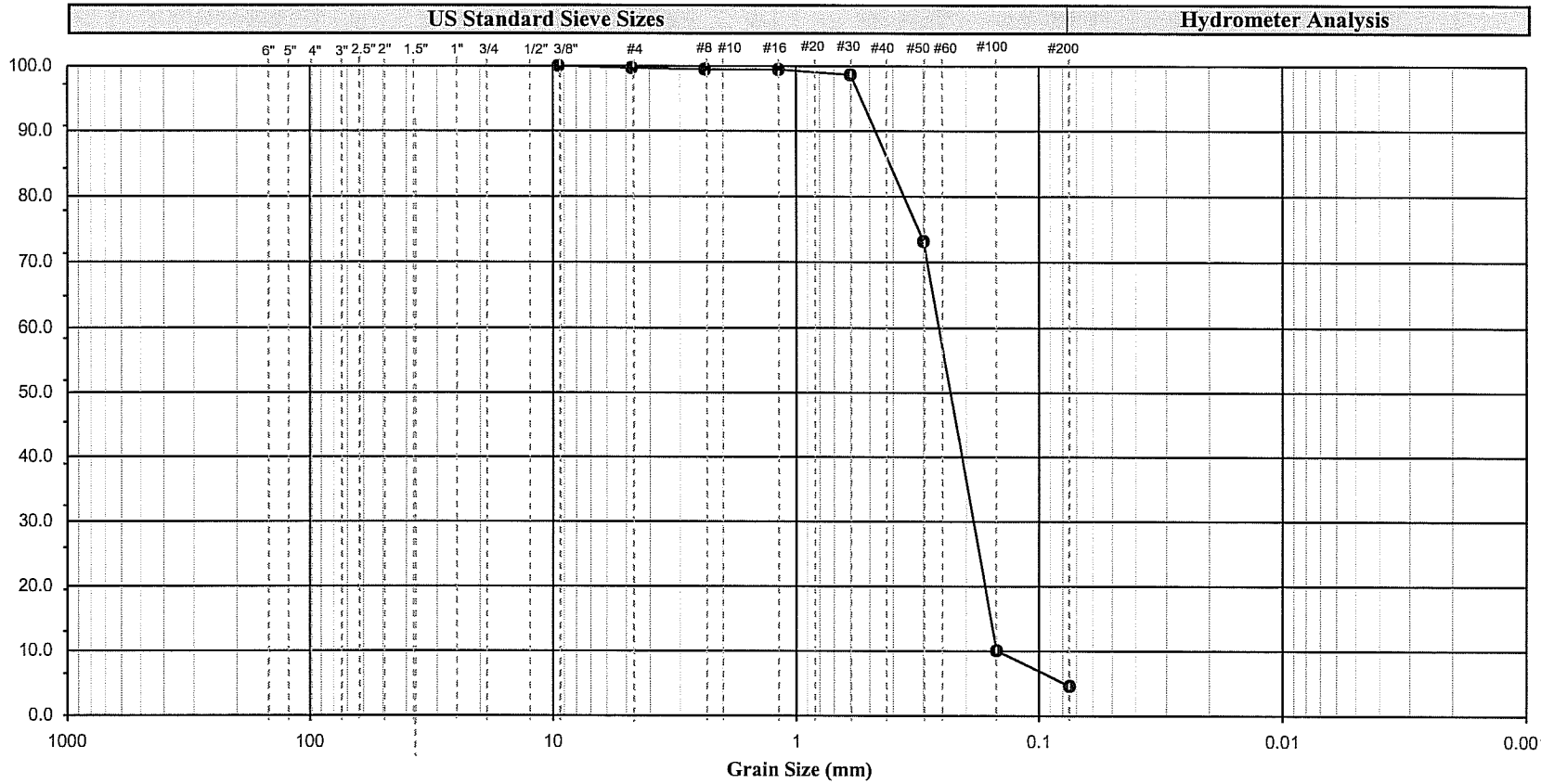
Earth Mechanics, Inc.
Geotechnical and Earthquake Engineering

BATA / Antioch Bridge

Project No. : 06-155 Date : 03/26/07

GRAIN SIZE ANALYSIS
(ASTM D-422-63)

Figure No. :



Cobbles	Gravel		Sand			Silt or Clay
	Coarse	Fine	Coarse	Medium	Fine	

Symbol	Boring Number	Sample Number	Depth (ft)		Depth (m)		Soil Color	Soil Description	U.S.C.S.
●	06-9	S-8	40.0	41.5	12.20	12.66	Dark Gray	Poorly graded sand with silt	SP-SM
Remark									

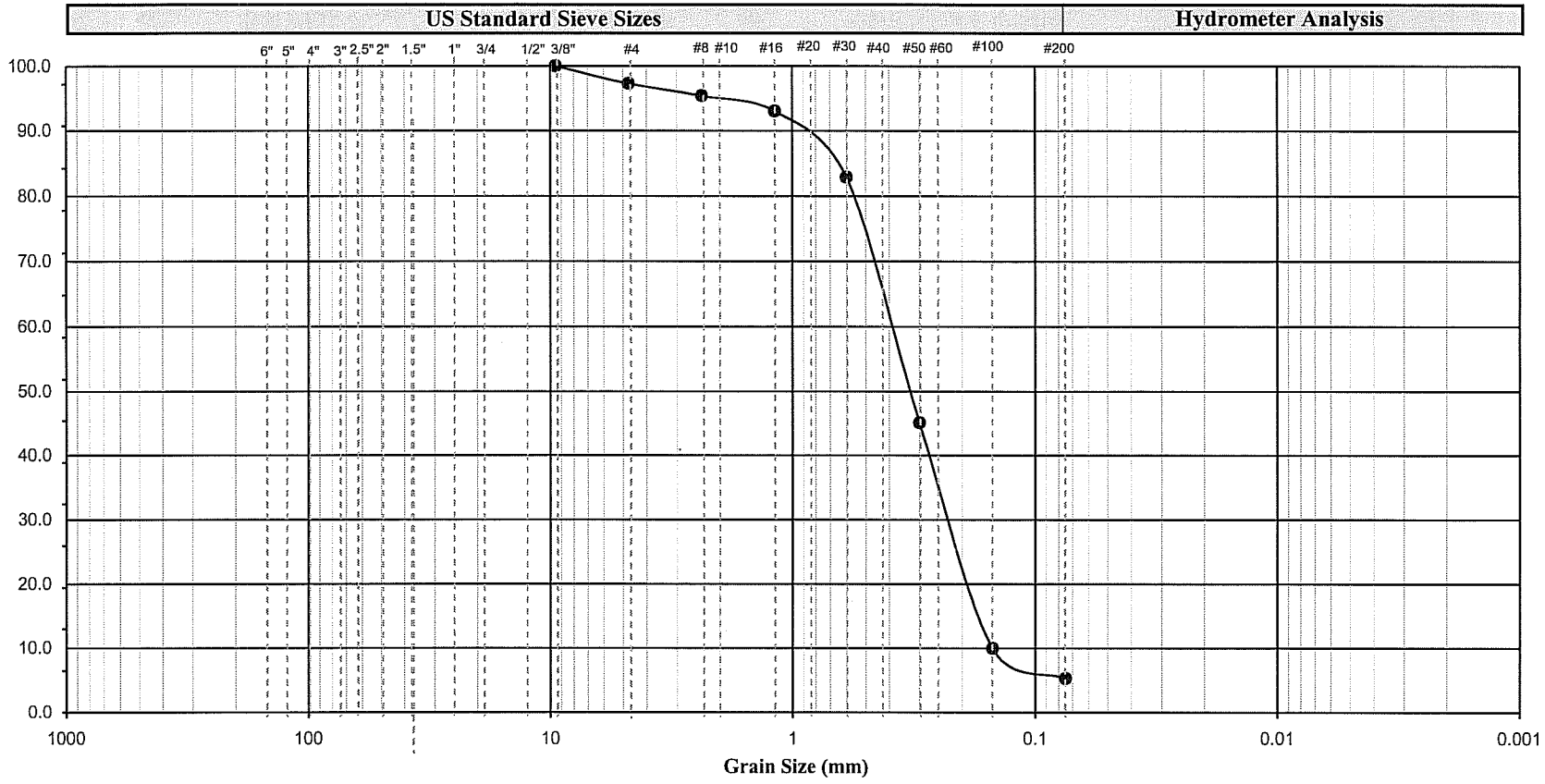
Earth Mechanics, Inc.
Geotechnical and Earthquake Engineering

BATA / Antioch Bridge

Project No. : *06-155* **Date :** *03/26/07*

GRAIN SIZE ANALYSIS
(ASTM D-422-63)

Figure No. :



Cobbles	Gravel		Sand			Silt or Clay
	Coarse	Fine	Coarse	Medium	Fine	

Symbol	Boring Number	Sample Number	Depth (ft)		Depth (m)		Soil Color	Soil Description	U.S.C.S.
●	06-9	S-12	60.0	61.5	18.30	18.76	Dark Gray	Poorly graded sand with silt	SP-SM
Remark									

Earth Mechanics, Inc.
Geotechnical and Earthquake Engineering

BATA / Antioch Bridge

Project No. : *06-155*

Date : *03/26/07*

GRAIN SIZE ANALYSIS
(ASTM D-422-63)

Figure No. :

PARTICLE SIZE ANALYSIS OF SOIL

ASTM D-422-63 (Rev. 1990) / CT - 202, 203

Project No : 06-155	Project Name : BATA / Antioch Bridge
Standard : ☑ CAL. TRAN. ☐ ASTM ☐ OTHER	

Prepared By : M.T.	Date : 04/02/07	Tested By : M.T.	Date : 04/06/07	Checked By : R.J.							
Washed By : M.T.	Date : 04/05/07	Computed By : C.Y.	Date : 05/30/07	Date : 05/30/07							
Boring No. : S-9	Depth : (ft) : 75.0	76.5									
Sample No. : D-15	(m) : 22.88	23.33									
Description : Dark Gray, Poorly Graded Sand (SP)											

	Before Washing Sample		After Wet Sieve
	Tested	Moisture	
Container Number	S-17	S-17	S-17
Wet Wt. of Soil + Cont. (gm)	434.59	434.59	
Dry Wt. of Soil + Cont. (gm)		382.79	376.03
Weight of Container (gm)	114.81	114.81	114.81
Weight of Dry Soil (gm)	267.98	267.98	261.22
Moisture Content (%)		19.33	

Sieve	Cimulative Weight	(%)	Sieve	Cimulative Weight	(%)
5"			No. 8	21.60	91.94
4"			No. 10		
3"			No. 16	31.54	88.23
2.5"			No. 20		
2.0"			No. 30	76.67	71.39
1.5"			No. 40		
1.0"			No. 50	209.74	21.73
3/4"			No. 60		
1/2"	0.00	100.00	No. 100	256.10	4.43
3/8"	3.83	98.57	No. 200	261.23	2.52
No. 4	13.39	95.00	Pan	261.32	
Cu :	2.7		Gravel	Sand	Fine
Cc :	1.2		5	92	3

Remark : 1

Prepared By : M.T.	Date : 04/02/07	Tested By : M.T.	Date : 04/06/07	Checked By : R.J.							
Washed By : M.T.	Date : 04/05/07	Computed By : C.Y.	Date : 05/30/07	Date : 05/30/07							
Boring No. : 06-10	Depth : (ft) : 16.0	17.5									
Sample No. : D-3	(m) : 4.88	5.34									
Description : Dark Bluish Gray, Silty Sand (SM)											

	Before Washing Sample		After Wet Sieve
	Tested	Moisture	
Container Number	S-2	S-2	S-2
Wet Wt. of Soil + Cont. (gm)	415.31	415.31	
Dry Wt. of Soil + Cont. (gm)		350.70	318.99
Weight of Container (gm)	116.85	116.85	116.85
Weight of Dry Soil (gm)	233.85	233.85	202.14
Moisture Content (%)		27.63	

Sieve	Cimulative Weight	(%)	Sieve	Cimulative Weight	(%)
5"			No. 8	0.00	100.00
4"			No. 10		
3"			No. 16	0.14	99.94
2.5"			No. 20		
2.0"			No. 30	0.95	99.59
1.5"			No. 40		
1.0"			No. 50	13.07	94.41
3/4"			No. 60		
1/2"			No. 100	151.70	35.13
3/8"			No. 200	200.96	14.06
No. 4	0.00	100.00	Pan	202.24	
Cu :	1.6		Gravel	Sand	Fine
Cc :	0.6		0	86	14

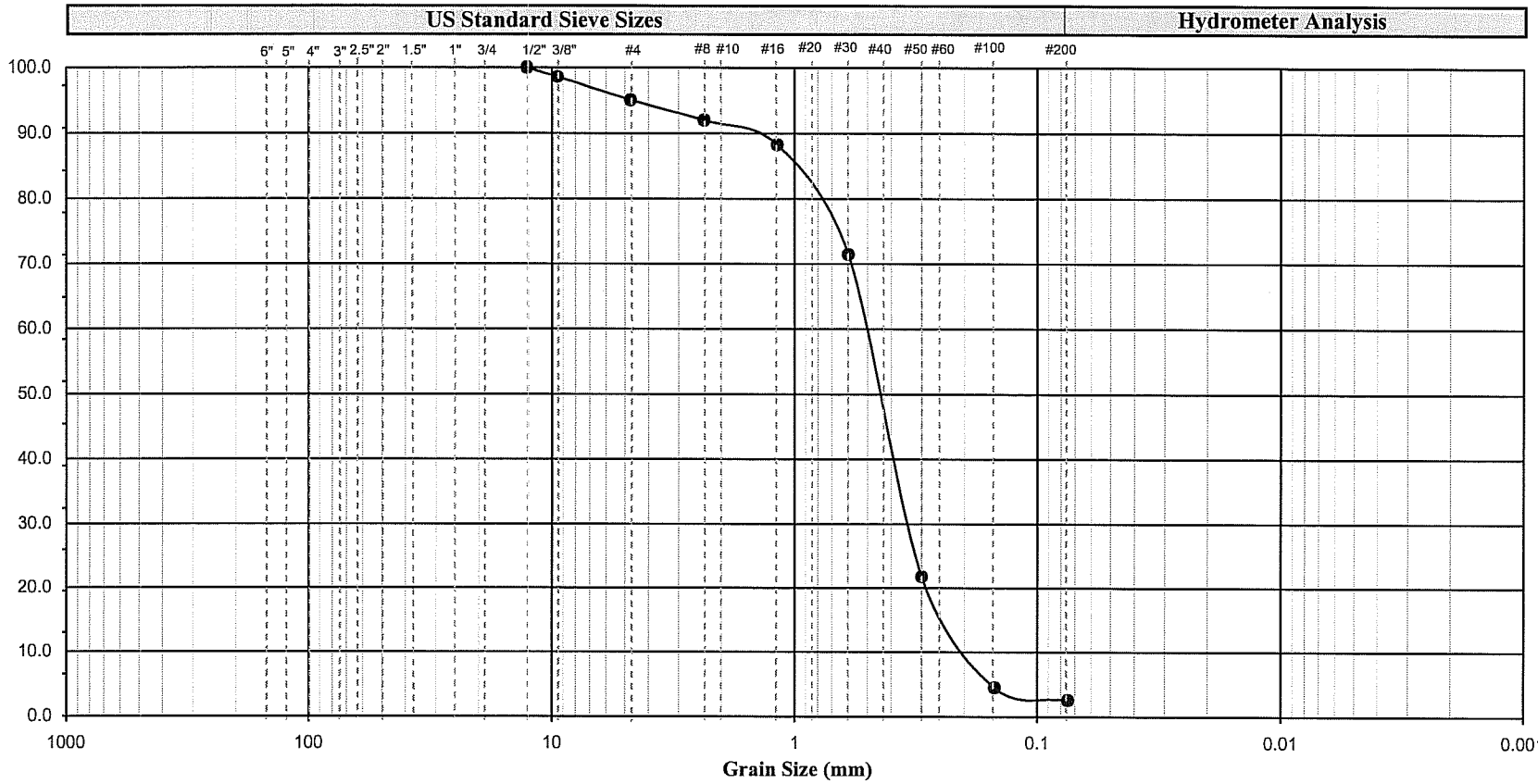
Remark : 2

Prepared By : M.T.	Date : 04/02/07	Tested By : M.T.	Date : 04/06/07	Checked By : R.J.							
Washed By : M.T.	Date : 04/05/07	Computed By : C.Y.	Date : 05/30/07	Date : 05/29/07							
Boring No. : 06-10	Depth : (ft) : 30.5	32.0									
Sample No. : S-6	(m) : 9.30	9.76									
Description : Dark Gray, Poorly Graded Sand with Silt (SP-SM)											

	Before Washing Sample		After Wet Sieve
	Tested	Moisture	
Container Number	S-5	S-5	S-5
Wet Wt. of Soil + Cont. (gm)	474.54	474.54	
Dry Wt. of Soil + Cont. (gm)		399.66	387.09
Weight of Container (gm)	117.80	117.80	117.80
Weight of Dry Soil (gm)	281.86	281.86	269.29
Moisture Content (%)		26.57	

Sieve	Cimulative Weight	(%)	Sieve	Cimulative Weight	(%)
5"			No. 8	0.00	100.00
4"			No. 10		
3"			No. 16	0.03	99.99
2.5"			No. 20		
2.0"			No. 30	0.99	99.65
1.5"			No. 40		
1.0"			No. 50	84.63	69.97
3/4"			No. 60		
1/2"			No. 100	250.62	11.08
3/8"			No. 200	269.09	4.53
No. 4	0.00	100.00	Pan	269.39	
Cu :	2.0		Gravel	Sand	Fine
Cc :	1.0		0	95	5

Remark : 3



Cobbles	Gravel		Sand			Silt or Clay
	Coarse	Fine	Coarse	Medium	Fine	

Symbol	Boring Number	Sample Number	Depth (ft)		Depth (m)		Soil Color	Soil Description	U.S.C.S.
●	S-9	D-15	75.0	76.5	22.88	23.33	Dark Gray	Poorly graded sand	SP
Remark									

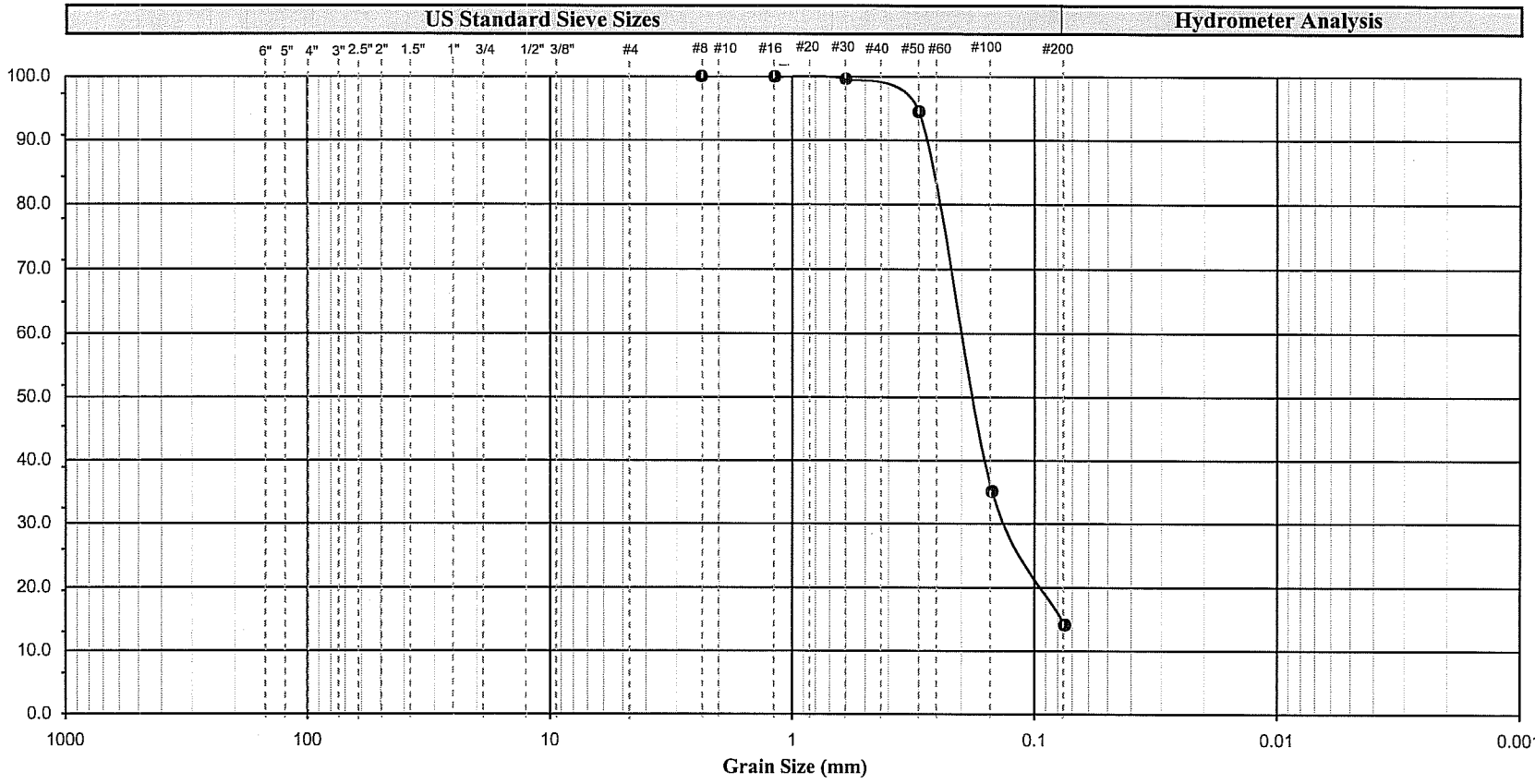
Earth Mechanics, Inc.
Geotechnical and Earthquake Engineering

BATA / Antioch Bridge

Project No. : *06-155* **Date :** *04/06/07*

GRAIN SIZE ANALYSIS
(ASTM D-422-63)

Figure No. :



Cobbles	Gravel		Sand			Silt or Clay
	Coarse	Fine	Coarse	Medium	Fine	

Symbol	Boring Number	Sample Number	Depth (ft)		Depth (m)		Soil Color	Soil Description	U.S.C.S.
●	06-10	D-3	16.0	17.5	4.88	5.34	Dark Bluish Gray	Silty sand	SM
Remark									

Earth Mechanics, Inc.
Geotechnical and Earthquake Engineering

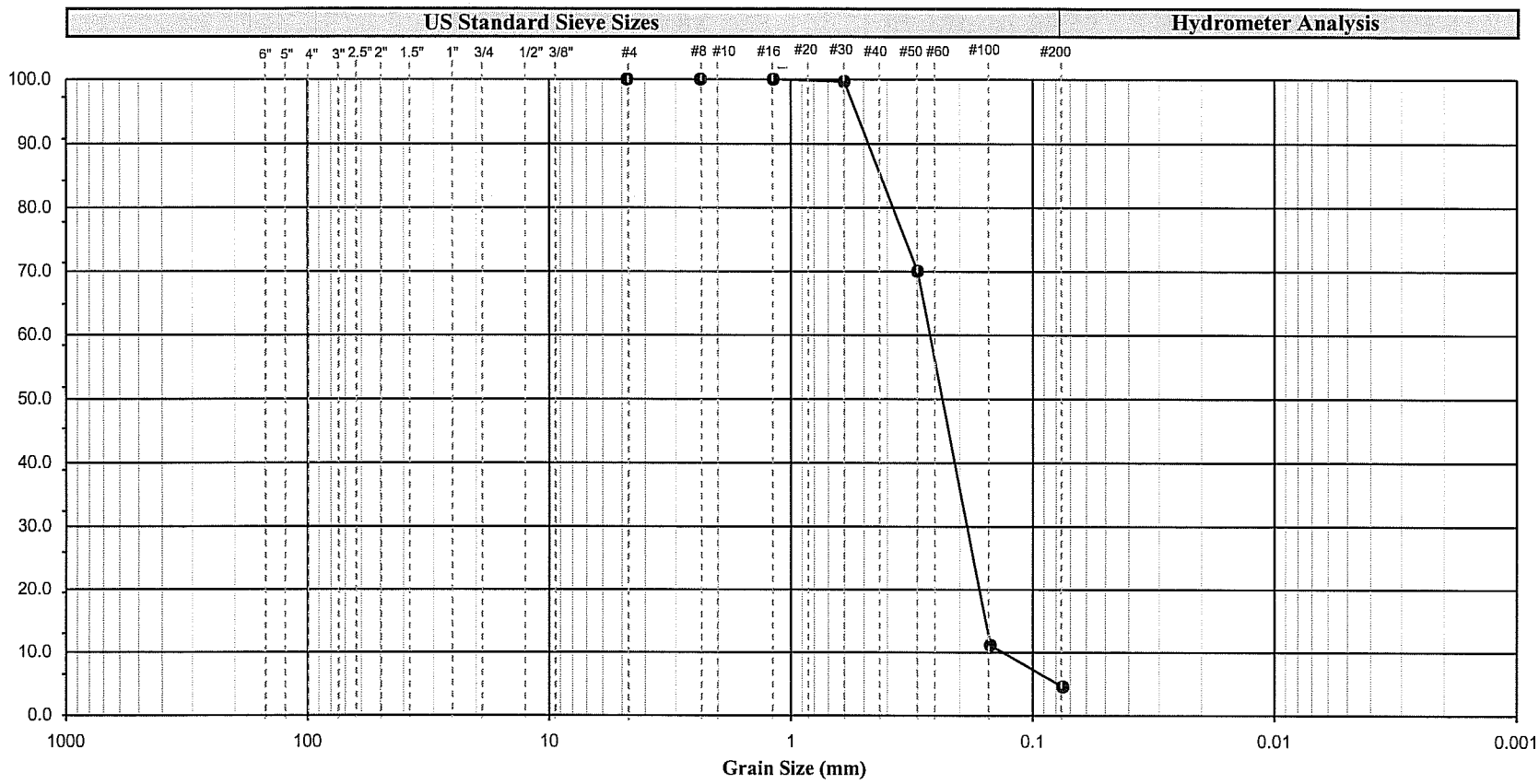
BATA / Antioch Bridge

Project No. : 06-155

Date : 04/06/07

GRAIN SIZE ANALYSIS
(ASTM D-422-63)

Figure No. :



Cobbles	Gravel		Sand			Silt or Clay
	Coarse	Fine	Coarse	Medium	Fine	

Symbol	Boring Number	Sample Number	Depth (ft)		Depth (m)		Soil Color	Soil Description	U.S.C.S.
●	06-10	S-6	30.5	32.0	9.30	9.76	Dark Gray	Poorly graded sand with silt	SP-SM
Remark									

Earth Mechanics, Inc.
Geotechnical and Earthquake Engineering

BATA / Antioch Bridge

Project No. : *06-155* **Date :** *04/06/07*

GRAIN SIZE ANALYSIS
(ASTM D-422-63)

Figure No. :

PARTICLE SIZE ANALYSIS OF SOIL

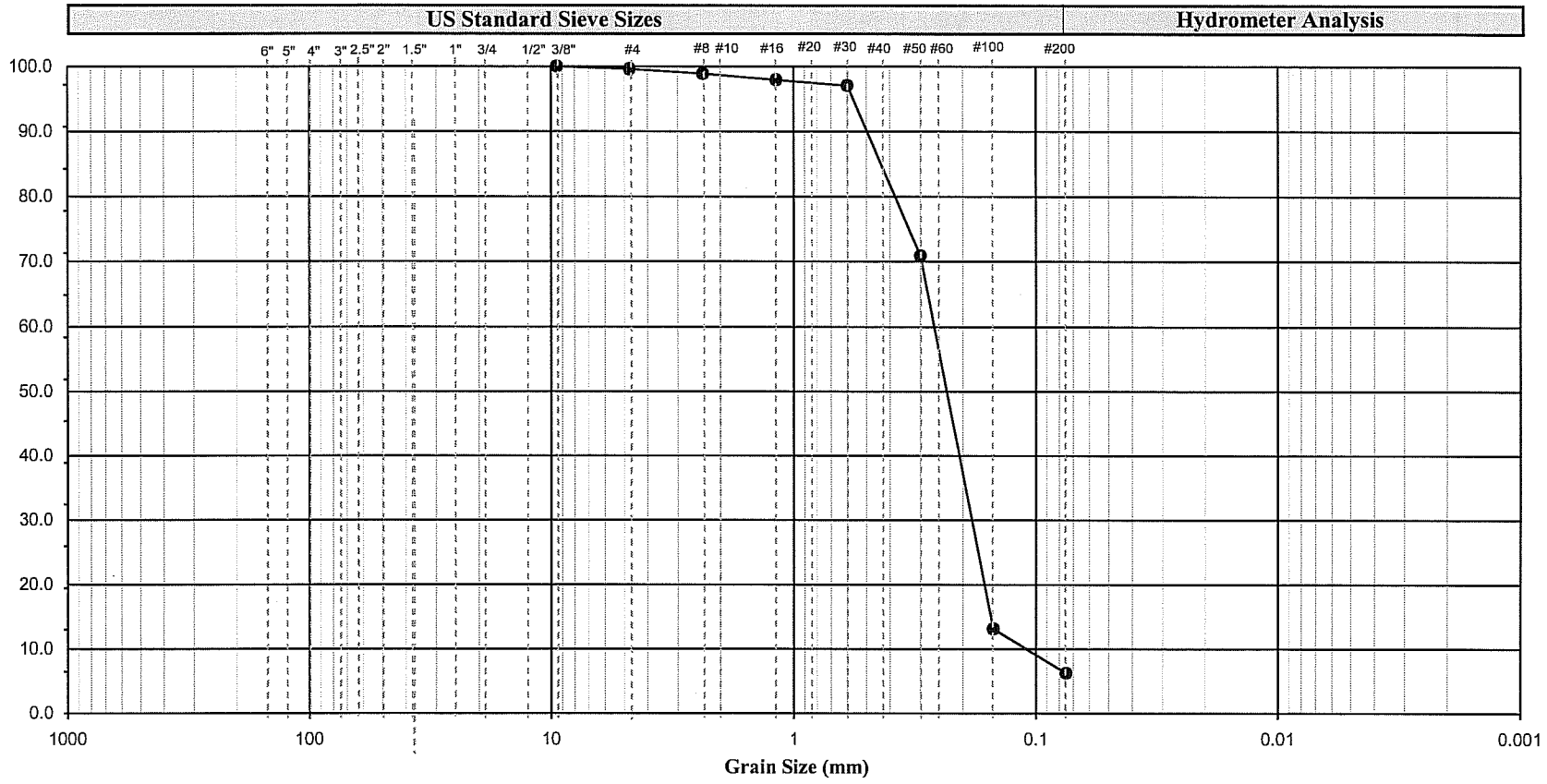
ASTM D-422-63 (Rev. 1990) / CT - 202, 203

Project No : 06-155	Project Name : BATA / Antioch Bridge
Standard : ☑ CAL. TRAN. ☐ ASTM ☐ OTHER	

Prepared By : M.T.	Date : 04/02/07	Tested By : M.T.	Date : 04/06/07	Checked By : R.J.							
Washed By : M.T.	Date : 04/05/07	Computed By : C.Y.	Date : 05/30/07	Date : 05/30/07							
Boring No. : 06-10	Depth : (ft) : 51.0	52.5		Sieve	Cimulative Weight	(%)		Sieve	Cimulative Weight	(%)	
Sample No. : S-10	(m) : 15.56	16.01		5"				No. 8	3.27	98.92	
Description : Dark Olive Gray, Poorly Graded Sand with Silt (SP-SM)				4"				No. 10			
	Before Washing Sample		After Wet Sieve	3"				No. 16	6.27	97.93	
	Tested	Moisture		2.5"				No. 20			
Container Number	S-13	S-13	S-13	2.0"				No. 30	8.93	97.06	
Wet Wt. of Soil + Cont. (gm)	491.80	491.80		1.5"				No. 40			
Dry Wt. of Soil + Cont. (gm)		417.03	398.43	1.0"				No. 50	88.33	70.89	
Weight of Container (gm)	113.63	113.63	113.63	3/4"				No. 60			
Weight of Dry Soil (gm)	303.40	303.4	284.8	1/2"				No. 100	263.76	13.07	
Moisture Content (%)		24.64		3/8"	0.00	100.00		No. 200	284.43	6.25	
Remark :				No. 4	1.31	99.57		Pan	284.90		
				Cu :	2.3			Gravel	Sand	Fine	
4				Cc :	1.2			0	94	6	

Prepared By : M.T.	Date : 04/02/07	Tested By : M.T.	Date : 04/06/07	Checked By : R.J.							
Washed By : M.T.	Date : 04/05/07	Computed By : C.Y.	Date : 05/30/07	Date : 05/29/07							
Boring No. : 06-10	Depth : (ft) : 71.0	72.5		Sieve	Cimulative Weight	(%)		Sieve	Cimulative Weight	(%)	
Sample No. : S-14	(m) : 21.66	22.11		5"				No. 8	163.89	50.18	
Description : Dark Gray, Well Graded Sand with Silt and Gravel (SW-SM)				4"				No. 10			
	Before Washing Sample		After Wet Sieve	3"				No. 16	249.50	24.16	
	Tested	Moisture		2.5"				No. 20			
Container Number	S-8	S-8	S-8	2.0"				No. 30	276.81	15.86	
Wet Wt. of Soil + Cont. (gm)	493.16	493.16		1.5"				No. 40			
Dry Wt. of Soil + Cont. (gm)		447.27	422.90	1.0"				No. 50	290.19	11.79	
Weight of Container (gm)	118.28	118.28	118.28	3/4"				No. 60			
Weight of Dry Soil (gm)	328.99	328.99	304.62	1/2"	0.00	100.00		No. 100	301.06	8.49	
Moisture Content (%)		13.95		3/8"	16.36	95.03		No. 200	304.20	7.54	
Remark :				No. 4	73.85	77.55		Pan	304.45		
				Cu :	14.7			Gravel	Sand	Fine	
5				Cc :	3.0			22	70	8	

Prepared By : M.T.	Date : 04/02/07	Tested By : M.T.	Date : 04/06/07	Checked By : R.J.							
Washed By : M.T.	Date : 04/05/07	Computed By : C.Y.	Date : 05/30/07	Date : 05/30/07							
Boring No. : 06-10	Depth : (ft) : 76.0	77.5		Sieve	Cimulative Weight	(%)		Sieve	Cimulative Weight	(%)	
Sample No. : S-16	(m) : 23.18	23.64		5"				No. 8	29.13	90.57	
Description : Dark Gray, Poorly Graded Sand (SP)				4"				No. 10			
	Before Washing Sample		After Wet Sieve	3"				No. 16	45.42	85.30	
	Tested	Moisture		2.5"				No. 20			
Container Number	S-10	S-10	S-10	2.0"				No. 30	105.21	65.95	
Wet Wt. of Soil + Cont. (gm)	483.05	483.05		1.5"				No. 40			
Dry Wt. of Soil + Cont. (gm)		428.11	414.76	1.0"				No. 50	233.20	24.53	
Weight of Container (gm)	119.12	119.12	119.12	3/4"				No. 60			
Weight of Dry Soil (gm)	308.99	308.99	295.64	1/2"	0.00	100.00		No. 100	285.89	7.48	
Moisture Content (%)		17.78		3/8"	3.63	98.83		No. 200	295.43	4.39	
Remark :				No. 4	18.12	94.14		Pan	295.69		
				Cu :	3.2			Gravel	Sand	Fine	
6				Cc :	1.2			6	90	4	



Cobbles	Gravel		Sand			Silt or Clay
	Coarse	Fine	Coarse	Medium	Fine	

Symbol	Boring Number	Sample Number	Depth (ft)		Depth (m)		Soil Color	Soil Description	U.S.C.S.
●	06-10	S-10	51.0	52.5	15.56	16.01	Dark Olive Gray	Poorly graded sand with silt	SP-SM
Remark									

Earth Mechanics, Inc.
Geotechnical and Earthquake Engineering

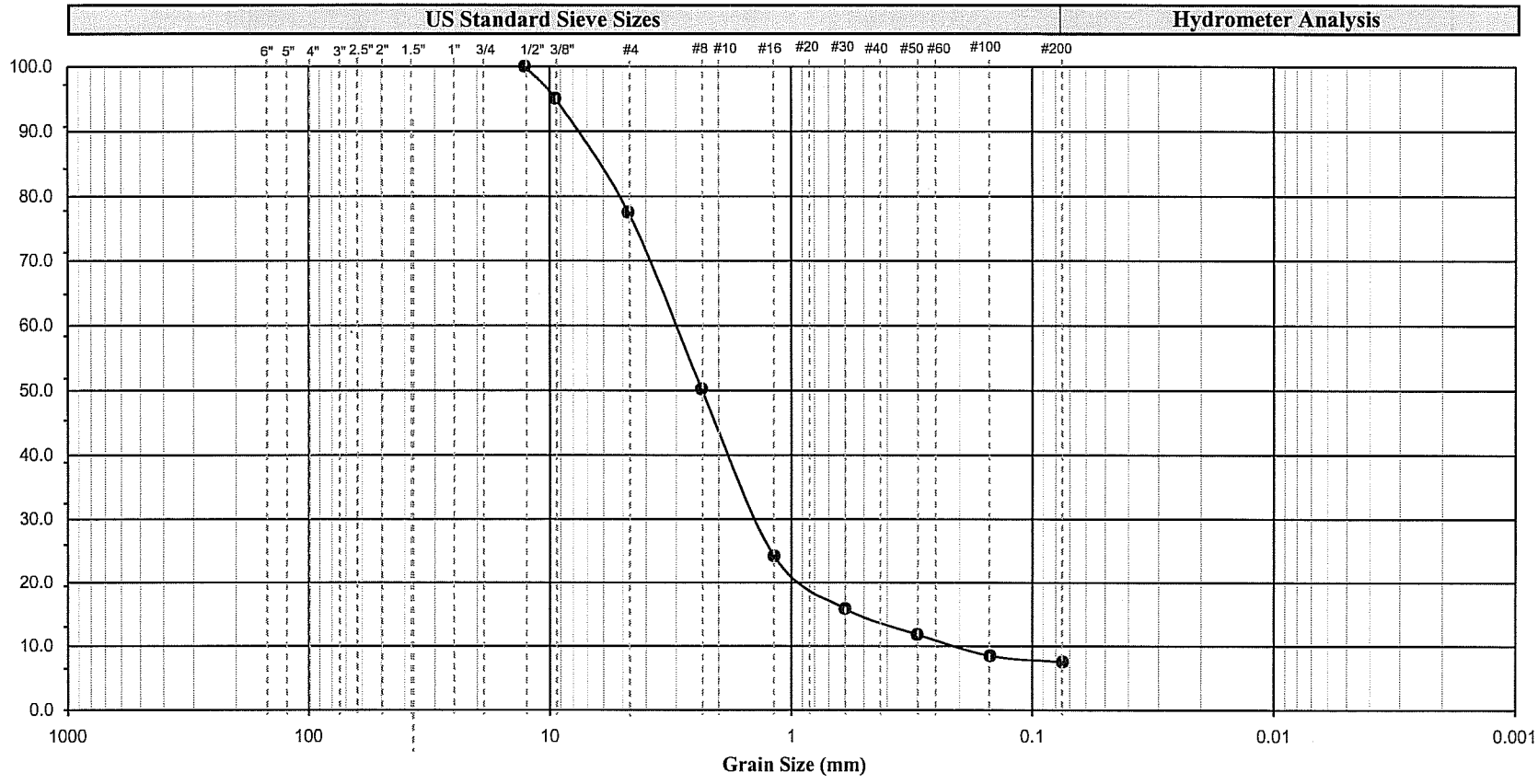
BATA / Antioch Bridge

Project No. : 06-155

Date : 04/06/07

GRAIN SIZE ANALYSIS
(ASTM D-422-63)

Figure No. :



Cobbles	Gravel		Sand			Silt or Clay
	Coarse	Fine	Coarse	Medium	Fine	

Symbol	Boring Number	Sample Number	Depth (ft)		Depth (m)		Soil Color	Soil Description	U.S.C.S.
●	06-10	S-14	71.0	72.5	21.66	22.11	Dark Gray	Well graded sand with silt with gravel	SW-SM
Remark									

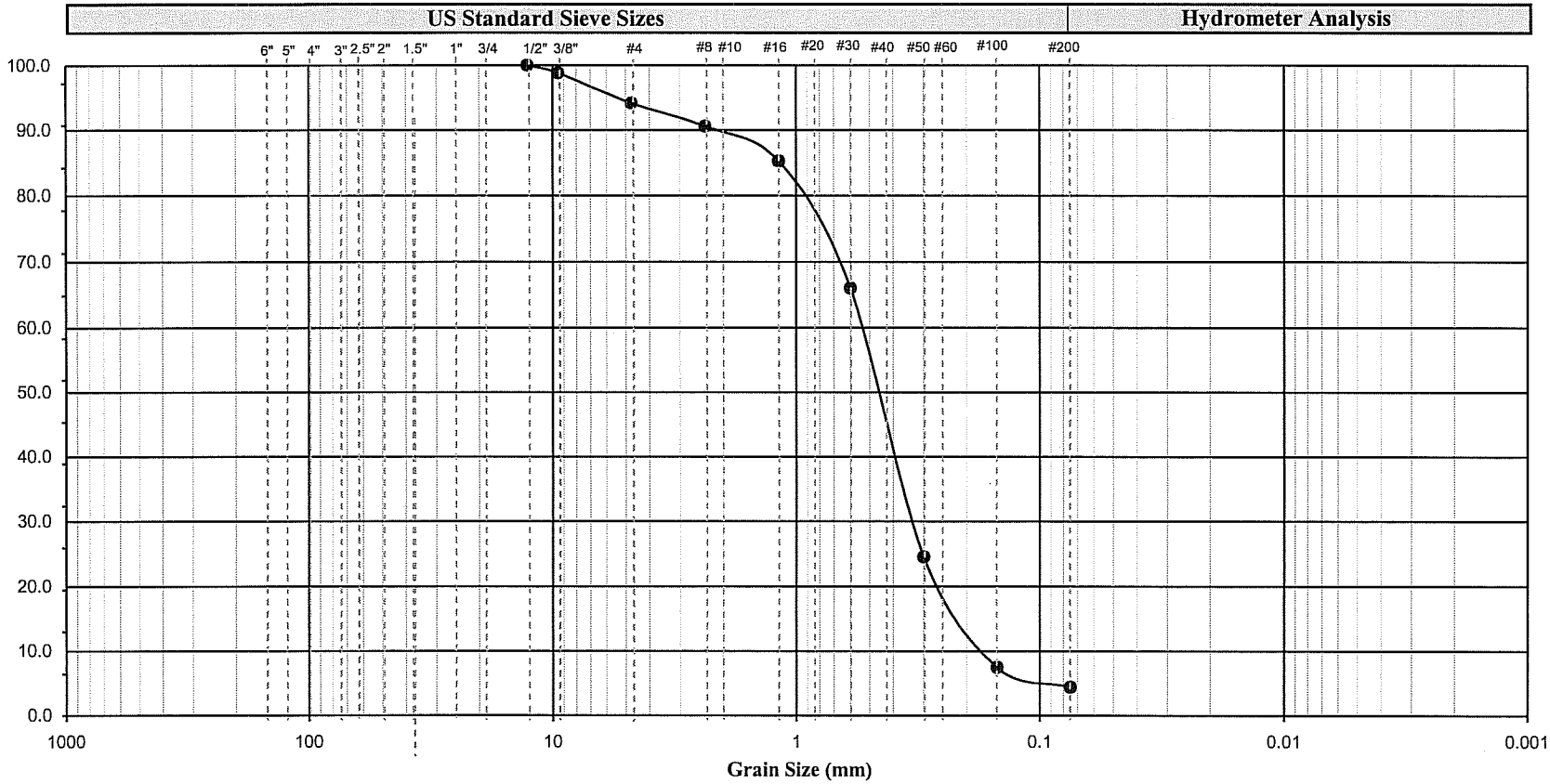
Earth Mechanics, Inc.
Geotechnical and Earthquake Engineering

BATA / Antioch Bridge

Project No. : 06-155 Date : 04/06/07

GRAIN SIZE ANALYSIS
(ASTM D-422-63)

Figure No. :



Cobbles	Gravel		Sand			Silt or Clay
	Coarse	Fine	Coarse	Medium	Fine	

Symbol	Boring Number	Sample Number	Depth (ft)		Depth (m)		Soil Color	Soil Description	U.S.C.S.
●	06-10	S-16	76.0	77.5	23.18	23.64	Dark Gray	Poorly graded sand	SP
Remark									

Earth Mechanics, Inc.
Geotechnical and Earthquake Engineering

BATA / Antioch Bridge

Project No. : *06-155* **Date :** *04/06/07*

GRAIN SIZE ANALYSIS
(ASTM D-422-63)

Figure No. :

ATTERBERG LIMITS

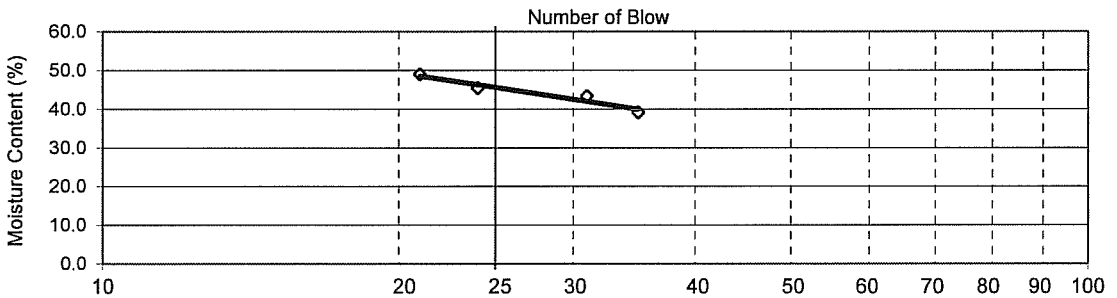
ASTM D-4318-84 / CT-204

Project No: 06-155 Project Name: BATA/ Antioch Bridge

Boring Number: 06-6	Depth (ft/m): 46.0 ft				1
Sample Number: S-9	Description: CL				
Prepared By: M.T.	Date: 03/28/07	Checked By:			
Pulverized By:	Date:			Container Number	
Tested By: M.T.	Date: 03/29/07			Air:	G-3
Computed By: M.T.	Date: 03/30/07			Field:	

Trial Number	Field Moisture					Plastic Limit	
		1	2	3	4	1	2
Number of Blow		35	31	24	21		
Can Number		25	16	18	28	29	30
Wt. Wet Soil +Can (gm)		51.63	45.04	47.37	50.07	37.02	35.00
Wt. Dry Soil +Can (gm)		45.61	38.54	40.24	43.32	35.30	33.39
Weight of Can (gm)		30.24	23.55	24.54	29.54	27.49	25.96
Water Content (%)		39.2	43.4	45.4	49.0	22.0	21.7

Liquid Limit (LL, %):	46	Plastic Limit (PL, %):	22	Plastic Index (PI, %):	24

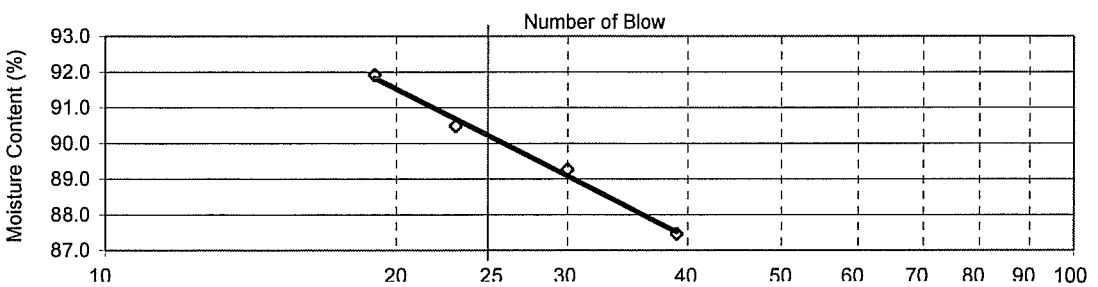


Remark:

Boring Number: 06-8	Depth (ft/m): 36.0 ft				2
Sample Number: D-8	Description: MH				
Prepared By: M.T.	Date: 04/04/07	Checked By:		Date:	
Pulverized By:	Date:			Container Number	
Tested By: M.T.	Date: 04/07/07			Air:	G-2
Computed By: M.T.	Date: 04/08/07			Field:	

Trial Number	Field Moisture					Plastic Limit	
		1	2	3	4	1	2
Number of Blow		39	30	23	19		
Can Number		25	26	27	28	29	30
Wt. Wet Soil +Can (gm)		46.84	46.84	46.52	45.68	37.67	36.12
Wt. Dry Soil +Can (gm)		39.10	39.44	38.44	37.95	34.76	33.16
Weight of Can (gm)		30.25	31.15	29.51	29.54	27.49	25.97
Water Content (%)		87.5	89.3	90.5	91.9	40.0	41.2

Liquid Limit (LL,%)	90	Plastic Limit PL,%)	41	Plastic Index (PI,%)	49



Remark:

ATTERBERG LIMITS

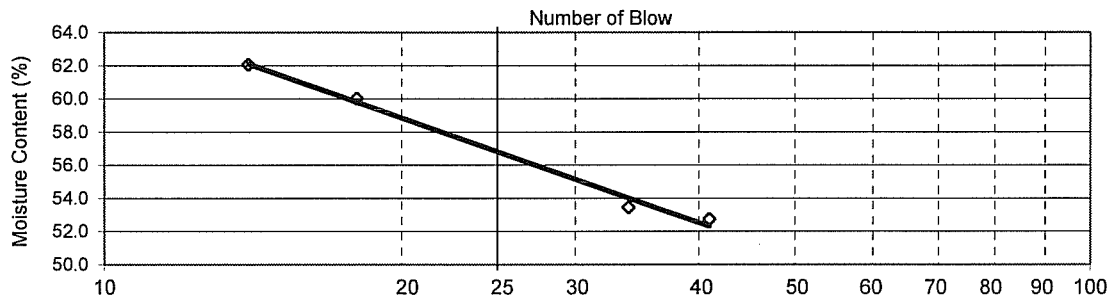
ASTM D-4318-84 / CT-204

Project No: 06-155 Project Name: BATA/ Antioch Bridge

Boring Number: 06-9	Depth (ft/m): 100.0 ft				1
Sample Number: S-20	Description: CH				
Prepared By: M.T.	Date: 04/04/07	Checked By:			
Pulverized By:	Date:			Container Number	
Tested By: M.T.	Date: 04/07/07			Air:	G-7
Computed By: M.T.	Date: 04/08/07			Field:	

Trial Number	Field Moisture					Plastic Limit	
		1	2	3	4	1	2
Number of Blow		41	34	18	14		
Can Number		31	32	33	34	35	36
Wt. Wet Soil +Can (gm)		44.33	42.29	42.77	43.15	31.11	32.07
Wt. Dry Soil +Can (gm)		36.71	35.33	34.74	35.23	28.97	30.12
Weight of Can (gm)		22.26	22.31	21.36	22.47	21.14	22.94
Water Content (%)		52.7	53.5	60.0	62.1	27.3	27.2

Liquid Limit (LL, %):	**57**	**Plastic Limit (PL, %):**	**27**	**Plastic Index (PI, %):**	**30**

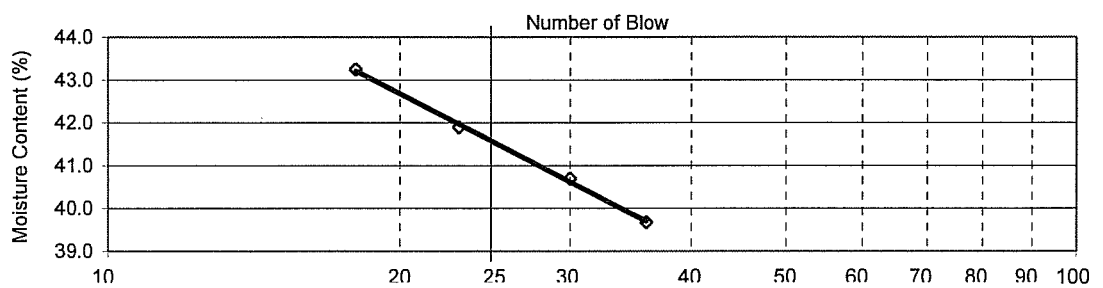


Remark:

Boring Number: 06-10	Depth (ft/m): 101.0 ft				2
Sample Number: S-21	Description: CL				
Prepared By: M.T.	Date: 04/04/07	Checked By:		Date:	
Pulverized By:	Date:			Container Number	
Tested By: M.T.	Date: 04/07/07			Air:	G-10
Computed By: M.T.	Date: 04/08/07			Field:	

Trial Number	Field Moisture					Plastic Limit	
		1	2	3	4	1	2
Number of Blow		36	30	23	18		
Can Number		13	14	15	16	17	18
Wt. Wet Soil +Can (gm)		49.10	44.51	44.27	45.61	35.59	34.77
Wt. Dry Soil +Can (gm)		43.12	38.41	38.25	38.95	34.04	33.25
Weight of Can (gm)		28.05	23.42	23.88	23.55	25.45	24.55
Water Content (%)		39.7	40.7	41.9	43.2	18.0	17.5

Liquid Limit (LL,%)	**42**	**Plastic Limit PL,%)**	**18**	**Plastic Index (PI,%)**	**24**



Remark:

ONE-DIMENSIONAL CONSOLIDATION OF SOIL

ASTM D-2435 / CT-219

Device No. : 1

Project Name : *BATA / Antioch Bridge*
Project No. : *06-155*
Boring No. : *06-6*
Sample No. : *D-3*
Depth (ft / m) : *15.0* *4.58*
File No. :
Soil Description : *Dark Gray, Lean Clay with Organic (CL)*

Set up By :	*R.J*	**Date :**	*3/20/2007*
Tested By :	*R.J*	**Date :**	*3/20-3/30/2007*
Time Rate Took By :	*R.J*	**Date :**	*3/25/2007*
Computer By :	*CY*	**Date :**	*5/31/2007*
Checked By :	*R.J*	**Date :**	*5/31/2007*

Method (A) : ☑ Constant load increment duration of 24 hours or multiples there for. Minium of two Time -deformation reading are required.

Method (B) : ☐ Time-deformation reading are required on all load increments. Successive load increments are applied after 100 % primary consolidation is reached, or at constant time increments are described in Test Method (A)

1

Sample	(inch)	(mm)	Vertical Load	(ksf)	(kPa)	Vertical Load	(ksf)	(kPa)
Internal Diameter	2.42	61.47	Add Water at	0.25	11.97	Reload to	-	-
Height (Intial)	1.00	25.40	Load to	8.00	383.04	Rebound to	-	-
Height (Final)	0.5973	15.17	Rebound to	0.25	11.97	Time rate taking at	4.00	190.81

Date	Time	Elapsed Time (min.)	Load (ksf)	Load (kPa)	Dial Reading (in)	Dial Reading (mm)	Consol. (%)
3/20/2007	12:25	0:00:00	Seating Load		0.04520	1.15	
	12:35		2.0	95.8	0.05000	1.27	0.00
3/21/2007	7:57	0:00:00	0.25	12.0	0.07050	1.79	2.05
			Add Water				
3/22/2007	8:05	0:00:00	0.25	12.0	0.07030	1.79	2.03
3/23/2007	8:09	0:00:00	0.50	23.9	0.10095	2.56	5.10
3/24/2007	7:19	0:00:00	1.00	47.9	0.19210	4.88	14.21
3/25/2007	8:16	0:00:00	2.00	95.8	0.33300	8.46	28.30
3/25/2007	8:31	0.00	4.0	191.5			0.00
		0.10	4.0	191.5	0.33700	8.56	28.70
		0.25	4.0	191.5	0.33890	8.61	28.89
		0.50	4.0	191.5	0.34080	8.66	29.08
		1	4.0	191.5	0.34420	8.74	29.42
		2	4.0	191.5	0.34930	8.87	29.93
		4	4.0	191.5	0.35680	9.06	30.68
		8	4.0	191.5	0.36770	9.34	31.77
		16	4.0	191.5	0.37720	9.58	32.72
		30	4.0	191.5	0.38800	9.86	33.80
		60	4.0	191.5	0.39870	10.13	34.87
		120	4.0	191.5	0.40690	10.34	35.69
		256	4.0	191.5	0.41380	10.51	36.38
		500	4.0	191.5	0.42090	10.69	37.09
		1475	4.0	191.5	0.42620	10.83	37.62
3/27/2007	7:50	0:00:00	8.00	383.0	0.5097	12.95	45.97
3/28/2007	8:07	0:00:00	2.00	95.8	0.4911	12.47	44.11
3/29/2007	8:09	0:00:00	0.25	12.0	0.4479	11.38	39.79

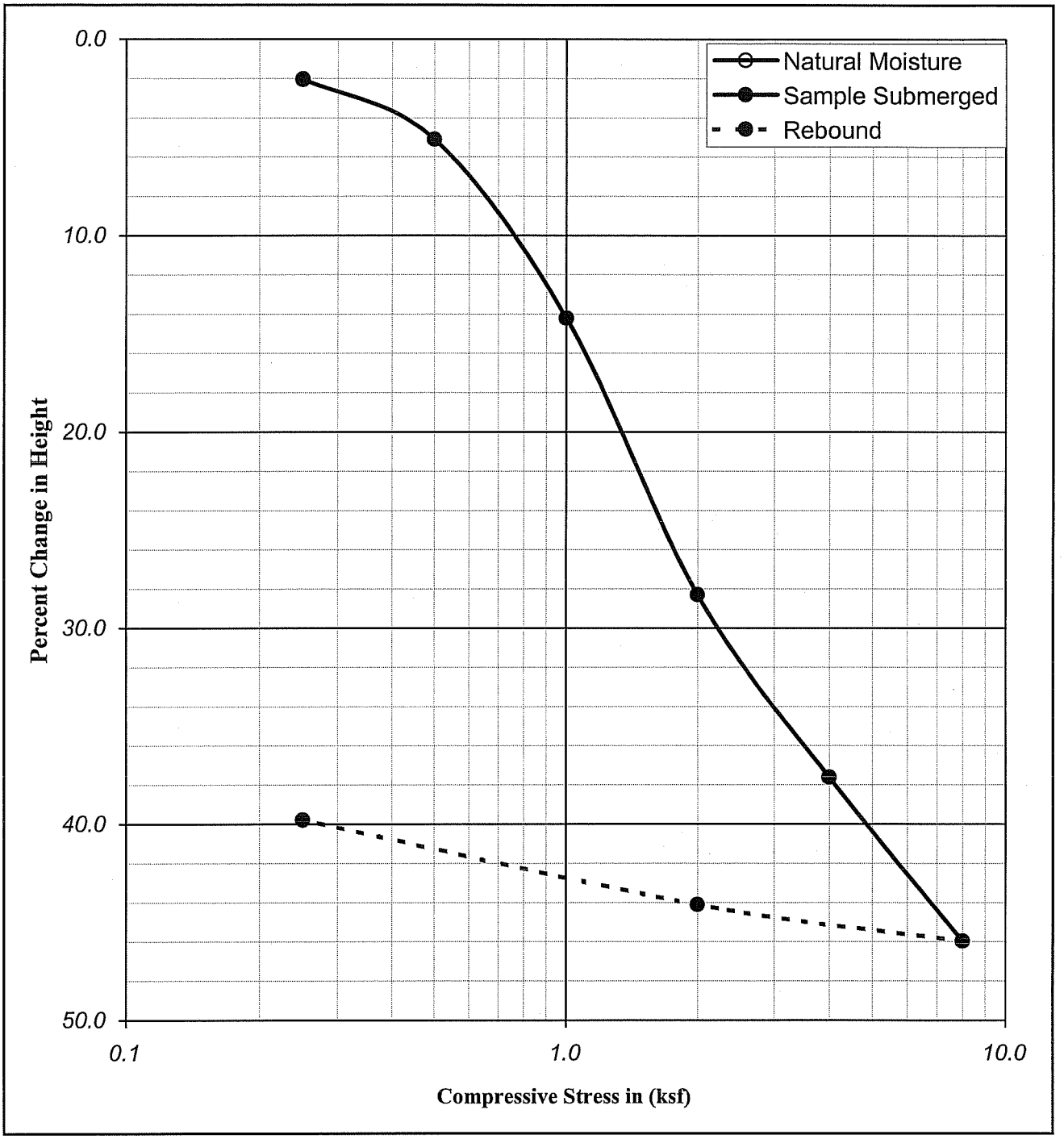
	Before	After
Weight of wet soil + ring (gm)	140.36	
Weight of ring (gm)	42.90	
Weight of wet soil + ring + container (gm)		170.66
Weight of dry soil + ring + container (gm)		141.39
No. 16 Weight of container (gm)		57.41
Weight of ring + container (gm)		100.31
Moisture Content (%)	137.24	71.25
Dial Reading (inch)	0.05	0.04
Sample Volume (ft^3)	0.0027	0.0016
Wet Density (pcf)	80.7	97.5
Dry Density (pcf)	34.02	56.96

SQRT Time
0.00
0.32
0.50
0.71
1.00
1.41
2.00
2.83
4.00
5.48
7.75
10.95
16.00
22.36
38.41

Date	Time	Elapsed Time (min.)	Load (ksf)	Load (kPa)	Dial Reading (in)	Dial Reading (mm)	Consol. (%)

Remark

Final Dial Reading 0.4479



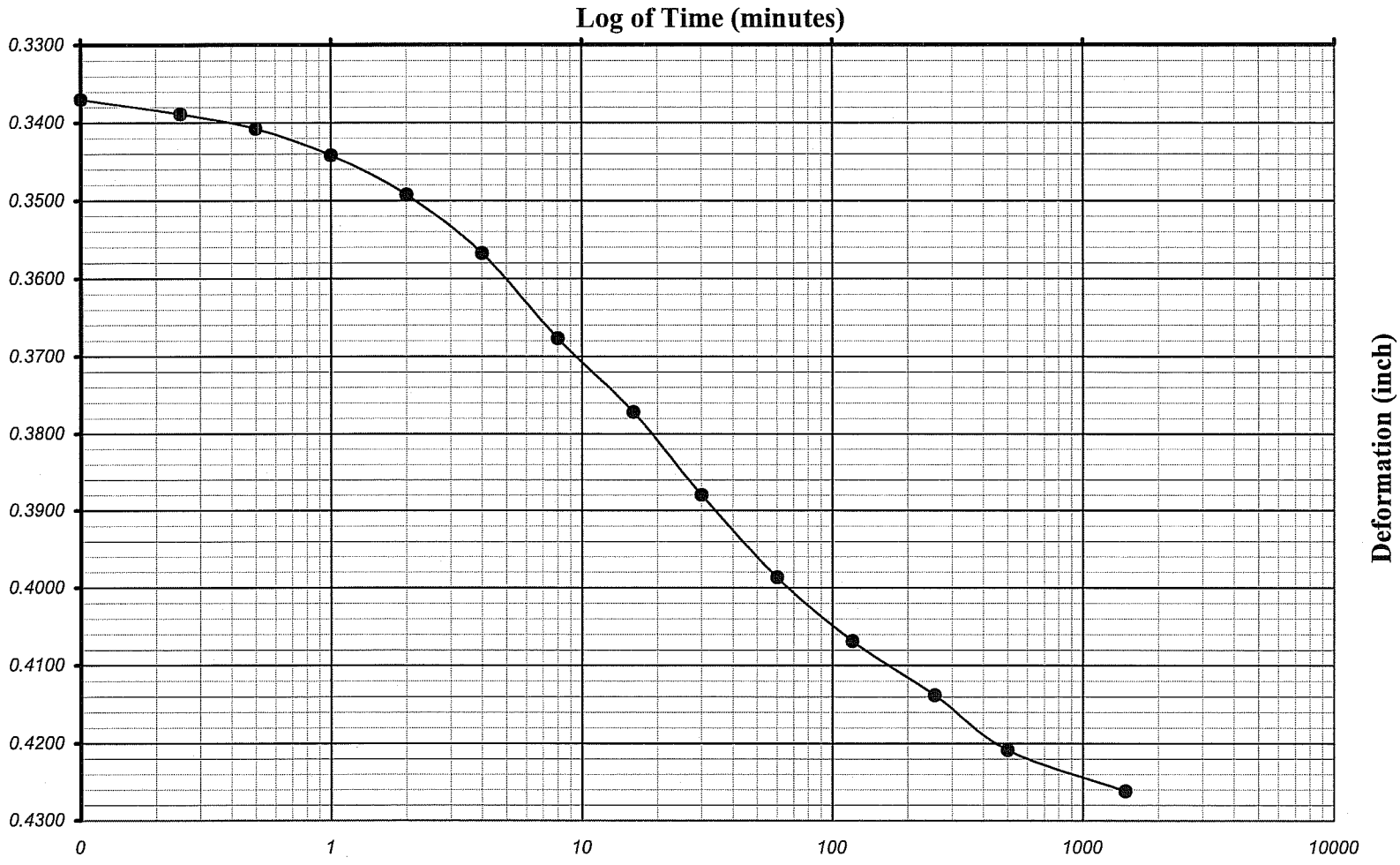
Boring No.		:	06-6		Liquid Limit :	-		Moisture Content (%)	Dry Density (pcf)	Dry Density (kN/m³)	Percent Saturation	Void Ratio
Sample No.		:	D-3		Plastic Limit :	-						
Depth	(ft)	:	15.0	16.5	Plastic Index :	-	Initial	137.24	34.02	5.36	93.71	3.95
	(m)	:	4.58	5.03	Specific Gravity :	2.70	Final	71.25	56.96	8.97	98.19	1.96
Description		:	Dark Gray, Lean Clay with Organic (CL)									

Earth Mechanics, Inc.
Geotechnical and Earthquake Engineering

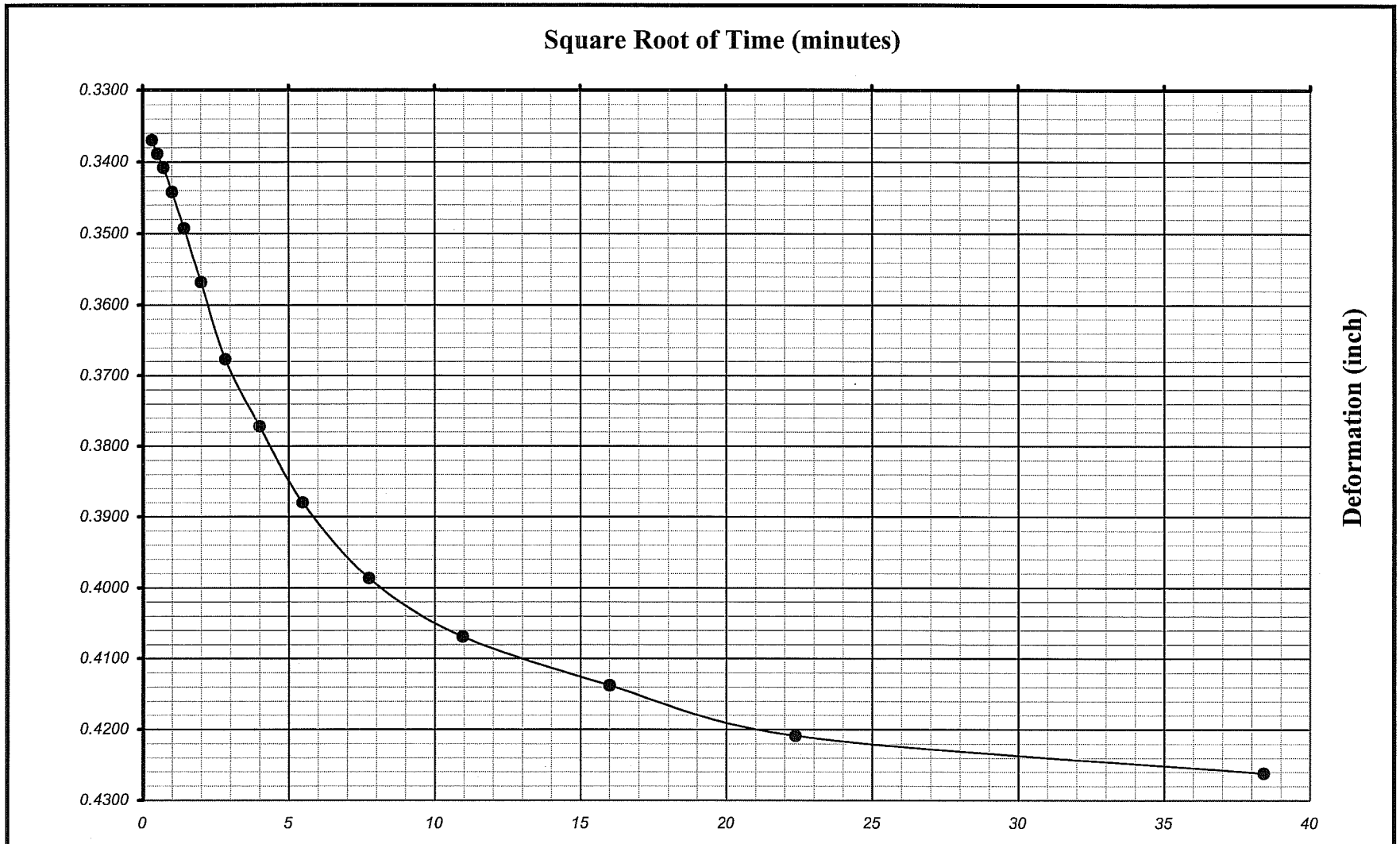
BATA / Antioch Bridge

Project No. : 06-155 05/31/07

CONSOLIDATION TEST
(ASTM D-2435 / CT-219)



Earth Mechanics, Inc. Geotechnical and Earthquake Engineering	***BATA / Antioch Bridge***	**Boring No. :** *06-6*	**One-Dimensional Consolidation of Soil** **Time-Deformation Curve (Log of Time Method)**
		Sample No. : *D-3*	
EMI Project No. : *06-155*		**Depth (ft/m) :** *15.0* *4.6*	**Veritcal Load (ksf/kpa) :** *4.00* *191.5*



Earth Mechanics, Inc. Geotechnical and Earthquake Engineering	***BATA / Antioch Bridge***	**Boring No. :** *06-6*	**One-Dimensional Consolidation of Soil** **Time-Deformation Curve (Square Root of Time Method)**
		Sample No. : *D-3*	
EMI Project No. : *06-155*		**Depth (ft/m) :** *15.0* *4.6*	**Veritcal Load (ksf/kpa) :** *4.0* *191.5*

ONE-DIMENSIONAL CONSOLIDATION OF SOIL

ASTM D-2435 / CT-219

Device No. : 5

Project Name : *BATA / Antioch Bridge*
Project No. : *06-155*
Boring No. : *06-6*
Sample No. : *D-22*
Depth (ft / m) : *100.0* | *30.50*
File No. :
Soil Description : *Light Brown, Lean Clay with Sand (CL)*

Set up By :	*R.J*	**Date :**	*3/23/2007*
Tested By :	*R.J*	**Date :**	*3/22-4/2/2007*
Time Rate Took By :	*R.J*	**Date :**	*3/29/2007*
Computer By :	*CY*	**Date :**	*5/31/2007*
Checked By :	*R.J*	**Date :**	*5/31/2007*

Method (A) : ☑ Constant load increment duration of 24 hours or multiples there for. Minium of two Time -deformation reading are required.

Method (B) : ☐ Time-deformation reading are required on all load increments. Successive load increments are applied after 100 % primary consolidation is reached, or at constant time increments are described in Test Method (A)

1

Sample	(inch)	(mm)	Vertical Load	(ksf)	(kPa)	Vertical Load	(ksf)	(kPa)
Internal Diameter	2.42	61.47	Add Water at	0.25	11.97	Reload to	-	-
Height (Intial)	1.00	25.40	Load to	16.00	766.08	Rebound to	-	-
Height (Final)	0.9716	24.68	Rebound to	0.25	11.97	Time rate taking at	8.00	381.62

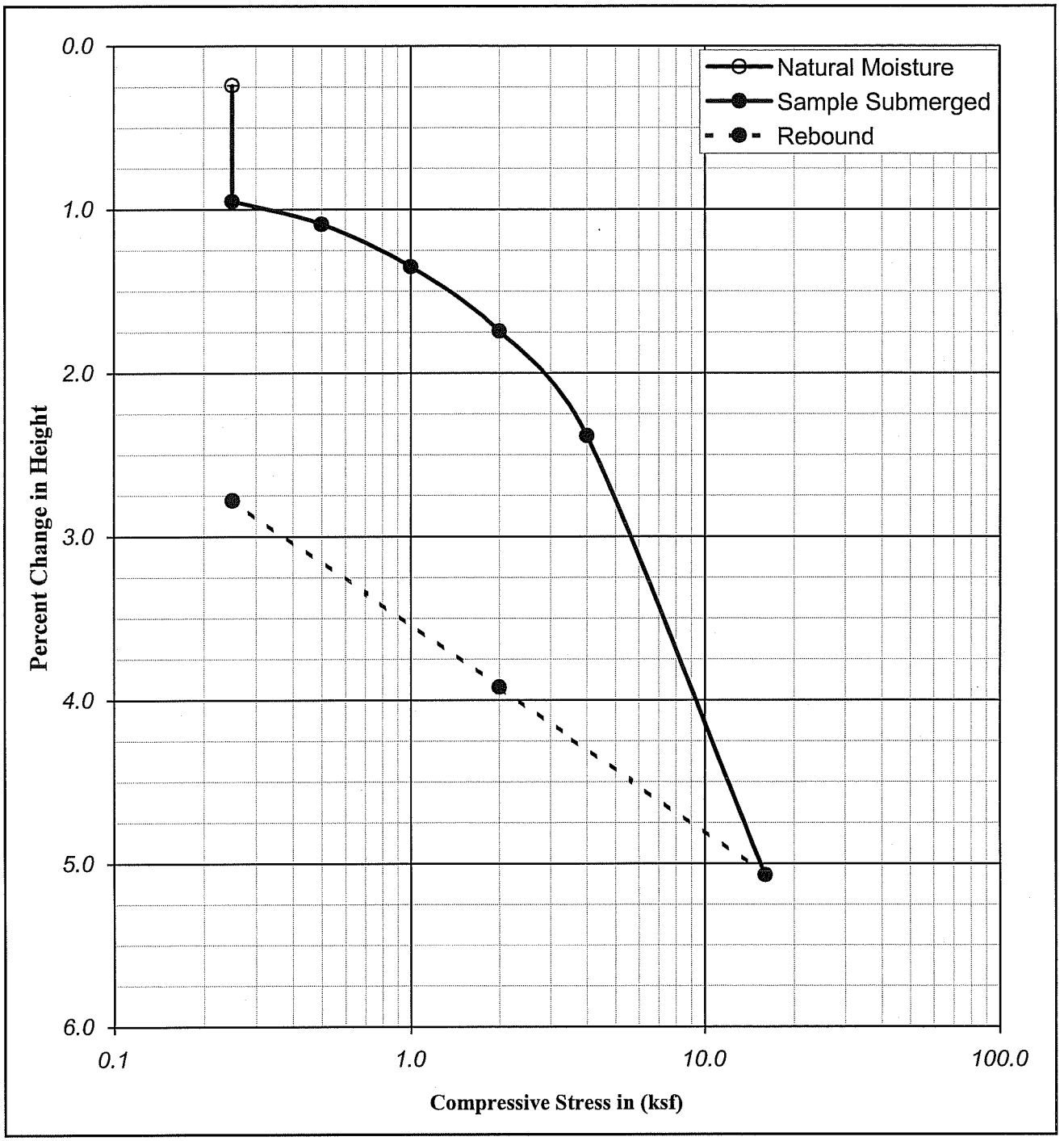
Date	Time	Elapsed Time (min.)	Load (ksf)	Load (kPa)	Dial Reading (in)	Dial Reading (mm)	Consol. (%)
3/23/2007	14:03	0:00:00	Seating		0.03940	1.00	
			Load				
	14:40		2.0	95.8	0.04000	1.02	0.00
3/24/2007	7:22	0:00:00	0.25	12.0	0.04240	1.08	0.24
			Add Water				
3/25/2007	8:17	0:00:00	0.25	12.0	0.04950	1.26	0.95
3/26/2007	8:00	0:00:00	0.50	23.9	0.05090	1.29	1.09
3/27/2007	7:51	0:00:00	1.00	47.9	0.05350	1.36	1.35
3/28/2007	8:09	0:00:00	2.00	95.8	0.05745	1.46	1.74
3/29/2007	8:11	0:00:00	4.00	191.5	0.06385	1.62	2.38
3/29/2007	9:00	0.00	8.0	383.0			
		0.10	8.0	383.0	0.06720	1.71	2.72
		0.25	8.0	383.0	0.06770	1.72	2.77
		0.50	8.0	383.0	0.06825	1.73	2.83
		1	8.0	383.0	0.06895	1.75	2.90
		2	8.0	383.0	0.06975	1.77	2.97
		4	8.0	383.0	0.07065	1.79	3.07
		8	8.0	383.0	0.07140	1.81	3.14
		15	8.0	383.0	0.07190	1.83	3.19
		30	8.0	383.0	0.07240	1.84	3.24
		60	8.0	383.0	0.07275	1.85	3.27
		120	8.0	383.0	0.07320	1.86	3.32
		240	8.0	383.0	0.07380	1.87	3.38
		480	8.0	383.0	0.07450	1.89	3.45
		1440	8.0	383.0	0.07490	1.90	3.49
3/31/2007	7:56	0:00:00	16.00	766.1	0.0907	2.30	5.07
4/1/2007	8:10	0:00:00	2.00	95.8	0.0792	2.01	3.92
4/2/2007	9:20	0:00:00	0.25	12.0	0.0678	1.72	2.78

	Before	After
Weight of wet soil + ring (gm)	181.29	
Weight of ring (gm)	43.26	
Weight of wet soil + ring + container (gm)		239.63
Weight of dry soil + ring + container (gm)		201.47
No. 38 — Weight of container (gm)		58.47
Weight of ring + container (gm)		101.73
Moisture Content (%)	38.39	38.26
Dial Reading (inch)	0.04	0.04
Sample Volume (ft³)	0.0027	0.0026
Wet Density (pcf)	114.3	117.6
Dry Density (pcf)	82.61	85.02

SQRT Time
0.00
0.32
0.50
0.71
1.00
1.41
2.00
2.83
3.87
5.48
7.75
10.95
15.49
21.91
37.95

Date	Time	Elapsed Time (min.)	Load (ksf)	Load (kPa)	Dial Reading (in)	Dial Reading (mm)	Consol. (%)

Remark *Final Dial Reading 0.0678*



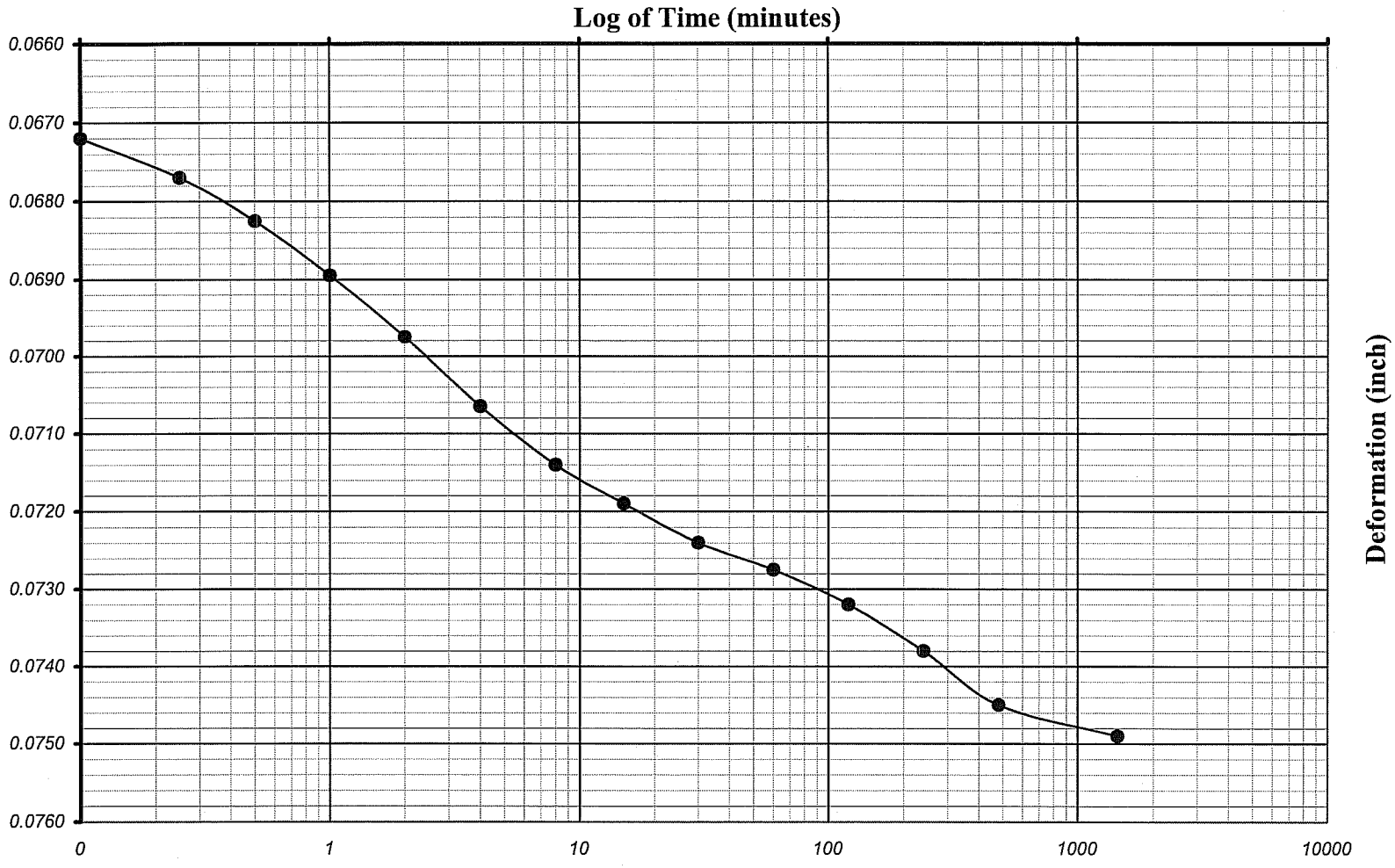
Boring No. : 06-6			Liquid Limit :	-		Moisture Content (%)	Dry Density (pcf)	Dry Density (kN/m³)	Percent Saturation	Void Ratio
Sample No. : D-22			Plastic Limit :	-						
Depth	(ft) : 100.0	101.5	Plastic Index :	-	Initial	38.39	82.61	13.00	99.62	1.04
	(m) : 30.50	30.96	Specific Gravity :	2.70	Final	38.26	85.02	13.38	105.13	0.98
Description : Light Brown, Lean Clay with Sand (CL)										

Earth Mechanics, Inc.
Geotechnical and Earthquake Engineering

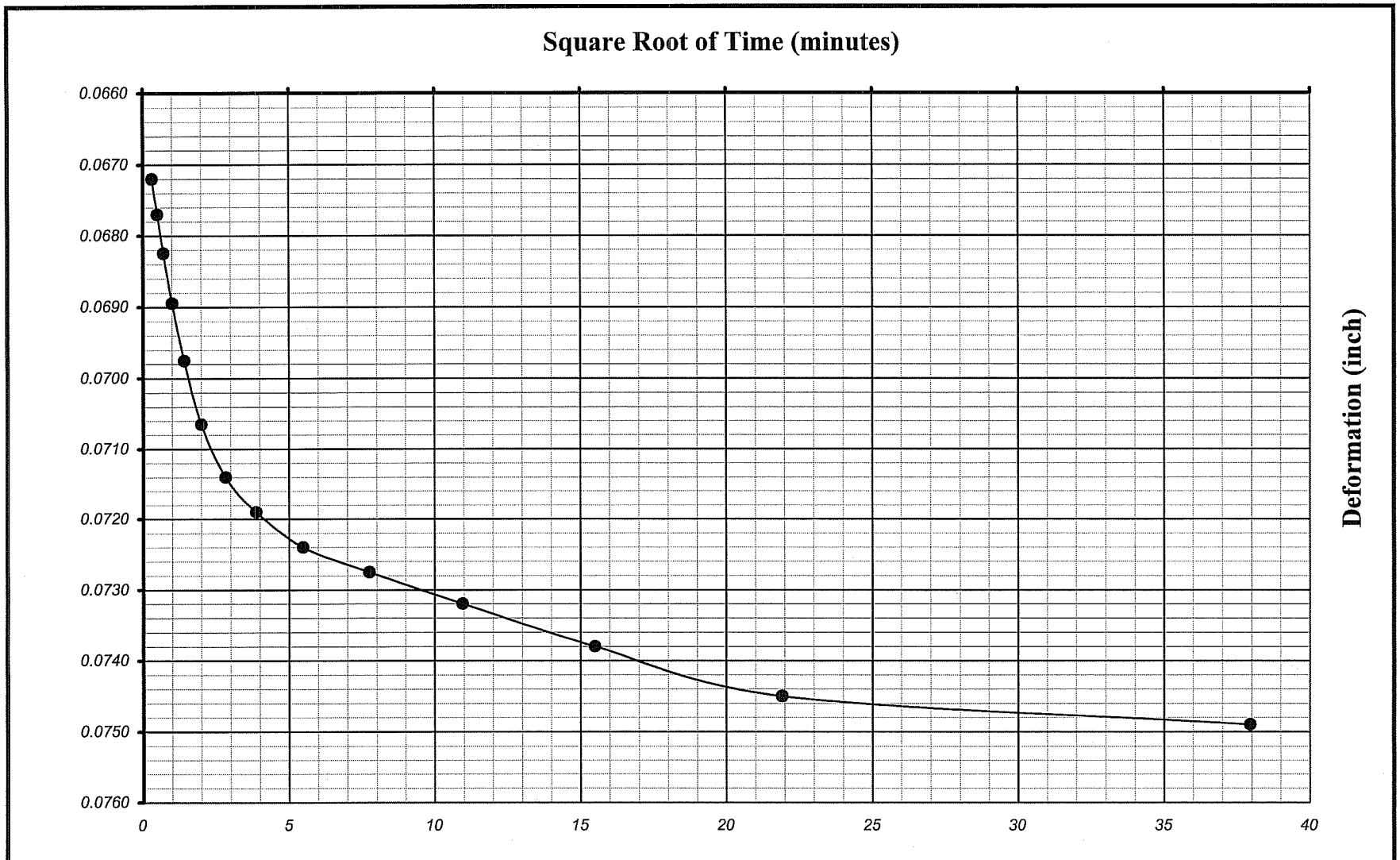
BATA / Antioch Bridge

Project No. : 06-155 05/31/07

CONSOLIDATION TEST
(ASTM D-2435 / CT-219)



Earth Mechanics, Inc. Geotechnical and Earthquake Engineering	***BATA / Antioch Bridge***	**Boring No. :** *06-6*	**One-Dimensional Consolidation of Soil** **Time-Deformation Curve (Log of Time Method)**
		Sample No. : *D-22*	
EMI Project No. : *06-155*		**Depth (ft/m) :** *100.0* *30.5*	**Veritcal Load (ksf/kpa) :** *8.00* *383.0*



Earth Mechanics, Inc. Geotechnical and Earthquake Engineering	***BATA / Antioch Bridge***	**Boring No. :** *06-6*	**One-Dimensional Consolidation of Soil** **Time-Deformation Curve (Square Root of Time Method)**
		Sample No. : *D-22*	
EMI Project No. : *06-155*		**Depth (ft/m) :** *100.0* *30.5*	**Veritcal Load (ksf/kpa) :** *8.0* *383.0*

ONE-DIMENSIONAL CONSOLIDATION OF SOIL

ASTM D-2435 / CT-219

Device No. : 2

Project Name : *BATA / Antioch Bridge*
Project No. : *06-155*
Boring No. : *06-7*
Sample No. : *D-19*
Depth (ft / m) : *94.0* | *28.67*
File No. :
Soil Description : *Olive Gray, Silt with Sand (ML)*

Set up By :	*R.J*	**Date :**	*4/1/2007*
Tested By :	*R.J*	**Date :**	*4/1-4/10/2007*
Time Rate Took By :	*R.J*	**Date :**	*4/6/2007*
Computer By :	*CY*	**Date :**	*5/31/2007*
Checked By :	*R.J*	**Date :**	*5/31/2007*

Method (A) : ☑ Constant load increment duration of 24 hours or multiples there for. Minium of two Time -deformation reading are required.

Method (B) : ☐ Time-deformation reading are required on all load increments. Successive load increments are applied after 100 % primary consolidation is reached, or at constant time increments are described in Test Method (A)

1

Sample	(inch)	(mm)
Internal Diameter	2.42	61.47
Height (Intial)	1.00	25.40
Height (Final)	0.9564	24.29

Vertical Load	(ksf)	(kPa)
Add Water at	0.25	11.97
Load to	16.00	766.08
Rebound to	0.25	11.97

Vertical Load	(ksf)	(kPa)
Reload to	-	-
Rebound to	-	-
Time rate taking at	8.00	381.62

Date	Time	Elapsed Time (min.)	Load (ksf)	Load (kPa)	Dial Reading (in)	Dial Reading (mm)	Consol. (%)
4/1/2007	11:16	0:00:00	Seating Load		0.04950	1.26	
	11:26		2.0	95.8	0.05000	1.27	0.00
4/2/2007	9:19	0:00:00	0.25	12.0	0.05415	1.38	0.41
			Add Water				
4/3/2007	8:07	0:00:00	0.25	12.0	0.05300	1.35	0.30
4/4/2007	8:16	0:00:00	0.50	23.9	0.05410	1.37	0.41
4/5/2007	7:53	0:00:00	1.00	47.9	0.05820	1.48	0.82
4/6/2007	7:40	0:00:00	2.00	95.8	0.06650	1.69	1.65
4/7/2007	7:49	0:00:00	4.00	191.5	0.07660	1.95	2.66
4/7/2007	8:10	0.00	8.0	383.0			
		0.10	8.0	383.0	0.08600	2.18	3.60
		0.25	8.0	383.0	0.08750	2.22	3.75
		0.50	8.0	383.0	0.08830	2.24	3.83
		1	8.0	383.0	0.08900	2.26	3.90
		2	8.0	383.0	0.08955	2.27	3.96
		4	8.0	383.0	0.09010	2.29	4.01
		8	8.0	383.0	0.09070	2.30	4.07
		15	8.0	383.0	0.09120	2.32	4.12
		30	8.0	383.0	0.09180	2.33	4.18
		60	8.0	383.0	0.09230	2.34	4.23
		120	8.0	383.0	0.09285	2.36	4.29
		240	8.0	383.0	0.09345	2.37	4.35
		480	8.0	383.0	0.09410	2.39	4.41
		1440	8.0	383.0	0.09490	2.41	4.49
4/9/2007	6:10	0:00:00	16.00	766.1	0.1175	2.98	6.75
4/10/2007	8:02	0:00:00	2.00	95.8	0.1057	2.68	5.57
4/10/2007	17:55	0:00:00	0.25	12.0	0.0931	2.36	4.31

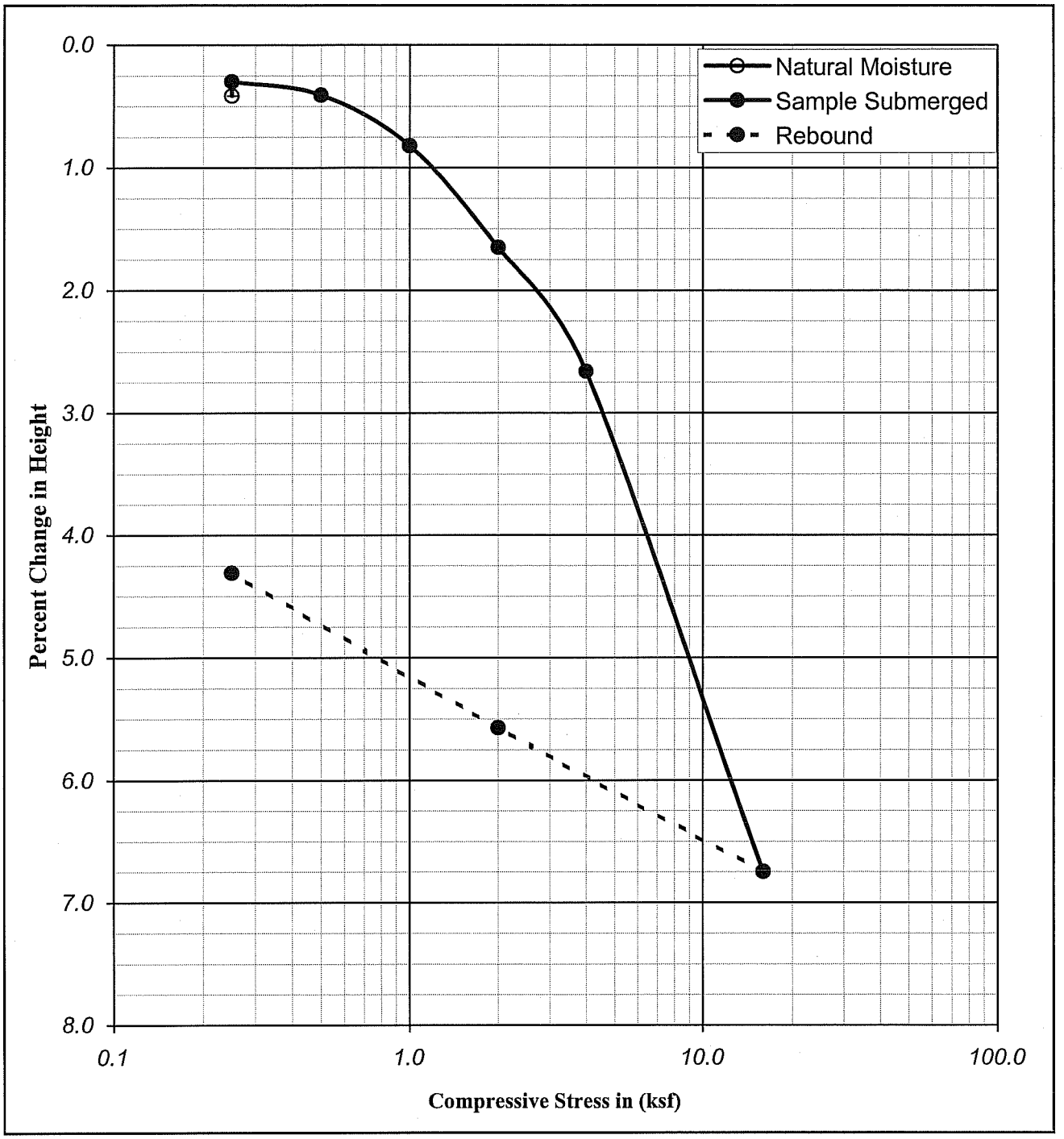
SQRT Time
0.00
0.32
0.50
0.71
1.00
1.41
2.00
2.83
3.87
5.48
7.75
10.95
15.49
21.91
37.95

	Before	After
Weight of wet soil + ring (gm)	188.30	
Weight of ring (gm)	44.89	
Weight of wet soil + ring + container (gm)		245.23
Weight of dry soil + ring + container (gm)		211.03
No. 38 Weight of container (gm)		58.01
Weight of ring + container (gm)		102.90
Moisture Content (%)	32.63	31.63
Dial Reading (inch)	0.05	0.04
Sample Volume (ft³)	0.0027	0.0025
Wet Density (pcf)	118.8	123.3
Dry Density (pcf)	89.56	93.64

Date	Time	Elapsed Time (min.)	Load (ksf)	Load (kPa)	Dial Reading (in)	Dial Reading (mm)	Consol. (%)

Remark

Final Dial Reading 0.0931



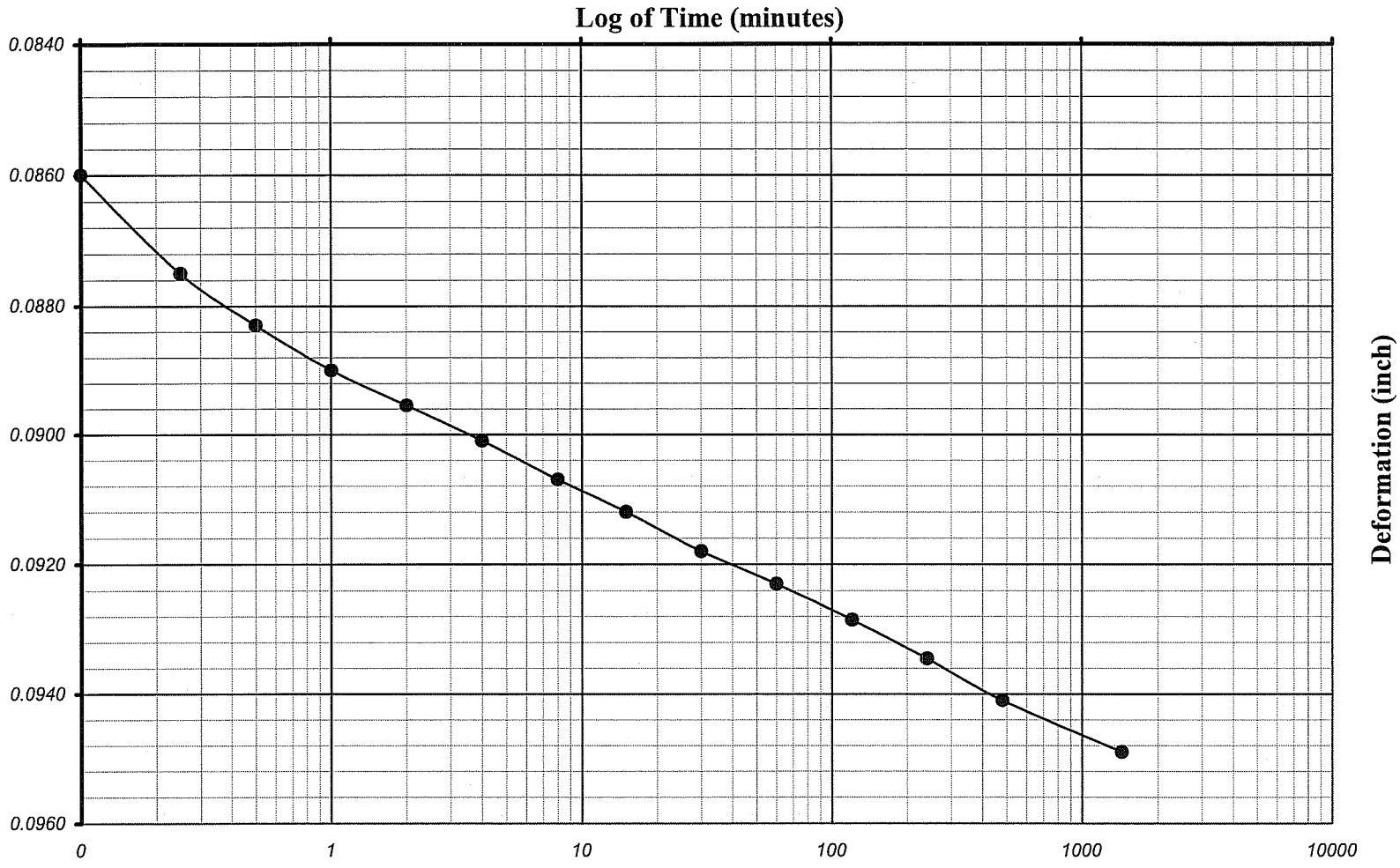
Boring No. : 06-7			Liquid Limit :	-		Moisture Content (%)	Dry Density		Percent Saturation	Void Ratio
Sample No. : D-19			Plastic Limit :	-			(pcf)	(kN/m³)		
Depth	(ft) : 94.0	95.5	Plastic Index :	-	Initial	32.63	89.56	14.10	99.86	0.88
	(m) : 28.67	29.13	Specific Gravity :	2.70	Final	31.63	93.64	14.74	106.73	0.80
Description : Olive Gray, Silt with Sand (ML)										

Earth Mechanics, Inc.
Geotechnical and Earthquake Engineering

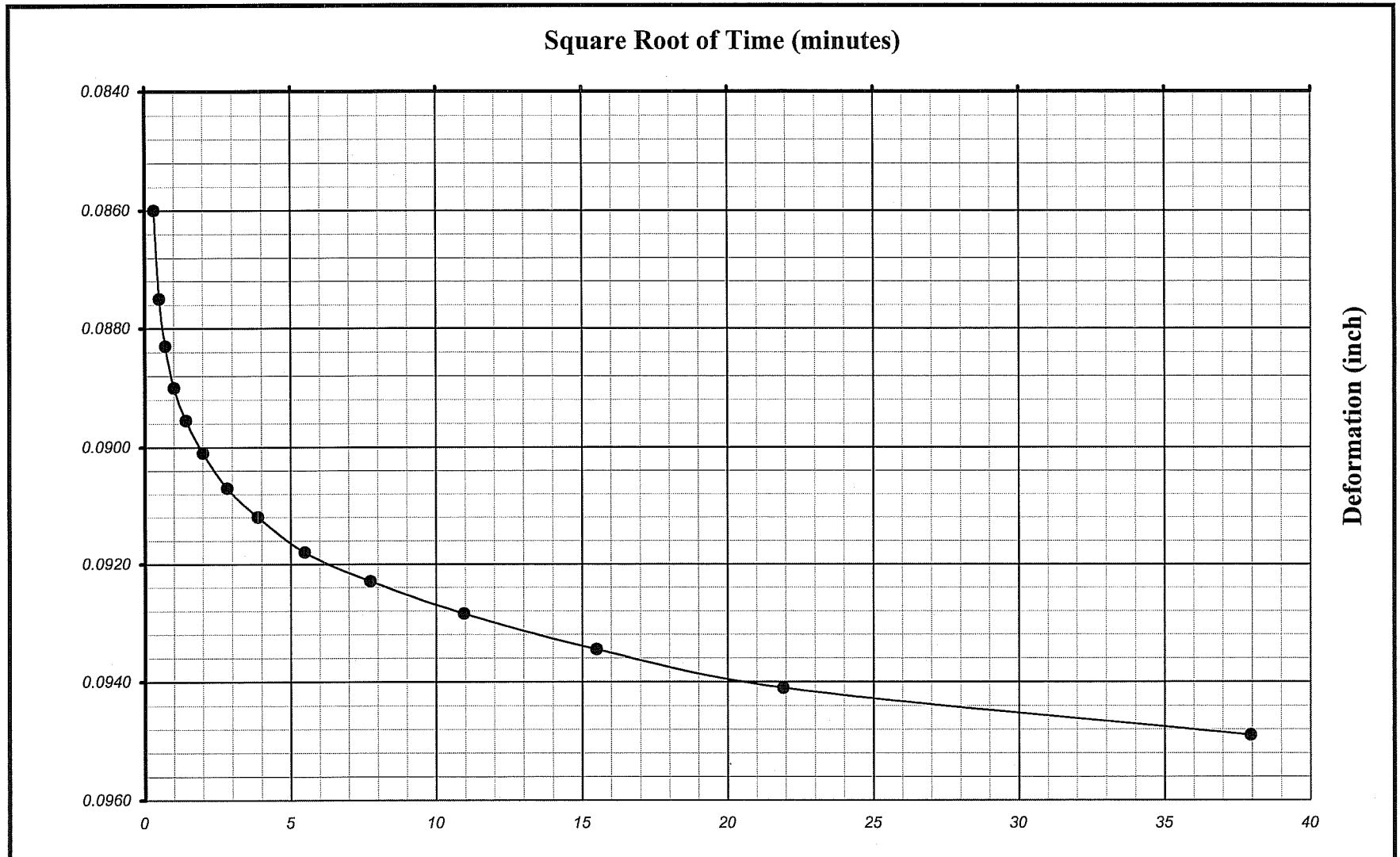
BATA / Antioch Bridge

Project No. : 06-155 05/31/07

CONSOLIDATION TEST
(ASTM D-2435 / CT-219)



Earth Mechanics, Inc. Geotechnical and Earthquake Engineering	***BATA / Antioch Bridge***	**Boring No. :** *06-7*	**One-Dimensional Consolidation of Soil** **Time-Deformation Curve (Log of Time Method)**
		Sample No. : *D-19*	
EMI Project No. : *06-155*		**Depth (ft/m) :** *94.0* *28.7*	**Veritcal Load (ksf/kpa) :** *8.00* *383.0*



Earth Mechanics, Inc. Geotechnical and Earthquake Engineering	***BATA / Antioch Bridge***	**Boring No. :** *06-7*	**One-Dimensional Consolidation of Soil** **Time-Deformation Curve (Square Root of Time Method)**
		Sample No. : *D-19*	
EMI Project No. : *06-155*		**Depth (ft/m) :** *94.0* *28.7*	**Veritcal Load (ksf/kpa) :** *8.0* *383.0*

ONE-DIMENSIONAL CONSOLIDATION OF SOIL

ASTM D-2435 / CT-219

Device No. : 3

Project Name : *BATA / Antioch Bridge*
Project No. : *06-155*
Boring No. : *06-8*
Sample No. : *D-5*
Depth (ft / m) : *21.0* | *6.41*
File No. :

Set up By : *R.J* **Date :** *4/1/2007*
Tested By : *R.J* **Date :** *4/1-4/10/2007*
Time Rate Took By : *R.J* **Date :** *4/6/2007*
Computer By : *CY* **Date :** *5/31/2007*
Checked By : *R.J* **Date :** *5/31/2007*

Soil Description : *Very Dark Gray, Silt with Clay and Peat (ML)*

Method (A) : ☑ Constant load increment duration of 24 hours or multiples there for. Minium of two Time -deformation reading are required.

Method (B) : ☐ Time-deformation reading are required on all load increments. Successive load increments are applied after 100 % primary consolidation is reached, or at constant time increments are described in Test Method (A)

1

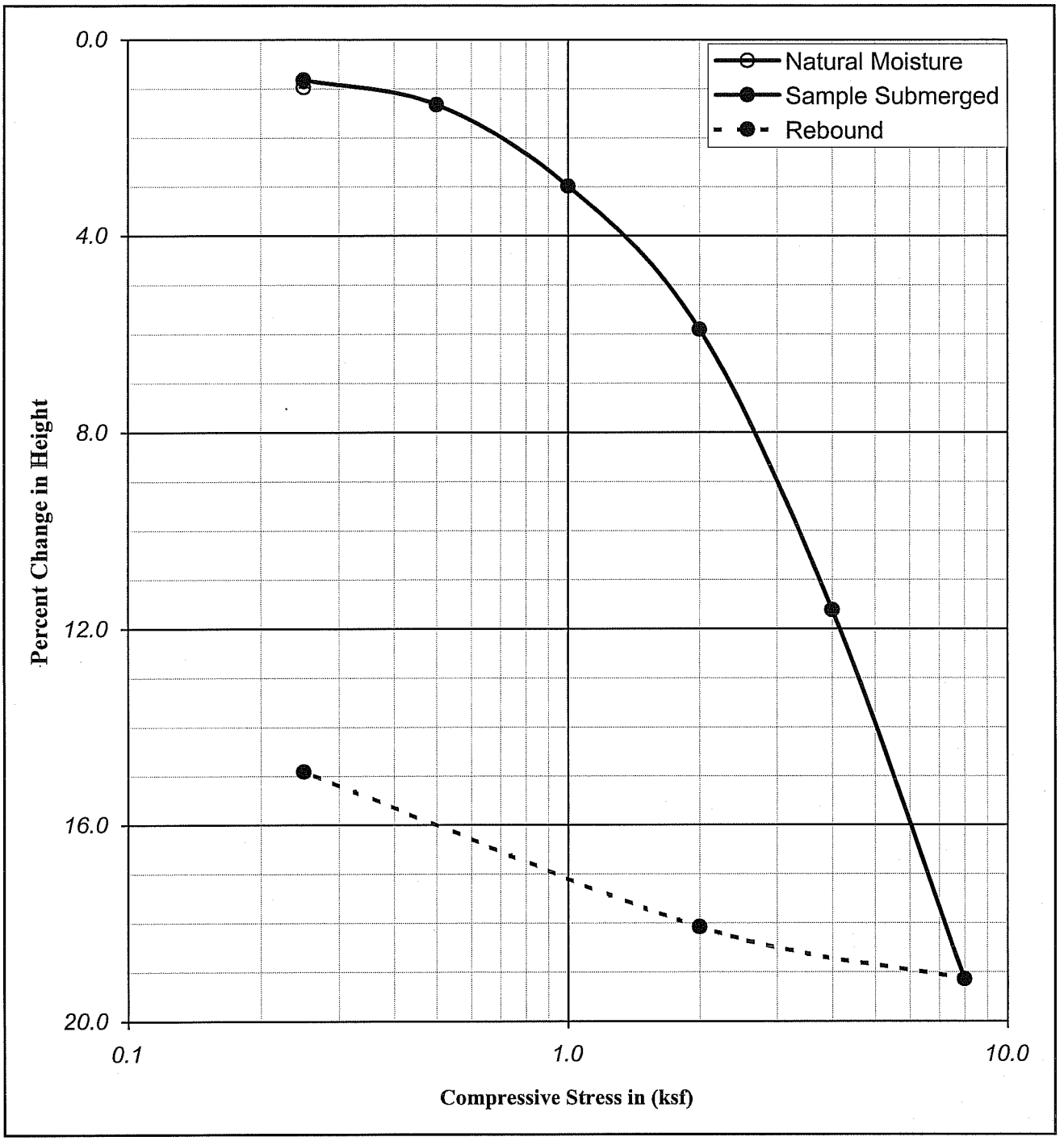
Sample	(inch)	(mm)	Vertical Load	(ksf)	(kPa)	Vertical Load	(ksf)	(kPa)
Internal Diameter	2.42	61.47	Add Water at	0.25	11.97	Reload to	-	-
Height (Intial)	1.00	25.40	Load to	8.00	383.04	Rebound to	-	-
Height (Final)	0.8499	21.59	Rebound to	0.25	11.97	Time rate taking at	4.00	190.81

Date	Time	Elapsed Time (min.)	Load (ksf)	Load (kPa)	Dial Reading (in)	Dial Reading (mm)	Consol. (%)
4/1/2007	11:16	0:00:00	Seating Load		0.04900	1.24	
	11:26		2.0	95.8	0.05000	1.27	0.00
4/2/2007	9:19	0:00:00	0.25	12.0	0.05975	1.52	0.97
			Add Water				
4/3/2007	8:07	0:00:00	0.25	12.0	0.05820	1.48	0.82
4/4/2007	8:16	0:00:00	0.50	23.9	0.06330	1.61	1.33
4/5/2007	7:53	0:00:00	1.00	47.9	0.07990	2.03	2.99
4/6/2007	7:40	0:00:00	2.00	95.8	0.10910	2.77	5.91
4/6/2007	8:00	0.00	4.0	191.5			
		0.10	4.0	191.5	0.11400	2.90	6.40
		0.25	4.0	191.5	0.11690	2.97	6.69
		0.50	4.0	191.5	0.11950	3.04	6.95
		1	4.0	191.5	0.12310	3.13	7.31
		2	4.0	191.5	0.12770	3.24	7.77
		4	4.0	191.5	0.13360	3.39	8.36
		8	4.0	191.5	0.13920	3.54	8.92
		16	4.0	191.5	0.14480	3.68	9.48
		30	4.0	191.5	0.14900	3.78	9.90
		60	4.0	191.5	0.15450	3.92	10.45
		133	4.0	191.5	0.15640	3.97	10.64
		250	4.0	191.5	0.15890	4.04	10.89
		500	4.0	191.5	0.16210	4.12	11.21
		1440	4.0	191.5	0.16615	4.22	11.62
4/8/2007	7:38	0:00:00	8.00	383.0	0.2414	6.13	19.14
4/9/2007	6:10	0:00:00	2.00	95.8	0.2308	5.86	18.08
4/10/2007	9:00	0:00:00	0.25	12.0	0.1991	5.06	14.91

	Before	After
Weight of wet soil + ring (gm)	166.17	
Weight of ring (gm)	43.28	
Weight of wet soil + ring + container (gm)		214.64
Weight of dry soil + ring + container (gm)		178.13
No. 16 Weight of container (gm)		58.90
Weight of ring + container (gm)		102.18
Moisture Content (%)	61.80	48.07
Dial Reading (inch)	0.05	0.04
Sample Volume (ft^3)	0.0027	0.0023
Wet Density (pcf)	101.8	109.6
Dry Density (pcf)	62.90	74.01

SQRT Time	Date	Time	Elapsed Time (min.)	Load (ksf)	Load (kPa)	Dial Reading (in)	Dial Reading (mm)	Consol. (%)
0.00								
0.32								
0.50								
0.71								
1.00								
1.41								
2.00								
2.83								
4.00								
5.48								
7.75								
11.53								
15.81								
22.36								
37.95								

Remark *Final Dial Reading 0.1991*



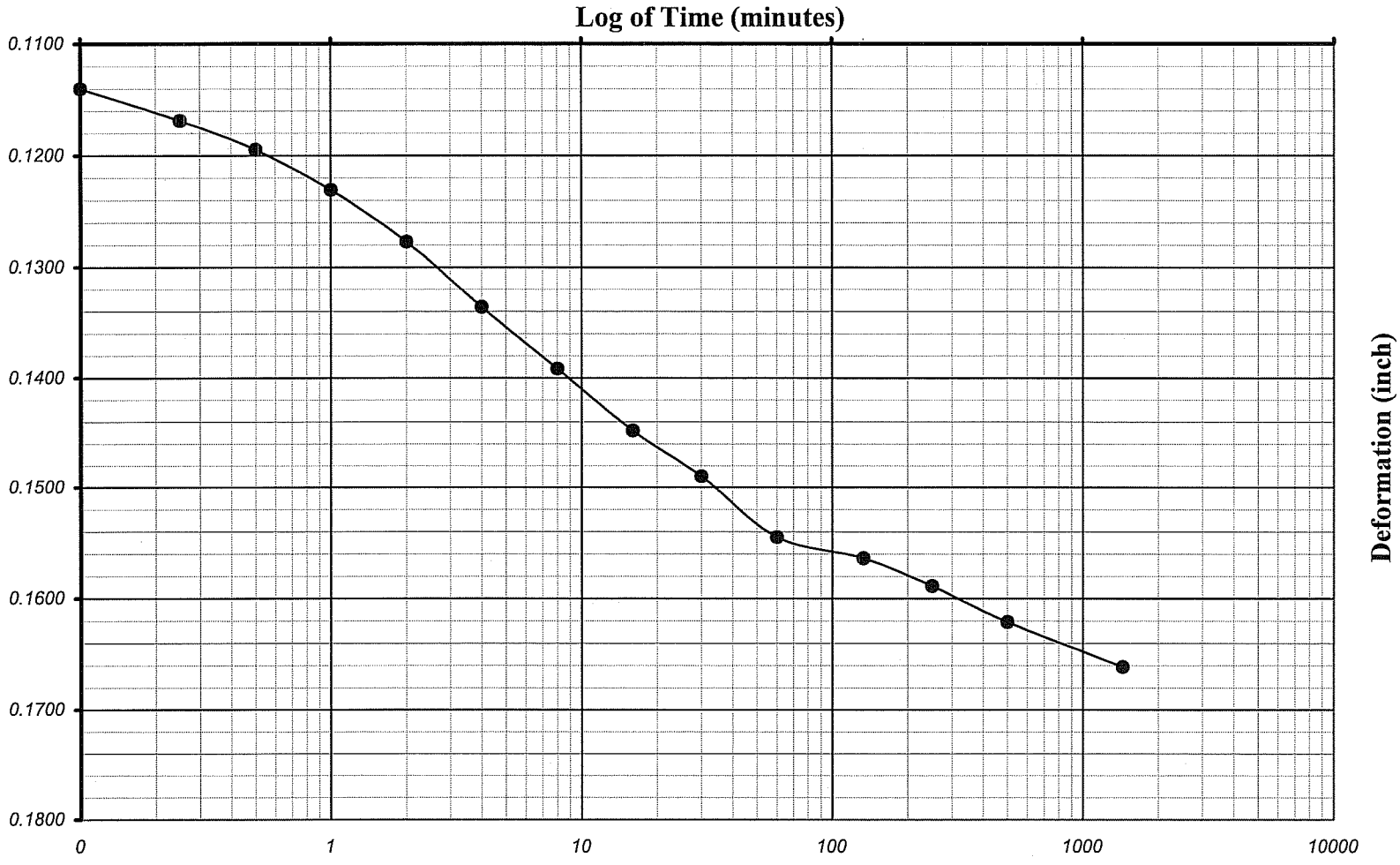
Boring No. : 06-8				Liquid Limit :	-		Moisture Content (%)	Dry Density		Percent Saturation	Void Ratio
Sample No. : D-5				Plastic Limit :	-			(pcf)	(kN/m³)		
Depth	(ft) :	21.0	22.5	Plastic Index :	-	Initial	61.80	62.90	9.90	99.35	1.68
	(m) :	6.41	6.86	Specific Gravity :	2.70	Final	48.07	74.01	11.65	101.60	1.28
Description : Very Dark Gray, Silt with Clay and Peat (ML)											

Earth Mechanics, Inc.
Geotechnical and Earthquake Engineering

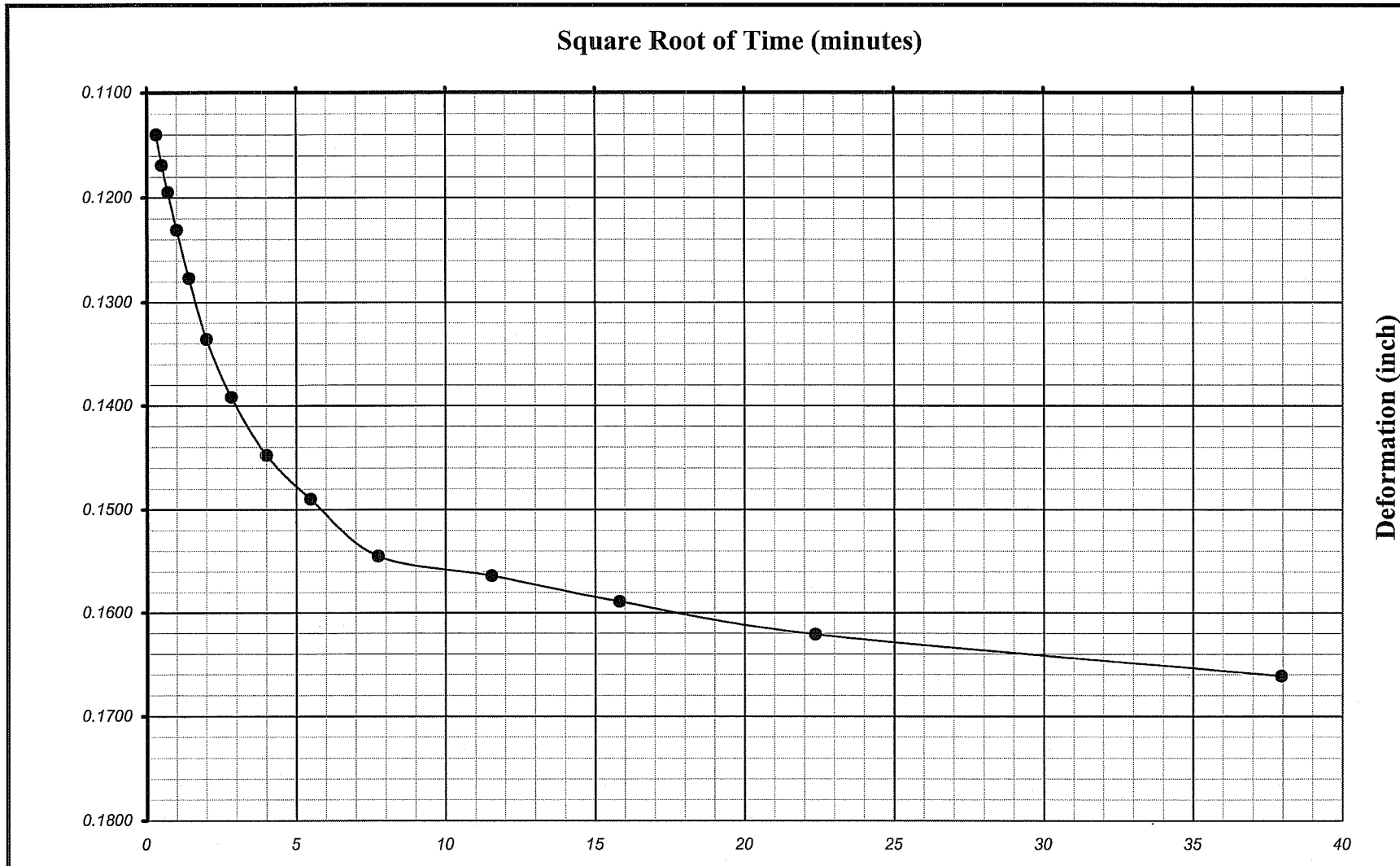
BATA / Antioch Bridge

Project No. : 06-155 05/31/07

CONSOLIDATION TEST
(ASTM D-2435 / CT-219)



Earth Mechanics, Inc. Geotechnical and Earthquake Engineering	***BATA / Antioch Bridge***	**Boring No. :** *06-8*	**One-Dimensional Consolidation of Soil** **Time-Deformation Curve (Log of Time Method)**
		Sample No. : *D-5*	
EMI Project No. : *06-155*		**Depth (ft/m) :** *21.0* *6.4*	**Veritcal Load (ksf/kpa) :** *4.00* *191.5*



Earth Mechanics, Inc. Geotechnical and Earthquake Engineering	***BATA / Antioch Bridge***	**Boring No. :** *06-8*	**One-Dimensional Consolidation of Soil** **Time-Deformation Curve(Square Root of Time Method)**
		Sample No. : *D-5*	
EMI Project No. : *06-155*		**Depth (ft/m) :** *21.0* *6.4*	**Veritcal Load (ksf/kpa) :** *4.0* *191.5*

ONE-DIMENSIONAL CONSOLIDATION OF SOIL

ASTM D-2435 / CT-219

Device No. : 4

Project Name : *BATA / Antioch Bridge*
Project No. : *06-155*
Boring No. : *06-8*
Sample No. : *D-22*
Depth (ft / m) : *100.0* | *30.50*
File No. :
Soil Description : *Light Olive Brown, Elastic Silt (MH)*

Set up By :	*R.J*	**Date :**	*4/1/2007*
Tested By :	*R.J*	**Date :**	*4/1-4/10/2007*
Time Rate Took By :	*R.J*	**Date :**	*4/6/2007*
Computer By :	*CY*	**Date :**	*5/31/2007*
Checked By :	*R.J*	**Date :**	*5/31/2007*

Method (A) : ☑ Constant load increment duration of 24 hours or multiples there for. Minium of two Time -deformation reading are required.

Method (B) : ☐ Time-deformation reading are required on all load increments. Successive load increments are applied after 100 % primary consolidation is reached, or at constant time increments are described in Test Method (A)

1

Sample	(inch)	(mm)	Vertical Load	(ksf)	(kPa)	Vertical Load	(ksf)	(kPa)
Internal Diameter	2.42	61.47	Add Water at	0.25	11.97	Reload to	-	-
Height (Intial)	1.00	25.40	Load to	16.00	766.08	Rebound to	-	-
Height (Final)	1.0005	25.41	Rebound to	0.25	11.97	Time rate taking at	8.00	381.62

Date	Time	Elapsed Time (min.)	Load (ksf)	Load (kPa)	Dial Reading (in)	Dial Reading (mm)	Consol. (%)
4/1/2007	11:16	0:00:00	Seating Load		0.04920	1.25	
	11:26		2.0	95.8	0.05000	1.27	0.00
4/2/2007	9:19	0:00:00	0.25	12.0	0.05335	1.36	0.33
			Add Water				
4/3/2007	8:07	0:00:00	0.25	12.0	0.03885	0.99	-1.11
4/4/2007	8:16	0:00:00	0.50	23.9	0.03985	1.01	-1.02
4/5/2007	7:53	0:00:00	1.00	47.9	0.04280	1.09	-0.72
4/6/2007	7:40	0:00:00	2.00	95.8	0.04750	1.21	-0.25
4/7/2007	7:49	0:00:00	4.00	191.5	0.05405	1.37	0.41
4/7/2007	8:10	0.00	8.0	383.0			
		0.10	8.0	383.0	0.05640	1.43	0.64
		0.25	8.0	383.0	0.05675	1.44	0.67
		0.50	8.0	383.0	0.05705	1.45	0.70
		1	8.0	383.0	0.05745	1.46	0.74
		2	8.0	383.0	0.05795	1.47	0.79
		4	8.0	383.0	0.05855	1.49	0.85
		8	8.0	383.0	0.05935	1.51	0.94
		15	8.0	383.0	0.06010	1.53	1.01
		30	8.0	383.0	0.06095	1.55	1.09
		60	8.0	383.0	0.06155	1.56	1.16
		120	8.0	383.0	0.06195	1.57	1.19
		240	8.0	383.0	0.06220	1.58	1.22
		480	8.0	383.0	0.06245	1.59	1.24
		1440	8.0	383.0	0.06285	1.60	1.29
4/9/2007	6:10	0:00:00	16.00	766.1	0.0757	1.92	2.57
4/10/2007	8:02	0:00:00	2.00	95.8	0.0617	1.57	1.17
4/10/2007	17:55	0:00:00	0.25	12.0	0.0487	1.24	-0.13

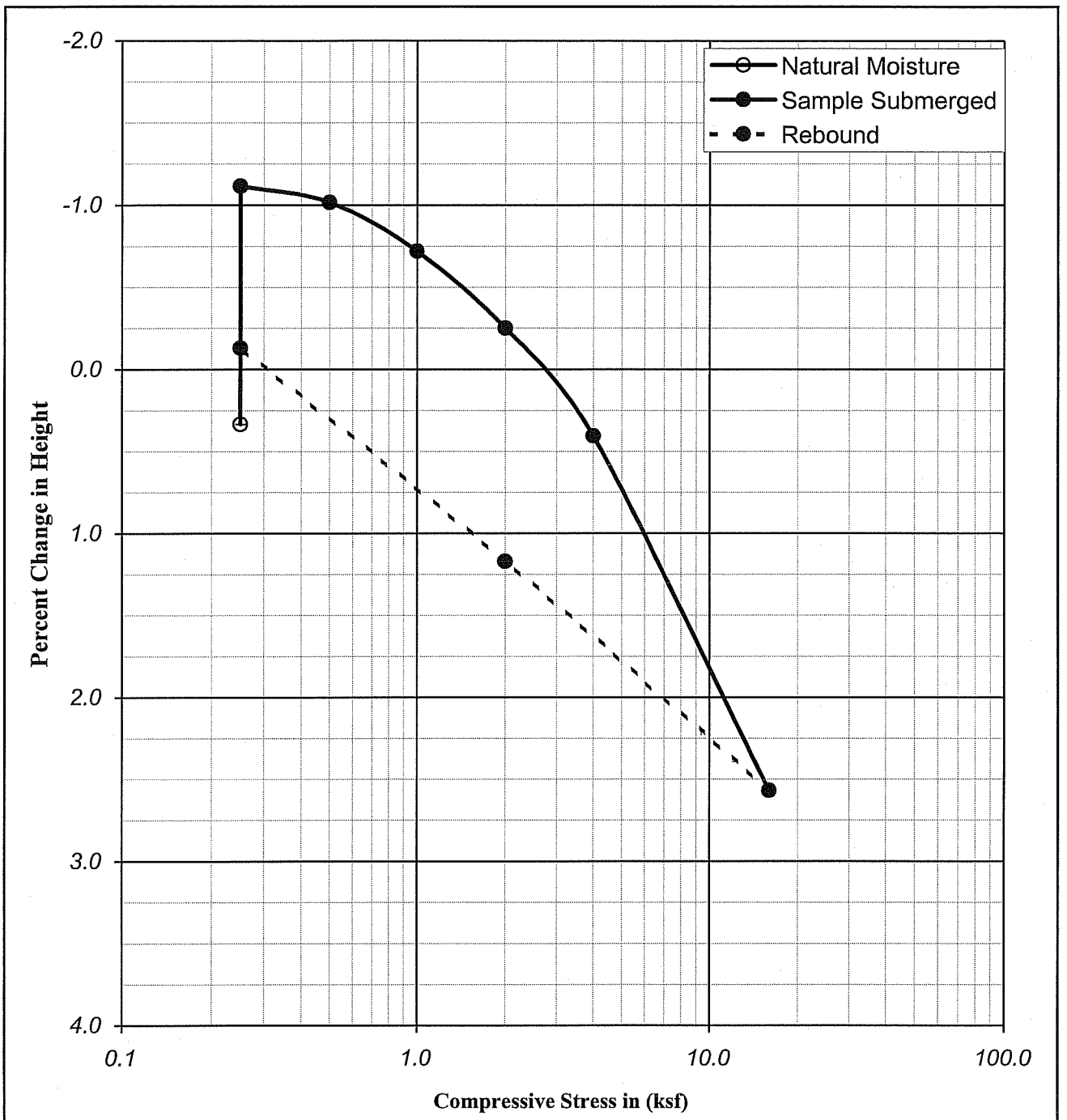
	Before	After
Weight of wet soil + ring (gm)	185.21	
Weight of ring (gm)	42.62	
Weight of wet soil + ring + container (gm)		243.62
Weight of dry soil + ring + container (gm)		207.08
No. 39 — Weight of container (gm)		57.07
Weight of ring + container (gm)		99.69
Moisture Content (%)	32.78	34.03
Dial Reading (inch)	0.05	0.04
Sample Volume (ft^3)	0.0027	0.0027
Wet Density (pcf)	118.1	119.1
Dry Density (pcf)	88.94	88.90

SQRT Time

Date	Time	Elapsed Time (min.)	Load (ksf)	Load (kPa)	Dial Reading (in)	Dial Reading (mm)	Consol. (%)

Remark

Final Dial Reading 0.0487



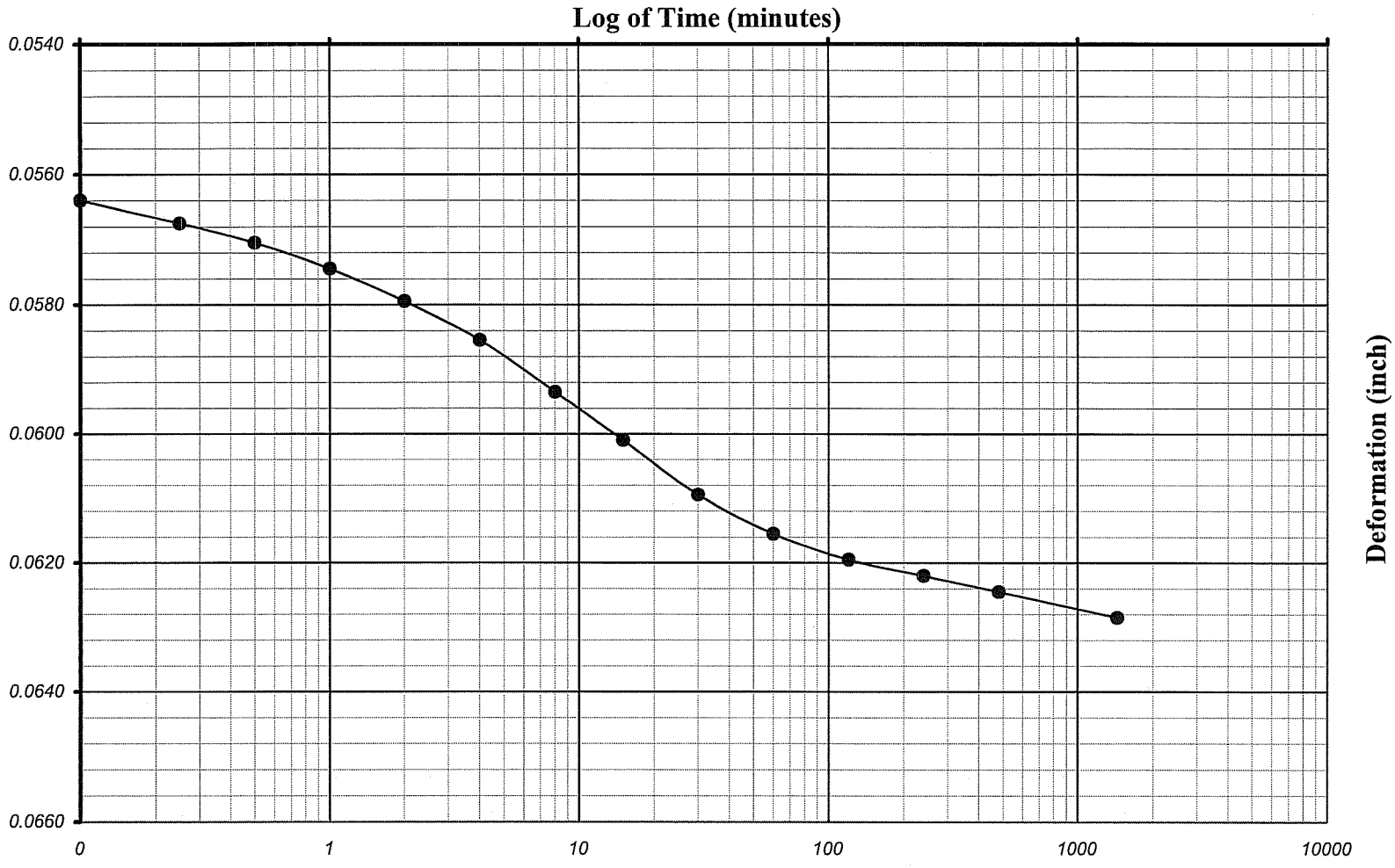
Boring No.	:	06-8		Liquid Limit :	-		Moisture Content (%)	Dry Density (pcf)	Dry Density (kN/m³)	Percent Saturation	Void Ratio
Sample No.	:	D-22		Plastic Limit :	-						
Depth (ft)	:	100.0	101.5	Plastic Index :	-	Initial	32.78	88.94	14.00	98.87	0.90
Depth (m)	:	30.50	30.96	Specific Gravity :	2.70	Final	34.03	88.90	13.99	102.52	0.90
Description : Light Olive Brown, Elastic Silt (MH)											

Earth Mechanics, Inc.
Geotechnical and Earthquake Engineering

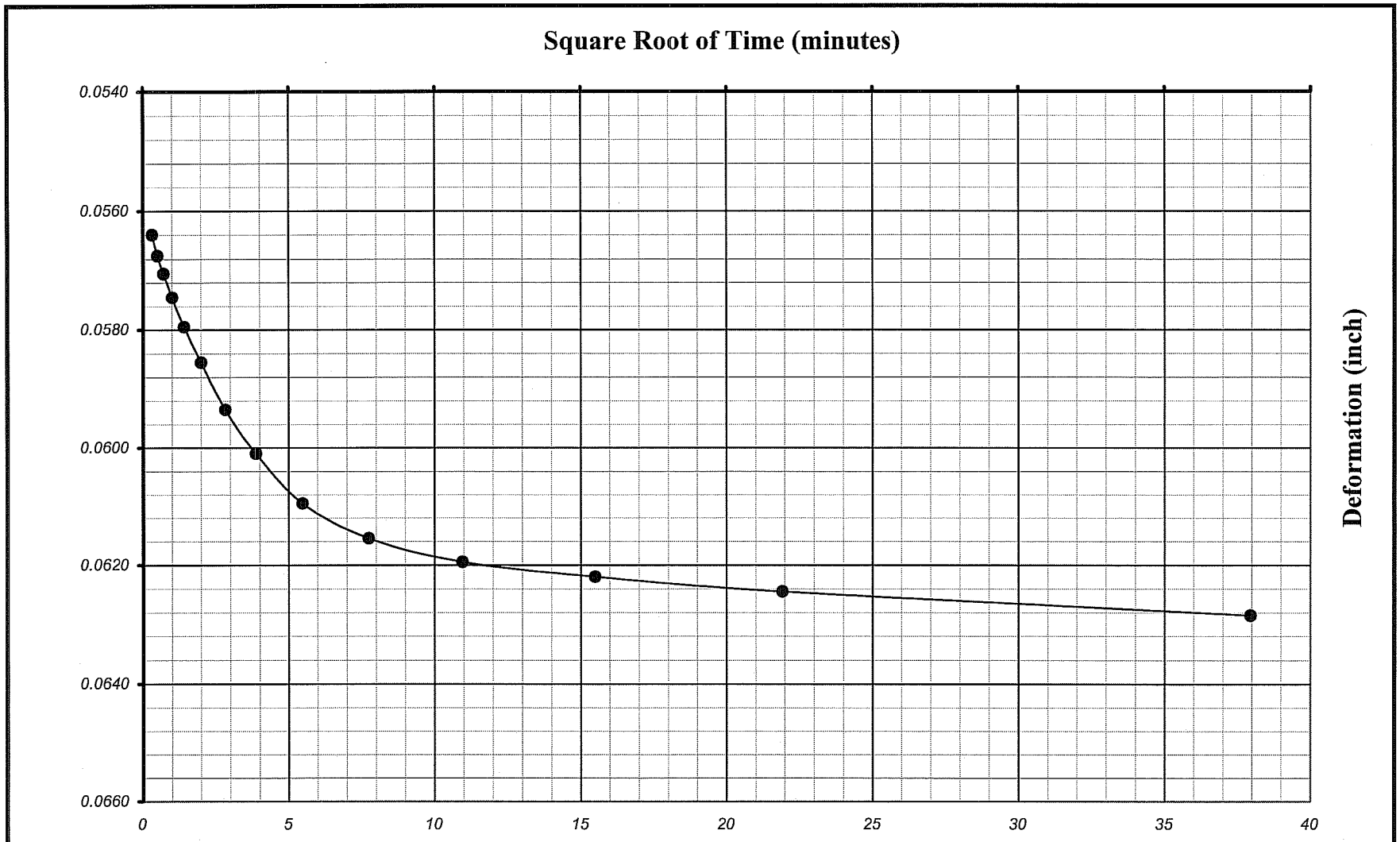
BATA / Antioch Bridge

Project No. : 06-155 05/31/07

CONSOLIDATION TEST
(ASTM D-2435 / CT-219)



Earth Mechanics, Inc. Geotechnical and Earthquake Engineering	***BATA / Antioch Bridge***	**Boring No. :** *06-8*	**One-Dimensional Consolidation of Soil** **Time-Deformation Curve (Log of Time Method)**
		Sample No. : *D-22*	
EMI Project No. : *06-155*		**Depth (ft/m) :** *100.0* *30.5*	**Veritcal Load (ksf/kpa) :** *8.00* *383.0*



Earth Mechanics, Inc. Geotechnical and Earthquake Engineering	*BATA / Antioch Bridge*	Boring No. : *06-8*	**One-Dimensional Consolidation of Soil** Time-Deformation Curve(Square Root of Time Method)
		Sample No. : *D-22*	
EMI Project No. : *06-155*		Depth (ft/m) : *100.0* *30.5*	Veritcal Load (ksf/kpa) : *8.0* *383.0*

ONE-DIMENSIONAL CONSOLIDATION OF SOIL

ASTM D-2435 / CT-219

Device No. : 1

Project Name : *BATA / Antioch Bridge*
Project No. : *06-155*
Boring No. : *06-10*
Sample No. : *D-23*
Depth (ft / m) : *121.0* | *36.91*
File No. :
Soil Description : *Light Olive Brown, Lean Clay (CL)*

Set up By : *R.J* **Date :** *4/4/2007*
Tested By : *R.J* **Date :** *4/4-4/14/2007*
Time Rate Took By : *R.J* **Date :** *4/10/2007*
Computer By : *CY* **Date :** *5/31/2007*
Checked By : *R.J* **Date :** *5/31/2007*

Method (A) : ☑ Constant load increment duration of 24 hours or multiples there for. Minium of two Time -deformation reading are required.
Method (B) : ☐ Time-deformation reading are required on all load increments. Successive load increments are applied after 100 % primary consolidation is reached, or at constant time increments are described in Test Method (A)

1

Sample	(inch)	(mm)
Internal Diameter	2.42	61.47
Height (Intial)	1.00	25.40
Height (Final)	1.0068	25.57

Vertical Load	(ksf)	(kPa)
Add Water at	0.25	11.97
Load to	16.00	766.08
Rebound to	0.25	11.97

Vertical Load	(ksf)	(kPa)
Reload to	-	-
Rebound to	-	-
Time rate taking at	8.00	381.62

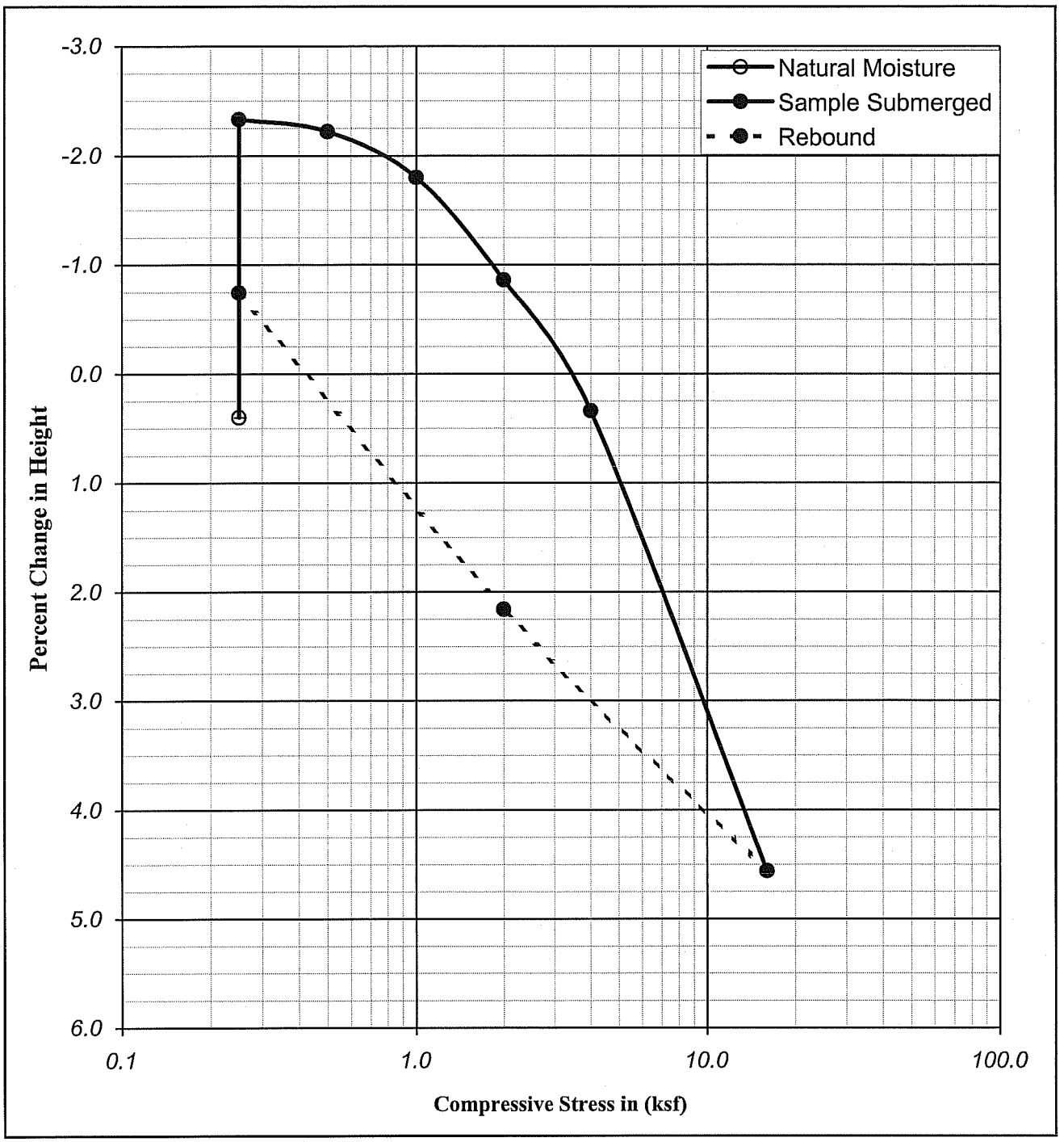
Date	Time	Elapsed Time (min.)	Load (ksf)	Load (kPa)	Dial Reading (in)	Dial Reading (mm)	Consol. (%)	SQRT Time
4/4/2007	10:50	0:00:00	Seating Load		0.04930	1.25		
	11:00		2.0	95.8	0.05000	1.27	0.00	
4/5/2007	9:00	0:00:00	0.25	12.0	0.05400	1.37	0.40	
			Add Water					
4/6/2007	7:40	0:00:00	0.25	12.0	0.02670	0.68	-2.33	
4/7/2007	7:48	0:00:00	0.50	23.9	0.02780	0.71	-2.22	
4/8/2007	7:36	0:00:00	1.00	47.9	0.03200	0.81	-1.80	
4/9/2007	6:12	0:00:00	2.00	95.8	0.04140	1.05	-0.86	
4/10/2007	7:59	0:00:00	4.00	191.5	0.05340	1.36	0.34	
4/10/2007	8:00	0.00	8.0	383.0				0.00
		0.10	8.0	383.0	0.05600	1.42	0.60	0.32
		0.25	8.0	383.0	0.05640	1.43	0.64	0.50
		0.50	8.0	383.0	0.05670	1.44	0.67	0.71
		1	8.0	383.0	0.05720	1.45	0.72	1.00
		2	8.0	383.0	0.05800	1.47	0.80	1.41
		4	8.0	383.0	0.05900	1.50	0.90	2.00
		8	8.0	383.0	0.06065	1.54	1.07	2.83
		16	8.0	383.0	0.06210	1.58	1.21	4.00
		30	8.0	383.0	0.06340	1.61	1.34	5.48
		60	8.0	383.0	0.06540	1.66	1.54	7.75
		120	8.0	383.0	0.06770	1.72	1.77	10.95
		240	8.0	383.0	0.06980	1.77	1.98	15.49
		480	8.0	383.0	0.07140	1.81	2.14	21.91
		1440	8.0	383.0	0.07230	1.84	2.23	37.95
4/12/2007	7:55	0:00:00	16.00	766.1	0.0956	2.43	4.56	
4/13/2007	7:52	0:00:00	2.00	95.8	0.0716	1.82	2.16	
4/14/2007	8:12	0:00:00	0.25	12.0	0.0426	1.08	-0.74	

	Before	After
Weight of wet soil + ring (gm)	187.49	
Weight of ring (gm)	45.03	
Weight of wet soil + ring + container (gm)		248.64
Weight of dry soil + ring + container (gm)		211.67
No. 58 Weight of container (gm)		59.34
Weight of ring + container (gm)		104.37
Moisture Content (%)	32.77	34.45
Dial Reading (inch)	0.05	0.04
Sample Volume (ft^3)	0.0027	0.0027
Wet Density (pcf)	118.0	118.7
Dry Density (pcf)	88.87	88.27

Date	Time	Elapsed Time (min.)	Load (ksf)	Load (kPa)	Dial Reading (in)	Dial Reading (mm)	Consol. (%)

Remark

Final Dial Reading 0.0426



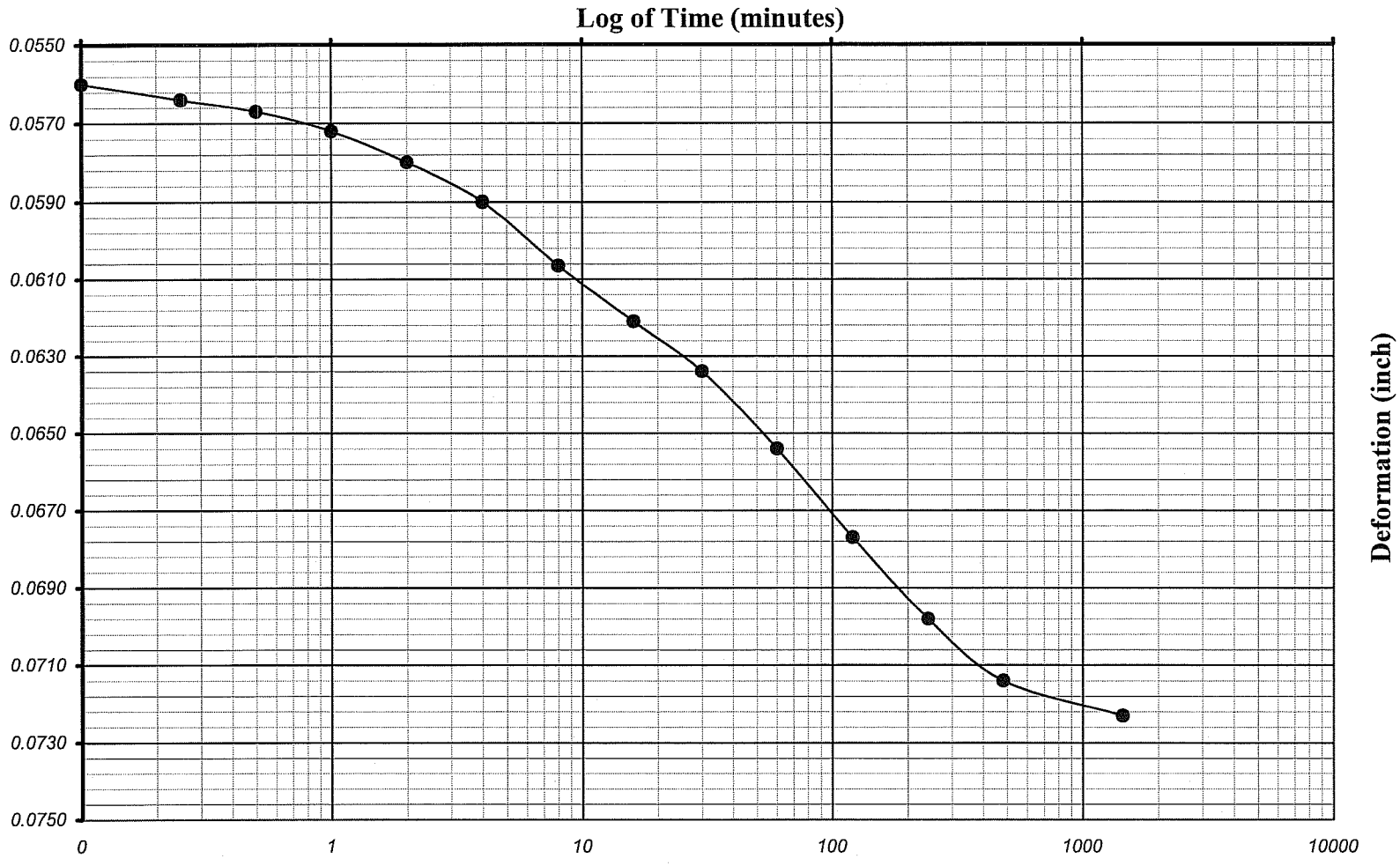
Boring No. : 06-10				Liquid Limit :	-		Moisture Content (%)	Dry Density		Percent Saturation	Void Ratio
Sample No. : D-23				Plastic Limit :	-			(pcf)	(kN/m³)		
Depth	(ft)	: 121.0	122.5	Plastic Index :	-	Initial	32.77	88.87	13.99	98.66	0.90
	(m)	: 36.91	37.36	Specific Gravity :	2.70	Final	34.45	88.27	13.89	102.28	0.91
Description : Light Olive Brown, Lean Clay (CL)											

Earth Mechanics, Inc.
Geotechnical and Earthquake Engineering

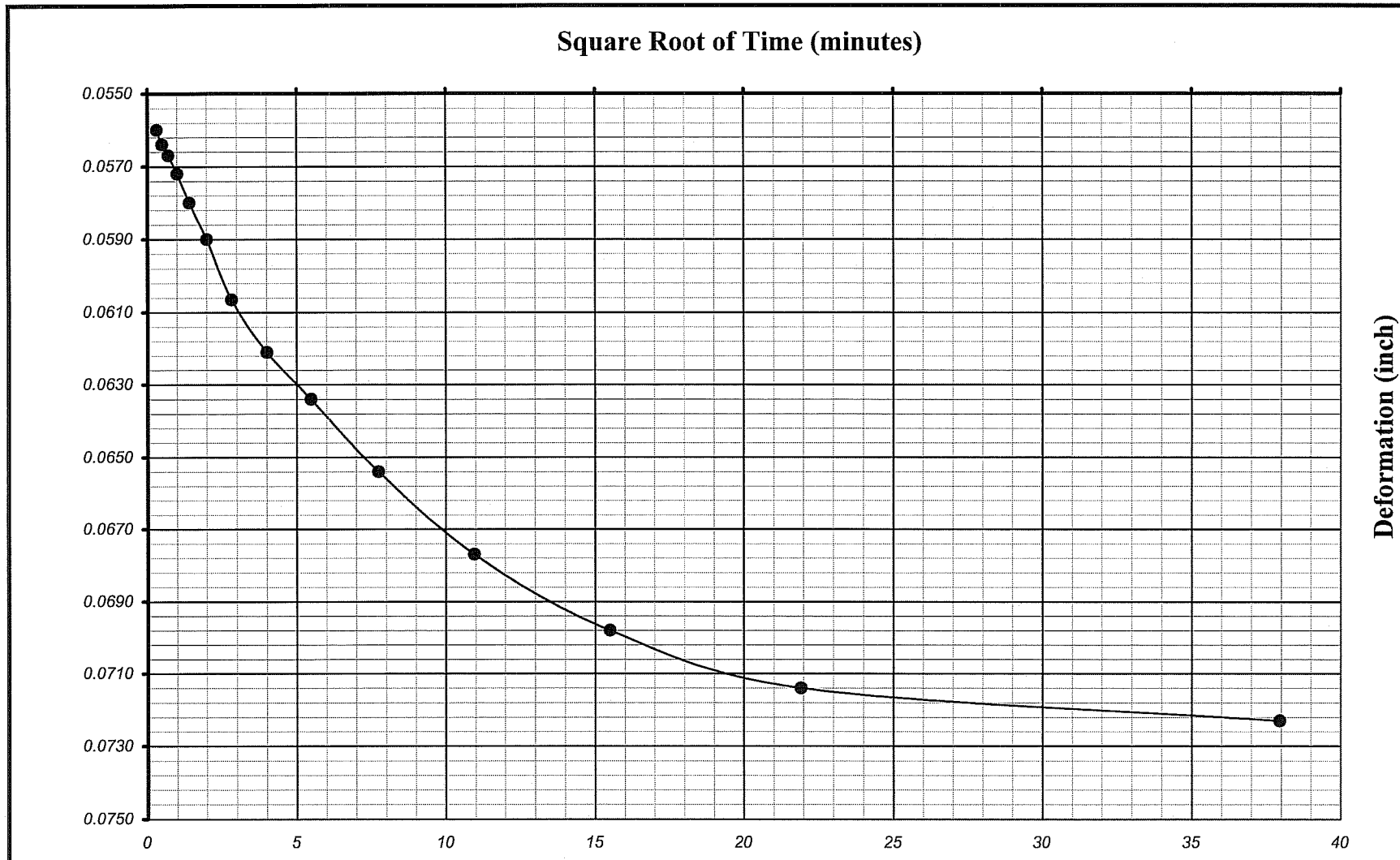
BATA / Antioch Bridge

Project No. : 06-155 05/31/07

CONSOLIDATION TEST
(ASTM D-2435 / CT-219)



Earth Mechanics, Inc. Geotechnical and Earthquake Engineering	***BATA / Antioch Bridge***	**Boring No. :** *06-10*	**One-Dimensional Consolidation of Soil** **Time-Deformation Curve (Log of Time Method)**
		Sample No. : *D-23*	
EMI Project No. : *06-155*		**Depth (ft/m) :** *121.0* *36.9*	**Veritcal Load (ksf/kpa) :** *8.00* *383.0*



Earth Mechanics, Inc. Geotechnical and Earthquake Engineering	***BATA / Antioch Bridge***	**Boring No. :** *06-10*	**One-Dimensional Consolidation of Soil** **Time-Deformation Curve (Square Root of Time Method)**
		Sample No. : *D-23*	
EMI Project No. : *06-155*		**Depth (ft/m) :** *121.0* *36.9*	**Veritcal Load (ksf/kpa) :** *8.0* *383.0*

UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

ASTM D2850

Project Name:	BATA / Antioch Bridge			**Project No:**	06-155
Boring No.:	06-2	**Tested by:**	R.J.	**Date:**	04/12/07
Depth (ft):	60	**Checked by:**		**Date:**	
Sample No.	D-12	**Sample Type:**	R		

Sample Description: Olive, Elastic SILT (MH)

	1	2	3		
Diameter (in.):	2.425	2.418	2.415	Average:	2.419
Height (in.):	5.017	5.009	5.037	Average:	5.021

Moisture Content Calculation	
Wt. Wet Sample + Container (gms):	179.21
Wt. Dry Sample + Container (gms):	140.78
Container (gms) No. 22	58.94
Moisture Content (%)	**47.0**

Density and Saturation	
Wt. Wet Sample + Container (gms)	866.8
Container (gms)	228.92
Wet Density (pcf)	**105.2**
Dry Density (pcf)	**71.6**
Void Ratio	**1.353**
% Saturation	**93.7**

Assume Gs=2.70

Test Data Filename:	06155B2D12.trx

SKETCH / PHOTO AFTER TEST:

PHOTO FILE NAME: D:\06-155 Antioch\lab\100_3572.JPG

Shear	
Rate of Deformation (% strain / min) =	**1**
Confining Stress (ksf):	**4.90**

Failure Criterion: **criterion 1 is used**

1. the maximum deviator stress within 15% strain
2. the stress at 10% strain for no peak stress.

At Failure	
Deviator Stress (ksf)	**2.38**
Eff. Minor Principal Stress (ksf)=	**4.90**
Eff. Major Principal Stress (ksf)=	**7.27**
Axial Strain (%)=	**14.67**

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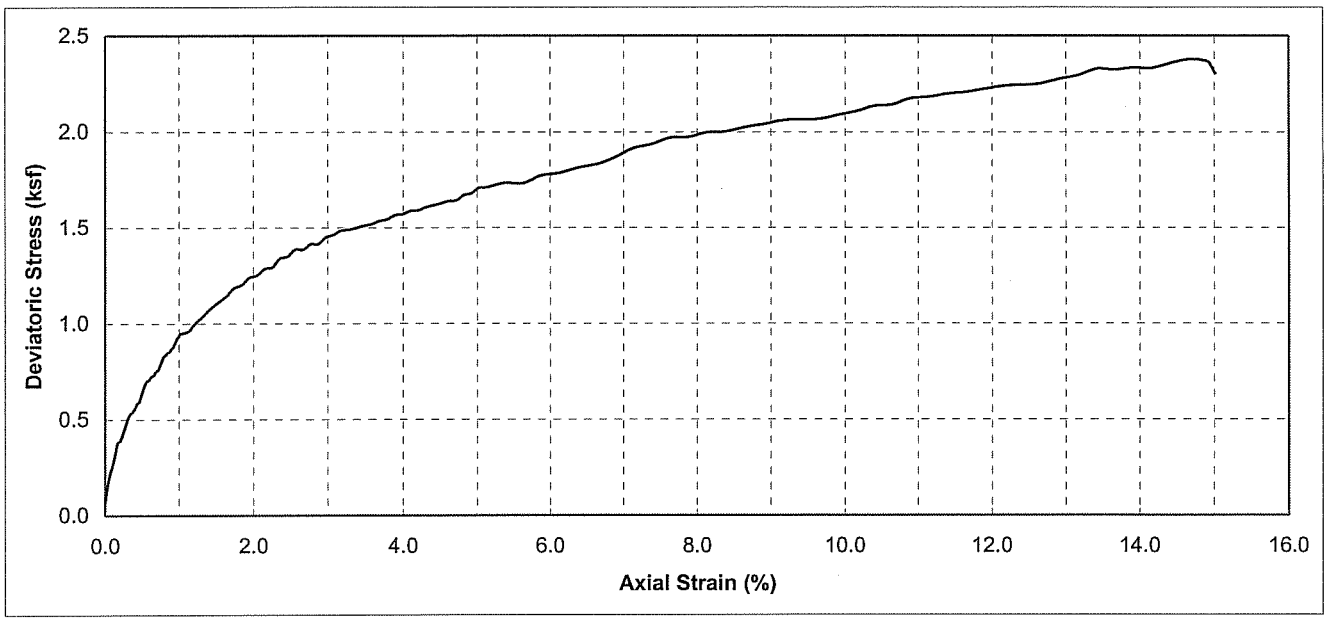
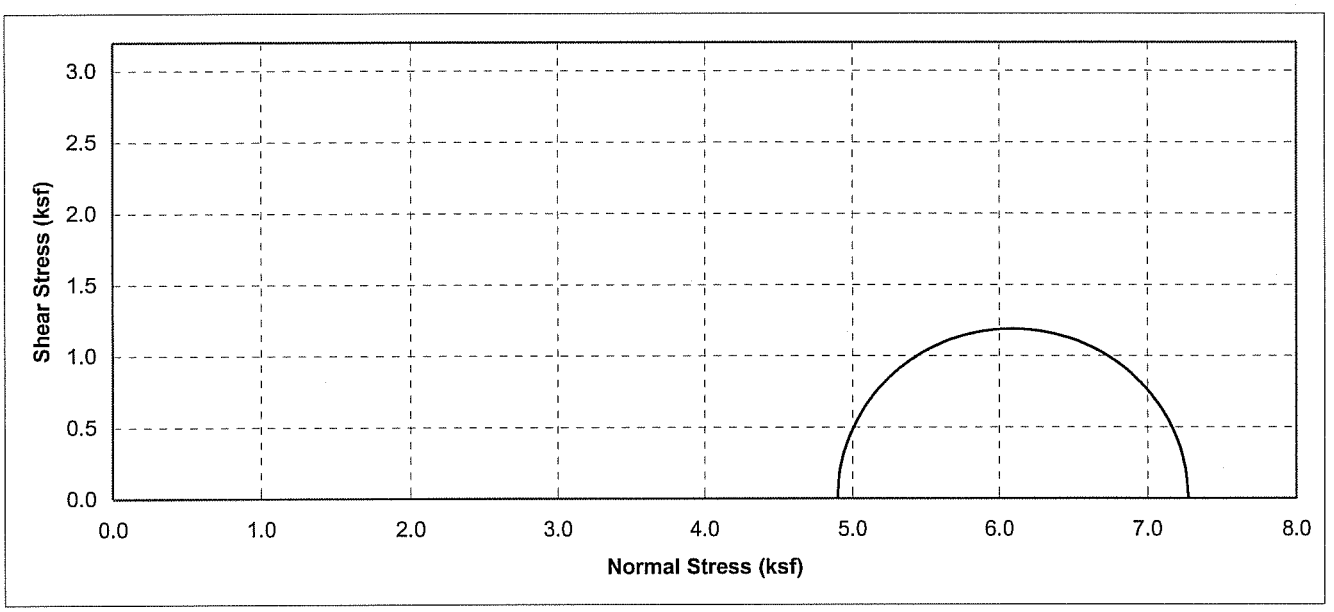




Boring No.	Sample No.	Depth (ft)	Soil Type	Dry Density (pcf)	Moisture Content (%)	Conf. Stress (ksf)	Max. Dev. Stress (ksf)	Initial Saturation (%)
06-2	D-12	60	Olive, Elastic SILT (MH)	71.6	46.96	4.90	2.38	93.7

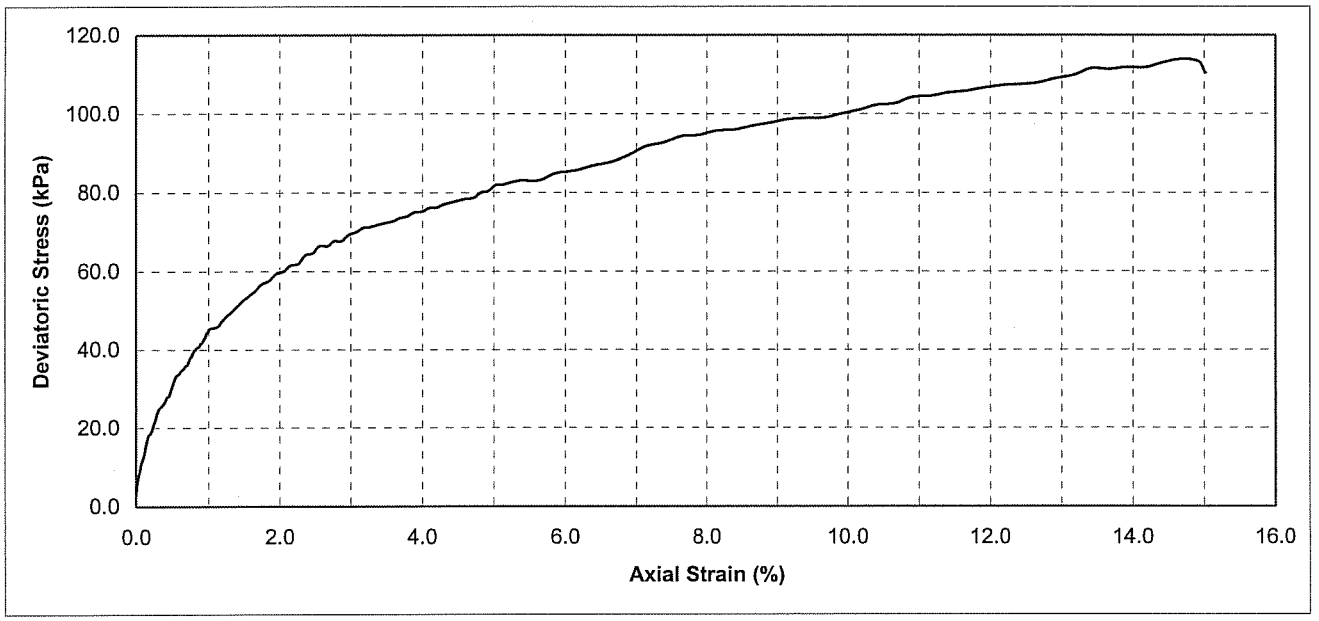
Earth Mechanics, Inc.
Geotechnical and Earthquake Engineering

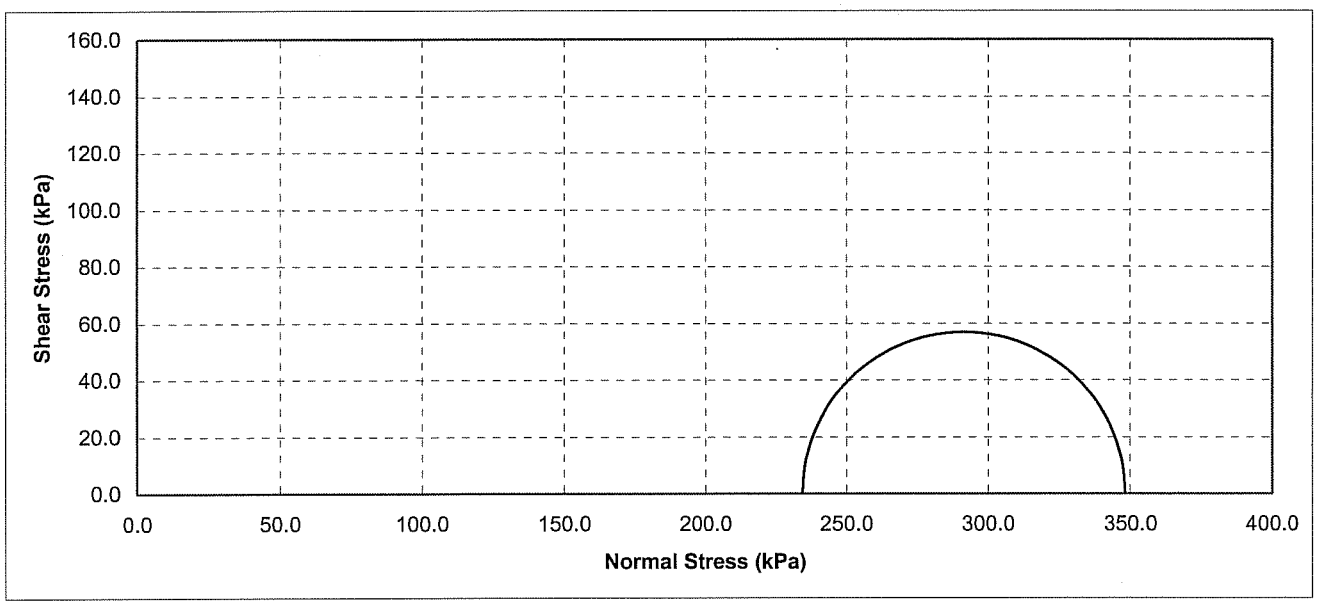
BATA / Antioch Bridge

UNCONSOLIDATED UNDRAINED TEST
(ASTM D2850)

Project No. : 06-155 **Date :** 04/12/07

Figure No. :





Boring No.	Sample No.	Depth (m)	Soil Type	Dry Density (kN/m^3)	Moisture Content (%)	Conf. Stress (kPa)	Max. Dev. Stress (kPa)	Initial Saturation (%)
06-2	D-12	18.29	Olive, Elastic SILT (MH)	11.3	47.0	234.5	113.8	93.7

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Geotechnical and Earthquake Engineering

BATA / Antioch Bridge

UNCONSOLIDATED UNDRAINED TEST
(ASTM D2850)

Project No. : 06-155 **Date :** 04/12/07

Figure No. :

UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

ASTM D2850

Project Name:	BATA / Antioch Bridge			**Project No:**	06-155
Boring No.:	06-2	**Tested by:**	R.J.	**Date:**	04/12/07
Depth (ft):	135	**Checked by:**		**Date:**	
Sample No.	D-24	**Sample Type:**	R		

Sample Description: Olive Brown, FAT CLAY (CH)

	1	2	3		
Diameter (in.):	2.422	2.414	2.416	Average:	2.417
Height (in.):	5.045	5.039	5.037	Average:	5.040

Moisture Content Calculation	
Wt. Wet Sample + Container (gms):	213
Wt. Dry Sample + Container (gms):	177.06
Container (gms) No. 23	58.24
Moisture Content (%)	**30.2**

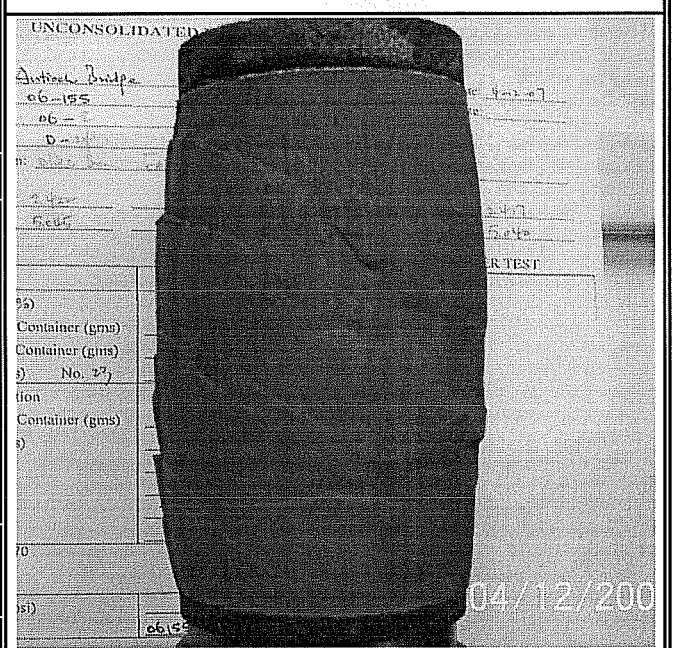
Density and Saturation	
Wt. Wet Sample + Container (gms)	963.02
Container (gms)	228.92
Wet Density (pcf)	**120.8**
Dry Density (pcf)	**92.8**
Void Ratio	**0.816**
% Saturation	**100.1**

Assume Gs=2.70

Test Data Filename:	06155B2D24.xls

SKETCH / PHOTO AFTER TEST:

PHOTO FILE NAME: D:\06-155 Antioch\lab\100_3573.JPG



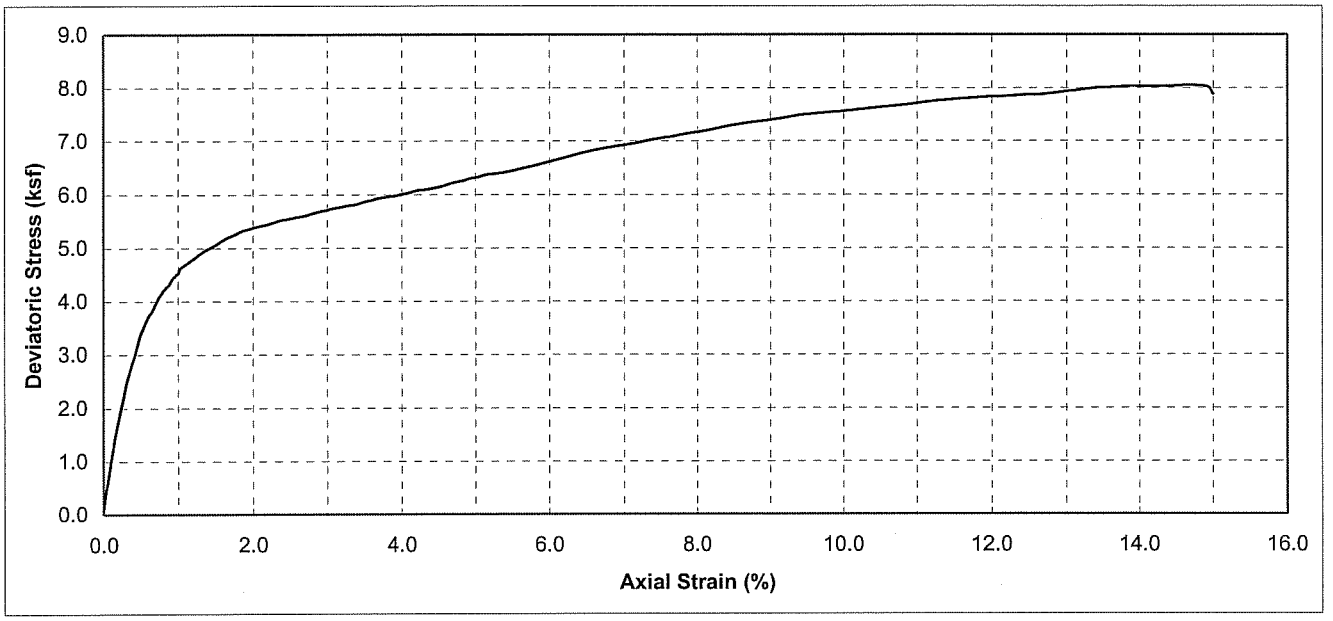
Shear	
Rate of Deformation (% strain / min) =	**1**
Confining Stress (ksf):	**7.20**

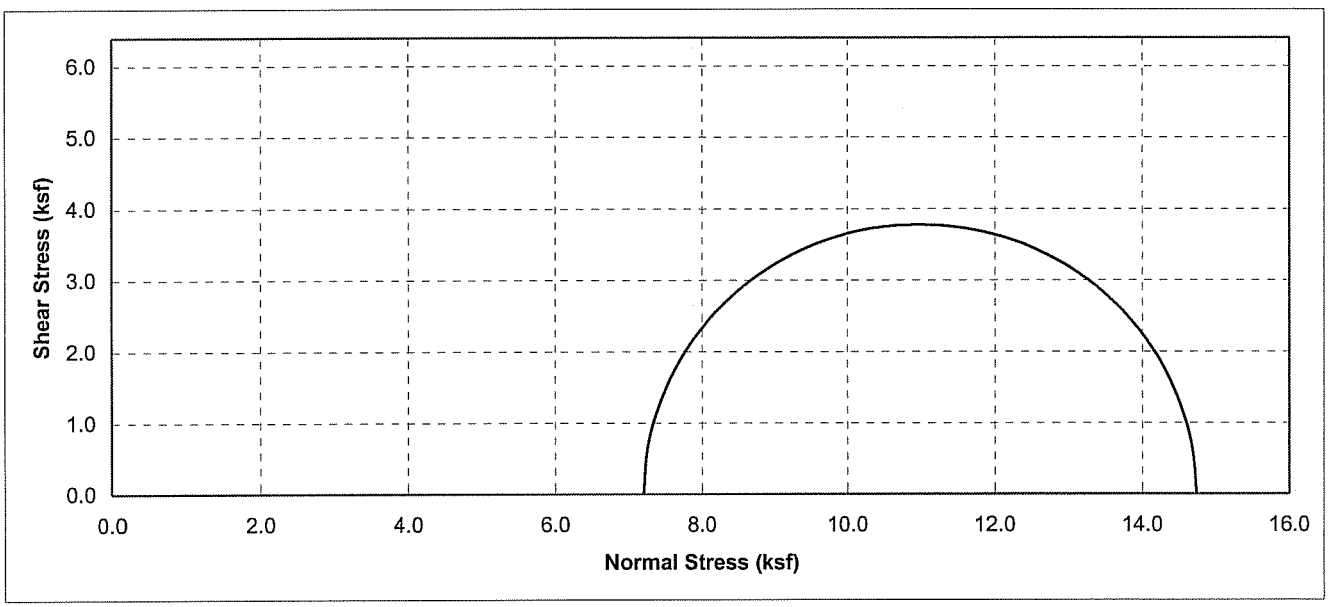
Failure Criterion: **criterion 2 is used**

1. the maximum deviator stress within 15% strain
2. the stress at 10% strain for no peak stress.

At Failure	
Deviator Stress (ksf)	**7.55**
Eff. Minor Principal Stress (ksf)=	**7.20**
Eff. Major Principal Stress (ksf)=	**14.75**
Axial Strain (%)=	**9.90**

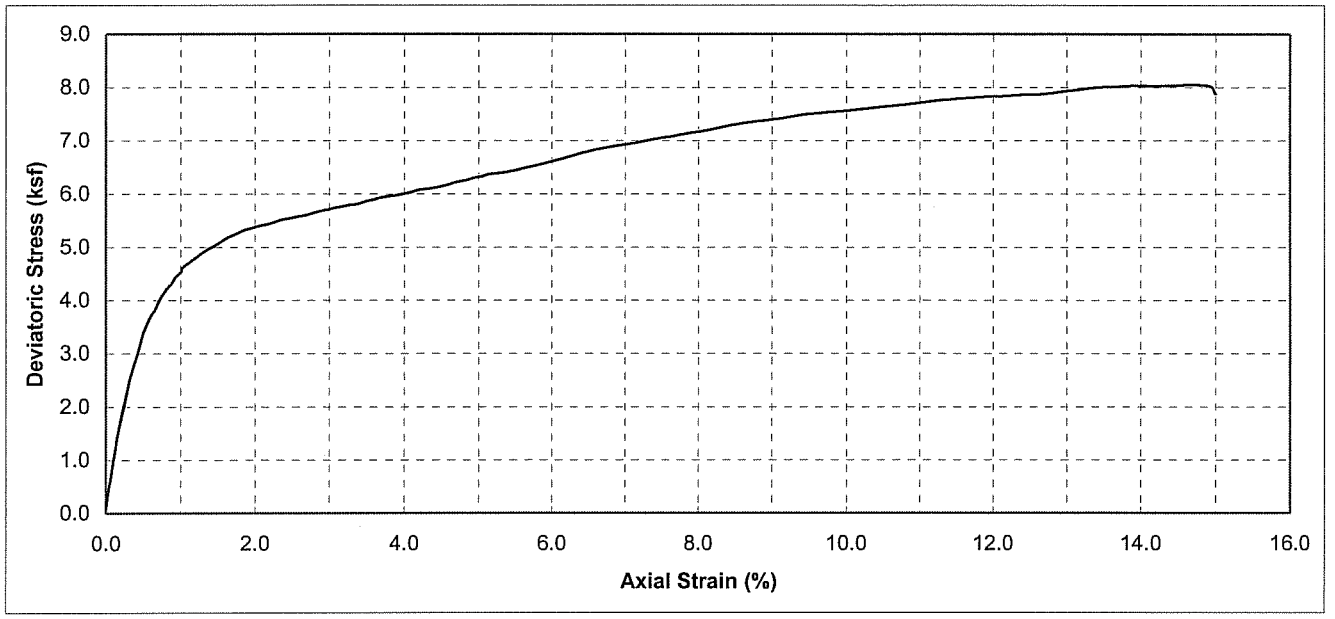
Earth Mechanics, Inc.
Geotechnical and Earthquake Engineering

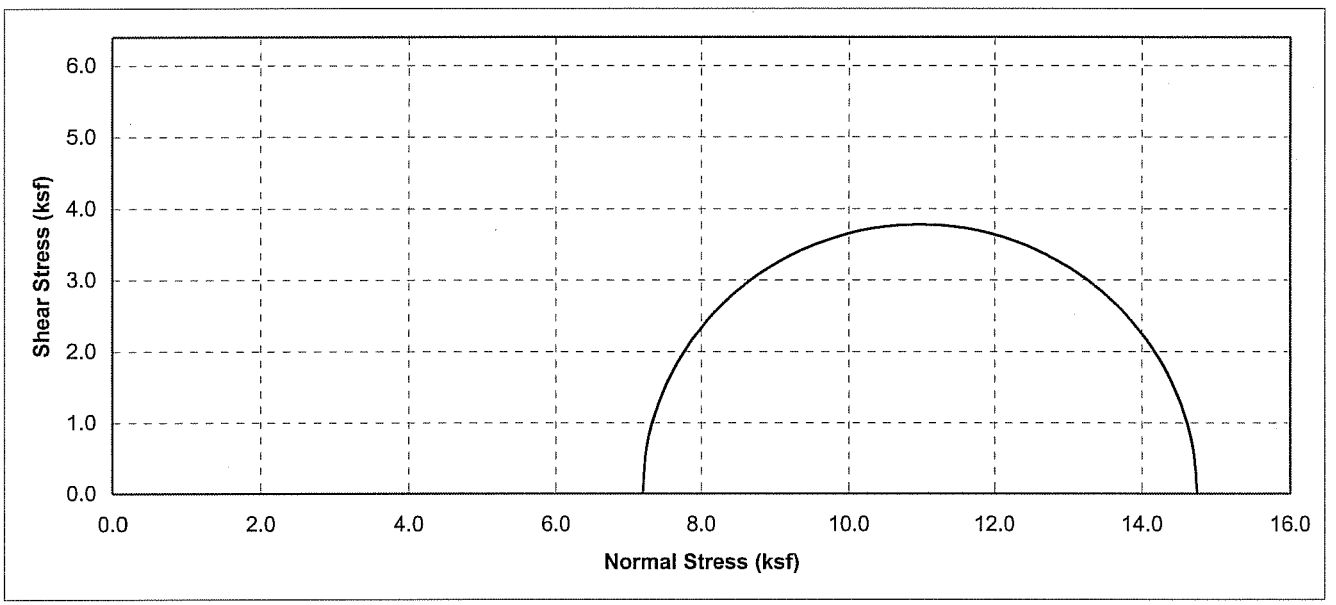




Boring No.	Sample No.	Depth (ft)	Soil Type	Dry Density (pcf)	Moisture Content (%)	Conf. Stress (ksf)	Max. Dev. Stress (ksf)	Initial Saturation (%)
06-2	D-24	135	Olive Brown, FAT CLAY (CH)	92.8	30.25	7.20	7.55	100.1

Earth Mechanics, Inc. Geotechnical and Earthquake Engineering	**BATA / Antioch Bridge**
Project No. : 06-155 **Date :** 04/12/07	**UNCONSOLIDATED UNDRAINED TEST** **(ASTM D2850)** Figure No. :





Boring No.	Sample No.	Depth (ft)	Soil Type	Dry Density (pcf)	Moisture Content (%)	Conf. Stress (ksf)	Max. Dev. Stress (ksf)	Initial Saturation (%)
06-2	D-24	135	Olive Brown, FAT CLAY (CH)	92.8	30.25	7.20	7.55	100.1

Earth Mechanics, Inc. Geotechnical and Earthquake Engineering	**BATA / Antioch Bridge**
	UNCONSOLIDATED UNDRAINED TEST
Project No. : 06-155 **Date :** 04/12/07	**(ASTM D2850)** Figure No. :

UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

ASTM D2850

Project Name:	BATA / Antioch Bridge			**Project No:**	06-155
Boring No.:	06-6	**Tested by:**	R.J.	**Date:**	04/13/07
Depth (ft):	31	**Checked by:**		**Date:**	
Sample No.	D-6	**Sample Type:**	R		

Sample Description: Dark Bluish Gray, SILT With Sand (ML)

	1	2	3		
Diameter (in.):	2.414	2.414	2.415	Average:	2.414
Height (in.):	5.020	5.041	5.037	Average:	5.033

Moisture Content Calculation		
Wt. Wet Sample + Container (gms):		198.43
Wt. Dry Sample + Container (gms):		164.85
Container (gms)	No. 40	58.46
Moisture Content (%)		**31.6**

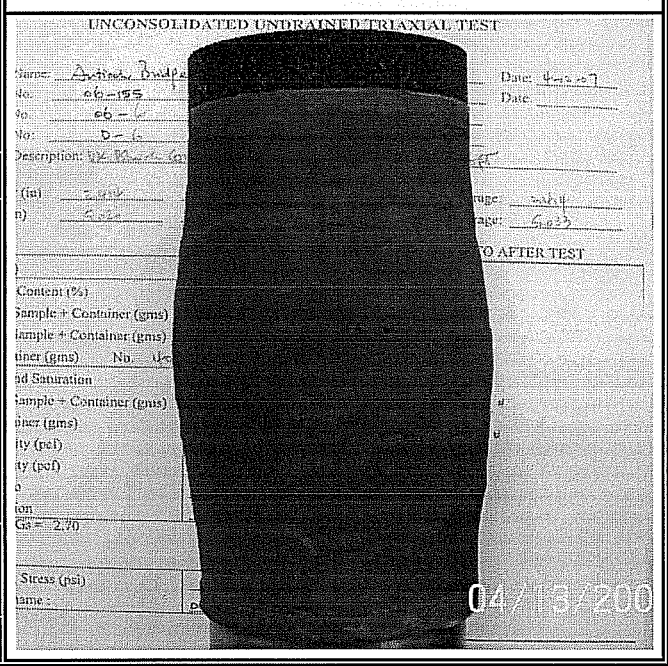
Density and Saturation	
Wt. Wet Sample + Container (gms)	960.53
Container (gms)	228.92
Wet Density (pcf)	**120.9**
Dry Density (pcf)	**91.9**
Void Ratio	**0.834**
% Saturation	**102.2**

Assume Gs=2.70

Test Data Filename:	06155B6D6.trx

SKETCH / PHOTO AFTER TEST:

PHOTO FILE NAME: D:\06-155 Antioch\lab\100_3575.JPG



Shear	
Rate of Deformation (% strain / min) =	**1**
Confining Stress (ksf):	**2.44**

Failure Criterion: **criterion 2 is used**

1. the maximum deviator stress within 15% strain
2. the stress at 10% strain for no peak stress.

At Failure	
Deviator Stress (ksf)	**1.94**
Eff. Minor Principal Stress (ksf)=	**2.44**
Eff. Major Principal Stress (ksf)=	**4.38**
Axial Strain (%)=	**9.91**

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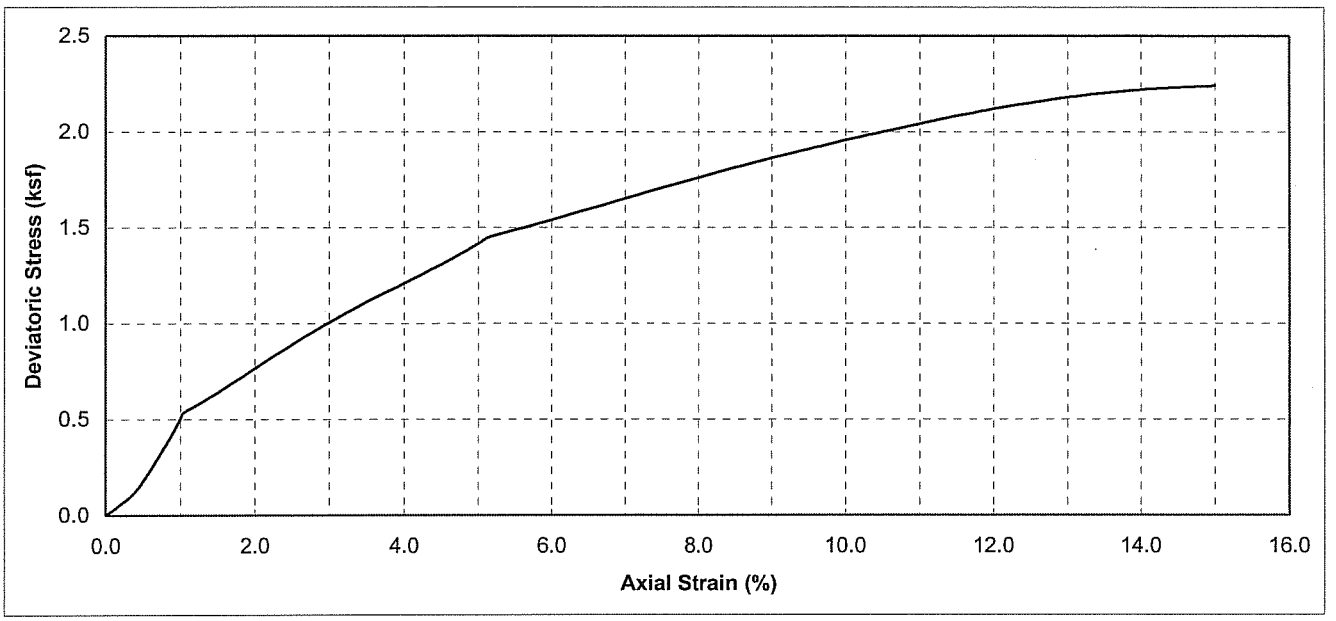
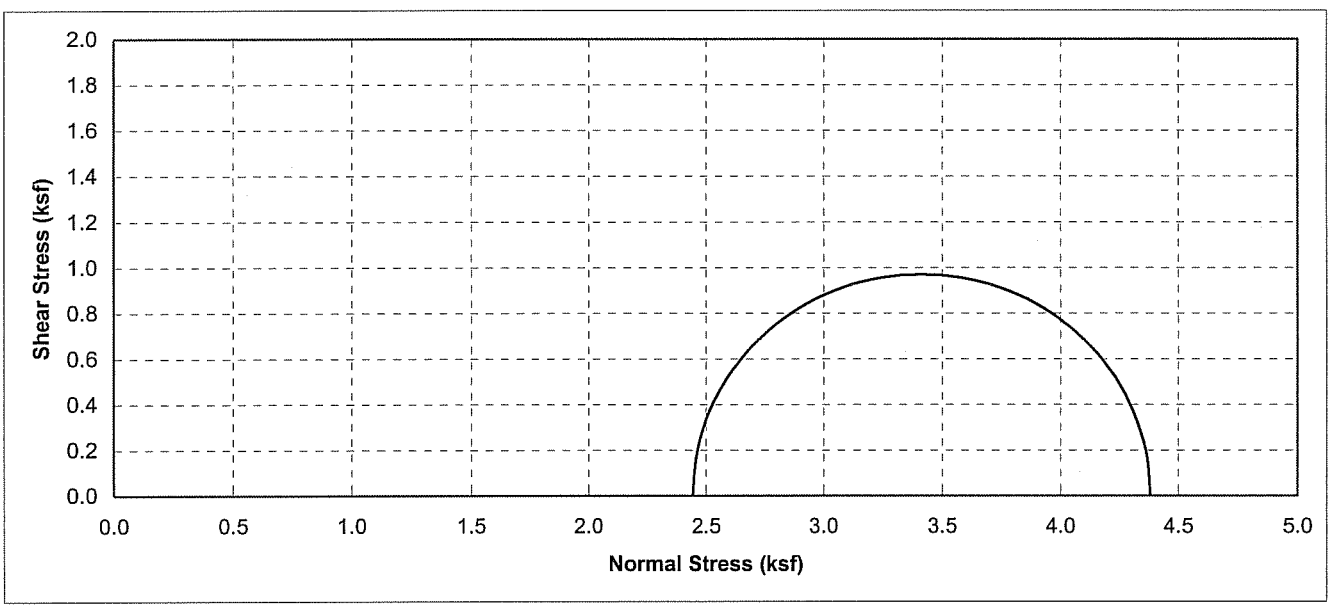
Geotechnical and Earthquake Engineering





Boring No.	Sample No.	Depth (ft)	Soil Type	Dry Density (pcf)	Moisture Content (%)	Conf. Stress (ksf)	Max. Dev. Stress (ksf)	Initial Saturation (%)
06-6	D-6	31	Dark Bluish Gray, SILT With Sand (ML)	91.9	31.56	2.44	1.94	102.2

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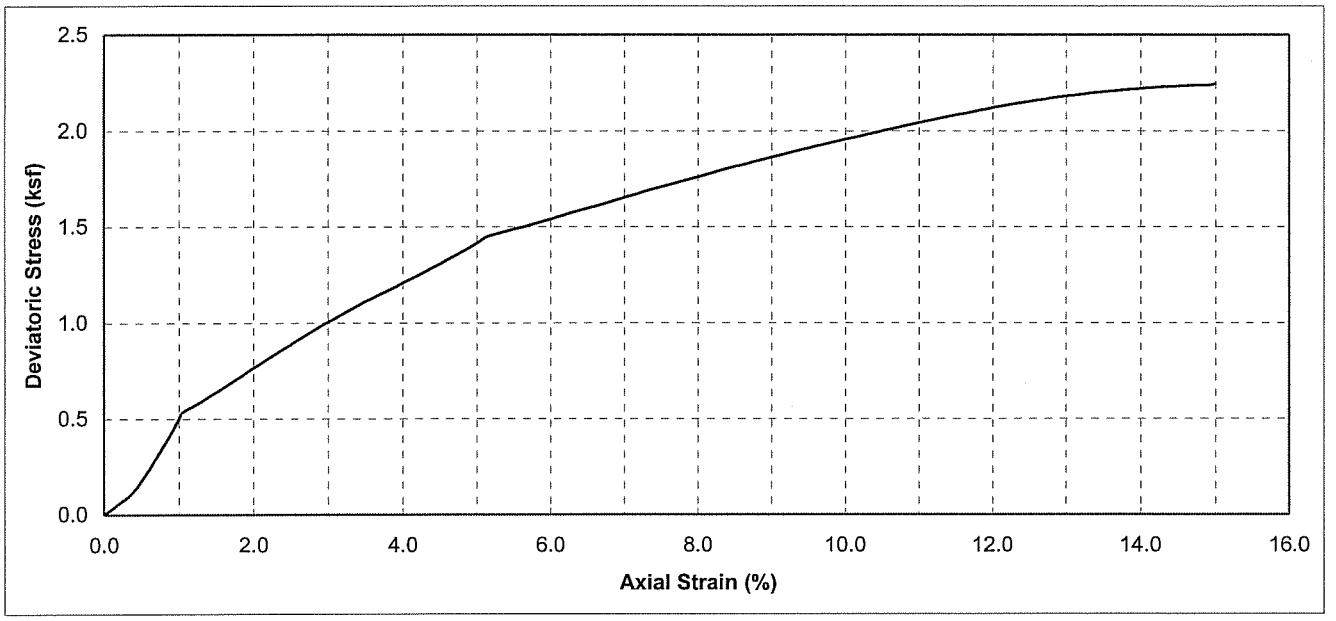
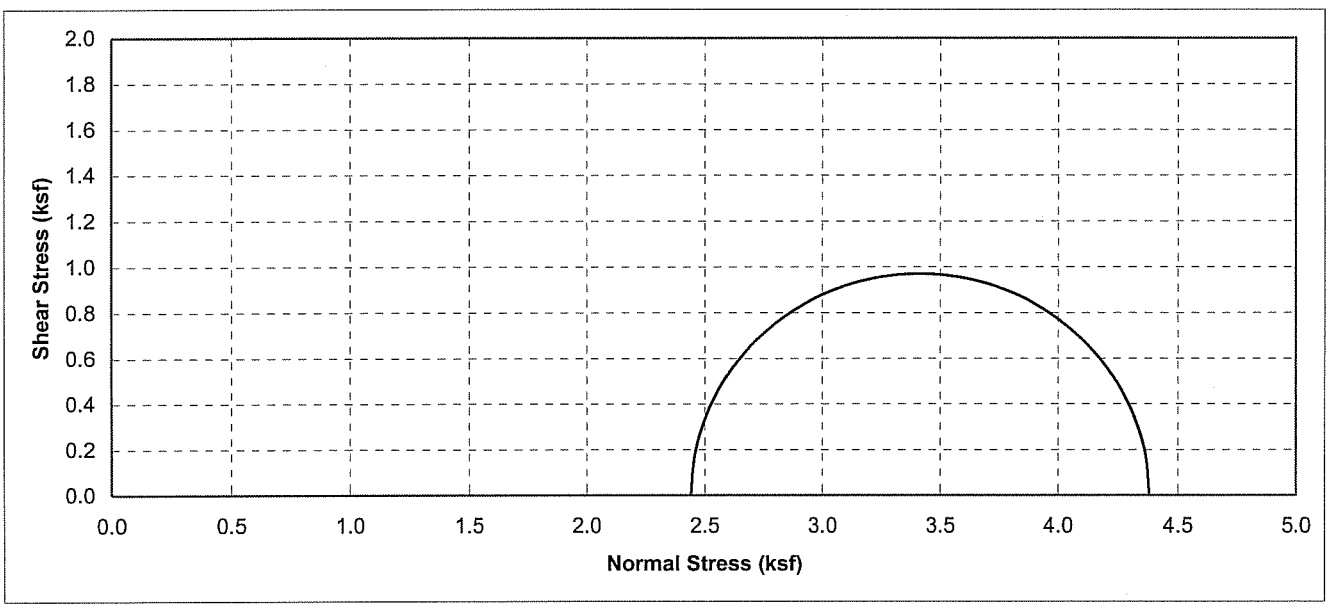
Geotechnical and Earthquake Engineering

BATA / Antioch Bridge

UNCONSOLIDATED UNDRAINED TEST
(ASTM D2850)

Project No. : 06-155 **Date :** 04/13/07 **Figure No. :**





Boring No.	Sample No.	Depth (ft)	Soil Type	Dry Density (pcf)	Moisture Content (%)	Conf. Stress (ksf)	Max. Dev. Stress (ksf)	Initial Saturation (%)
06-6	D-6	31	Dark Bluish Gray, SILT With Sand (ML)	91.9	31.56	2.44	1.94	102.2

Earth Mechanics, Inc.
Geotechnical and Earthquake Engineering

BATA / Antioch Bridge

UNCONSOLIDATED UNDRAINED TEST
(ASTM D2850)

Project No. : 06-155 **Date :** 04/13/07 **Figure No. :**

UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

ASTM D2850

Project Name:	BATA / Antioch Bridge			**Project No:**	06-155
Boring No.:	06-6	**Tested by:**	R.J.	**Date:**	04/13/07
Depth (ft):	91	**Checked by:**		**Date:**	
Sample No.	D-20	**Sample Type:**	R		

Sample Description: Light Olive Brown, FAT CLAY (CH)

	1	2	3		
Diameter (in.):	2.416	2.417	2.416	Average:	2.416
Height (in.):	5.028	5.023	5.027	Average:	5.026

Moisture Content Calculation	
Wt. Wet Sample + Container (gms):	209.82
Wt. Dry Sample + Container (gms):	178.45
Container (gms) No. 41	58.84
Moisture Content (%)	**26.2**

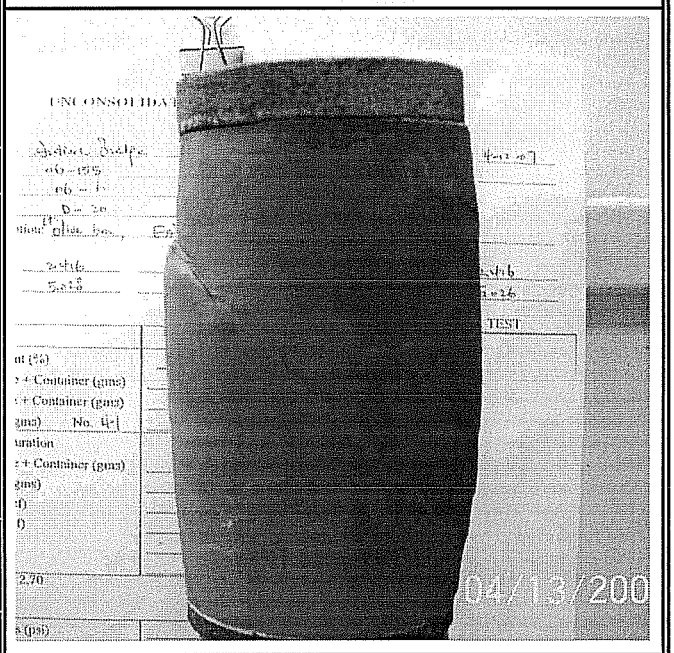
Density and Saturation	
Wt. Wet Sample + Container (gms)	982.22
Container (gms)	228.92
Wet Density (pcf)	**124.4**
Dry Density (pcf)	**98.6**
Void Ratio	**0.709**
% Saturation	**99.9**

Assume Gs=2.70

Test Data Filename:	06155B6D20.trx

SKETCH / PHOTO AFTER TEST:

PHOTO FILE NAME: D:\06-155 Antioch\lab\100_3576.JPG



Shear	
Rate of Deformation (% strain / min) =	**1**
Confining Stress (ksf):	**7.20**

Failure Criterion: **criterion 1 is used**

1. the maximum deviator stress within 15% strain
2. the stress at 10% strain for no peak stress.

At Failure	
Deviator Stress (ksf)	**10.43**
Eff. Minor Principal Stress (ksf)=	**7.20**
Eff. Major Principal Stress (ksf)=	**17.64**
Axial Strain (%)=	**13.92**

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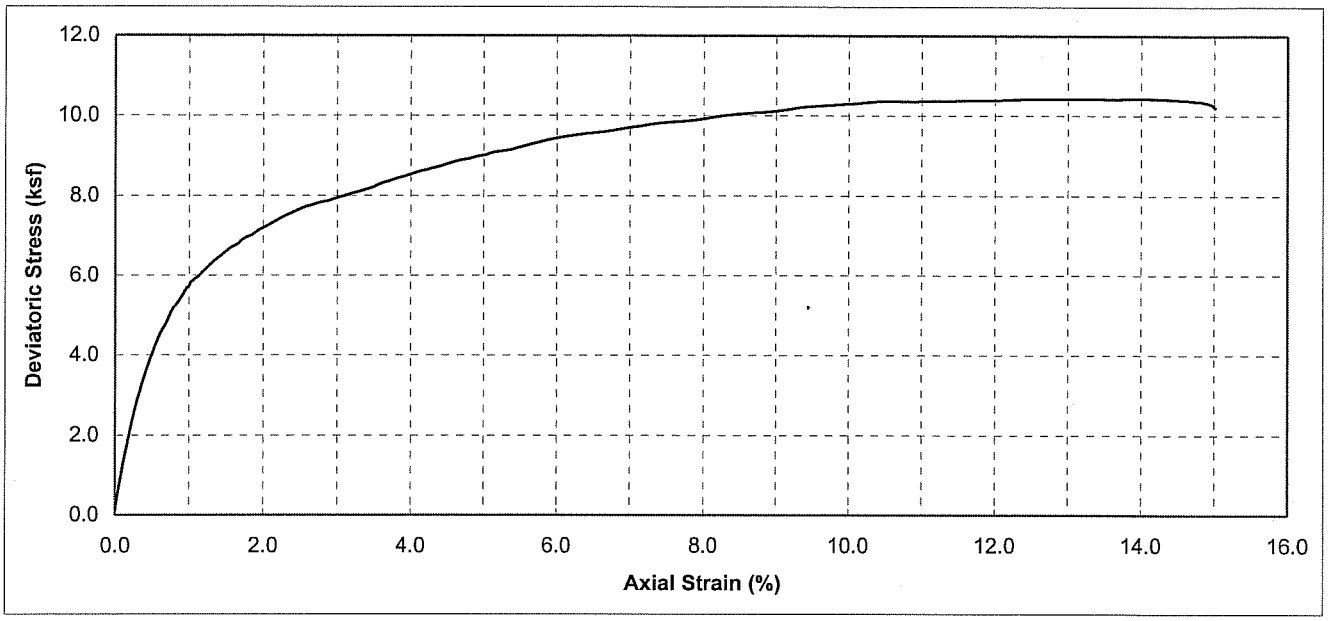
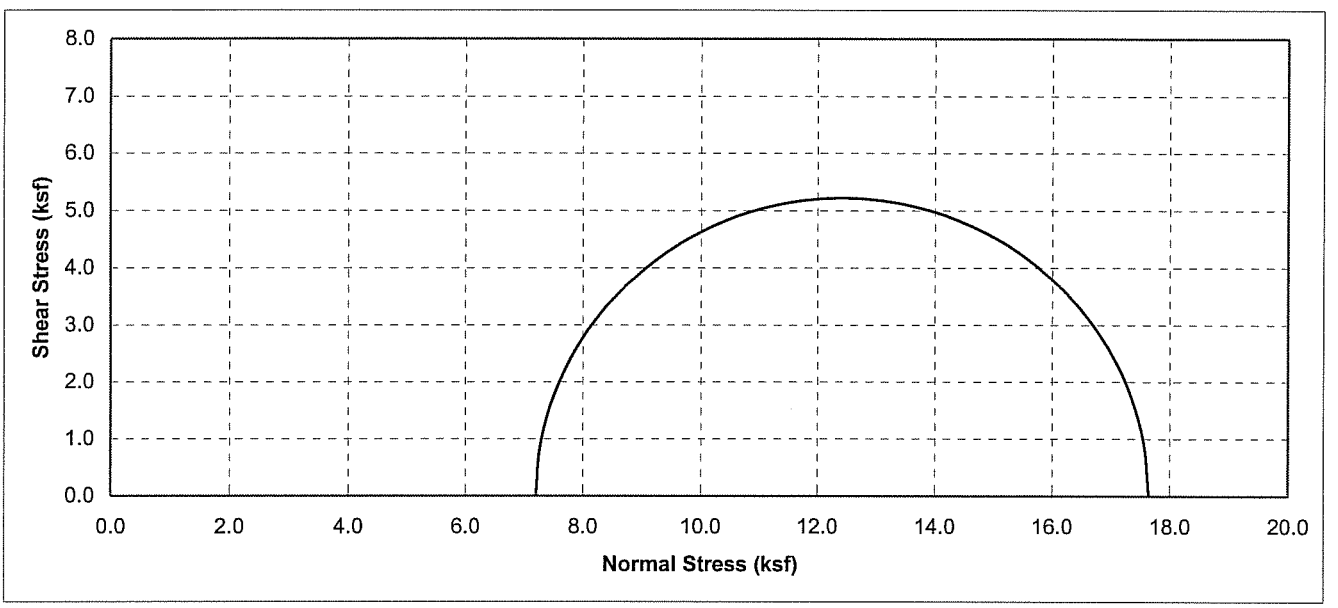
Geotechnical and Earthquake Engineering





Boring No.	Sample No.	Depth (ft)	Soil Type	Dry Density (pcf)	Moisture Content (%)	Conf. Stress (ksf)	Max. Dev. Stress (ksf)	Initial Saturation (%)
06-6	D-20	91	Light Olive Brown, FAT CLAY (CH)	98.6	26.23	7.20	10.43	99.9

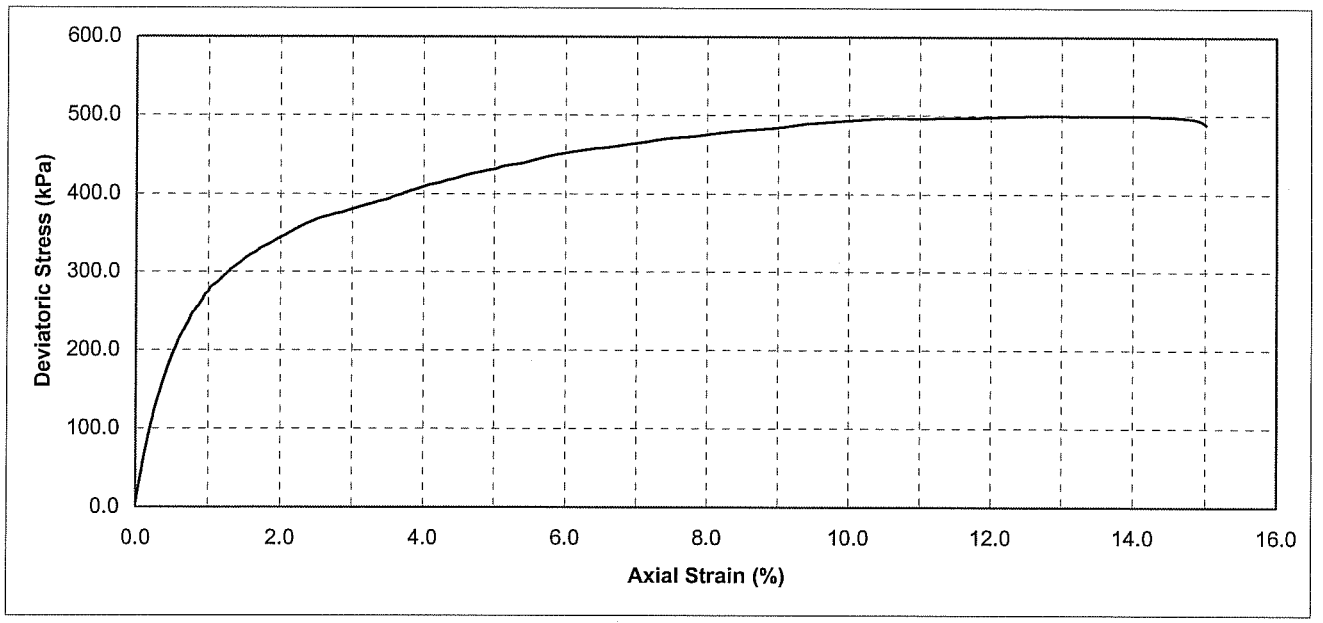
Earth Mechanics, Inc.
Geotechnical and Earthquake Engineering

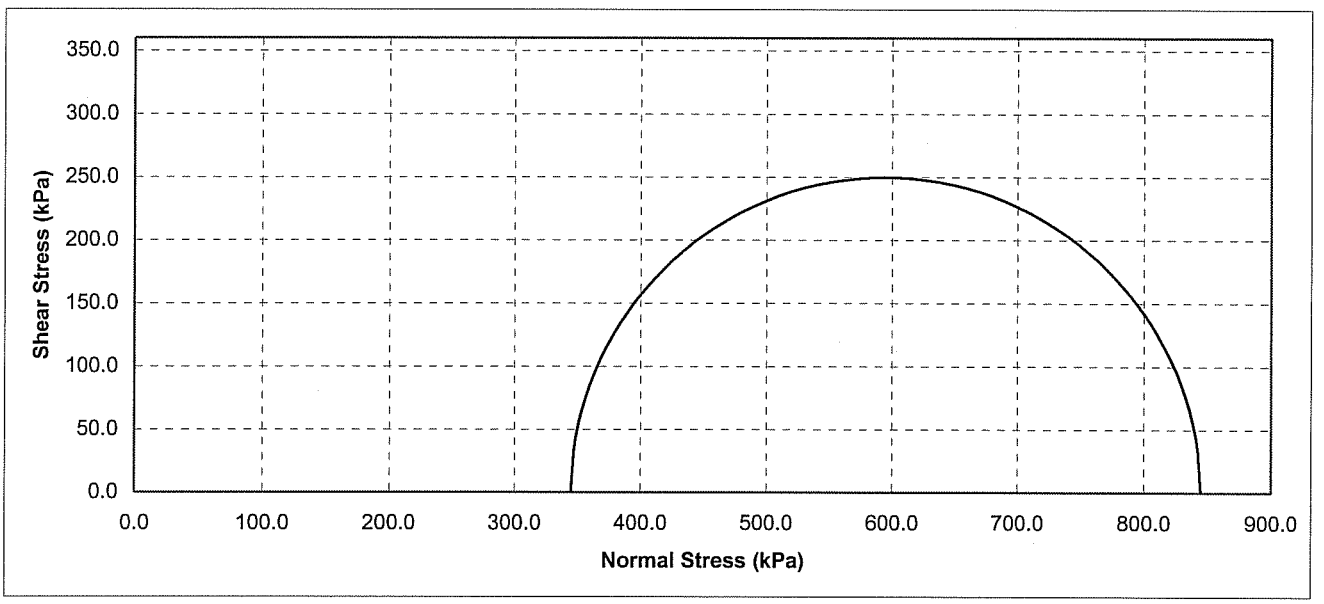
BATA / Antioch Bridge

UNCONSOLIDATED UNDRAINED TEST
(ASTM D2850)

Project No. : 06-155 **Date :** 04/13/07

Figure No. :





Boring No.	Sample No.	Depth (m)	Soil Type	Dry Density (kN/m^3)	Moisture Content (%)	Conf. Stress (kPa)	Max. Dev. Stress (kPa)	Initial Saturation (%)
06-6	D-20	27.74	Light Olive Brown, FAT CLAY (CH)	15.5	26.2	344.8	499.6	99.9

Earth Mechanics, Inc.
Geotechnical and Earthquake Engineering

BATA / Antioch Bridge

UNCONSOLIDATED UNDRAINED TEST
(ASTM D2850)

Project No. : 06-155 **Date :** 04/13/07

Figure No. :

UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

ASTM D2850

Project Name:	BATA / Antioch Bridge			**Project No:**	06-155
Boring No.:	06-8	**Tested by:**	R.J.	**Date:**	04/15/07
Depth (ft):	46	**Checked by:**		**Date:**	
Sample No.	D-10	**Sample Type:**	R		

Sample Description: Dark Bluish Gray, SANDY SILT (ML)

	1	2	3		
Diameter (in.):	2.417	2.419	2.425	Average:	2.420
Height (in.):	4.943	4.931	4.922	Average:	4.932

Moisture Content Calculation	
Wt. Wet Sample + Container (gms):	191.42
Wt. Dry Sample + Container (gms):	159.58
Container (gms) No. 63	58.38
Moisture Content (%)	**31.5**

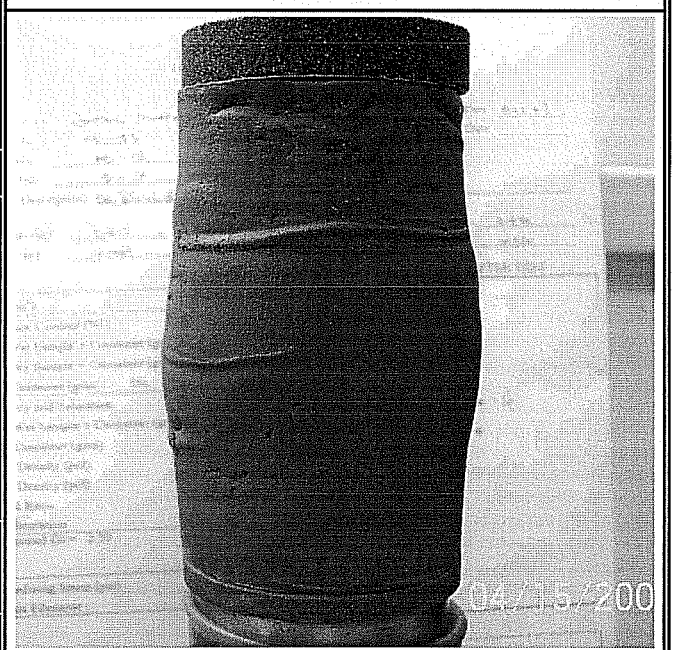
Density and Saturation	
Wt. Wet Sample + Container (gms)	935.99
Container (gms)	228.92
Wet Density (pcf)	**119.4**
Dry Density (pcf)	**90.8**
Void Ratio	**0.855**
% Saturation	**99.4**

Assume Gs=2.70

Test Data Filename:	06155B8D10.xls

SKETCH / PHOTO AFTER TEST:

PHOTO FILE NAME: D:\06-155 Antioch\lab\100_3577.JPG



Shear	
Rate of Deformation (% strain / min) =	**1**
Confining Stress (ksf):	**3.74**

Failure Criterion: **criterion 2 is used**

1. the maximum deviator stress within 15% strain
2. the stress at 10% strain for no peak stress.

At Failure	
Deviator Stress (ksf)	**0.00**
Eff. Minor Principal Stress (ksf)=	**3.74**
Eff. Major Principal Stress (ksf)=	**3.74**
Axial Strain (%)=	**0.00**

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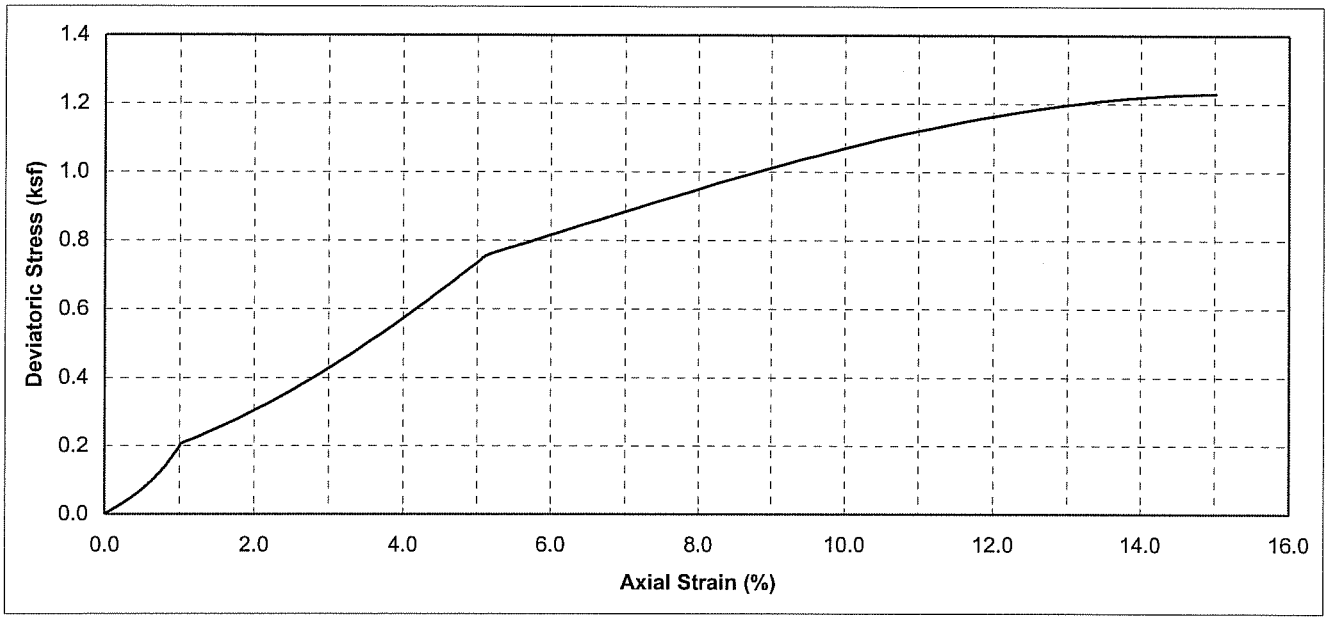
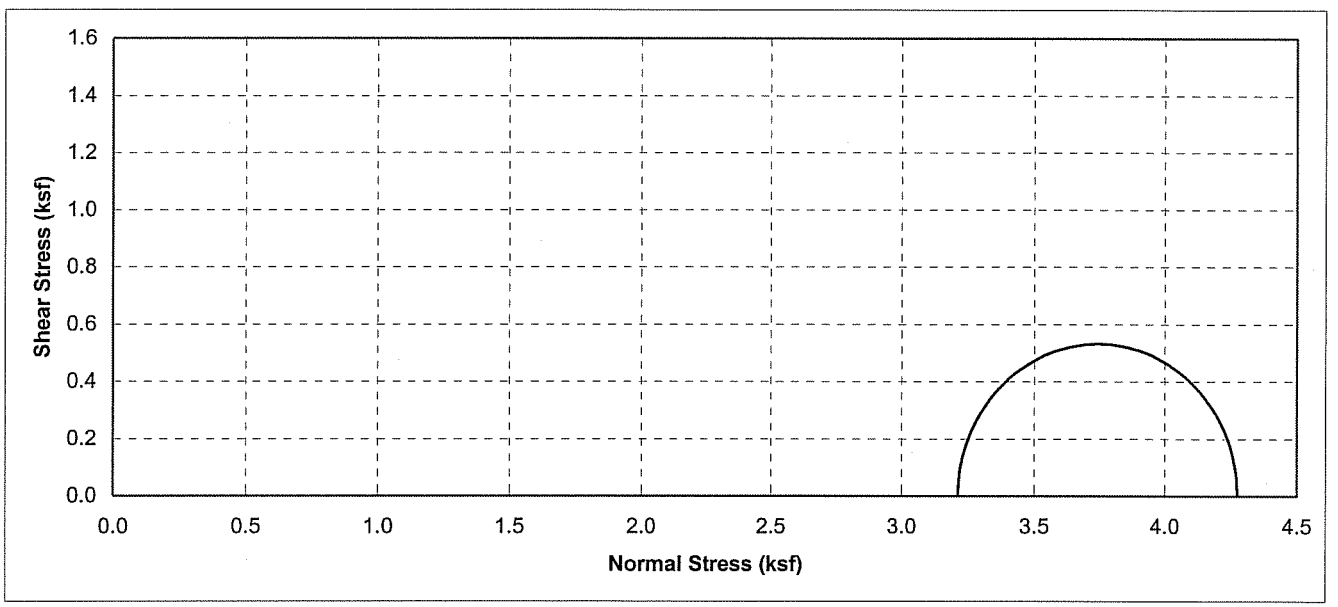
Geotechnical and Earthquake Engineering





Boring No.	Sample No.	Depth (ft)	Soil Type	Dry Density (pcf)	Moisture Content (%)	Conf. Stress (ksf)	Max. Dev. Stress (ksf)	Initial Saturation (%)
06-8	D-10	46	Dark Bluish Gray, SANDY SILT (ML)	90.8	31.46	3.74	0.00	99.4

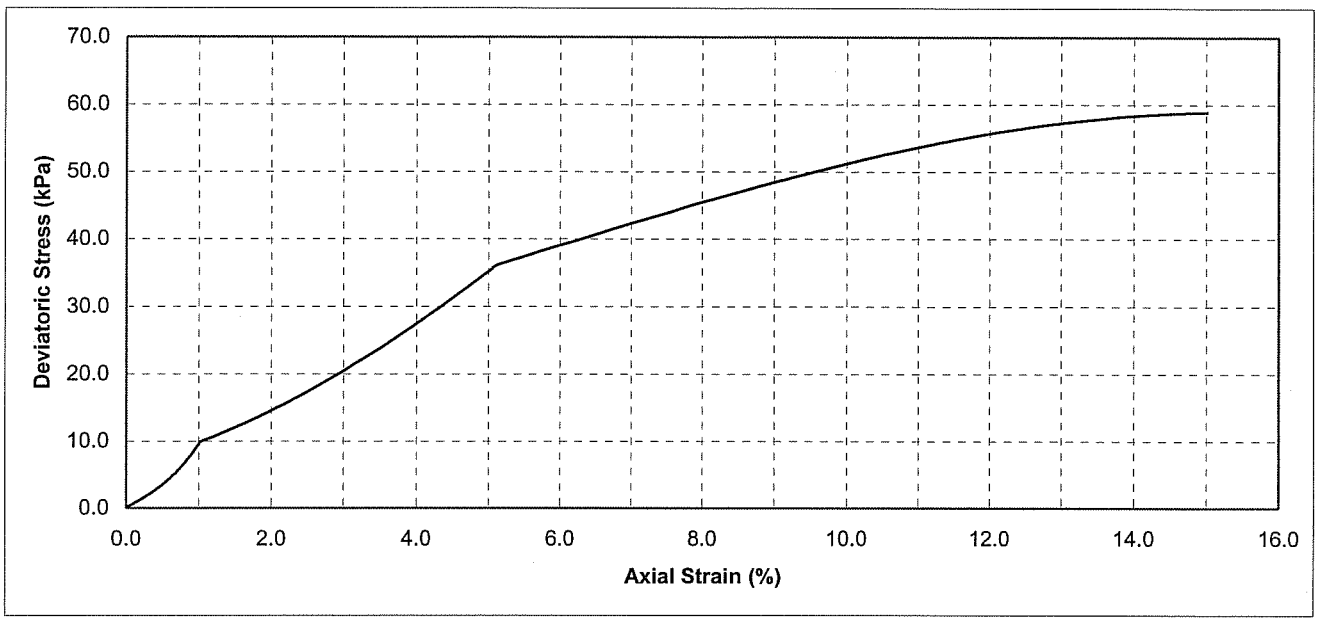
Earth Mechanics, Inc.
Geotechnical and Earthquake Engineering

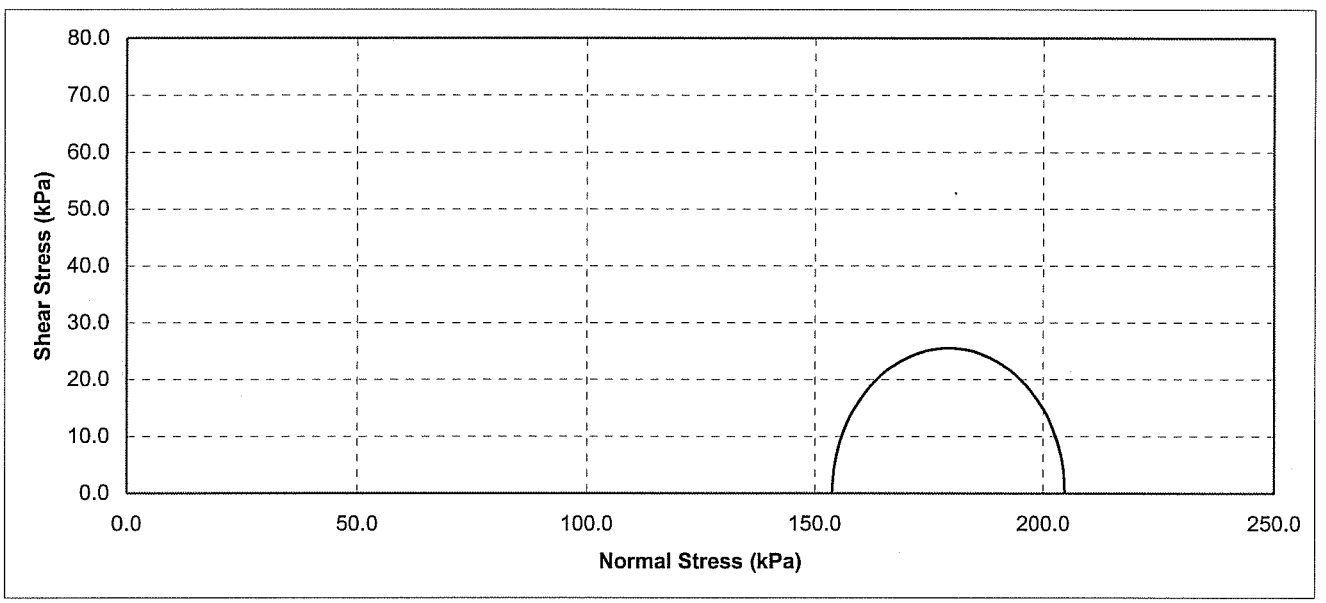
BATA / Antioch Bridge

UNCONSOLIDATED UNDRAINED TEST
(ASTM D2850)

Project No. : 06-155 **Date :** 04/15/07

Figure No. :





Boring No.	Sample No.	Depth (m)	Soil Type	Dry Density (kN/m^3)	Moisture Content (%)	Conf. Stress (kPa)	Max. Dev. Stress (kPa)	Initial Saturation (%)
06-8	D-10	14.02	Dark Bluish Gray, SANDY SILT (ML)	14.3	31.5	179.3	0.0	99.4

Earth Mechanics, Inc.
Geotechnical and Earthquake Engineering

BATA / Antioch Bridge

UNCONSOLIDATED UNDRAINED TEST
(ASTM D2850)

Project No. : 06-155 **Date :** 04/15/07 **Figure No. :**

UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

ASTM D2850

Project Name:	BATA / Antioch Bridge			**Project No:**	06-155
Boring No.:	06-8	**Tested by:**	R.J.	**Date:**	04/15/07
Depth (ft):	120	**Checked by:**		**Date:**	
Sample No.	D-24	**Sample Type:**	R		

Sample Description: Light Olive Brown , LEAN CLAY (CL)

	1	2	3		
Diameter (in.):	2.413	2.412	2.411	Average:	2.412
Height (in.):	5.047	5.035	5.043	Average:	5.042

Moisture Content Calculation	
Wt. Wet Sample + Container (gms):	210.44
Wt. Dry Sample + Container (gms):	176.6
Container (gms) No. 64	57.42
Moisture Content (%)	**28.4**

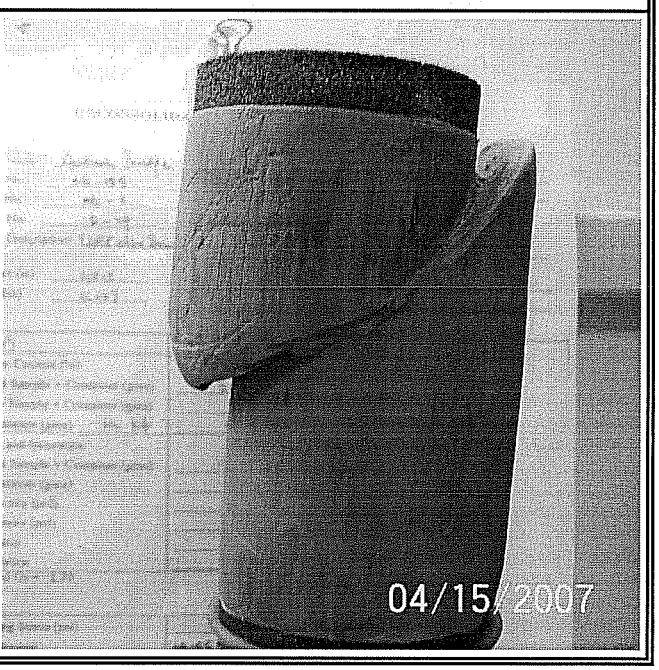
Density and Saturation	
Wt. Wet Sample + Container (gms)	953.77
Container (gms)	228.92
Wet Density (pcf)	**119.8**
Dry Density (pcf)	**93.3**
Void Ratio	**0.806**
% Saturation	**95.1**

Assume Gs=2.70

Test Data Filename:	06155B8D24.trx

SKETCH / PHOTO AFTER TEST:

PHOTO FILE NAME: D:\06-155 Antioch\lab\100_3579.JPG



Shear	
Rate of Deformation (% strain / min) =	**1**
Confining Stress (ksf):	**7.20**

Failure Criterion: **criterion 1 is used**

1. the maximum deviator stress within 15% strain
2. the stress at 10% strain for no peak stress.

At Failure	
Deviator Stress (ksf)	**6.55**
Eff. Minor Principal Stress (ksf)=	**7.20**
Eff. Major Principal Stress (ksf)=	**13.75**
Axial Strain (%)=	**12.41**

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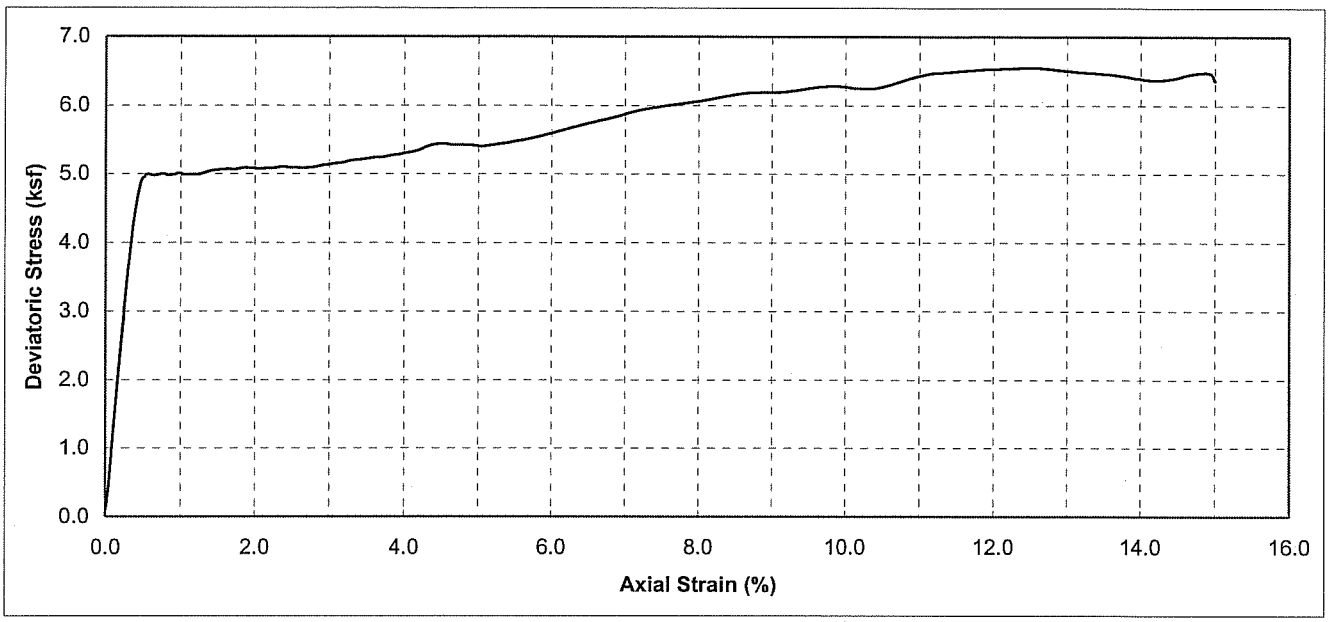
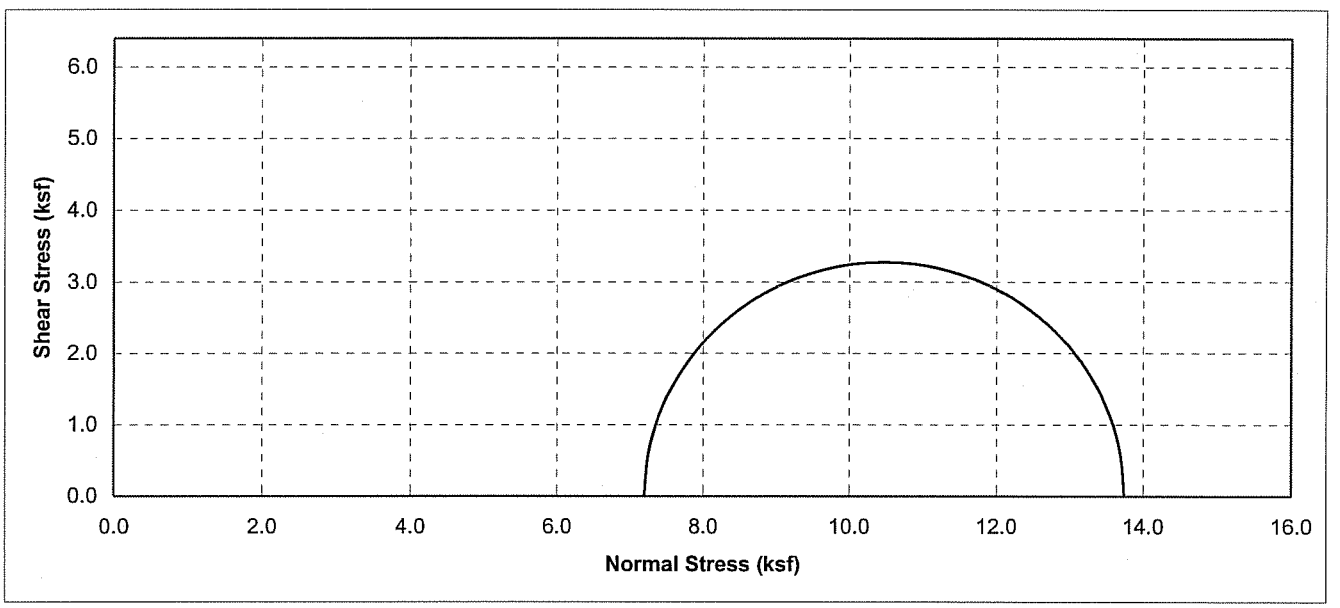
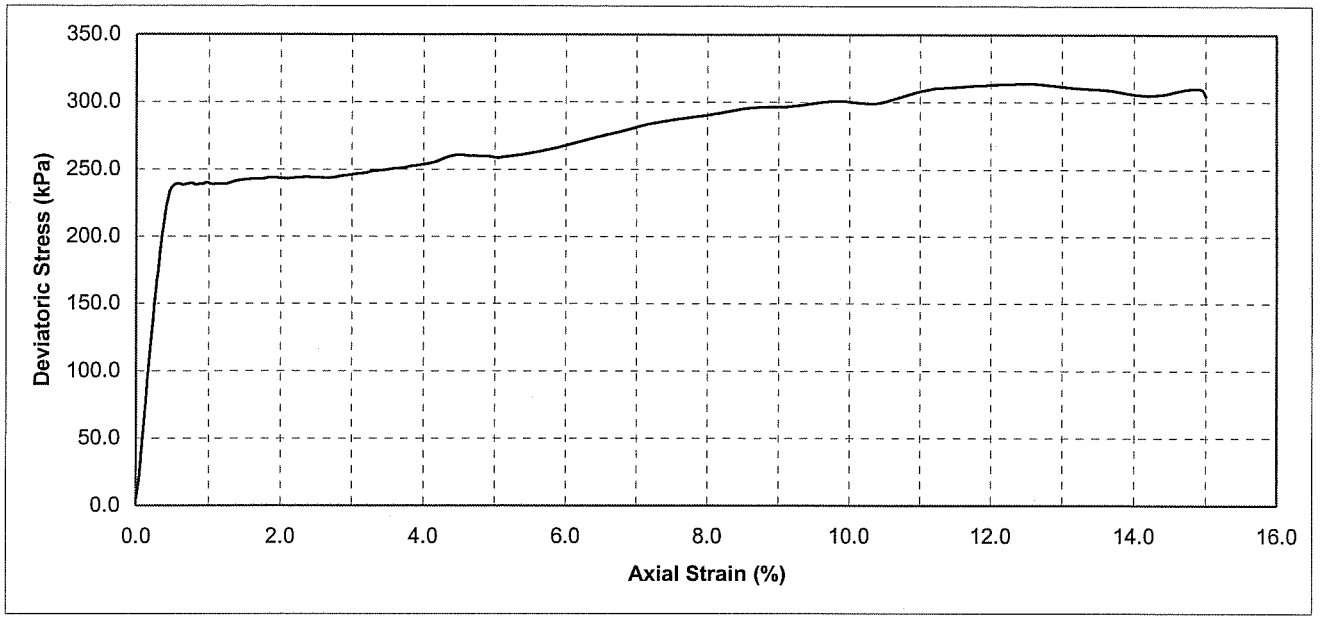
Geotechnical and Earthquake Engineering

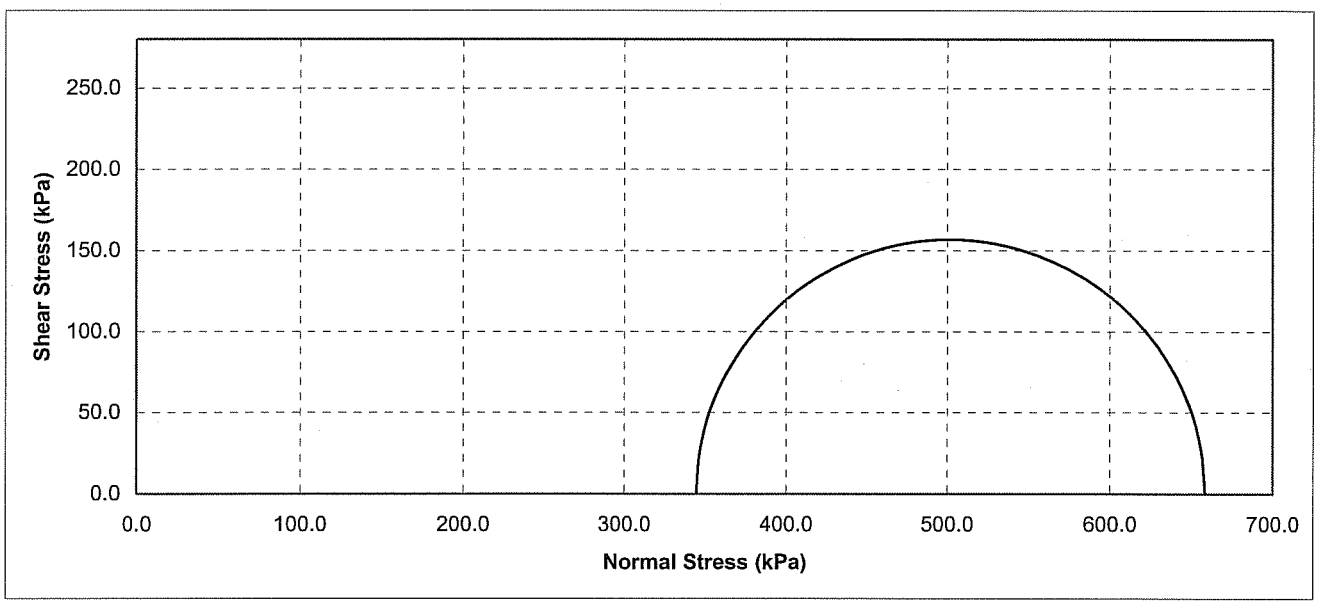




Boring No.	Sample No.	Depth (ft)	Soil Type	Dry Density (pcf)	Moisture Content (%)	Conf. Stress (ksf)	Max. Dev. Stress (ksf)	Initial Saturation (%)
06-8	D-24	120	Light Olive Brown , LEAN CLAY (CL)	93.3	28.39	7.20	6.55	95.1

Earth Mechanics, Inc. Geotechnical and Earthquake Engineering	**BATA / Antioch Bridge**
Project No. : 06-155 **Date :** 04/15/07	**UNCONSOLIDATED UNDRAINED TEST** **(ASTM D2850)** Figure No. :





Boring No.	Sample No.	Depth (m)	Soil Type	Dry Density (kN/m^3)	Moisture Content (%)	Conf. Stress (kPa)	Max. Dev. Stress (kPa)	Initial Saturation (%)
06-8	D-24	36.58	Light Olive Brown , LEAN CLAY (CL)	14.7	28.4	344.7	313.5	95.1

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BATA / Antioch Bridge

UNCONSOLIDATED UNDRAINED TEST
(ASTM D2850)

Project No. : 06-155 **Date :** 04/15/07 **Figure No. :**

UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

ASTM D2850

Project Name:	BATA / Antioch Bridge			**Project No:**	06-155
Boring No.:	06-9	**Tested by:**	R.J.	**Date:**	04/15/07
Depth (ft):	65	**Checked by:**		**Date:**	
Sample No.	D-13	**Sample Type:**	R		

Sample Description: Light Bluish Gray With Gray, SILT (ML)

	1	2	3		
Diameter (in.):	2.422	2.421	2.425	Average:	2.423
Height (in.):	5.036	5.006	5.002	Average:	5.015

Moisture Content Calculation	
Wt. Wet Sample + Container (gms):	164.41
Wt. Dry Sample + Container (gms):	119.23
Container (gms) No. 65	59.03
Moisture Content (%)	**75.0**

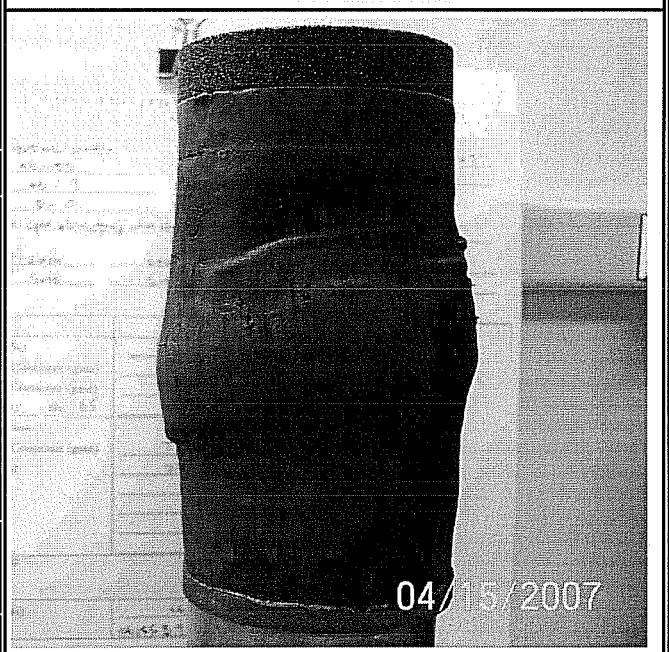
Density and Saturation	
Wt. Wet Sample + Container (gms)	777.43
Container (gms)	228.92
Wet Density (pcf)	**90.3**
Dry Density (pcf)	**51.6**
Void Ratio	**2.267**
% Saturation	**89.4**

Assume Gs=2.70

Test Data Filename:

SKETCH / PHOTO AFTER TEST:

PHOTO FILE NAME: D:\06-155 Antioch\lab\100_3581.JPG



Shear	
Rate of Deformation (% strain / min) =	**1**
Confining Stress (ksf):	**5.18**

Failure Criterion: **criterion 1 is used**

1. the maximum deviator stress within 15% strain
2. the stress at 10% strain for no peak stress.

At Failure	
Deviator Stress (ksf)	**0.00**
Eff. Minor Principal Stress (ksf)=	**5.18**
Eff. Major Principal Stress (ksf)=	**5.18**
Axial Strain (%)=	**0.00**

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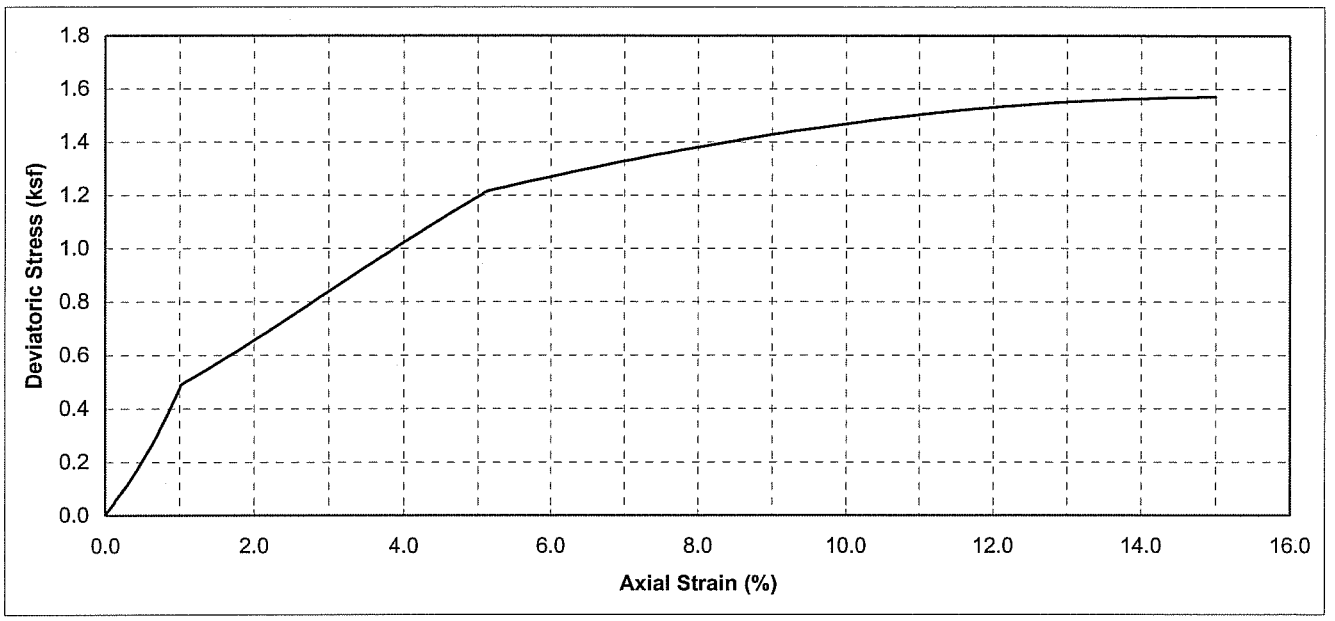
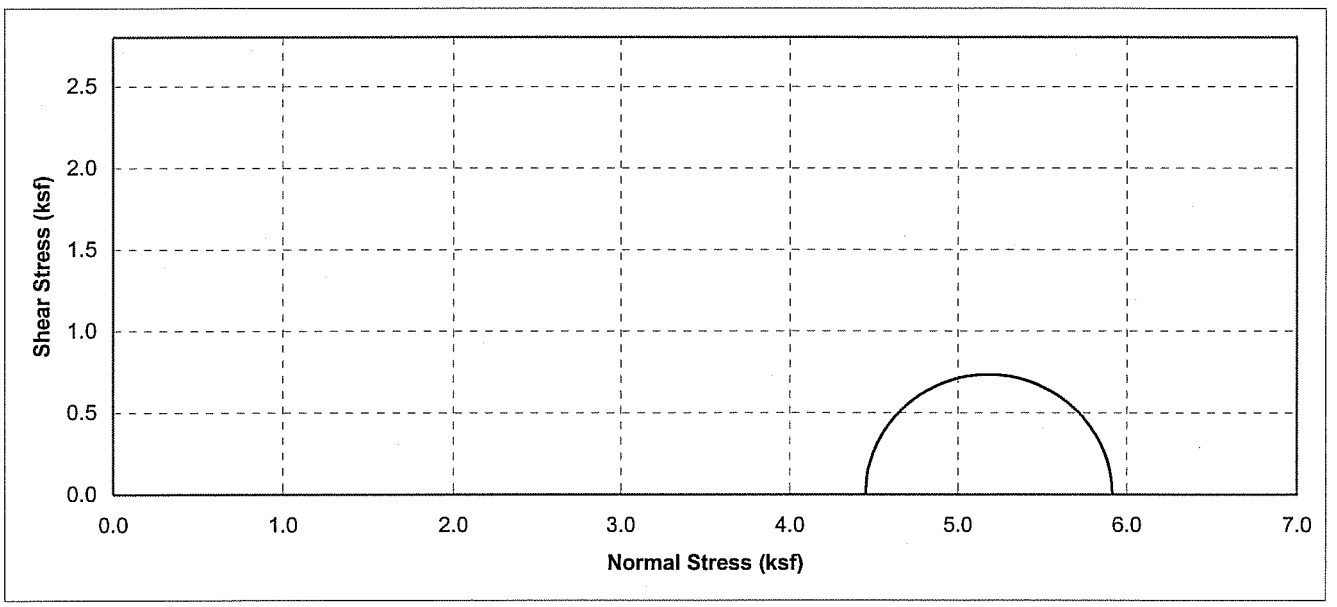




Boring No.	Sample No.	Depth (ft)	Soil Type	Dry Density (pcf)	Moisture Content (%)	Conf. Stress (ksf)	Max. Dev. Stress (ksf)	Initial Saturation (%)
06-9	D-13	65	Light Bluish Gray With Gray, SILT (ML)	51.6	75.05	5.18	0.00	89.4

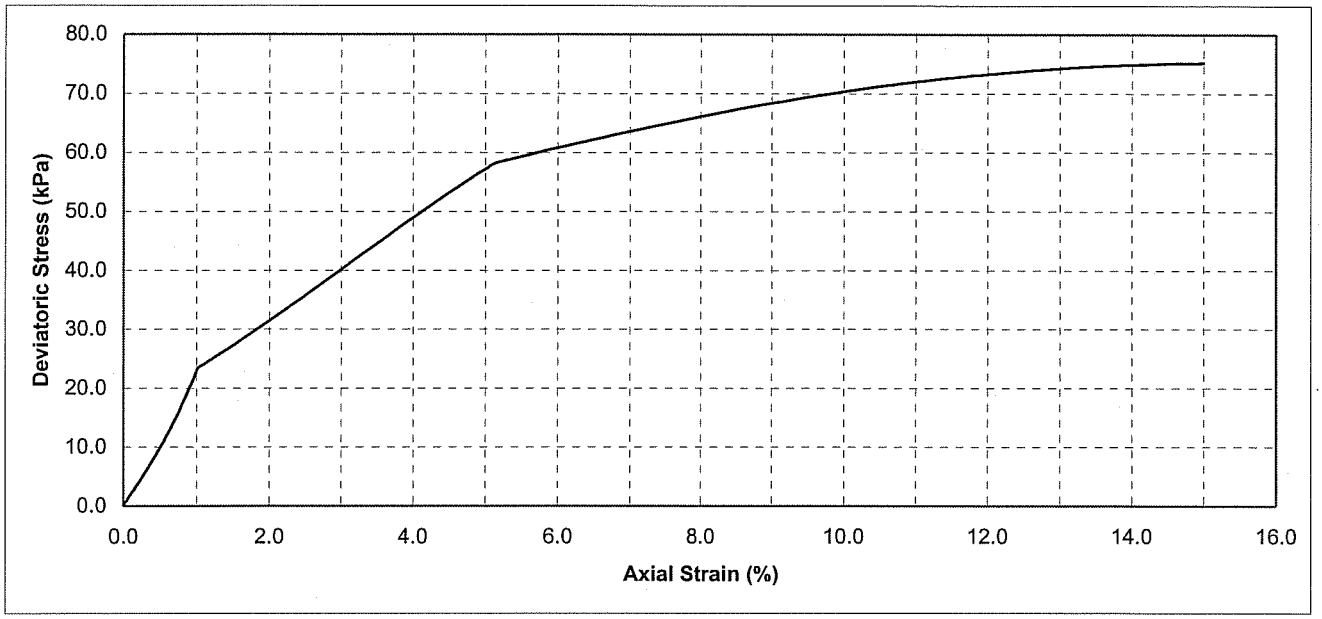
Earth Mechanics, Inc.
Geotechnical and Earthquake Engineering

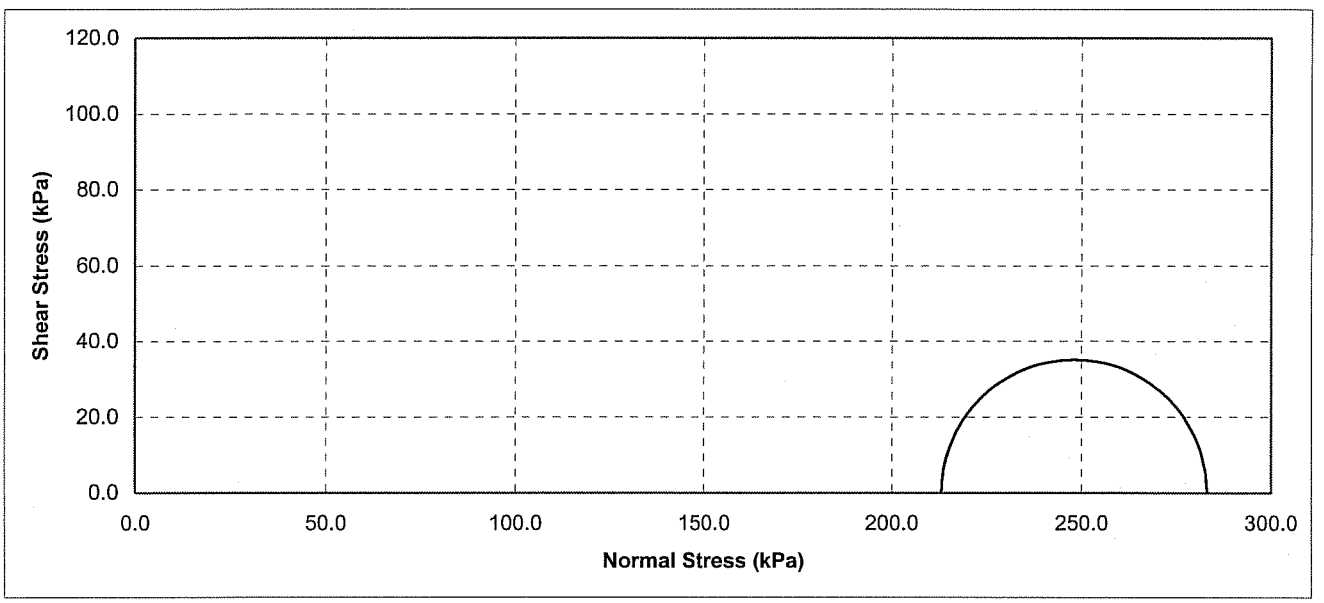
BATA / Antioch Bridge

UNCONSOLIDATED UNDRAINED TEST
(ASTM D2850)

Project No. : 06-155 **Date :** 04/15/07

Figure No. :





Boring No.	Sample No.	Depth (m)	Soil Type	Dry Density (kN/m^3)	Moisture Content (%)	Conf. Stress (kPa)	Max. Dev. Stress (kPa)	Initial Saturation (%)
06-9	D-13	19.81	Light Bluish Gray With Gray, SILT (ML)	8.1	75.0	248.2	0.0	89.4

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BATA / Antioch Bridge

UNCONSOLIDATED UNDRAINED TEST
(ASTM D2850)

Project No. : 06-155 **Date :** 04/15/07 **Figure No. :**

UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

ASTM D2850

Project Name:	BATA / Antioch Bridge			**Project No:**	06-155
Boring No.:	06-9	**Tested by:**	R.J.	**Date:**	04/15/07
Depth (ft):	110	**Checked by:**		**Date:**	
Sample No.	D-21	**Sample Type:**	R		

Sample Description: Light Olive Brown, FAT CLAY (CH)

	1	2	3		
Diameter (in.):	2.415	2.415	2.416	Average:	2.415
Height (in.):	5.023	5.025	5.014	Average:	5.021

Moisture Content Calculation	
Wt. Wet Sample + Container (gms):	225.31
Wt. Dry Sample + Container (gms):	187.56
Container (gms) No. 66	59.6
Moisture Content (%)	**29.5**

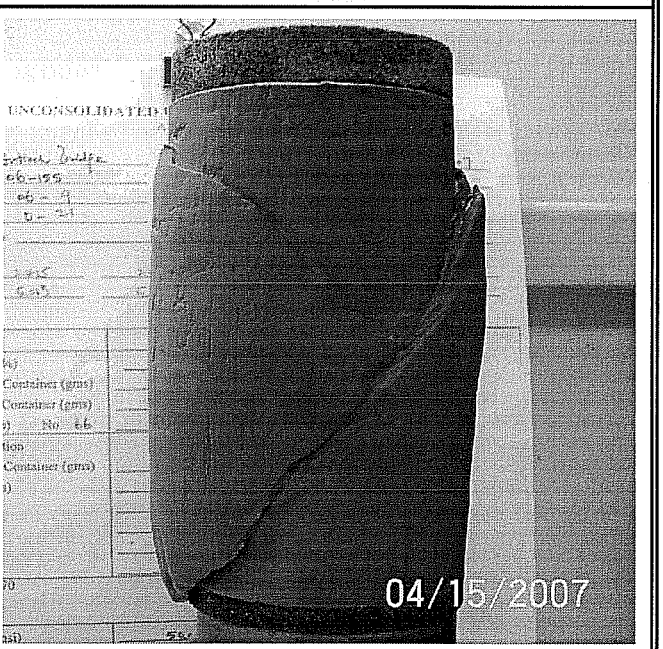
Density and Saturation	
Wt. Wet Sample + Container (gms)	960.05
Container (gms)	228.92
Wet Density (pcf)	**121.0**
Dry Density (pcf)	**93.4**
Void Ratio	**0.803**
% Saturation	**99.2**

Assume Gs=2.70

Test Data Filename:	06155B9D21.trx

SKETCH / PHOTO AFTER TEST:

PHOTO FILE NAME: D:\06-155 Antioch\lab\100_3582.JPG



Shear	
Rate of Deformation (% strain / min) =	**1**
Confining Stress (ksf):	**7.20**

Failure Criterion: **criterion 1 is used**

1. the maximum deviator stress within 15% strain
2. the stress at 10% strain for no peak stress.

At Failure	
Deviator Stress (ksf)	**6.96**
Eff. Minor Principal Stress (ksf)=	**7.20**
Eff. Major Principal Stress (ksf)=	**14.16**
Axial Strain (%)=	**4.31**

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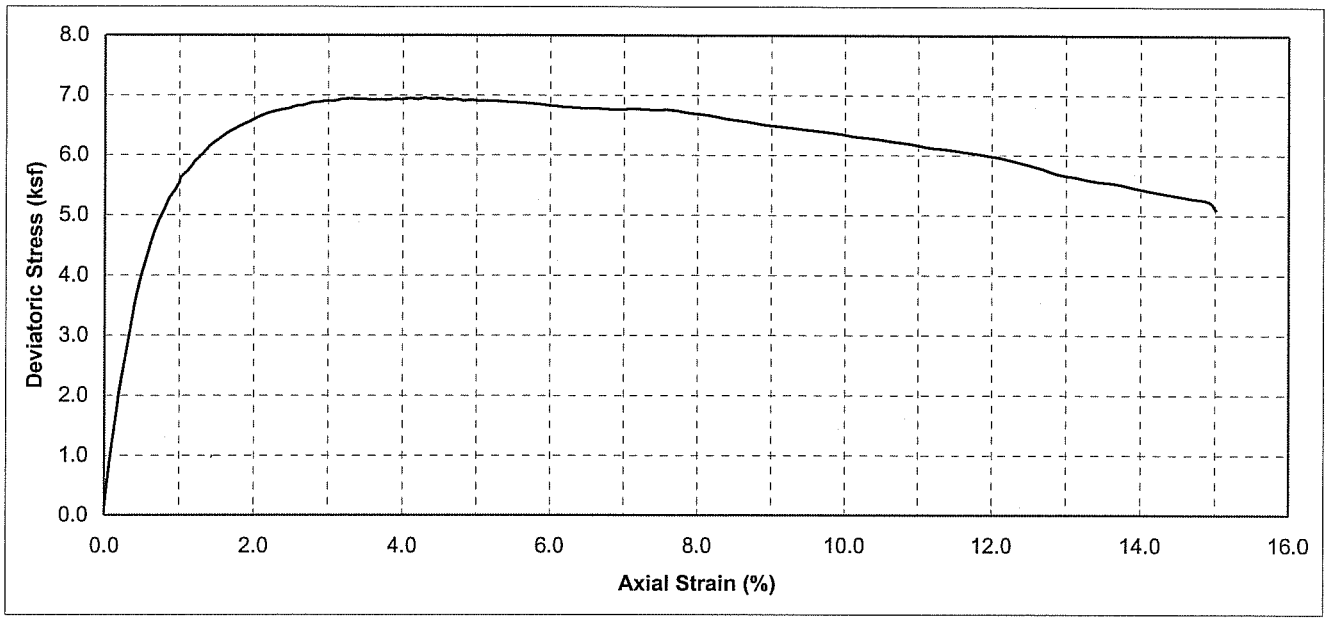

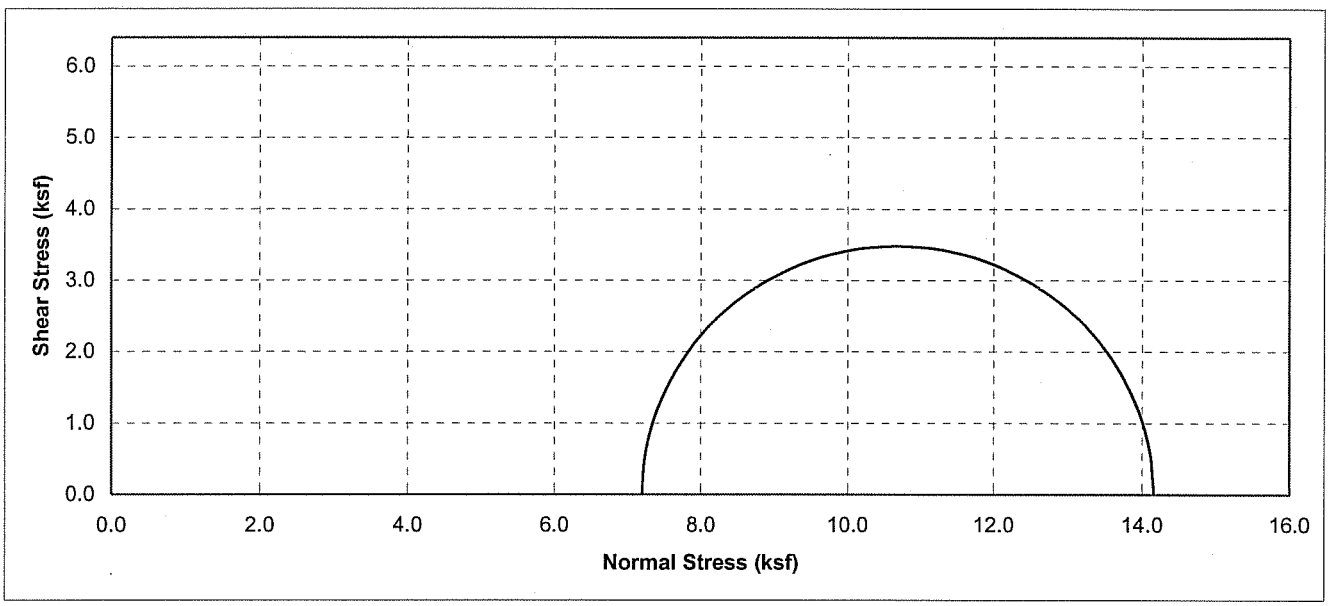

Boring No.	Sample No.	Depth (ft)	Soil Type	Dry Density (pcf)	Moisture Content (%)	Conf. Stress (ksf)	Max. Dev. Stress (ksf)	Initial Saturation (%)
06-9	D-21	110	Light Olive Brown, FAT CLAY (CH)	93.4	29.50	7.20	6.96	99.2

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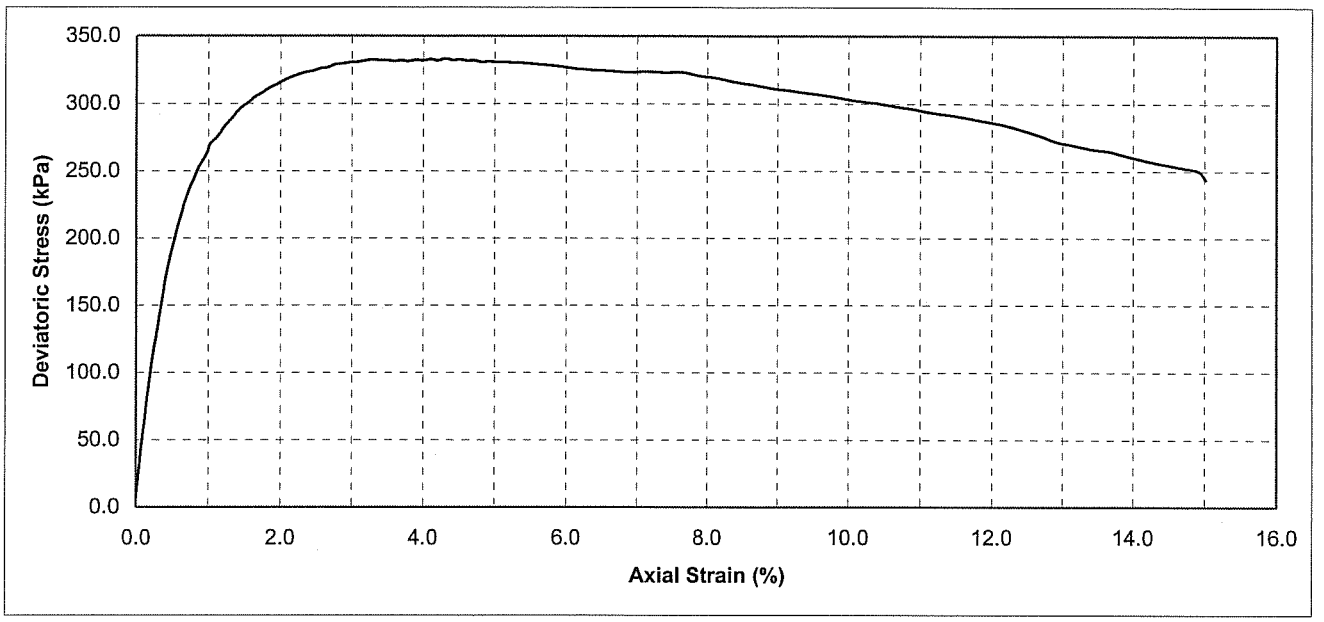
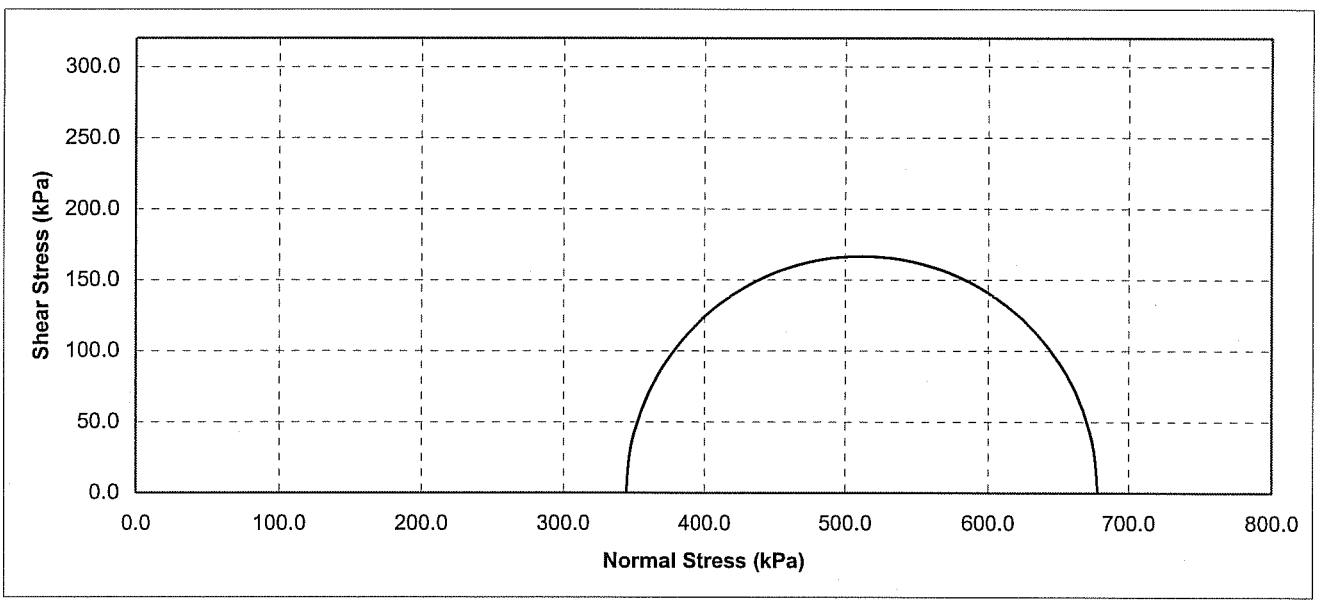
BATA / Antioch Bridge

UNCONSOLIDATED UNDRAINED TEST
(ASTM D2850)

Project No. : 06-155 **Date :** 04/15/07 **Figure No. :**





Boring No.	Sample No.	Depth (m)	Soil Type	Dry Density (kN/m^3)	Moisture Content (%)	Conf. Stress (kPa)	Max. Dev. Stress (kPa)	Initial Saturation (%)
06-9	D-21	33.53	Light Olive Brown, FAT CLAY (CH)	14.7	29.5	344.8	333.2	99.2

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BATA / Antioch Bridge

UNCONSOLIDATED UNDRAINED TEST
(ASTM D2850)

Project No. : 06-155 **Date :** 04/15/07 **Figure No. :**

UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

ASTM D2850

Project Name:	BATA / Antioch Bridge			**Project No:**	06-155
Boring No.:	06-10	**Tested by:**	R.J.	**Date:**	04/15/07
Depth (ft):	97.5	**Checked by:**		**Date:**	
Sample No.	D-20	**Sample Type:**	R		

Sample Description: Light Olive Brown , FAT CLAY (CH)

	1	2	3		
Diameter (in.):	2.402	2.402	2.405	Average:	2.403
Height (in.):	5.034	4.990	5.045	Average:	5.023

Moisture Content Calculation	
Wt. Wet Sample + Container (gms):	197.57
Wt. Dry Sample + Container (gms):	167.82
Container (gms) No. 67	58.59
Moisture Content (%)	**27.2**

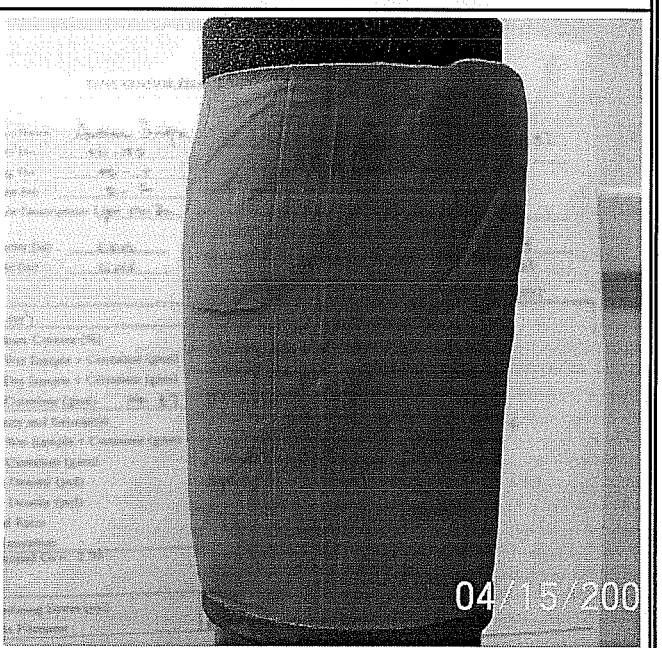
Density and Saturation	
Wt. Wet Sample + Container (gms)	961.3
Container (gms)	228.92
Wet Density (pcf)	**122.4**
Dry Density (pcf)	**96.2**
Void Ratio	**0.752**
% Saturation	**97.8**

Assume Gs=2.70

Test Data Filename:	06155B10D20.xls

SKETCH / PHOTO AFTER TEST:

PHOTO FILE NAME: D:\06-155 Antioch\lab\100_3583.JPG



Shear	
Rate of Deformation (% strain / min) =	**1**
Confining Stress (ksf):	**7.20**

Failure Criterion: **criterion 2 is used**

1. the maximum deviator stress within 15% strain
2. the stress at 10% strain for no peak stress.

At Failure	
Deviator Stress (ksf)	
Eff. Minor Principal Stress (ksf)=	**7.20**
Eff. Major Principal Stress (ksf)=	**7.20**
Axial Strain (%)=	

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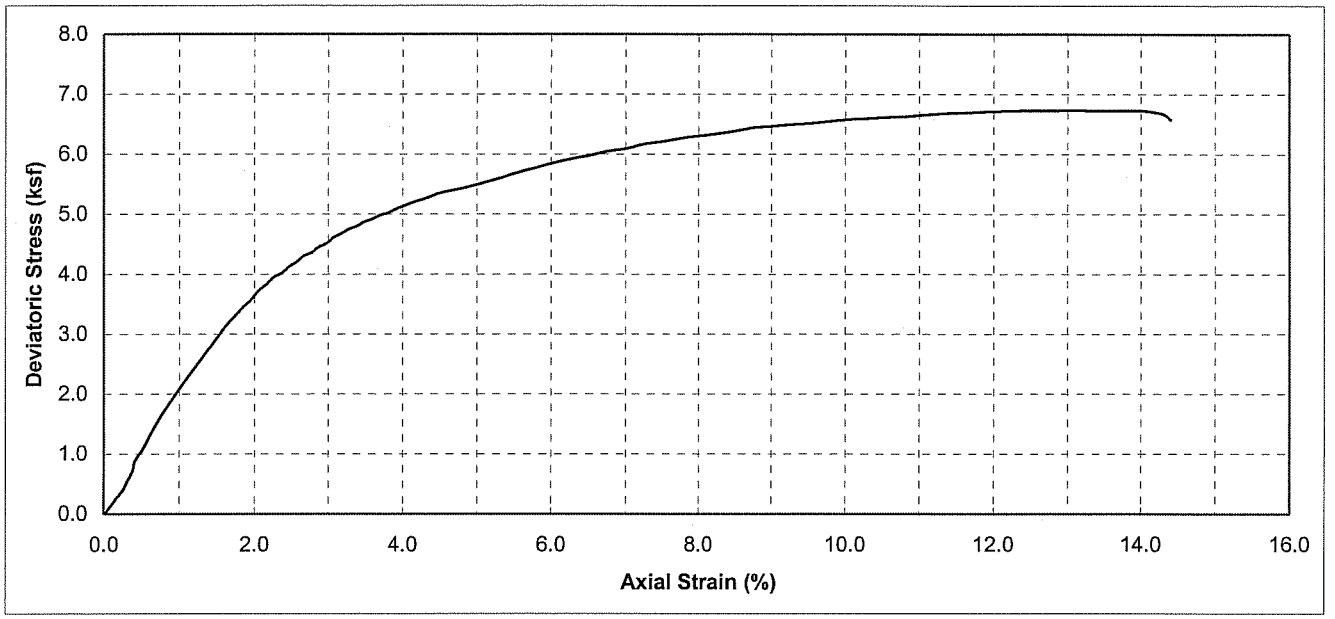
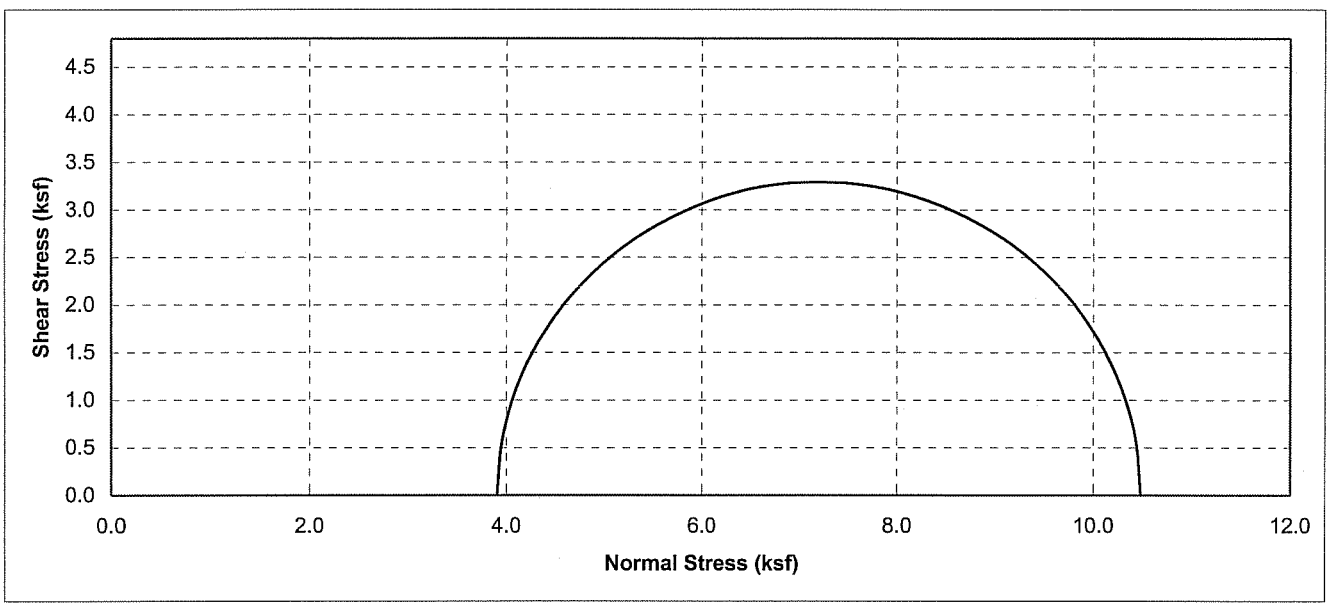




Boring No.	Sample No.	Depth (ft)	Soil Type	Dry Density (pcf)	Moisture Content (%)	Conf. Stress (ksf)	Max. Dev. Stress (ksf)	Initial Saturation (%)
06-10	D-20	97.5	Light Olive Brown , FAT CLAY (CH)	96.2	27.24	7.20		97.8

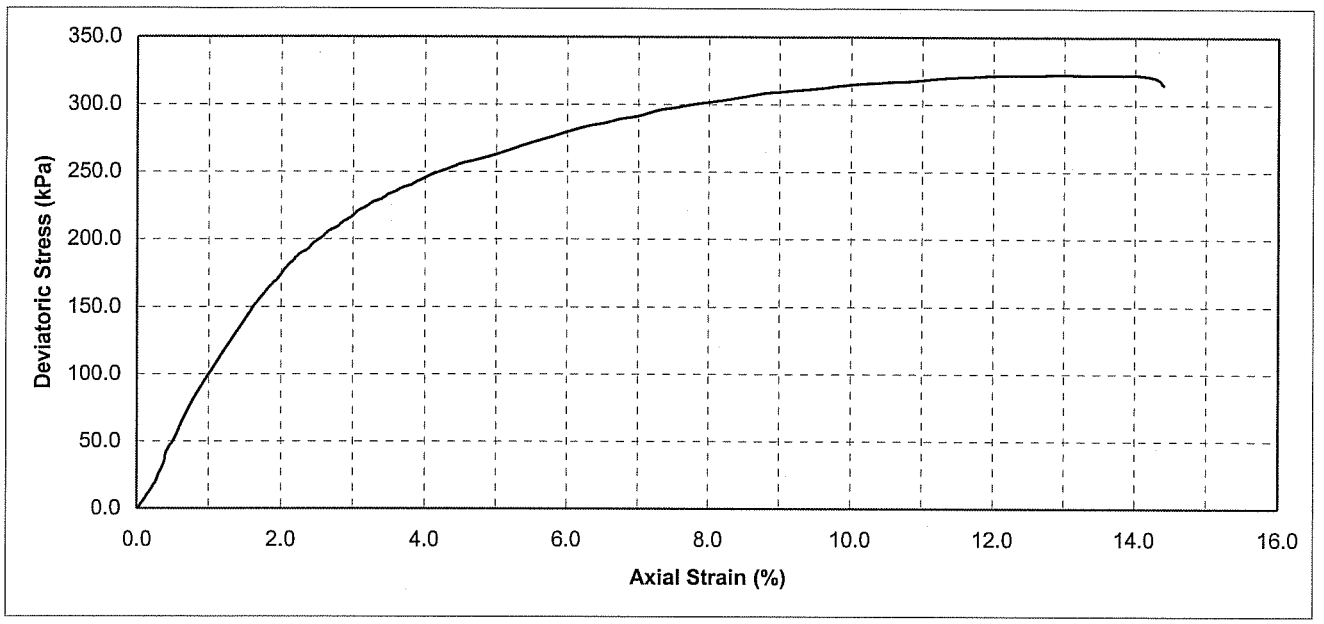
Earth Mechanics, Inc.
Geotechnical and Earthquake Engineering

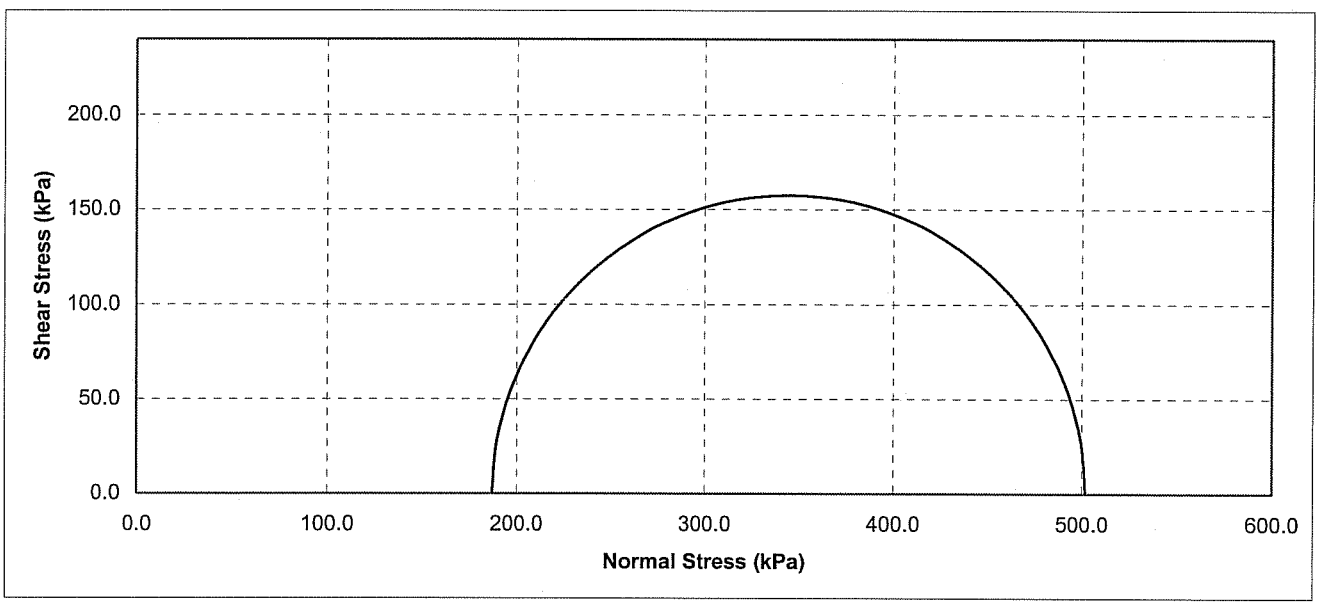
BATA / Antioch Bridge

UNCONSOLIDATED UNDRAINED TEST
(ASTM D2850)

Project No. : 06-155 **Date :** 04/15/07

Figure No. :





Boring No.	Sample No.	Depth (m)	Soil Type	Dry Density (kN/m^3)	Moisture Content (%)	Conf. Stress (kPa)	Max. Dev. Stress (kPa)	Initial Saturation (%)
06-10	D-20	29.72	Light Olive Brown , FAT CLAY (CH)	15.1	27.2	344.6	0.0	97.8

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Geotechnical and Earthquake Engineering

BATA / Antioch Bridge

UNCONSOLIDATED UNDRAINED TEST
(ASTM D2850)

Project No. : 06-155 **Date :** 04/15/07 **Figure No. :**

DIRECT SHEAR TEST

ASTM D-3080-90

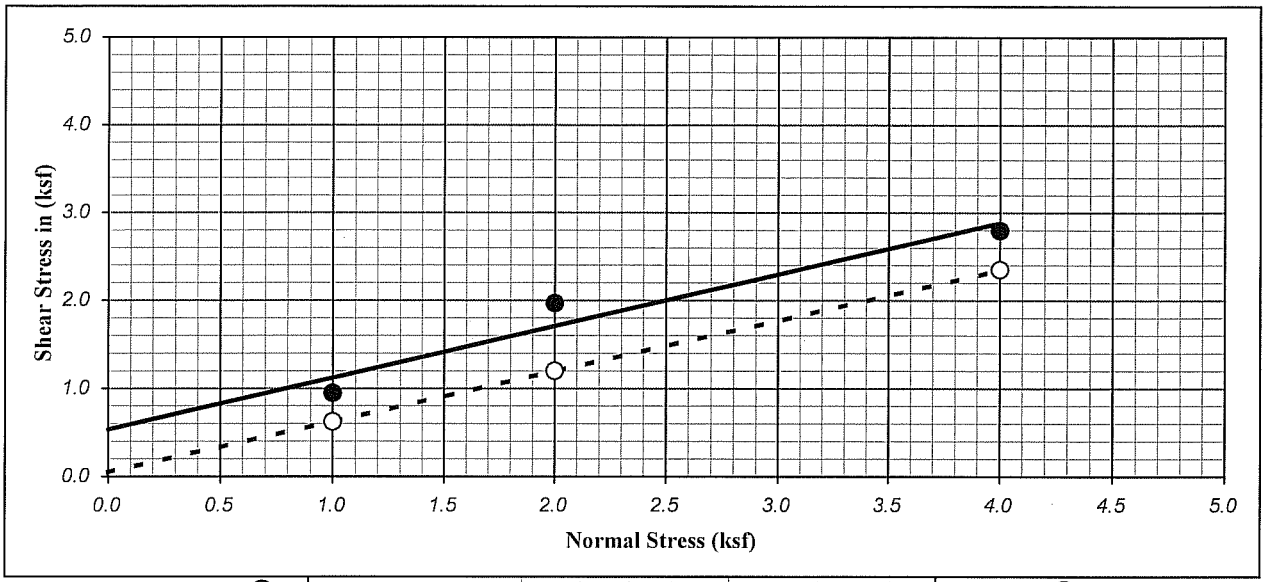
Project No. : 06-155 **Project Name :** BATA/Antioch Bridge

Boring No. : 06-1			Saturated		Field Moisture	x	Inundated	**Specific Gravity** (Assumed) :	2.70
Sample No. : D-4		x	Undisturbed		Remolded		Consolidated-Drained	**Shear Rate** (inch/min) :	0.02
Depth (ft/m) :	20.0 6.10	x	Shear Once		Reshear		Residual	**Data File Number :**	615501
Description :	Silty Sand (SM) and Lean Clay (CL)								

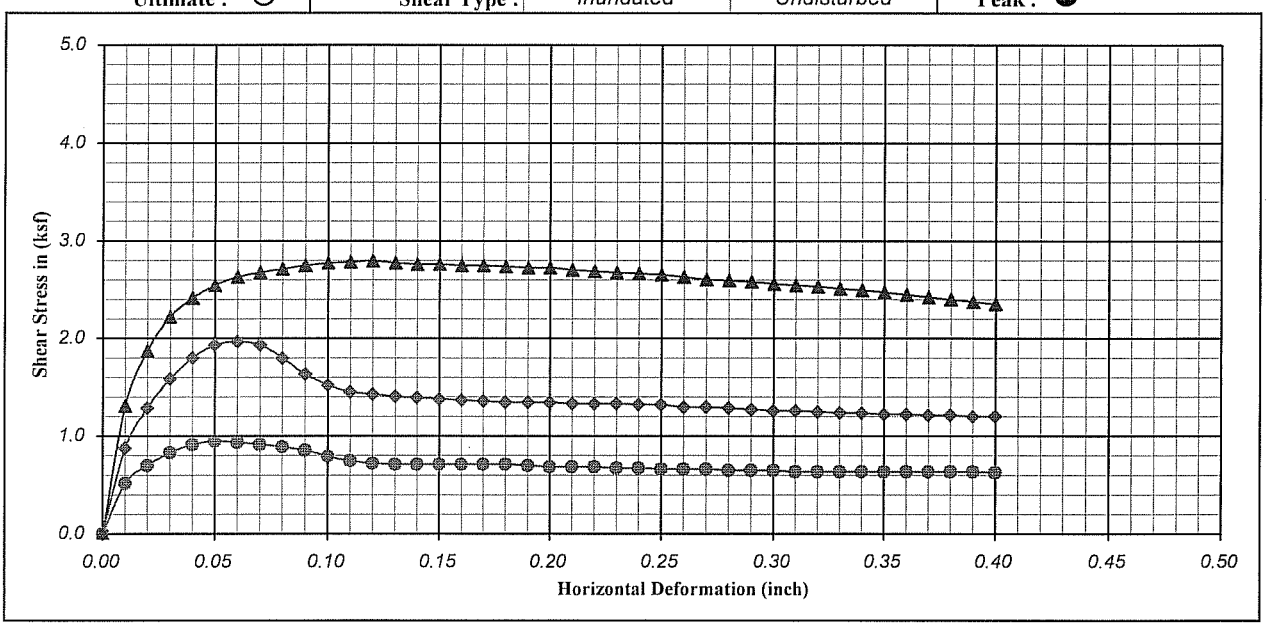
Percent Saturation (%)	89.19	**File No. :**	615501 1																	
Prepared By : RJ	**Date :** 04/05/07	**Normal Stress**																		
Tested By : RJ	**Date :** 04/05/07																			
Computed By : LCC	**Date :** 04/13/07	**1.00**	(ksf)																	
Checked By :	**Date :**																			
Percent Consolidation (%)		**Before**		**After**																
Height of Sample (inch)		1.00		1.0000																
Diameter of Sample (inch)		2.42		2.42																
Dial Reading-Consolidation (inch)																				
Weight of Soil + Ring (gm)		193.08																		
Weight of Ring (gm)		43.58																		
Weight of Wet Soil + Cont. (gm)				159.18																
Weight of Dry Soil + Cont. (gm)				131.47																
Weight of Cont. (gm) **No.**				3.71																
Moisture Content (%)				21.69																
Wet Density (pcf / kN/m³)		123.82	19.49																	
Dry Density (pcf / kN/m³)		101.75	16.02																	
Percent Saturation (%)	109.70	**File No. :**	615501 2																	
Prepared By : RJ	**Date :** 04/05/07	**Normal Stress**																		
Tested By : RJ	**Date :** 04/05/07	**2.00**	(ksf)																	
Percent Consolidation (%)		**Before**		**After**																
Height of Sample (inch)		1.00		1.0000																
Diameter of Sample (inch)		2.42		2.42																
Dial Reading-Consolidation (inch)																				
Weight of Soil + Ring (gm)		200.76																		
Weight of Ring (gm)		43.72																		
Weight of Wet Soil + Cont. (gm)				165.01																
Weight of Dry Soil + Cont. (gm)				132.33																
Weight of Cont. (gm) **No.**				3.67																
Moisture Content (%)				25.40																
Wet Density (pcf / kN/m³)		130.06	20.47																	
Dry Density (pcf / kN/m³)		103.72	16.33																	
Percent Saturation (%)	106.51	**File No. :**	615501 3																	
Prepared By : RJ	**Date :** 04/05/07	**Normal Stress**																		
Tested By : RJ	**Date :** 04/05/07	**4.00**	(ksf)																	
Percent Consolidation (%)		**Before**		**After**																
Height of Sample (inch)		1.00		1.0000																
Diameter of Sample (inch)		2.42		2.42																
Dial Reading-Consolidation (inch)																				
Weight of Soil + Ring (gm)		196.87																		
Weight of Ring (gm)		43.58																		
Weight of Wet Soil + Cont. (gm)				156.75																
Weight of Dry Soil + Cont. (gm)				124.06																
Weight of Cont. (gm) **No.**				3.62																
Moisture Content (%)				27.14																
Wet Density (pcf / kN/m³)		126.96	19.98																	
Dry Density (pcf / kN/m³)		99.86	15.72																	

Strength	(ksf)	(kPa)	(ksf)	(kPa)	(ksf)	(kPa)
Peak	0.95	45.39	1.97	94.23	2.80	133.87
Ultimate	0.62	29.88	1.20	57.46	2.35	112.61

Shear Deflection (inch)	(mm)	**Normal Stress (psf/ksf/kPa)** 1000	1.00	47.9	2000	2.0	95.8	4000	4.0	191.5
		Shear Stress (psf/ksf/kPa)								
0.00	0.00	0.0	0.0	0.0	0.00	0.0	0.00	0.00	0.0	0.0
0.010	0.03	516	0.52	24.7	876	0.88	41.9	1308	1.31	62.4
0.020	0.05	696	0.70	33.3	1284	1.28	61.5	1872	1.87	89.3
0.030	0.08	828	0.83	39.6	1584	1.58	75.8	2220	2.22	105.9
0.040	0.10	912	0.91	43.7	1800	1.80	86.2	2412	2.41	115.1
0.050	0.13	948	0.95	45.4	1932	1.93	92.5	2544	2.54	121.4
0.060	0.15	936	0.94	44.8	1968	1.97	94.2	2628	2.63	125.4
0.070	0.18	912	0.91	43.7	1932	1.93	92.5	2676	2.68	127.7
0.080	0.20	888	0.89	42.5	1800	1.80	86.2	2712	2.71	129.4
0.090	0.23	852	0.85	40.8	1632	1.63	78.1	2748	2.75	131.1
0.100	0.25	792	0.79	37.9	1524	1.52	73.0	2772	2.77	132.2
0.110	0.28	744	0.74	35.6	1452	1.45	69.5	2784	2.78	132.8
0.120	0.30	720	0.72	34.5	1428	1.43	68.4	2796	2.80	133.4
0.130	0.33	708	0.71	33.9	1404	1.40	67.2	2772	2.77	132.2
0.140	0.36	708	0.71	33.9	1392	1.39	66.6	2760	2.76	131.7
0.150	0.38	708	0.71	33.9	1380	1.38	66.1	2760	2.76	131.7
0.160	0.41	708	0.71	33.9	1368	1.37	65.5	2748	2.75	131.1
0.170	0.43	708	0.71	33.9	1356	1.36	64.9	2748	2.75	131.1
0.180	0.46	708	0.71	33.9	1344	1.34	64.4	2736	2.74	130.5
0.190	0.48	696	0.70	33.3	1344	1.34	64.4	2724	2.72	129.9
0.200	0.51	684	0.68	32.7	1344	1.34	64.4	2724	2.72	129.9
0.210	0.53	684	0.68	32.7	1332	1.33	63.8	2700	2.70	128.8
0.220	0.56	684	0.68	32.7	1332	1.33	63.8	2688	2.69	128.2
0.230	0.58	672	0.67	32.2	1332	1.33	63.8	2676	2.68	127.7
0.240	0.61	672	0.67	32.2	1320	1.32	63.2	2664	2.66	127.1
0.250	0.64	660	0.66	31.6	1320	1.32	63.2	2652	2.65	126.5
0.260	0.66	660	0.66	31.6	1296	1.30	62.1	2628	2.63	125.4
0.270	0.69	660	0.66	31.6	1296	1.30	62.1	2604	2.60	124.2
0.280	0.71	648	0.65	31.0	1284	1.28	61.5	2592	2.59	123.6
0.290	0.74	648	0.65	31.0	1272	1.27	60.9	2580	2.58	123.1
0.300	0.76	648	0.65	31.0	1260	1.26	60.3	2556	2.56	121.9
0.310	0.79	636	0.64	30.5	1260	1.26	60.3	2544	2.54	121.4
0.320	0.81	636	0.64	30.5	1248	1.25	59.8	2532	2.53	120.8
0.330	0.84	636	0.64	30.5	1236	1.24	59.2	2508	2.51	119.6
0.340	0.86	636	0.64	30.5	1236	1.24	59.2	2496	2.50	119.1
0.350	0.89	636	0.64	30.5	1224	1.22	58.6	2472	2.47	117.9
0.360	0.91	636	0.64	30.5	1224	1.22	58.6	2448	2.45	116.8
0.370	0.94	636	0.64	30.5	1212	1.21	58.0	2424	2.42	115.6
0.380	0.97	636	0.64	30.5	1212	1.21	58.0	2400	2.40	114.5
0.390	0.99	636	0.64	30.5	1200	1.20	57.5	2376	2.38	113.3
0.400	1.02	624	0.62	29.9	1200	1.20	57.5	2352	2.35	112.2
	0.00									
	0.00									
	0.00									
	0.00									
	0.00									



Ultimate : ○	Shear Type :	Inundated	Undisturbed	Peak : ●



Boring No.	: 06-1		**Strength Intercept (C) :**	0.53	(ksf)		0.05	(ksf)	
Sample No.	: D-4			25.57	(kPa)	**Peak**	2.30	(kPa)	**Ultimate**
Depth (ft/m)	: 20.0	6.10	**Friction Angle (ϕ) :**	30.42	Degree		29.94	Degree	
Description	: Silty Sand (SM) and Lean Clay (CL)						**Shear Rate** (inch/minute) :		0.02

SYMBOL	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	DRY DENSITY (kN/m^3)	VOID RATIO	NORMAL STRESS (ksf)	NORMAL STRESS (kPa)	PEAK STRESS (ksf)	PEAK STRESS (kPa)	ULTIMATE STRESS (ksf)	ULTIMATE STRESS (kPa)
●	21.69	101.75	16.02	0.66	1.00	47.88	0.95	45.39	0.62	29.88
◆	25.40	103.72	16.33	0.63	2.00	95.76	1.97	94.23	1.20	57.46
▲	27.14	99.86	15.72	0.69	4.00	191.52	2.80	133.87	2.35	112.61

Earth Mechanics, Inc.
Geotechnical and Earthquake Engineering

Antioch Bridge

DIRECT SHEAR TEST (ASTM D-3080)

Project No. : 06-155 | **Date :** 04/05/07

Figure No. :

DIRECT SHEAR TEST

ASTM D-3080-90

Project No. : 06-155 **Project Name :** BATA/Antioch Bridge

Boring No. : 06-1			Saturated		Field Moisture	x	Inundated	**Specific Gravity** (Assumed) :	2.70
Sample No. : D-12		x	Undisturbed		Remolded		Consolidated-Drained	**Shear Rate** (inch/min) :	0.02
Depth (ft/m) :	60.0 / 18.30	x	Shear Once		Reshear		Residual	**Data File Number :**	615502
Description :	Sand with Silt (SP-SM)								

Percent Saturation (%)	106.39		**File No. :**	615502 1																	
Prepared By : RJ	**Date :** 04/05/07		**Normal Stress**																		
Tested By : RJ	**Date :** 04/05/07																				
Computed By : LCC	**Date :** 04/13/07		**2.50**	(ksf)																	
Checked By :	**Date :**																				
Percent Consolidation (%)		**Before**		**After**																	
Height of Sample (inch)		1.00		1.0000																	
Diameter of Sample (inch)		2.42		2.42																	
Dial Reading-Consolidation (inch)																					
Weight of Soil + Ring (gm)		197.30																			
Weight of Ring (gm)		43.47																			
Weight of Wet Soil + Cont. (gm)				156.44																	
Weight of Dry Soil + Cont. (gm)				124.34																	
Weight of Cont. (gm) **No.**				3.62																	
Moisture Content (%)				26.59																	
Wet Density (pcf / kN/m³)		127.41	20.05																		
Dry Density (pcf / kN/m³)		100.64	15.84																		
Percent Saturation (%)	109.58		**File No. :**	615502 2																	
Prepared By : RJ	**Date :** 04/05/07		**Normal Stress**																		
Tested By : RJ	**Date :** 04/05/07		**5.00**	(ksf)																	
Percent Consolidation (%)		**Before**		**After**																	
Height of Sample (inch)		1.00		1.0000																	
Diameter of Sample (inch)		2.42		2.42																	
Dial Reading-Consolidation (inch)																					
Weight of Soil + Ring (gm)		199.08																			
Weight of Ring (gm)		43.39																			
Weight of Wet Soil + Cont. (gm)				157.70																	
Weight of Dry Soil + Cont. (gm)				125.37																	
Weight of Cont. (gm) **No.**				3.63																	
Moisture Content (%)				26.56																	
Wet Density (pcf / kN/m³)		128.95	20.30																		
Dry Density (pcf / kN/m³)		101.89	16.04																		
Percent Saturation (%)	105.27		**File No. :**	615502 3																	
Prepared By : RJ	**Date :** 04/05/07		**Normal Stress**																		
Tested By : RJ	**Date :** 04/05/07		**10.00**	(ksf)																	
Percent Consolidation (%)		**Before**		**After**																	
Height of Sample (inch)		1.00		1.0000																	
Diameter of Sample (inch)		2.42		2.42																	
Dial Reading-Consolidation (inch)																					
Weight of Soil + Ring (gm)		196.55																			
Weight of Ring (gm)		43.42																			
Weight of Wet Soil + Cont. (gm)				155.50																	
Weight of Dry Soil + Cont. (gm)				123.56																	
Weight of Cont. (gm) **No.**				3.62																	
Moisture Content (%)				26.63																	
Wet Density (pcf / kN/m³)		126.83	19.96																		
Dry Density (pcf / kN/m³)		100.16	15.76																		

Strength	(ksf)	(kPa)	(ksf)	(kPa)	(ksf)	(kPa)
Peak	2.24	107.44	4.14	198.22	7.79	372.84
Ultimate	1.46	70.10	2.95	141.34	5.68	271.72

Shear Deflection (inch)	(mm)	**Normal Stress (psf/ksf/kPa)**								
		2500	2.50	119.7	5000	5.0	239.4	10000	10.0	478.8
		Shear Stress (psf/ksf/kPa)								
0.000	0.00	0.0	0.0	0.0	0.00	0.0	0.00	0.0	0.0	0.0
0.010	0.03	948	0.95	45.4	1488	1.49	71.2	2208	2.21	105.3
0.020	0.05	1488	1.49	71.2	2376	2.38	113.8	3864	3.86	184.3
0.030	0.08	1848	1.85	88.5	3036	3.04	145.4	5052	5.05	241.0
0.040	0.10	2088	2.09	100.0	3516	3.52	168.3	5963	5.96	284.4
0.050	0.13	2208	2.21	105.7	3828	3.83	183.3	6647	6.65	317.1
0.060	0.15	2244	2.24	107.4	4020	4.02	192.5	7151	7.15	341.1
0.070	0.18	2220	2.22	106.3	4128	4.13	197.6	7487	7.49	357.1
0.080	0.20	2160	2.16	103.4	4140	4.14	198.2	7691	7.69	366.9
0.090	0.23	2076	2.08	99.4	4104	4.10	196.5	7751	7.75	369.7
0.100	0.25	2004	2.00	96.0	4020	4.02	192.5	7787	7.79	371.5
0.110	0.28	1908	1.91	91.4	3876	3.88	185.6	7739	7.74	369.2
0.120	0.30	1836	1.84	87.9	3720	3.72	178.1	7679	7.68	366.3
0.130	0.33	1776	1.78	85.0	3540	3.54	169.5	7571	7.57	361.2
0.140	0.36	1716	1.72	82.2	3396	3.40	162.6	7427	7.43	354.3
0.150	0.38	1656	1.66	79.3	3240	3.24	155.1	7211	7.21	344.0
0.160	0.41	1620	1.62	77.6	3132	3.13	150.0	6923	6.92	330.2
0.170	0.43	1572	1.57	75.3	3060	3.06	146.5	6635	6.64	316.5
0.180	0.46	1548	1.55	74.1	3000	3.00	143.6	6299	6.30	300.5
0.190	0.48	1536	1.54	73.5	2976	2.98	142.5	6059	6.06	289.0
0.200	0.51	1524	1.52	73.0	2964	2.96	141.9	5903	5.90	281.6
0.210	0.53	1512	1.51	72.4	2952	2.95	141.3	5771	5.77	275.3
0.220	0.56	1500	1.50	71.8	2976	2.98	142.5	5699	5.70	271.9
0.230	0.58	1500	1.50	71.8	2964	2.96	141.9	5687	5.69	271.3
0.240	0.61	1488	1.49	71.2	2976	2.98	142.5	5699	5.70	271.9
0.250	0.64	1476	1.48	70.7	2976	2.98	142.5	5675	5.68	270.7
0.260	0.66	1464	1.46	70.1	2988	2.99	143.1	5675	5.68	270.7
0.270	0.69	1476	1.48	70.7	2988	2.99	143.1	5699	5.70	271.9
0.280	0.71	1488	1.49	71.2	2964	2.96	141.9	5771	5.77	275.3
0.290	0.74	1488	1.49	71.2	3012	3.01	144.2	5771	5.77	275.3
0.300	0.76	1476	1.48	70.7	2964	2.96	141.9	5795	5.80	276.4
0.310	0.79	1500	1.50	71.8	2988	2.99	143.1	5819	5.82	277.6
0.320	0.81	1500	1.50	71.8	2988	2.99	143.1	5843	5.84	278.7
0.330	0.84	1512	1.51	72.4	2988	2.99	143.1	5855	5.86	279.3
0.340	0.86	1512	1.51	72.4	2976	2.98	142.5	5867	5.87	279.9
0.350	0.89	1524	1.52	73.0	2964	2.96	141.9	5867	5.87	279.9
0.360	0.91	1524	1.52	73.0	2976	2.98	142.5	5891	5.89	281.0
0.370	0.94	1524	1.52	73.0	2976	2.98	142.5	5891	5.89	281.0
0.380	0.97	1524	1.52	73.0	2976	2.98	142.5	5915	5.92	282.2
0.390	0.99	1524	1.52	73.0	2976	2.98	142.5	5903	5.90	281.6
0.400	1.02	1536	1.54	73.5	3000	3.00	143.6	5903	5.90	281.6
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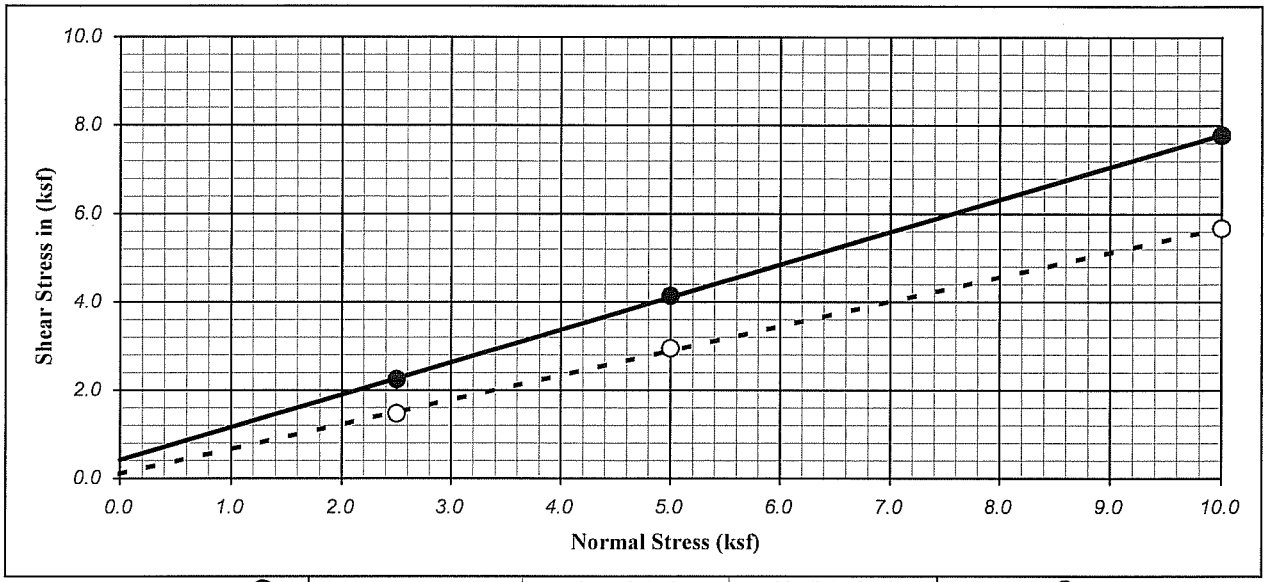
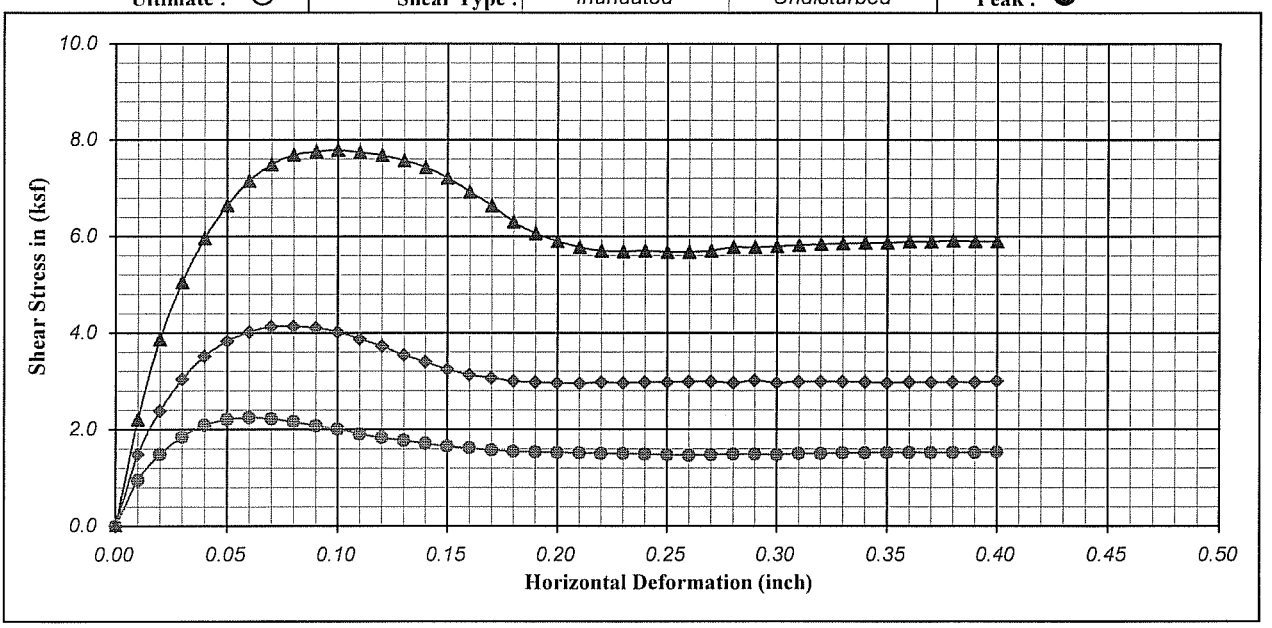


Ultimate : ○	Shear Type :	Inundated	Undisturbed	Peak : ●



Boring No. : 06-1		**Strength Intercept (C) :**	0.42	(ksf)	**Peak**	0.10	(ksf)	**Ultimate**
Sample No. : D-12			20.13	(kPa)		4.91	(kPa)	
Depth (ft/m) : 60.0	18.30	**Friction Angle (ϕ) :**	36.42	Degree		29.21	Degree	
Description : Sand with Silt (SP-SM)						**Shear Rate** (inch/minute) :		0.02

SYMBOL	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	DRY DENSITY (kN/m^3)	VOID RATIO	NORMAL STRESS (ksf)	NORMAL STRESS (kPa)	PEAK STRESS (ksf)	PEAK STRESS (kPa)	ULTIMATE STRESS (ksf)	ULTIMATE STRESS (kPa)
●	26.59	100.64	15.84	0.67	2.50	119.70	2.24	107.44	1.46	70.10
◆	26.56	101.89	16.04	0.65	5.00	239.40	4.14	198.22	2.95	141.34
▲	26.63	100.16	15.76	0.68	10.00	478.80	7.79	372.84	5.68	271.72

Earth Mechanics, Inc.
Geotechnical and Earthquake Engineering

Antioch Bridge

DIRECT SHEAR TEST (ASTM D-3080)

Project No. : 06-155 **Date :** 04/05/07

Figure No. :

DIRECT SHEAR TEST

ASTM D-3080-90

Project No. : 06-155 **Project Name :** BATA/Antioch Bridge

Boring No. : 06-1			Saturated		Field Moisture	x	Inundated	**Specific Gravity** (Assumed) :	2.70
Sample No. : D-20		x	Undisturbed		Remolded		Consolidated-Drained	**Shear Rate** (inch/min) :	0.02
Depth (ft/m) :	100.0 30.50	x	Shear Once		Reshear		Residual	**Data File Number :**	615503
Description :	Sand (SP)								

Percent Saturation (%)	99.57		**File No. :**	615503 1																		
Prepared By : RJ	**Date :** 04/08/07																					
Tested By : RJ	**Date :** 04/08/07																					
Computed By : LCC	**Date :** 04/13/07																					
Checked By :	**Date :**																					
Percent Consolidation (%)		**Before**		**After**																		
Height of Sample (inch)		1.00		1.0000																		
Diameter of Sample (inch)		2.42		2.42																		
Dial Reading-Consolidation (inch)																						
Weight of Soil + Ring (gm)		200.81																				
Weight of Ring (gm)		43.88																				
Weight of Wet Soil + Cont. (gm)				160.23																		
Weight of Dry Soil + Cont. (gm)				133.08																		
Weight of Cont. (gm) **No.**				3.70																		
Moisture Content (%)				20.98																		
Wet Density (pcf / kN/m³)		129.97	20.46																			
Dry Density (pcf / kN/m³)		107.43	16.91																			
Percent Saturation (%)	105.72		**File No. :**	615503 2																		
Prepared By : RJ	**Date :** 04/08/07																					
Tested By : RJ	**Date :** 04/08/07																					
Percent Consolidation (%)		**Before**		**After**																		
Height of Sample (inch)		1.00		1.0000																		
Diameter of Sample (inch)		2.42		2.42																		
Dial Reading-Consolidation (inch)																						
Weight of Soil + Ring (gm)		200.31																				
Weight of Ring (gm)		43.26																				
Weight of Wet Soil + Cont. (gm)				159.59																		
Weight of Dry Soil + Cont. (gm)				129.90																		
Weight of Cont. (gm) **No.**				3.67																		
Moisture Content (%)				23.52																		
Wet Density (pcf / kN/m³)		130.07	20.47																			
Dry Density (pcf / kN/m³)		105.30	16.57																			
Percent Saturation (%)	104.15		**File No. :**	615503 3																		
Prepared By : RJ	**Date :** 04/08/07																					
Tested By : RJ	**Date :** 04/08/07																					
Percent Consolidation (%)		**Before**		**After**																		
Height of Sample (inch)		1.00		1.0000																		
Diameter of Sample (inch)		2.42		2.42																		
Dial Reading-Consolidation (inch)																						
Weight of Soil + Ring (gm)		201.99																				
Weight of Ring (gm)		43.63																				
Weight of Wet Soil + Cont. (gm)				159.60																		
Weight of Dry Soil + Cont. (gm)				131.67																		
Weight of Cont. (gm) **No.**				3.63																		
Moisture Content (%)				21.81																		
Wet Density (pcf / kN/m³)		131.16	20.64																			
Dry Density (pcf / kN/m³)		107.67	16.95																			

Strength	(ksf)	(kPa)	(ksf)	(kPa)	(ksf)	(kPa)
Peak	2.16	103.42	3.95	189.03	7.57	362.50
Ultimate	1.46	70.10	2.83	135.60	5.81	278.04

Normal Stress

2.50	(ksf)	

Shear Deflection		**Normal Stress (psf/ksf/kPa)**								
		2500	2.50	119.7	5000	5.0	239.4	10000	10.0	478.8
(inch)	(mm)	**Shear Stress (psf/ksf/kPa)**								
0.000	0.00	0.0	0.0	0.0	0.00	0.0	0.00	0.0	0.0	0.0
0.010	0.03	936	0.94	44.8	1368	1.37	65.5	1980	1.98	94.5
0.020	0.05	1404	1.40	67.2	2172	2.17	104.0	3408	3.41	162.6
0.030	0.08	1716	1.72	82.2	2796	2.80	133.9	4512	4.51	215.2
0.040	0.10	1908	1.91	91.4	3228	3.23	154.6	5364	5.36	255.9
0.050	0.13	2040	2.04	97.7	3540	3.54	169.5	6059	6.06	289.0
0.060	0.15	2124	2.12	101.7	3756	3.76	179.8	6599	6.60	314.8
0.070	0.18	2160	2.16	103.4	3876	3.88	185.6	7019	7.02	334.8
0.080	0.20	2160	2.16	103.4	3936	3.94	188.5	7283	7.28	347.4
0.090	0.23	2136	2.14	102.3	3948	3.95	189.0	7475	7.48	356.6
0.100	0.25	2088	2.09	100.0	3924	3.92	187.9	7559	7.56	360.6
0.110	0.28	2052	2.05	98.2	3852	3.85	184.4	7571	7.57	361.2
0.120	0.30	2004	2.00	96.0	3756	3.76	179.8	7523	7.52	358.9
0.130	0.33	1944	1.94	93.1	3660	3.66	175.2	7415	7.42	353.7
0.140	0.36	1860	1.86	89.1	3576	3.58	171.2	7295	7.30	348.0
0.150	0.38	1824	1.82	87.3	3468	3.47	166.0	7127	7.13	340.0
0.160	0.41	1764	1.76	84.5	3396	3.40	162.6	6935	6.94	330.8
0.170	0.43	1716	1.72	82.2	3324	3.32	159.2	6695	6.70	319.4
0.180	0.46	1656	1.66	79.3	3252	3.25	155.7	6491	6.49	309.6
0.190	0.48	1596	1.60	76.4	3180	3.18	152.3	6323	6.32	301.6
0.200	0.51	1596	1.60	76.4	3156	3.16	151.1	6191	6.19	295.3
0.210	0.53	1560	1.56	74.7	3096	3.10	148.2	6059	6.06	289.0
0.220	0.56	1548	1.55	74.1	3048	3.05	145.9	5939	5.94	283.3
0.230	0.58	1512	1.51	72.4	3024	3.02	144.8	5855	5.86	279.3
0.240	0.61	1512	1.51	72.4	2988	2.99	143.1	5843	5.84	278.7
0.250	0.64	1500	1.50	71.8	2976	2.98	142.5	5819	5.82	277.6
0.260	0.66	1500	1.50	71.8	2952	2.95	141.3	5831	5.83	278.2
0.270	0.69	1476	1.48	70.7	2940	2.94	140.8	5819	5.82	277.6
0.280	0.71	1476	1.48	70.7	2928	2.93	140.2	5819	5.82	277.6
0.290	0.74	1464	1.46	70.1	2916	2.92	139.6	5807	5.81	277.0
0.300	0.76	1464	1.46	70.1	2892	2.89	138.5	5807	5.81	277.0
0.310	0.79	1464	1.46	70.1	2868	2.87	137.3	5843	5.84	278.7
0.320	0.81	1476	1.48	70.7	2832	2.83	135.6	5843	5.84	278.7
0.330	0.84	1476	1.48	70.7	2844	2.84	136.2	5867	5.87	279.9
0.340	0.86	1476	1.48	70.7	2844	2.84	136.2	5867	5.87	279.9
0.350	0.89	1488	1.49	71.2	2868	2.87	137.3	5831	5.83	278.2
0.360	0.91	1476	1.48	70.7	2856	2.86	136.7	5819	5.82	277.6
0.370	0.94	1476	1.48	70.7	2856	2.86	136.7	5867	5.87	279.9
0.380	0.97	1488	1.49	71.2	2868	2.87	137.3	5843	5.84	278.7
0.390	0.99	1512	1.51	72.4	2868	2.87	137.3	5843	5.84	278.7
0.400	1.02	1488	1.49	71.2	2892	2.89	138.5	5843	5.84	278.7
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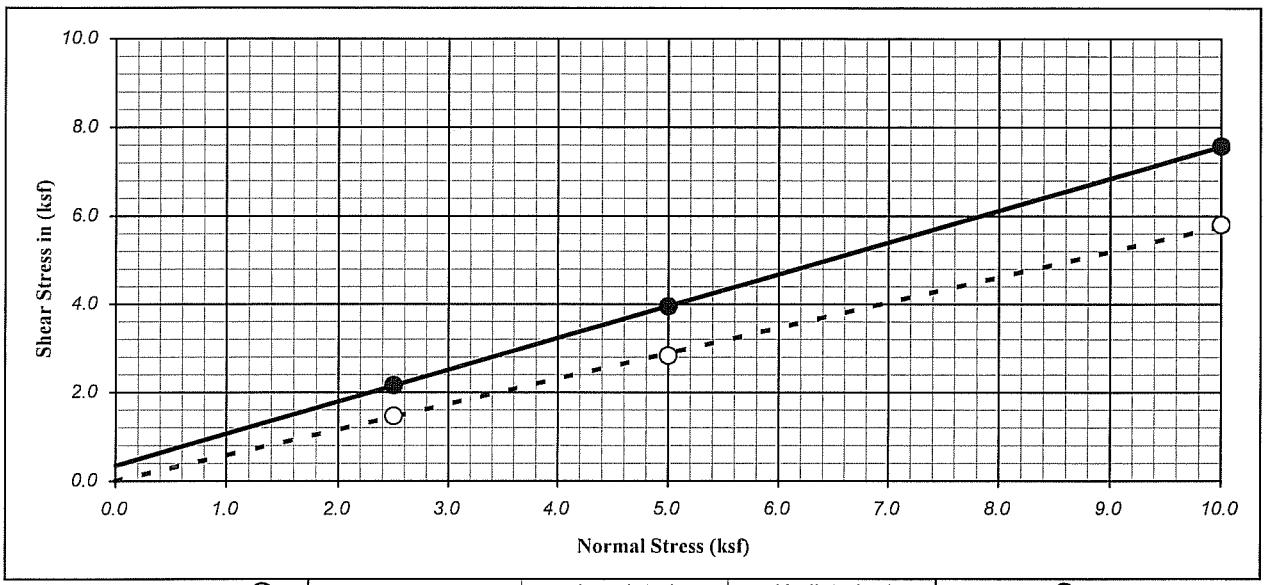
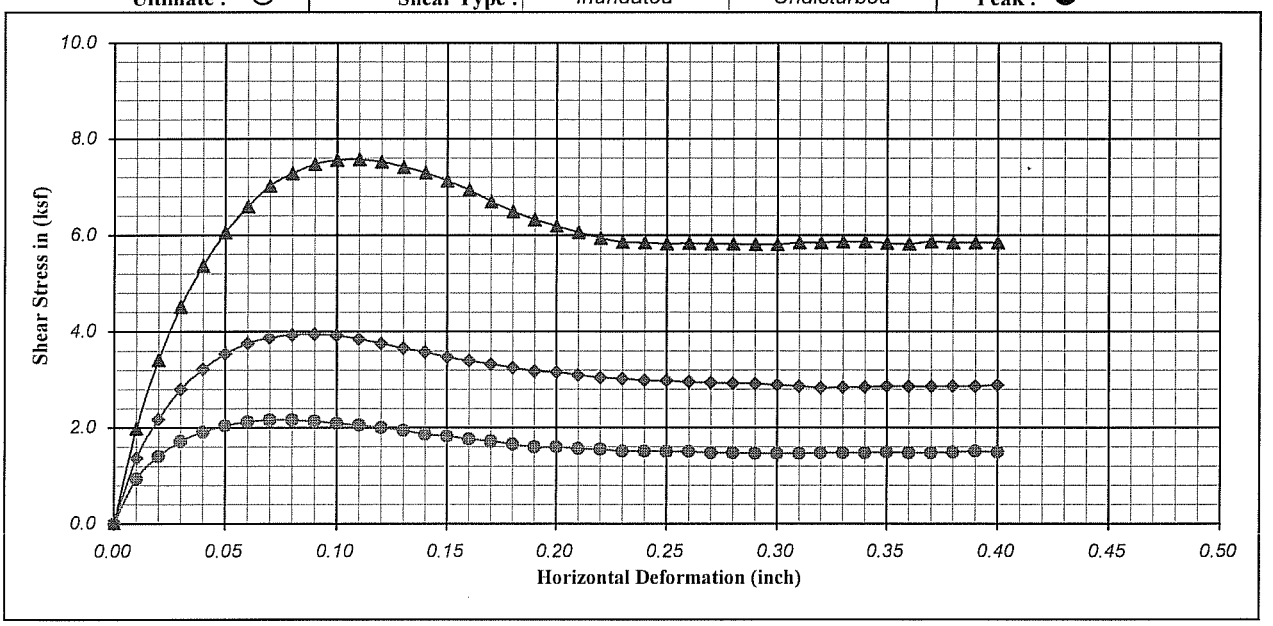


Ultimate : ○	Shear Type :	Inundated	Undisturbed	Peak : ●



Boring No. : 06-1		**Strength Intercept (C) :**	0.35	(ksf)	**Peak**	0.00	(ksf)	**Ultimate**
Sample No. : D-20			16.69	(kPa)		0.00	(kPa)	
Depth (ft/m) : ####	30.50	**Friction Angle (ϕ) :**	35.83	Degree		30.04	Degree	
Description : Sand (SP)						**Shear Rate** (inch/minute) :		0.02

SYMBOL	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	DRY DENSITY (kN/m^3)	VOID RATIO	NORMAL STRESS (ksf)	NORMAL STRESS (kPa)	PEAK STRESS (ksf)	PEAK STRESS (kPa)	ULTIMATE STRESS (ksf)	ULTIMATE STRESS (kPa)
●	20.98	107.43	16.91	0.57	2.50	119.70	2.16	103.42	1.46	70.10
◆	23.52	105.30	16.57	0.60	5.00	239.40	3.95	189.03	2.83	135.60
▲	21.81	107.67	16.95	0.57	10.00	478.80	7.57	362.50	5.81	278.04

Earth Mechanics, Inc.
Geotechnical and Earthquake Engineering

Antioch Bridge

DIRECT SHEAR TEST (ASTM D-3080)

Project No. : 06-155 **Date :** 04/08/07

Figure No. :

DIRECT SHEAR TEST

ASTM D-3080-90

Project No. : 06-155 **Project Name :** BATA/Antioch Bridge

Boring No. : 06-2			Saturated		Field Moisture	x	Inundated	**Specific Gravity** (Assumed) :	2.70
Sample No. : D-2		x	Undisturbed		Remolded		Consolidated-Drained	**Shear Rate** (inch/min) :	0.02
Depth (ft/m) :	10.0 / 3.05	x	Shear Once		Reshear		Residual	**Data File Number :**	615504

Description : Silty Sand with Organic Roots (SM)

Percent Saturation (%)	100.55		**File No. :**	615504 1																
Prepared By : RJ	**Date :** 04/05/07																			
Tested By : RJ	**Date :** 04/05/07		**Normal Stress**																	
Computed By : LCC	**Date :** 04/13/07		**0.50**	(ksf)																
Checked By :	**Date :**																			
Percent Consolidation (%)		**Before**		**After**																
Height of Sample (inch)		1.00		1.0000																
Diameter of Sample (inch)		2.42		2.42																
Dial Reading-Consolidation (inch)																				
Weight of Soil + Ring (gm)		193.40																		
Weight of Ring (gm)		43.44																		
Weight of Wet Soil + Cont. (gm)				155.76																
Weight of Dry Soil + Cont. (gm)				123.52																
Weight of Cont. (gm) No.				3.65																
Moisture Content (%)				26.90																
Wet Density (pcf / kN/m³)		124.20	19.55																	
Dry Density (pcf / kN/m³)		97.88	15.41																	
Percent Saturation (%)	98.97		**File No. :**	615504 2																
Prepared By : RJ	**Date :** 04/05/07		**Normal Stress**																	
Tested By : RJ	**Date :** 04/05/07		**1.00**	(ksf)																
Percent Consolidation (%)		**Before**		**After**																
Height of Sample (inch)		1.00		1.0000																
Diameter of Sample (inch)		2.42		2.42																
Dial Reading-Consolidation (inch)																				
Weight of Soil + Ring (gm)		192.69																		
Weight of Ring (gm)		43.57																		
Weight of Wet Soil + Cont. (gm)				153.07																
Weight of Dry Soil + Cont. (gm)				121.52																
Weight of Cont. (gm) No.				3.61																
Moisture Content (%)				26.76																
Wet Density (pcf / kN/m³)		123.51	19.44																	
Dry Density (pcf / kN/m³)		97.43	15.34																	
Percent Saturation (%)	96.44		**File No. :**	615504 3																
Prepared By : RJ	**Date :** 04/05/07		**Normal Stress**																	
Tested By : RJ	**Date :** 04/05/07		**2.00**	(ksf)																
Percent Consolidation (%)		**Before**		**After**																
Height of Sample (inch)		1.00		1.0000																
Diameter of Sample (inch)		2.42		2.42																
Dial Reading-Consolidation (inch)																				
Weight of Soil + Ring (gm)		187.11																		
Weight of Ring (gm)		43.39																		
Weight of Wet Soil + Cont. (gm)				146.95																
Weight of Dry Soil + Cont. (gm)				113.81																
Weight of Cont. (gm) No.				3.62																
Moisture Content (%)				30.08																
Wet Density (pcf / kN/m³)		119.03	18.74																	
Dry Density (pcf / kN/m³)		91.51	14.40																	

Strength	(ksf)	(kPa)	(ksf)	(kPa)	(ksf)	(kPa)
Peak	0.64	30.45	0.92	44.24	1.64	78.71
Ultimate	0.47	22.41	0.68	32.75	1.43	68.37

Shear Deflection (inch)	(mm)	**Normal Stress (psf/ksf/kPa)** 500	0.50	23.9	1000	1.0	47.9	2000	2.0	95.8
		Shear Stress (psf/ksf/kPa)								
0.000	0.00	0.0	0.0	0.0	0.00	0.0	0.00	0.0	0.0	0.0
0.010	0.03	264	0.26	12.6	336	0.34	16.1	468	0.47	22.3
0.020	0.05	384	0.38	18.4	480	0.48	23.0	708	0.71	33.8
0.030	0.08	456	0.46	21.8	600	0.60	28.7	912	0.91	43.5
0.040	0.10	516	0.52	24.7	696	0.70	33.3	1068	1.07	50.9
0.050	0.13	564	0.56	27.0	768	0.77	36.8	1188	1.19	56.7
0.060	0.15	600	0.60	28.7	816	0.82	39.1	1284	1.28	61.2
0.070	0.18	612	0.61	29.3	864	0.86	41.4	1356	1.36	64.7
0.080	0.20	636	0.64	30.5	900	0.90	43.1	1428	1.43	68.1
0.090	0.23	636	0.64	30.5	912	0.91	43.7	1488	1.49	71.0
0.100	0.25	636	0.64	30.5	924	0.92	44.2	1536	1.54	73.3
0.110	0.28	636	0.64	30.5	924	0.92	44.2	1572	1.57	75.0
0.120	0.30	636	0.64	30.5	912	0.91	43.7	1596	1.60	76.1
0.130	0.33	624	0.62	29.9	912	0.91	43.7	1620	1.62	77.3
0.140	0.36	612	0.61	29.3	900	0.90	43.1	1632	1.63	77.8
0.150	0.38	588	0.59	28.2	900	0.90	43.1	1644	1.64	78.4
0.160	0.41	564	0.56	27.0	888	0.89	42.5	1644	1.64	78.4
0.170	0.43	552	0.55	26.4	876	0.88	41.9	1644	1.64	78.4
0.180	0.46	540	0.54	25.9	852	0.85	40.8	1632	1.63	77.8
0.190	0.48	528	0.53	25.3	828	0.83	39.6	1596	1.60	76.1
0.200	0.51	516	0.52	24.7	828	0.83	39.6	1572	1.57	75.0
0.210	0.53	504	0.50	24.1	804	0.80	38.5	1548	1.55	73.8
0.220	0.56	504	0.50	24.1	804	0.80	38.5	1524	1.52	72.7
0.230	0.58	504	0.50	24.1	792	0.79	37.9	1500	1.50	71.6
0.240	0.61	504	0.50	24.1	780	0.78	37.3	1488	1.49	71.0
0.250	0.64	492	0.49	23.6	768	0.77	36.8	1488	1.49	71.0
0.260	0.66	492	0.49	23.6	756	0.76	36.2	1476	1.48	70.4
0.270	0.69	492	0.49	23.6	744	0.74	35.6	1476	1.48	70.4
0.280	0.71	492	0.49	23.6	732	0.73	35.0	1476	1.48	70.4
0.290	0.74	492	0.49	23.6	720	0.72	34.5	1476	1.48	70.4
0.300	0.76	480	0.48	23.0	720	0.72	34.5	1476	1.48	70.4
0.310	0.79	480	0.48	23.0	708	0.71	33.9	1464	1.46	69.8
0.320	0.81	480	0.48	23.0	708	0.71	33.9	1464	1.46	69.8
0.330	0.84	480	0.48	23.0	708	0.71	33.9	1464	1.46	69.8
0.340	0.86	480	0.48	23.0	696	0.70	33.3	1452	1.45	69.3
0.350	0.89	480	0.48	23.0	696	0.70	33.3	1440	1.44	68.7
0.360	0.91	480	0.48	23.0	696	0.70	33.3	1440	1.44	68.7
0.370	0.94	480	0.48	23.0	684	0.68	32.7	1440	1.44	68.7
0.380	0.97	480	0.48	23.0	684	0.68	32.7	1428	1.43	68.1
0.390	0.99	480	0.48	23.0	684	0.68	32.7	1428	1.43	68.1
0.400	1.02	468	0.47	22.4	684	0.68	32.7	1428	1.43	68.1
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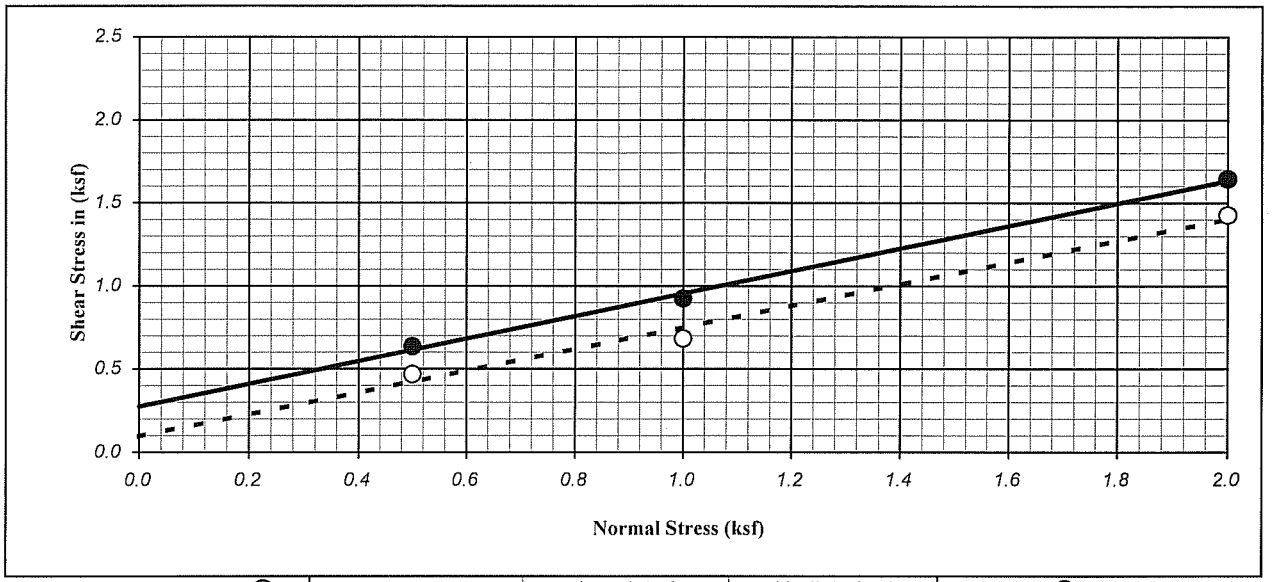
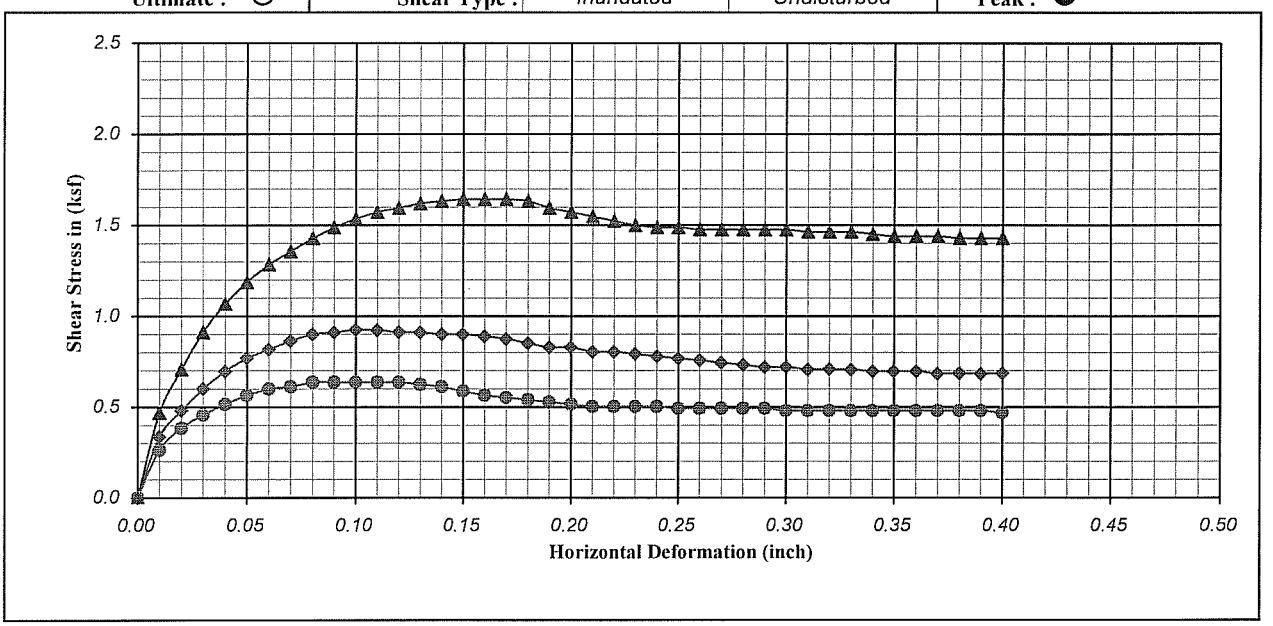


Ultimate : ○	Shear Type :	Inundated	Undisturbed	Peak : ●



Boring No. : 06-2		**Strength Intercept (C) :**	0.28	(ksf)		0.10	(ksf)	
Sample No. : D-2			13.21	(kPa)	**Peak**	4.60	(kPa)	**Ultimate**
Depth (ft/m) : 10.0	3.05	**Friction Angle (ϕ) :**	34.17	Degree		33.22	Degree	
Description : Silty Sand with Organic Roots (SM)						**Shear Rate** (inch/minute) :		0.02

SYMBOL	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	DRY DENSITY (kN/m^3)	VOID RATIO	NORMAL STRESS (ksf)	NORMAL STRESS (kPa)	PEAK STRESS (ksf)	PEAK STRESS (kPa)	ULTIMATE STRESS (ksf)	ULTIMATE STRESS (kPa)
●	26.90	97.88	15.41	0.72	0.50	23.94	0.64	30.45	0.47	22.41
◆	26.76	97.43	15.34	0.73	1.00	47.88	0.92	44.24	0.68	32.75
▲	30.08	91.51	14.40	0.84	2.00	95.76	1.64	78.71	1.43	68.37

Earth Mechanics, Inc.
Geotechnical and Earthquake Engineering

Antioch Bridge

DIRECT SHEAR TEST (ASTM D-3080)

Project No. : 06-155 | **Date :** 04/05/07 | **Figure No. :**

DIRECT SHEAR TEST

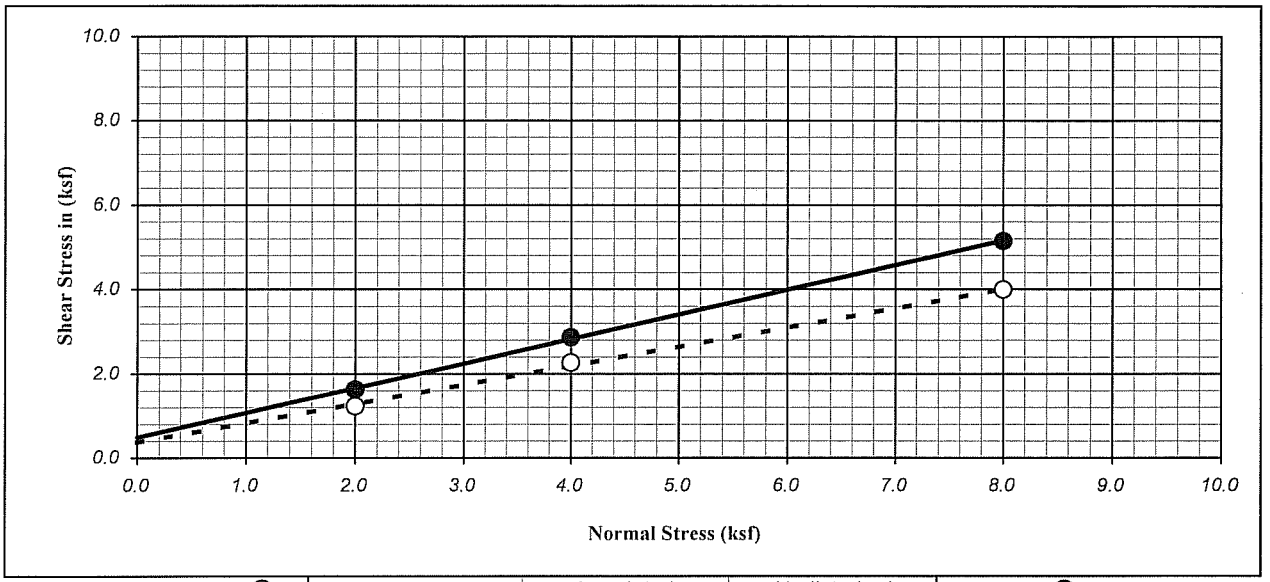
ASTM D-3080-90

Project No. : 06-155 **Project Name :** BATA/Antioch Bridge

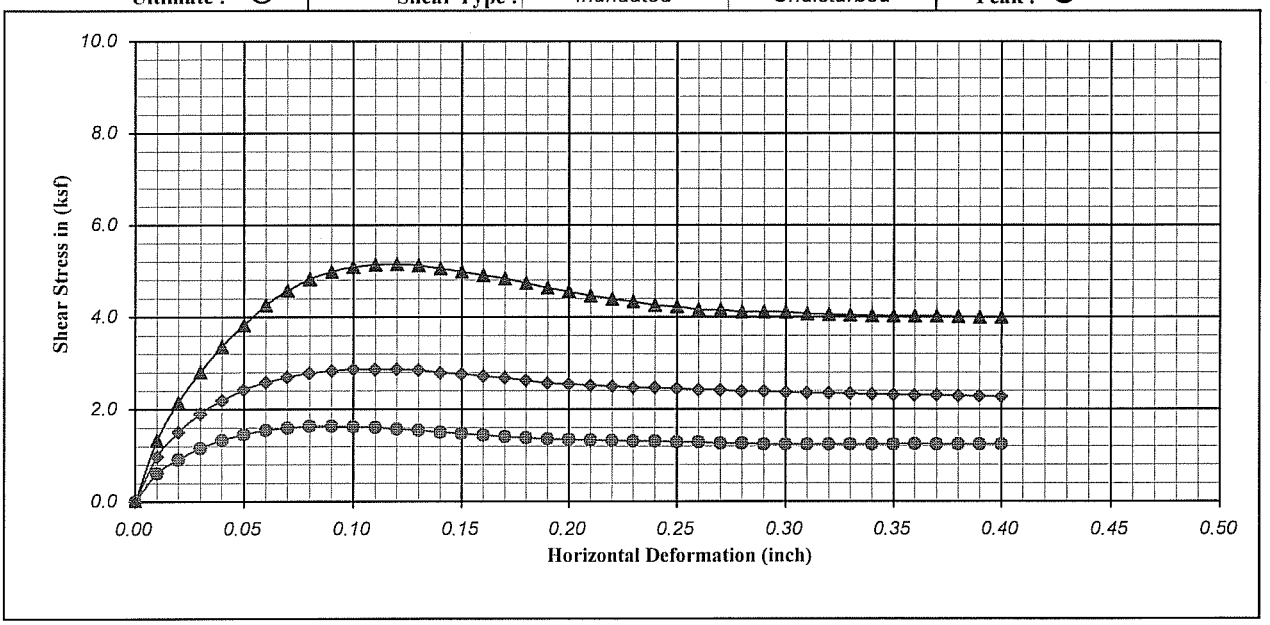
Boring No. : 06-2			Saturated		Field Moisture	x	Inundated	**Specific Gravity** (Assumed) :	2.70
Sample No. : D-8		x	Undisturbed		Remolded		Consolidated-Drained	**Shear Rate** (inch/min) :	0.02
Depth (ft/m) :	40.0 / 12.20	x	Shear Once		Reshear		Residual	**Data File Number :**	615505
Description :	Silty Sand with Pocket of Lean Clay (SM)								

Percent Saturation (%)	101.57		**File No. :**	615505 1			**Shear Deflection**		**Normal Stress (psf/ksf/kPa)**										
Prepared By : RJ	**Date :** 04/08/07		**Normal Stress**				2000	2.00	95.8	4000	4.0	191.5	8000	8.0	383.0				
Tested By : RJ	**Date :** 04/08/07						(inch)	(mm)	**Shear Stress (psf/ksf/kPa)**										
Computed By : LCC	**Date :** 04/13/07		2.00	(ksf)			0.000	0.00	0.0	0.0	0.0	0.00	0.0	0.00	0.0	0.0	0.0			
Checked By :	**Date :**						0.010	0.03	612	0.61	29.3	972	0.97	46.5	1332	1.33	63.5			
Percent Consolidation (%)		**Before**		**After**			0.020	0.05	912	0.91	43.7	1500	1.50	71.8	2148	2.15	102.5			
Height of Sample (inch)		1.00		1.0000			0.030	0.08	1152	1.15	55.2	1908	1.91	91.4	2808	2.81	133.9			
Diameter of Sample (inch)		2.42		2.42			0.040	0.10	1332	1.33	63.8	2184	2.18	104.6	3360	3.36	160.3			
Dial Reading-Consolidation (inch)							0.050	0.13	1452	1.45	69.5	2424	2.42	116.1	3828	3.83	182.6			
Weight of Soil + Ring (gm)		188.42					0.060	0.15	1548	1.55	74.1	2580	2.58	123.5	4260	4.26	203.2			
Weight of Ring (gm)		43.78					0.070	0.18	1596	1.60	76.4	2700	2.70	129.3	4572	4.57	218.1			
Weight of Wet Soil + Cont. (gm)				146.83			0.080	0.20	1632	1.63	78.1	2784	2.78	133.3	4824	4.82	230.1			
Weight of Dry Soil + Cont. (gm)				111.67			0.090	0.23	1632	1.63	78.1	2832	2.83	135.6	4980	4.98	237.6			
Weight of Cont. (gm) No.				3.61			0.100	0.25	1620	1.62	77.6	2868	2.87	137.3	5088	5.09	242.7			
Moisture Content (%)				32.54			0.110	0.28	1608	1.61	77.0	2868	2.87	137.3	5136	5.14	245.0			
Wet Density (pcf / kN/m^3)		119.79	18.86				0.120	0.30	1572	1.57	75.3	2868	2.87	137.3	5148	5.15	245.6			
Dry Density (pcf / kN/m^3)		90.39	14.23				0.130	0.33	1548	1.55	74.1	2844	2.84	136.2	5124	5.12	244.4			
Percent Saturation (%)	102.31		**File No. :**	615505 2			0.140	0.36	1500	1.50	71.8	2796	2.80	133.9	5052	5.05	241.0			
Prepared By : RJ	**Date :** 04/08/07		**Normal Stress**				0.150	0.38	1476	1.48	70.7	2772	2.77	132.7	4980	4.98	237.6			
Tested By : RJ	**Date :** 04/08/07		4.00	(ksf)			0.160	0.41	1440	1.44	68.9	2724	2.72	130.4	4908	4.91	234.1			
Percent Consolidation (%)		**Before**		**After**			0.170	0.43	1404	1.40	67.2	2676	2.68	128.1	4836	4.84	230.7			
Height of Sample (inch)		1.00		1.0000			0.180	0.46	1380	1.38	66.1	2628	2.63	125.8	4740	4.74	226.1			
Diameter of Sample (inch)		2.42		2.42			0.190	0.48	1356	1.36	64.9	2568	2.57	123.0	4632	4.63	221.0			
Dial Reading-Consolidation (inch)							0.200	0.51	1344	1.34	64.4	2544	2.54	121.8	4548	4.55	216.9			
Weight of Soil + Ring (gm)		179.99					0.210	0.53	1332	1.33	63.8	2520	2.52	120.7	4464	4.46	212.9			
Weight of Ring (gm)		43.74					0.220	0.56	1320	1.32	63.2	2496	2.50	119.5	4392	4.39	209.5			
Weight of Wet Soil + Cont. (gm)				139.31			0.230	0.58	1308	1.31	62.6	2472	2.47	118.4	4332	4.33	206.6			
Weight of Dry Soil + Cont. (gm)				98.44			0.240	0.61	1308	1.31	62.6	2460	2.46	117.8	4260	4.26	203.2			
Weight of Cont. (gm) No.				3.63			0.250	0.64	1284	1.28	61.5	2448	2.45	117.2	4224	4.22	201.5			
Moisture Content (%)				43.11			0.260	0.66	1284	1.28	61.5	2424	2.42	116.1	4164	4.16	198.6			
Wet Density (pcf / kN/m^3)		112.85	17.76				0.270	0.69	1260	1.26	60.3	2412	2.41	115.5	4152	4.15	198.1			
Dry Density (pcf / kN/m^3)		78.85	12.41				0.280	0.71	1260	1.26	60.3	2388	2.39	114.3	4116	4.12	196.3			
Percent Saturation (%)	102.98		**File No. :**	615505 3			0.290	0.74	1236	1.24	59.2	2388	2.39	114.3	4116	4.12	196.3			
Prepared By : RJ	**Date :** 04/08/07		**Normal Stress**				0.300	0.76	1236	1.24	59.2	2364	2.36	113.2	4104	4.10	195.8			
Tested By : RJ	**Date :** 04/08/07		10.00	(ksf)			0.310	0.79	1236	1.24	59.2	2352	2.35	112.6	4068	4.07	194.1			
Percent Consolidation (%)		**Before**		**After**			0.320	0.81	1236	1.24	59.2	2352	2.35	112.6	4056	4.06	193.5			
Height of Sample (inch)		1.00		1.0000			0.330	0.84	1236	1.24	59.2	2340	2.34	112.0	4044	4.04	192.9			
Diameter of Sample (inch)		2.42		2.42			0.340	0.86	1236	1.24	59.2	2316	2.32	110.9	4032	4.03	192.3			
Dial Reading-Consolidation (inch)							0.350	0.89	1236	1.24	59.2	2316	2.32	110.9	4020	4.02	191.8			
Weight of Soil + Ring (gm)		184.09					0.360	0.91	1248	1.25	59.8	2304	2.30	110.3	4020	4.02	191.8			
Weight of Ring (gm)		43.59					0.370	0.94	1236	1.24	59.2	2304	2.30	110.3	4020	4.02	191.8			
Weight of Wet Soil + Cont. (gm)				143.22			0.380	0.97	1236	1.24	59.2	2292	2.29	109.7	4008	4.01	191.2			
Weight of Dry Soil + Cont. (gm)				104.62			0.390	0.99	1236	1.24	59.2	2280	2.28	109.2	3996	4.00	190.6			
Weight of Cont. (gm) No.				3.64			0.400	1.02	1236	1.24	59.2	2268	2.27	108.6	3996	4.00	190.6			
Moisture Content (%)				38.23				0.00												
Wet Density (pcf / kN/m^3)		116.37	18.32					0.00												
Dry Density (pcf / kN/m^3)		84.19	13.25					0.00												

Strength	(ksf)	(kPa)	(ksf)	(kPa)	(ksf)	(kPa)		0.00												
Peak	1.63	78.14	2.87	137.32	5.15	246.49		0.00												
Ultimate	1.24	59.18	2.27	108.59	4.00	191.33		0.00												



Ultimate : ○	Shear Type :	Inundated	Undisturbed	Peak : ●



Boring No. : 06-2		**Strength Intercept (C) :**	0.49	(ksf)	**Peak**	0.37	(ksf)	**Ultimate**
Sample No. : D-8			23.56	(kPa)		17.81	(kPa)	
Depth (ft/m) : 40.0	12.20	**Friction Angle (ϕ) :**	30.27	Degree		24.51	Degree	
Description : Silty Sand with Pocket of Lean Clay (SM)						**Shear Rate** (inch/minute) :		0.02

SYMBOL	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	DRY DENSITY (kN/m^3)	VOID RATIO	NORMAL STRESS (ksf)	NORMAL STRESS (kPa)	PEAK STRESS (ksf)	PEAK STRESS (kPa)	ULTIMATE STRESS (ksf)	ULTIMATE STRESS (kPa)
●	32.54	90.39	14.23	0.86	2.00	95.76	1.63	78.14	1.24	59.18
◆	43.11	78.85	12.41	1.14	4.00	191.52	2.87	137.32	2.27	108.59
▲	38.23	84.19	13.25	1.00	8.00	383.04	5.15	246.49	4.00	191.33

Earth Mechanics, Inc.
Geotechnical and Earthquake Engineering

Antioch Bridge

DIRECT SHEAR TEST (ASTM D-3080)

Project No. : 06-155 | **Date :** 04/08/07

Figure No. :

DIRECT SHEAR TEST

ASTM D-3080-90

Project No. : 06-155 **Project Name :** BATA/Antioch Bridge

Boring No. : 06-6			Saturated		Field Moisture	x	Inundated	**Specific Gravity** (Assumed) :	2.70
Sample No. : D-16		x	Undisturbed		Remolded		Consolidated-Drained	**Shear Rate** (inch/min) :	0.02
Depth (ft/m) : 71.0	21.66	x	Shear Once		Reshear		Residual	**Data File Number :**	615506
Description : Sand with Silt (SP-SM)									

Percent Saturation (%)	105.08		**File No. :**	615506 1																		
Prepared By : RJ	**Date :** 04/05/07																					
Tested By : RJ	**Date :** 04/05/07																					
Computed By : LCC	**Date :** 04/13/07																					
Checked By :	**Date :**																					
Percent Consolidation (%)		**Before**		**After**																		
Height of Sample (inch)		1.00		1.0000																		
Diameter of Sample (inch)		2.42		2.42																		
Dial Reading-Consolidation (inch)																						
Weight of Soil + Ring (gm)		192.41																				
Weight of Ring (gm)		43.33																				
Weight of Wet Soil + Cont. (gm)				150.46																		
Weight of Dry Soil + Cont. (gm)				116.29																		
Weight of Cont. (gm) No.				3.61																		
Moisture Content (%)				30.32																		
Wet Density (pcf / kN/m³)		123.47	19.43																			
Dry Density (pcf / kN/m³)		94.74	14.91																			
Percent Saturation (%)	103.28		**File No. :**	615506 2																		
Prepared By : RJ	**Date :** 04/05/07		**Normal Stress**																			
Tested By : RJ	**Date :** 04/05/07		**5.00**	(ksf)																		
Percent Consolidation (%)		**Before**		**After**																		
Height of Sample (inch)		1.00		1.0000																		
Diameter of Sample (inch)		2.42		2.42																		
Dial Reading-Consolidation (inch)																						
Weight of Soil + Ring (gm)		190.95																				
Weight of Ring (gm)		43.44																				
Weight of Wet Soil + Cont. (gm)				149.23																		
Weight of Dry Soil + Cont. (gm)				114.97																		
Weight of Cont. (gm) No.				3.59																		
Moisture Content (%)				30.76																		
Wet Density (pcf / kN/m³)		122.17	19.23																			
Dry Density (pcf / kN/m³)		93.43	14.71																			
Percent Saturation (%)	106.62		**File No. :**	615506 3																		
Prepared By : RJ	**Date :** 04/05/07		**Normal Stress**																			
Tested By : RJ	**Date :** 04/05/07		**10.00**	(ksf)																		
Percent Consolidation (%)		**Before**		**After**																		
Height of Sample (inch)		1.00		1.0000																		
Diameter of Sample (inch)		2.42		2.42																		
Dial Reading-Consolidation (inch)																						
Weight of Soil + Ring (gm)		190.29																				
Weight of Ring (gm)		43.30																				
Weight of Wet Soil + Cont. (gm)				147.99																		
Weight of Dry Soil + Cont. (gm)				111.76																		
Weight of Cont. (gm) No.				3.64																		
Moisture Content (%)				33.51																		
Wet Density (pcf / kN/m³)		121.74	19.16																			
Dry Density (pcf / kN/m³)		91.19	14.35																			

Strength	(ksf)	(kPa)	(ksf)	(kPa)	(ksf)	(kPa)
Peak	2.02	96.53	4.02	192.48	7.16	342.96
Ultimate	1.48	70.67	2.99	143.07	5.77	276.32

Shear Deflection (inch)	(mm)	**Normal Stress (psf/ksf/kPa)**								
		2500	2.50	119.7	5000	5.0	239.4	10000	10.0	478.8
		Shear Stress (psf/ksf/kPa)								
0.000	0.00	0.0	0.0	0.0	0.00	0.0	0.00	0.0	0.0	0.0
0.010	0.03	828	0.83	39.6	1500	1.50	71.8	2004	2.00	95.6
0.020	0.05	1284	1.28	61.5	2388	2.39	114.3	3276	3.28	156.3
0.030	0.08	1584	1.58	75.8	2976	2.98	142.5	4356	4.36	207.8
0.040	0.10	1788	1.79	85.6	3408	3.41	163.2	5148	5.15	245.6
0.050	0.13	1908	1.91	91.4	3708	3.71	177.5	5771	5.77	275.3
0.060	0.15	1980	1.98	94.8	3900	3.90	186.7	6239	6.24	297.6
0.070	0.18	2016	2.02	96.5	3996	4.00	191.3	6587	6.59	314.2
0.080	0.20	2016	2.02	96.5	4020	4.02	192.5	6863	6.86	327.4
0.090	0.23	2004	2.00	96.0	3996	4.00	191.3	7019	7.02	334.8
0.100	0.25	1968	1.97	94.2	3924	3.92	187.9	7115	7.12	339.4
0.110	0.28	1920	1.92	91.9	3804	3.80	182.1	7163	7.16	341.7
0.120	0.30	1848	1.85	88.5	3564	3.56	170.6	7163	7.16	341.7
0.130	0.33	1776	1.78	85.0	3324	3.32	159.2	7163	7.16	341.7
0.140	0.36	1704	1.70	81.6	3156	3.16	151.1	7115	7.12	339.4
0.150	0.38	1644	1.64	78.7	3060	3.06	146.5	7067	7.07	337.1
0.160	0.41	1596	1.60	76.4	3012	3.01	144.2	7007	7.01	334.2
0.170	0.43	1572	1.57	75.3	3000	3.00	143.6	6947	6.95	331.4
0.180	0.46	1548	1.55	74.1	3000	3.00	143.6	6899	6.90	329.1
0.190	0.48	1536	1.54	73.5	2988	2.99	143.1	6851	6.85	326.8
0.200	0.51	1524	1.52	73.0	3012	3.01	144.2	6803	6.80	324.5
0.210	0.53	1512	1.51	72.4	2988	2.99	143.1	6755	6.76	322.2
0.220	0.56	1512	1.51	72.4	3000	3.00	143.6	6671	6.67	318.2
0.230	0.58	1512	1.51	72.4	3000	3.00	143.6	6575	6.58	313.6
0.240	0.61	1512	1.51	72.4	2988	2.99	143.1	6455	6.46	307.9
0.250	0.64	1500	1.50	71.8	3000	3.00	143.6	6275	6.28	299.3
0.260	0.66	1500	1.50	71.8	3000	3.00	143.6	6059	6.06	289.0
0.270	0.69	1488	1.49	71.2	3012	3.01	144.2	5939	5.94	283.3
0.280	0.71	1500	1.50	71.8	3012	3.01	144.2	5867	5.87	279.9
0.290	0.74	1488	1.49	71.2	3012	3.01	144.2	5831	5.83	278.2
0.300	0.76	1488	1.49	71.2	3012	3.01	144.2	5795	5.80	276.4
0.310	0.79	1476	1.48	70.7	3024	3.02	144.8	5807	5.81	277.0
0.320	0.81	1488	1.49	71.2	3036	3.04	145.4	5783	5.78	275.9
0.330	0.84	1488	1.49	71.2	3036	3.04	145.4	5795	5.80	276.4
0.340	0.86	1488	1.49	71.2	3036	3.04	145.4	5771	5.77	275.3
0.350	0.89	1488	1.49	71.2	3036	3.04	145.4	5783	5.78	275.9
0.360	0.91	1488	1.49	71.2	3036	3.04	145.4	5783	5.78	275.9
0.370	0.94	1488	1.49	71.2	3036	3.04	145.4	5795	5.80	276.4
0.380	0.97	1488	1.49	71.2	3048	3.05	145.9	5807	5.81	277.0
0.390	0.99	1488	1.49	71.2	3024	3.02	144.8	5819	5.82	277.6
0.400	1.02	1500	1.50	71.8	3024	3.02	144.8	5843	5.84	278.7
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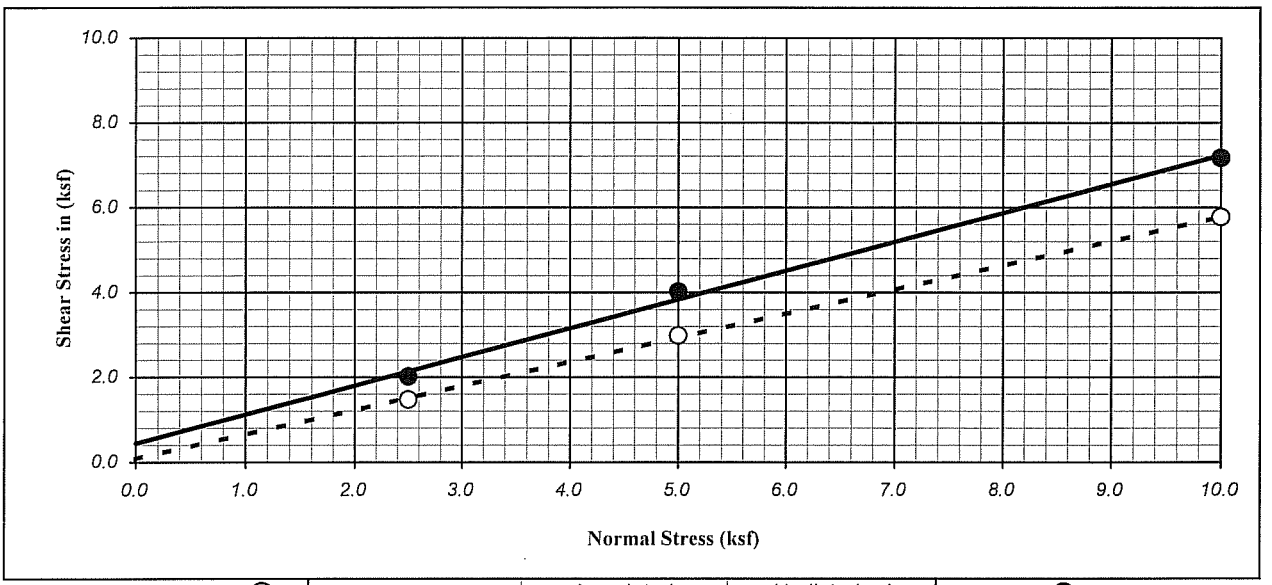
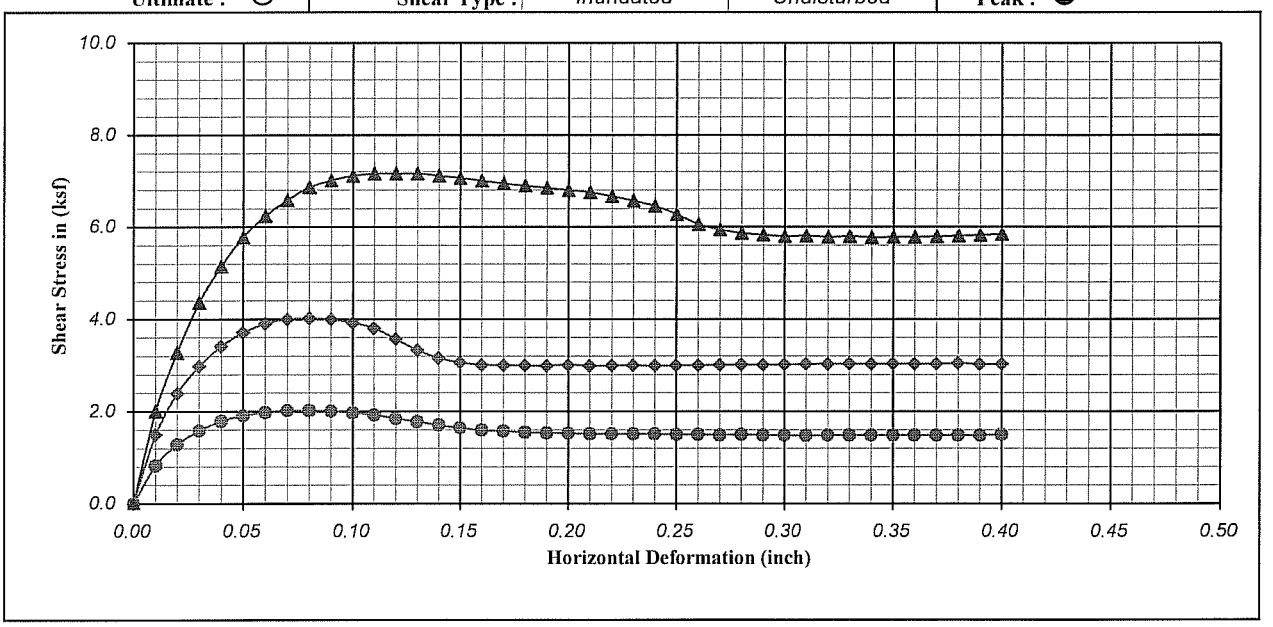


Ultimate : ○	Shear Type :	Inundated	Undisturbed	Peak : ●



Boring No. : 06-6		**Strength Intercept (C) :**	0.44	(ksf)	**Peak**	0.08	(ksf)	**Ultimate**
Sample No. : D-16			21.28	(kPa)		4.05	(kPa)	
Depth (ft/m) : 71.0	21.66	**Friction Angle (ϕ) :**	34.14	Degree		29.70	Degree	
Description : Sand with Silt (SP-SM)						**Shear Rate** (inch/minute) :		0.02

SYMBOL	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	DRY DENSITY (kN/m^3)	VOID RATIO	NORMAL STRESS (ksf)	NORMAL STRESS (kPa)	PEAK STRESS (ksf)	PEAK STRESS (kPa)	ULTIMATE STRESS (ksf)	ULTIMATE STRESS (kPa)
●	30.32	94.74	14.91	0.78	2.50	119.70	2.02	96.53	1.48	70.67
◆	30.76	93.43	14.71	0.80	5.00	239.40	4.02	192.48	2.99	143.07
▲	33.51	91.19	14.35	0.85	10.00	478.80	7.16	342.96	5.77	276.32

Earth Mechanics, Inc.
Geotechnical and Earthquake Engineering

Antioch Bridge

DIRECT SHEAR TEST (ASTM D-3080)

Project No. : 06-155 **Date :** 04/05/07

Figure No. :

DIRECT SHEAR TEST

ASTM D-3080-90

Project No. : 06-155 **Project Name :** BATA/Antioch Bridge

Boring No. : 06-7			Saturated		Field Moisture	x	Inundated	**Specific Gravity** (Assumed) :	2.70
Sample No. : D-14		x	Undisturbed		Remolded		Consolidated-Drained	**Shear Rate** (inch/min) :	0.02
Depth (ft/m) :	69.0 21.05	x	Shear Once		Reshear		Residual	**Data File Number :**	615507
Description :	Sand with Silt (SP-SM)								

Percent Saturation (%)	102.58	**File No. :**	615507 1																	
Prepared By : RJ	**Date :** 04/08/07	**Normal Stress**																		
Tested By : RJ	**Date :** 04/08/07																			
Computed By : LCC	**Date :** 04/13/07	**2.50**	(ksf)																	
Checked By :	**Date :**																			
Percent Consolidation (%)		**Before**		**After**																
Height of Sample (inch)		1.00		1.0000																
Diameter of Sample (inch)		2.42		2.42																
Dial Reading-Consolidation (inch)																				
Weight of Soil + Ring (gm)		195.29																		
Weight of Ring (gm)		43.37																		
Weight of Wet Soil + Cont. (gm)				153.92																
Weight of Dry Soil + Cont. (gm)				122.65																
Weight of Cont. (gm) No.				3.67																
Moisture Content (%)				26.28																
Wet Density (pcf / kN/m³)		125.82	19.80																	
Dry Density (pcf / kN/m³)		99.64	15.68																	
Percent Saturation (%)	102.56	**File No. :**	615507 2																	
Prepared By : RJ	**Date :** 04/08/07	**Normal Stress**																		
Tested By : RJ	**Date :** 04/08/07	**5.00**	(ksf)																	
Percent Consolidation (%)		**Before**		**After**																
Height of Sample (inch)		1.00		1.0000																
Diameter of Sample (inch)		2.42		2.42																
Dial Reading-Consolidation (inch)																				
Weight of Soil + Ring (gm)		194.29																		
Weight of Ring (gm)		43.62																		
Weight of Wet Soil + Cont. (gm)				152.68																
Weight of Dry Soil + Cont. (gm)				120.65																
Weight of Cont. (gm) No.				3.61																
Moisture Content (%)				27.37																
Wet Density (pcf / kN/m³)		124.79	19.64																	
Dry Density (pcf / kN/m³)		97.98	15.42																	
Percent Saturation (%)	102.49	**File No. :**	615507 3																	
Prepared By : RJ	**Date :** 04/08/07	**Normal Stress**																		
Tested By : RJ	**Date :** 04/08/07	**10.00**	(ksf)																	
Percent Consolidation (%)		**Before**		**After**																
Height of Sample (inch)		1.00		1.0000																
Diameter of Sample (inch)		2.42		2.42																
Dial Reading-Consolidation (inch)																				
Weight of Soil + Ring (gm)		194.63																		
Weight of Ring (gm)		43.73																		
Weight of Wet Soil + Cont. (gm)				151.29																
Weight of Dry Soil + Cont. (gm)				119.79																
Weight of Cont. (gm) No.				3.66																
Moisture Content (%)				27.12																
Wet Density (pcf / kN/m³)		124.98	19.67																	
Dry Density (pcf / kN/m³)		98.31	15.47																	

Strength	(ksf)	(kPa)	(ksf)	(kPa)	(ksf)	(kPa)
Peak	2.06	98.82	3.79	181.56	7.15	342.39
Ultimate	1.40	67.22	2.89	138.47	5.74	274.59

Shear Deflection (inch)	(mm)	**Normal Stress (psf/ksf/kPa)** 2500	2.50	119.7	5000	5.0	239.4	10000	10.0	478.8
		Shear Stress (psf/ksf/kPa)								
0.000	0.00	0.0	0.0	0.0	0.00	0.0	0.00	0.0	0.0	0.0
0.010	0.03	756	0.76	36.2	1356	1.36	64.9	1968	1.97	93.9
0.020	0.05	1176	1.18	56.3	2100	2.10	100.5	3132	3.13	149.4
0.030	0.08	1428	1.43	68.4	2616	2.62	125.3	4092	4.09	195.2
0.040	0.10	1632	1.63	78.1	3000	3.00	143.6	4812	4.81	229.5
0.050	0.13	1788	1.79	85.6	3288	3.29	157.4	5435	5.44	259.3
0.060	0.15	1896	1.90	90.8	3492	3.49	167.2	5915	5.92	282.2
0.070	0.18	1980	1.98	94.8	3636	3.64	174.1	6299	6.30	300.5
0.080	0.20	2028	2.03	97.1	3708	3.71	177.5	6587	6.59	314.2
0.090	0.23	2052	2.05	98.2	3768	3.77	180.4	6803	6.80	324.5
0.100	0.25	2064	2.06	98.8	3780	3.78	181.0	6959	6.96	332.0
0.110	0.28	2064	2.06	98.8	3792	3.79	181.6	7067	7.07	337.1
0.120	0.30	2052	2.05	98.2	3780	3.78	181.0	7115	7.12	339.4
0.130	0.33	2028	2.03	97.1	3756	3.76	179.8	7151	7.15	341.1
0.140	0.36	2004	2.00	96.0	3708	3.71	177.5	7139	7.14	340.5
0.150	0.38	1980	1.98	94.8	3660	3.66	175.2	7115	7.12	339.4
0.160	0.41	1932	1.93	92.5	3636	3.64	174.1	7079	7.08	337.7
0.170	0.43	1896	1.90	90.8	3588	3.59	171.8	7043	7.04	336.0
0.180	0.46	1848	1.85	88.5	3528	3.53	168.9	6971	6.97	332.5
0.190	0.48	1788	1.79	85.6	3468	3.47	166.0	6899	6.90	329.1
0.200	0.51	1728	1.73	82.7	3408	3.41	163.2	6791	6.79	323.9
0.210	0.53	1644	1.64	78.7	3348	3.35	160.3	6695	6.70	319.4
0.220	0.56	1584	1.58	75.8	3276	3.28	156.9	6563	6.56	313.1
0.230	0.58	1524	1.52	73.0	3204	3.20	153.4	6467	6.47	308.5
0.240	0.61	1464	1.46	70.1	3168	3.17	151.7	6347	6.35	302.8
0.250	0.64	1428	1.43	68.4	3108	3.11	148.8	6203	6.20	295.9
0.260	0.66	1404	1.40	67.2	3036	3.04	145.4	6059	6.06	289.0
0.270	0.69	1404	1.40	67.2	3000	3.00	143.6	5963	5.96	284.4
0.280	0.71	1404	1.40	67.2	2952	2.95	141.3	5891	5.89	281.0
0.290	0.74	1416	1.42	67.8	2940	2.94	140.8	5819	5.82	277.6
0.300	0.76	1416	1.42	67.8	2928	2.93	140.2	5819	5.82	277.6
0.310	0.79	1428	1.43	68.4	2916	2.92	139.6	5735	5.74	273.6
0.320	0.81	1440	1.44	68.9	2904	2.90	139.0	5747	5.75	274.1
0.330	0.84	1440	1.44	68.9	2892	2.89	138.5	5795	5.80	276.4
0.340	0.86	1440	1.44	68.9	2892	2.89	138.5	5747	5.75	274.1
0.350	0.89	1440	1.44	68.9	2904	2.90	139.0	5747	5.75	274.1
0.360	0.91	1440	1.44	68.9	2904	2.90	139.0	5759	5.76	274.7
0.370	0.94	1452	1.45	69.5	2916	2.92	139.6	5771	5.77	275.3
0.380	0.97	1464	1.46	70.1	2916	2.92	139.6	5783	5.78	275.9
0.390	0.99	1476	1.48	70.7	2928	2.93	140.2	5819	5.82	277.6
0.400	1.02	1464	1.46	70.1	2940	2.94	140.8	5819	5.82	277.6
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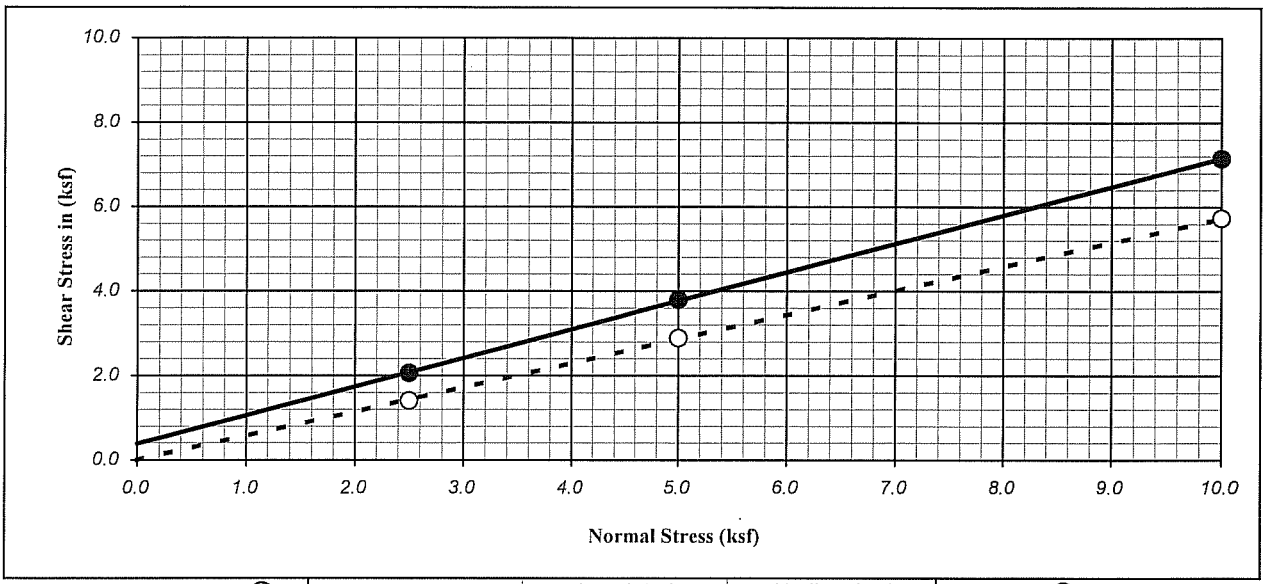
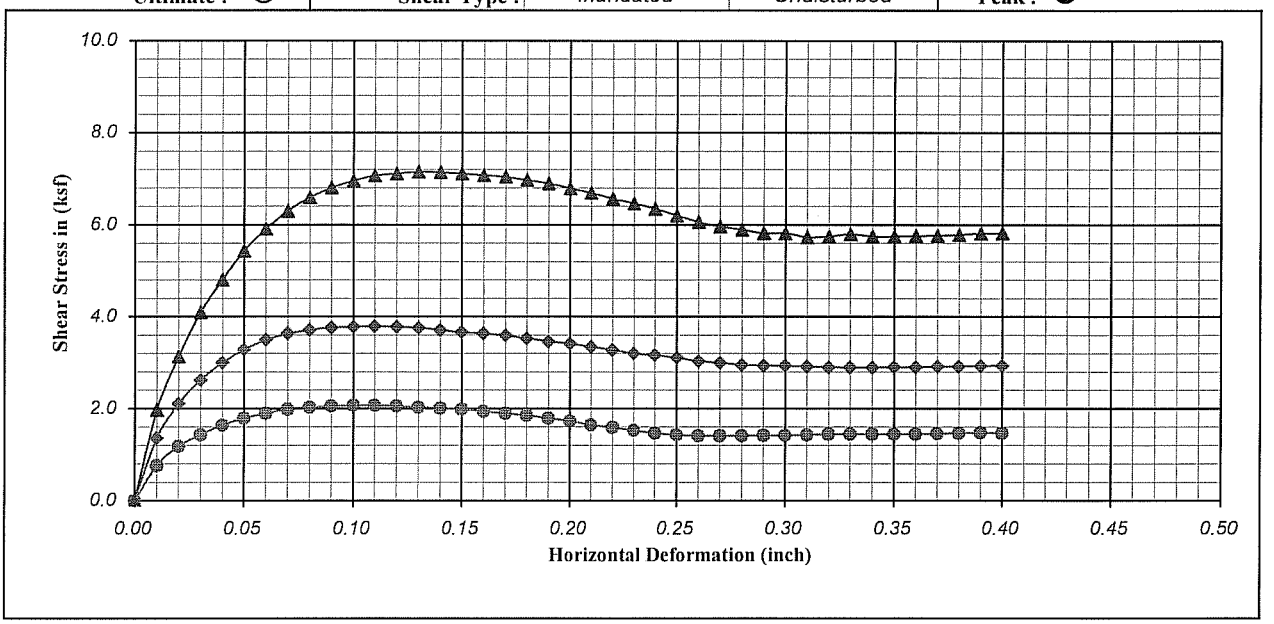


Ultimate : ○	Shear Type :	Inundated	Undisturbed	Peak : ●



Boring No.	: 06-7		**Strength Intercept (C) :**	0.38	(ksf)		0.00	(ksf)	
Sample No.	: D-14			18.41	(kPa)	**Peak**	0.00	(kPa)	**Ultimate**
Depth (ft/m)	: 69.0	21.05	**Friction Angle (ϕ) :**	34.11	Degree		29.85	Degree	
Description	: Sand with Silt (SP-SM)						**Shear Rate** (inch/minute) :		0.02

SYMBOL	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	DRY DENSITY (kN/m^3)	VOID RATIO	NORMAL STRESS (ksf)	NORMAL STRESS (kPa)	PEAK STRESS (ksf)	PEAK STRESS (kPa)	ULTIMATE STRESS (ksf)	ULTIMATE STRESS (kPa)
●	26.28	99.64	15.68	0.69	2.50	119.70	2.06	98.82	1.40	67.22
◆	27.37	97.98	15.42	0.72	5.00	239.40	3.79	181.56	2.89	138.47
▲	27.12	98.31	15.47	0.71	10.00	478.80	7.15	342.39	5.74	274.59

Earth Mechanics, Inc.
Geotechnical and Earthquake Engineering

Antioch Bridge

DIRECT SHEAR TEST (ASTM D-3080)

Project No. : 06-155 | **Date :** 04/08/07 | Figure No. :

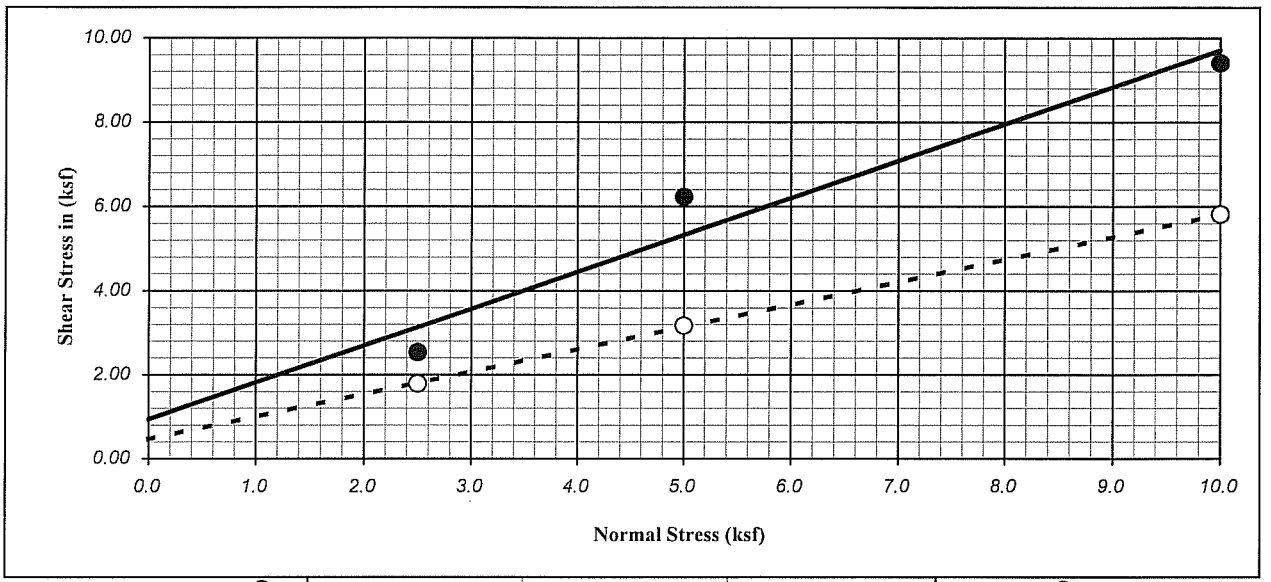
DIRECT SHEAR TEST

ASTM D-3080-90

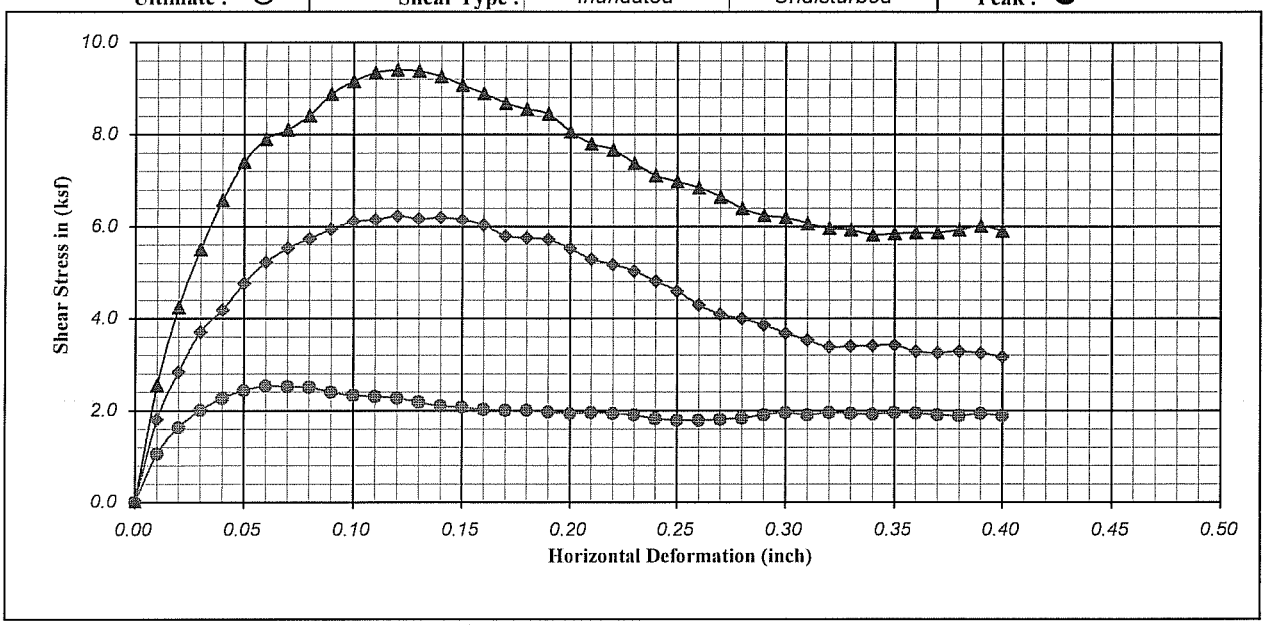
Project No. : 06-155 **Project Name :** BATA/Antioch Bridge

Boring No. : 06-7			Saturated		Field Moisture	x	Inundated	**Specific Gravity** (Assumed) :	2.70
Sample No. : D-16		x	Undisturbed		Remolded		Consolidated-Drained	**Shear Rate** (inch/min) :	0.02
Depth (ft/m) :	79.0 / 24.10	x	Shear Once		Reshear		Residual	**Data File Number :**	615508
Description :	Sand with Gravel (SP)								

Percent Saturation (%)	100.03	**File No. :**	615508 1				**Shear Deflection**		**Normal Stress (psf/ksf/kPa)**										
Prepared By : RJ	**Date :** 04/08/07	**Normal Stress**							2500	2.50	119.7	5000	5.0	239.4	10000	10.0	478.8		
Tested By : RJ	**Date :** 04/08/07						(inch)	(mm)	**Shear Stress (psf/ksf/kPa)**										
Computed By : LCC	**Date :** 04/13/07	**2.50**	(ksf)				0.000	0.00	0.0	0.0	0.0	0.00	0.0	0.00	0.0	0.0	0.0		
Checked By :	**Date :**						0.010	0.03	1056	1.06	50.6	1812	1.81	86.8	2544	2.54	121.4		
Percent Consolidation (%)		**Before**		**After**			0.020	0.05	1632	1.63	78.1	2844	2.84	136.2	4248	4.25	202.6		
Height of Sample (inch)		1.00		1.0000			0.030	0.08	2004	2.00	96.0	3708	3.71	177.5	5507	5.51	262.7		
Diameter of Sample (inch)		2.42		2.42			0.040	0.10	2268	2.27	108.6	4188	4.19	200.5	6575	6.58	313.6		
Dial Reading-Consolidation (inch)							0.050	0.13	2436	2.44	116.6	4764	4.76	228.1	7403	7.40	353.1		
Weight of Soil + Ring (gm)		212.17					0.060	0.15	2532	2.53	121.2	5220	5.22	249.9	7895	7.90	376.6		
Weight of Ring (gm)		43.49					0.070	0.18	2520	2.52	120.7	5531	5.53	264.8	8105	8.11	386.6		
Weight of Wet Soil + Cont. (gm)				171.70			0.080	0.20	2508	2.51	120.1	5735	5.74	274.6	8415	8.42	401.4		
Weight of Dry Soil + Cont. (gm)				151.27			0.090	0.23	2400	2.40	114.9	5951	5.95	284.9	8879	8.88	423.5		
Weight of Cont. (gm) No.				3.62			0.100	0.25	2328	2.33	111.5	6107	6.11	292.4	9155	9.16	436.7		
Moisture Content (%)				13.84			0.110	0.28	2304	2.30	110.3	6143	6.14	294.1	9347	9.35	445.9		
Wet Density (pcf / kN/m³)		139.71	21.99				0.120	0.30	2268	2.27	108.6	6227	6.23	298.1	9407	9.41	448.7		
Dry Density (pcf / kN/m³)		122.72	19.32				0.130	0.33	2184	2.18	104.6	6167	6.17	295.3	9383	9.38	447.6		
Percent Saturation (%)	98.57	**File No. :**	615508 2				0.140	0.36	2100	2.10	100.5	6191	6.19	296.4	9263	9.26	441.9		
Prepared By : RJ	**Date :** 04/08/07	**Normal Stress**					0.150	0.38	2076	2.08	99.4	6143	6.14	294.1	9071	9.07	432.7		
Tested By : RJ	**Date :** 04/08/07	**5.00**	(ksf)				0.160	0.41	2028	2.03	97.1	6035	6.04	289.0	8891	8.89	424.1		
Percent Consolidation (%)		**Before**		**After**			0.170	0.43	2004	2.00	96.0	5795	5.80	277.5	8675	8.68	413.8		
Height of Sample (inch)		1.00		1.0000			0.180	0.46	2004	2.00	96.0	5747	5.75	275.2	8555	8.56	408.1		
Diameter of Sample (inch)		2.42		2.42			0.190	0.48	1968	1.97	94.2	5711	5.71	273.4	8447	8.45	402.9		
Dial Reading-Consolidation (inch)							0.200	0.51	1932	1.93	92.5	5519	5.52	264.2	8063	8.06	384.6		
Weight of Soil + Ring (gm)		213.51					0.210	0.53	1956	1.96	93.7	5292	5.29	253.4	7799	7.80	372.0		
Weight of Ring (gm)		43.56					0.220	0.56	1932	1.93	92.5	5172	5.17	247.6	7667	7.67	365.7		
Weight of Wet Soil + Cont. (gm)				170.84			0.230	0.58	1908	1.91	91.4	5028	5.03	240.7	7379	7.38	352.0		
Weight of Dry Soil + Cont. (gm)				151.85			0.240	0.61	1824	1.82	87.3	4812	4.81	230.4	7115	7.12	339.4		
Weight of Cont. (gm) No.				3.63			0.250	0.64	1788	1.79	85.6	4596	4.60	220.1	6983	6.98	333.1		
Moisture Content (%)				12.81			0.260	0.66	1788	1.79	85.6	4296	4.30	205.7	6851	6.85	326.8		
Wet Density (pcf / kN/m³)		140.76	22.16				0.270	0.69	1812	1.81	86.8	4092	4.09	195.9	6647	6.65	317.1		
Dry Density (pcf / kN/m³)		124.77	19.64				0.280	0.71	1836	1.84	87.9	3996	4.00	191.3	6395	6.40	305.1		
Percent Saturation (%)	100.58	**File No. :**	615508 3				0.290	0.74	1908	1.91	91.4	3852	3.85	184.4	6239	6.24	297.6		
Prepared By : RJ	**Date :** 04/08/07	**Normal Stress**					0.300	0.76	1956	1.96	93.7	3684	3.68	176.4	6191	6.19	295.3		
Tested By : RJ	**Date :** 04/08/07	**10.00**	(ksf)				0.310	0.79	1908	1.91	91.4	3528	3.53	168.9	6071	6.07	289.6		
Percent Consolidation (%)		**Before**		**After**			0.320	0.81	1956	1.96	93.7	3372	3.37	161.5	5963	5.96	284.4		
Height of Sample (inch)		1.00		1.0000			0.330	0.84	1932	1.93	92.5	3396	3.40	162.6	5927	5.93	282.7		
Diameter of Sample (inch)		2.42		2.42			0.340	0.86	1920	1.92	91.9	3408	3.41	163.2	5819	5.82	277.6		
Dial Reading-Consolidation (inch)							0.350	0.89	1956	1.96	93.7	3420	3.42	163.7	5843	5.84	278.7		
Weight of Soil + Ring (gm)		211.17					0.360	0.91	1944	1.94	93.1	3288	3.29	157.4	5867	5.87	279.9		
Weight of Ring (gm)		43.62					0.370	0.94	1908	1.91	91.4	3252	3.25	155.7	5867	5.87	279.9		
Weight of Wet Soil + Cont. (gm)				169.11			0.380	0.97	1884	1.88	90.2	3288	3.29	157.4	5927	5.93	282.7		
Weight of Dry Soil + Cont. (gm)				148.02			0.390	0.99	1932	1.93	92.5	3240	3.24	155.1	6011	6.01	286.7		
Weight of Cont. (gm) No.				3.63			0.400	1.02	1884	1.88	90.2	3168	3.17	151.7	5903	5.90	281.6		
Moisture Content (%)				14.61				0.00											
Wet Density (pcf / kN/m³)		138.77	21.84					0.00											
Dry Density (pcf / kN/m³)		121.08	19.06					0.00											
Strength	(ksf) (kPa)	(ksf)	(kPa)	(ksf)	(kPa)			0.00											
Peak	2.53 121.23	6.23	298.15	9.41	450.41			0.00											
Ultimate	1.79 85.61	3.17	151.68	5.82	278.61			0.00											



Ultimate : ○	Shear Type :	Inundated	Undisturbed	Peak : ●



Boring No. : 06-7		**Strength Intercept (C) :**	0.94	(ksf)		0.46	(ksf)	
Sample No. : D-16			45.10	(kPa)	**Peak**	22.14	(kPa)	**Ultimate**
Depth (ft/m) : 79.0	24.10	**Friction Angle (ϕ) :**	41.24	Degree		28.21	Degree	
Description : Sand with Gravel (SP)						**Shear Rate** (inch/minute) :		0.02

SYMBOL	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	DRY DENSITY (kN/m^3)	VOID RATIO	NORMAL STRESS (ksf)	NORMAL STRESS (kPa)	PEAK STRESS (ksf)	PEAK STRESS (kPa)	ULTIMATE STRESS (ksf)	ULTIMATE STRESS (kPa)
●	13.84	122.72	19.32	0.37	2.50	119.70	2.53	121.23	1.79	85.61
◆	12.81	124.77	19.64	0.35	5.00	239.40	6.23	298.15	3.17	151.68
▲	14.61	121.08	19.06	0.39	10.00	478.80	9.41	450.41	5.82	278.61

Earth Mechanics, Inc.
Geotechnical and Earthquake Engineering

Antioch Bridge

DIRECT SHEAR TEST (ASTM D-3080)

Project No. : 06-155 **Date :** 04/08/07

Figure No. :

DIRECT SHEAR TEST

ASTM D-3080-90

Project No. : 06-155 **Project Name :** BATA/Antioch Bridge

Boring No. : 06-8			Saturated		Field Moisture	x	Inundated	**Specific Gravity** (Assumed) :	2.70
Sample No. : D-15		x	Undisturbed		Remolded		Consolidated-Drained	**Shear Rate** (inch/min) :	0.02
Depth (ft/m) :	66.0 20.13	x	Shear Once		Reshear		Residual	**Data File Number :**	615509
Description :	Silty Sand (SM)								

Percent Saturation (%)	103.75	**File No. :**	615509 1																	
Prepared By : RJ	**Date :** 05/04/07	**Normal Stress**																		
Tested By : RJ	**Date :** 05/04/07																			
Computed By : LCC	**Date :** 05/08/07	**2.50**	(ksf)																	
Checked By :	**Date :**																			
Percent Consolidation (%)		**Before**		**After**																
Height of Sample (inch)		1.00		1.0000																
Diameter of Sample (inch)		2.42		2.42																
Dial Reading-Consolidation (inch)																				
Weight of Soil + Ring (gm)		187.06																		
Weight of Ring (gm)		43.45																		
Weight of Wet Soil + Cont. (gm)				145.17																
Weight of Dry Soil + Cont. (gm)				108.32																
Weight of Cont. (gm) No.				3.62																
Moisture Content (%)				35.20																
Wet Density (pcf / kN/m³)		118.94	18.72																	
Dry Density (pcf / kN/m³)		87.98	13.85																	
Percent Saturation (%)	103.97	**File No. :**	615509 2																	
Prepared By : RJ	**Date :** 05/04/07	**Normal Stress**																		
Tested By : RJ	**Date :** 05/04/07	**5.00**	(ksf)																	
Percent Consolidation (%)		**Before**		**After**																
Height of Sample (inch)		1.00		1.0000																
Diameter of Sample (inch)		2.42		2.42																
Dial Reading-Consolidation (inch)																				
Weight of Soil + Ring (gm)		186.33																		
Weight of Ring (gm)		43.41																		
Weight of Wet Soil + Cont. (gm)				142.84																
Weight of Dry Soil + Cont. (gm)				105.87																
Weight of Cont. (gm) No.				3.61																
Moisture Content (%)				36.15																
Wet Density (pcf / kN/m³)		118.37	18.63																	
Dry Density (pcf / kN/m³)		86.94	13.68																	
Percent Saturation (%)	98.14	**File No. :**	615509 3																	
Prepared By : RJ	**Date :** 05/04/07	**Normal Stress**																		
Tested By : RJ	**Date :** 05/04/07	**10.00**	(ksf)																	
Percent Consolidation (%)		**Before**		**After**																
Height of Sample (inch)		1.00		1.0000																
Diameter of Sample (inch)		2.42		2.42																
Dial Reading-Consolidation (inch)																				
Weight of Soil + Ring (gm)		183.38																		
Weight of Ring (gm)		43.65																		
Weight of Wet Soil + Cont. (gm)				141.08																
Weight of Dry Soil + Cont. (gm)				105.26																
Weight of Cont. (gm) No.				3.67																
Moisture Content (%)				35.26																
Wet Density (pcf / kN/m³)		115.73	18.22																	
Dry Density (pcf / kN/m³)		85.56	13.47																	

Strength	(ksf)	(kPa)	(ksf)	(kPa)	(ksf)	(kPa)
Peak	1.86	89.06	3.34	159.73	6.32	302.75
Ultimate	1.52	72.97	2.86	136.75	5.78	276.89

Shear Deflection (inch)	(mm)	**Normal Stress (psf/ksf/kPa)** 2500	2.50	119.7	5000	5.0	239.4	10000	10.0	478.8
		Shear Stress (psf/ksf/kPa)								
0.00	0.00	0.0	0.0	0.0	0.00	0.0	0.00	0.00	0.0	0.0
0.010	0.03	600	0.60	28.7	996	1.00	47.7	1560	1.56	74.4
0.020	0.05	936	0.94	44.8	1584	1.58	75.8	2508	2.51	119.6
0.030	0.08	1200	1.20	57.5	2004	2.00	96.0	3372	3.37	160.9
0.040	0.10	1404	1.40	67.2	2340	2.34	112.0	4044	4.04	192.9
0.050	0.13	1548	1.55	74.1	2592	2.59	124.1	4572	4.57	218.1
0.060	0.15	1668	1.67	79.9	2796	2.80	133.9	5016	5.02	239.3
0.070	0.18	1752	1.75	83.9	2964	2.96	141.9	5364	5.36	255.9
0.080	0.20	1812	1.81	86.8	3084	3.08	147.7	5627	5.63	268.4
0.090	0.23	1848	1.85	88.5	3180	3.18	152.3	5867	5.87	279.9
0.100	0.25	1860	1.86	89.1	3252	3.25	155.7	6035	6.04	287.9
0.110	0.28	1860	1.86	89.1	3300	3.30	158.0	6155	6.16	293.6
0.120	0.30	1860	1.86	89.1	3324	3.32	159.2	6239	6.24	297.6
0.130	0.33	1836	1.84	87.9	3336	3.34	159.7	6299	6.30	300.5
0.140	0.36	1812	1.81	86.8	3336	3.34	159.7	6323	6.32	301.6
0.150	0.38	1788	1.79	85.6	3324	3.32	159.2	6323	6.32	301.6
0.160	0.41	1764	1.76	84.5	3288	3.29	157.4	6323	6.32	301.6
0.170	0.43	1740	1.74	83.3	3240	3.24	155.1	6299	6.30	300.5
0.180	0.46	1704	1.70	81.6	3180	3.18	152.3	6251	6.25	298.2
0.190	0.48	1680	1.68	80.4	3108	3.11	148.8	6179	6.18	294.8
0.200	0.51	1644	1.64	78.7	3048	3.05	145.9	6071	6.07	289.6
0.210	0.53	1620	1.62	77.6	3000	3.00	143.6	5987	5.99	285.6
0.220	0.56	1596	1.60	76.4	2952	2.95	141.3	5915	5.92	282.2
0.230	0.58	1560	1.56	74.7	2916	2.92	139.6	5879	5.88	280.4
0.240	0.61	1548	1.55	74.1	2892	2.89	138.5	5867	5.87	279.9
0.250	0.64	1524	1.52	73.0	2892	2.89	138.5	5843	5.84	278.7
0.260	0.66	1524	1.52	73.0	2880	2.88	137.9	5855	5.86	279.3
0.270	0.69	1524	1.52	73.0	2868	2.87	137.3	5843	5.84	278.7
0.280	0.71	1536	1.54	73.5	2868	2.87	137.3	5819	5.82	277.6
0.290	0.74	1536	1.54	73.5	2856	2.86	136.7	5819	5.82	277.6
0.300	0.76	1536	1.54	73.5	2868	2.87	137.3	5819	5.82	277.6
0.310	0.79	1548	1.55	74.1	2868	2.87	137.3	5819	5.82	277.6
0.320	0.81	1560	1.56	74.7	2880	2.88	137.9	5831	5.83	278.2
0.330	0.84	1560	1.56	74.7	2880	2.88	137.9	5819	5.82	277.6
0.340	0.86	1572	1.57	75.3	2880	2.88	137.9	5819	5.82	277.6
0.350	0.89	1596	1.60	76.4	2868	2.87	137.3	5819	5.82	277.6
0.360	0.91	1596	1.60	76.4	2892	2.89	138.5	5819	5.82	277.6
0.370	0.94	1596	1.60	76.4	2892	2.89	138.5	5819	5.82	277.6
0.380	0.97	1608	1.61	77.0	2892	2.89	138.5	5795	5.80	276.4
0.390	0.99	1608	1.61	77.0	2892	2.89	138.5	5807	5.81	277.0
0.400	1.02	1608	1.61	77.0	2892	2.89	138.5	5783	5.78	275.9
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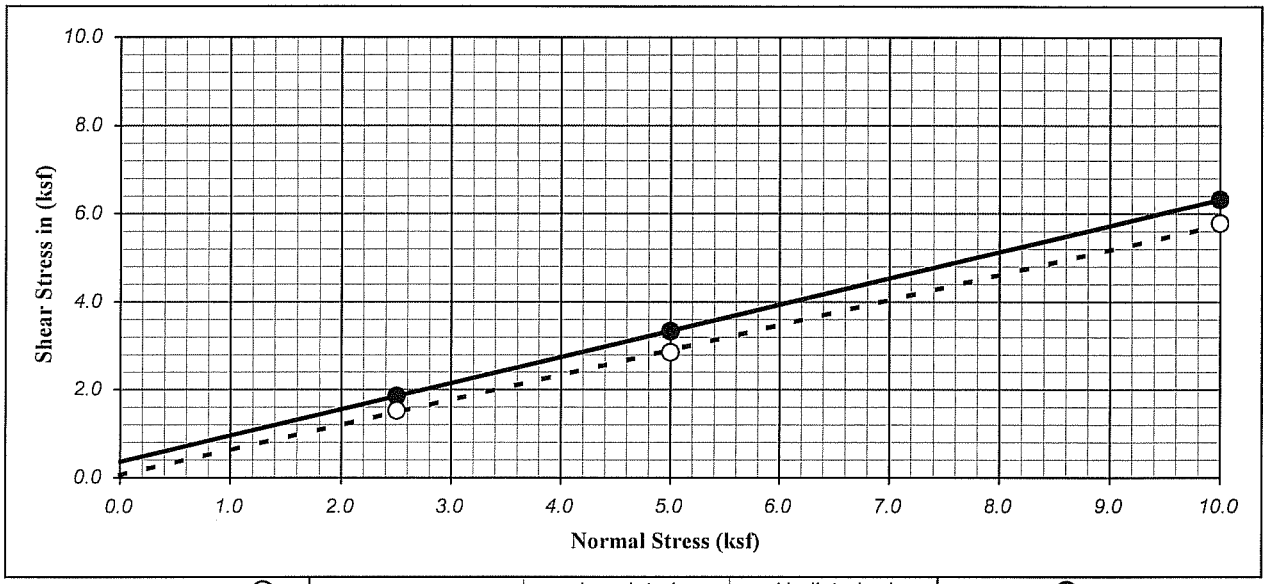
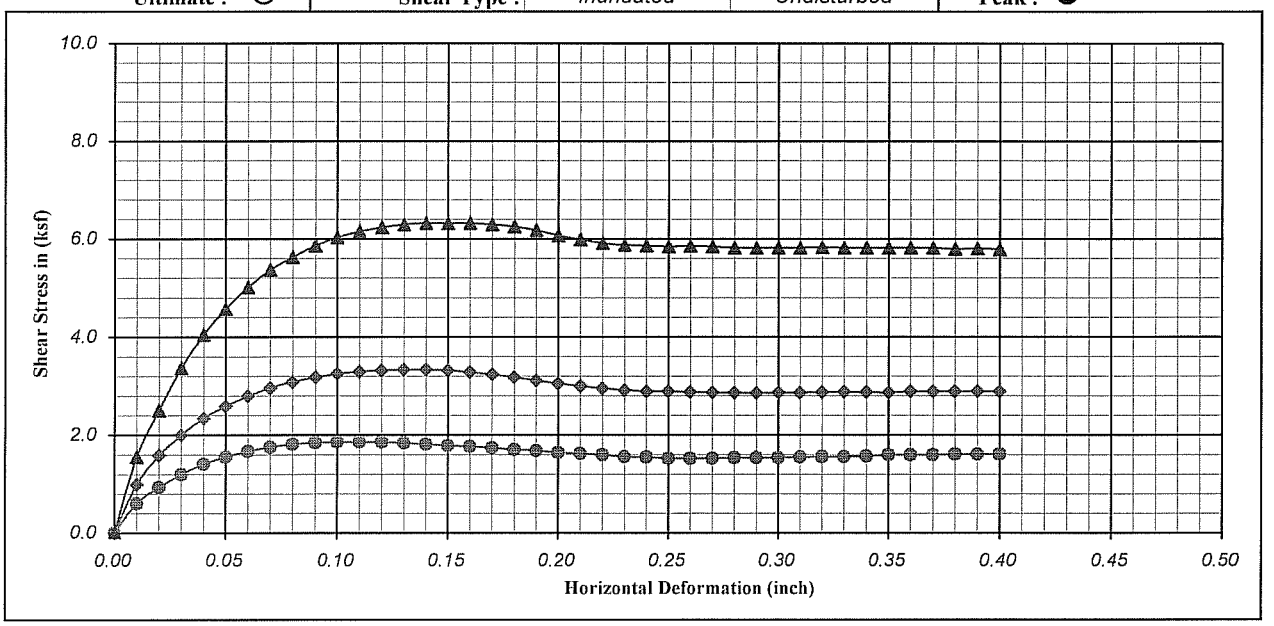
	0.00									
	0.00									



Ultimate : ○	Shear Type :	Inundated	Undisturbed	Peak : ●



Boring No.	: 06-8		**Strength Intercept (C) :**	0.37	(ksf)		0.06	(ksf)	
Sample No.	: D-15			17.55	(kPa)	**Peak**	2.90	(kPa)	**Ultimate**
Depth (ft/m)	: 66.0	20.13	**Friction Angle (ϕ) :**	30.77	Degree		29.70	Degree	
Description	: Silty Sand (SM)						**Shear Rate** (inch/minute) :		0.02

SYMBOL	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	DRY DENSITY (kN/m^3)	VOID RATIO	NORMAL STRESS (ksf)	NORMAL STRESS (kPa)	PEAK STRESS (ksf)	PEAK STRESS (kPa)	ULTIMATE STRESS (ksf)	ULTIMATE STRESS (kPa)
●	35.20	87.98	13.85	0.92	2.50	119.70	1.86	89.06	1.52	72.97
◆	36.15	86.94	13.68	0.94	5.00	239.40	3.34	159.73	2.86	136.75
▲	35.26	85.56	13.47	0.97	10.00	478.80	6.32	302.75	5.78	276.89

Earth Mechanics, Inc.
Geotechnical and Earthquake Engineering

Antioch Bridge

DIRECT SHEAR TEST (ASTM D-3080)

Project No. : 06-155 | **Date :** 05/04/07

Figure No. :

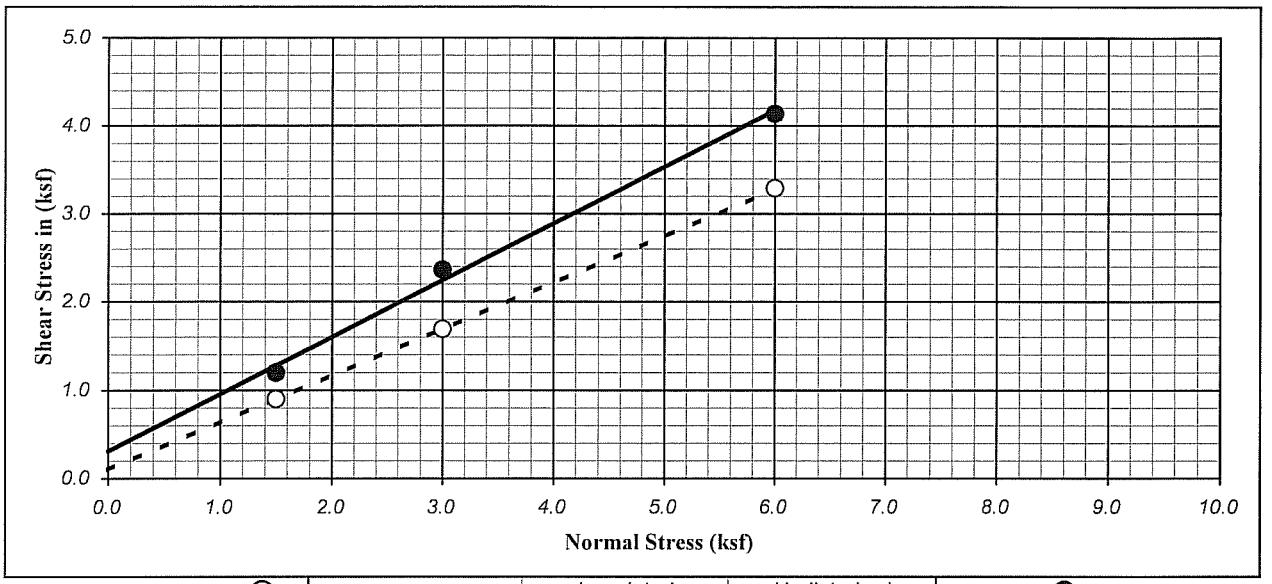
DIRECT SHEAR TEST

ASTM D-3080-90

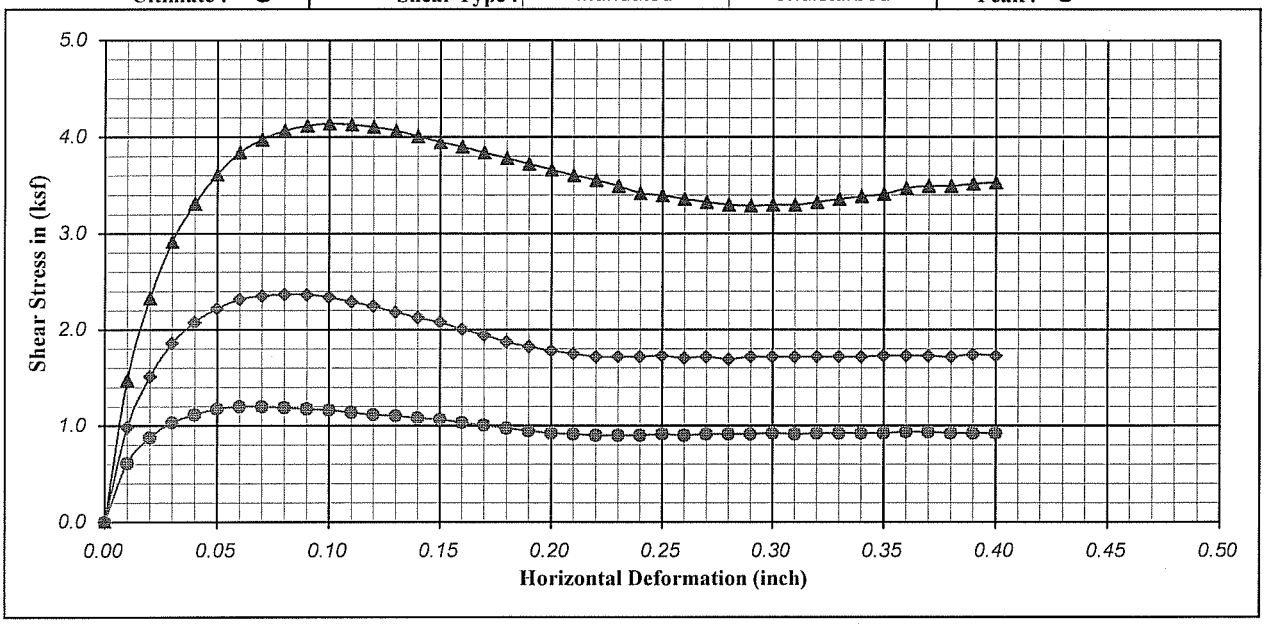
Project No. : 06-155 **Project Name :** BATA/Antioch Bridge

Boring No. : 06-9			Saturated		Field Moisture	x	Inundated	**Specific Gravity** (Assumed) :	2.70
Sample No. : D-5		x	Undisturbed		Remolded		Consolidated-Drained	**Shear Rate** (inch/min) :	0.02
Depth (ft/m) : 25.0	7.63	x	Shear Once		Reshear		Residual	**Data File Number :**	615510
Description : Sand with Silt (SP-SM)									

Percent Saturation (%)	99.13		**File No. :**	615510 1			**Shear Deflection**		**Normal Stress (psf/ksf/kPa)**											
Prepared By : RJ	**Date :** 05/04/07		**Normal Stress**						1500	1.50	71.8	3000	3.0	143.6	6000	6.0	287.3			
Tested By : RJ	**Date :** 05/04/07						(inch)	(mm)	**Shear Stress (psf/ksf/kPa)**											
Computed By : LCC	**Date :** 05/08/07		**1.50**	(ksf)			0.000	0.00	0.0	0.0	0.0	0.00	0.0	0.00	0.0	0.0	0.0			
Checked By :	**Date :**						0.010	0.03	612	0.61	29.3	984	0.98	47.1	1476	1.48	70.4			
Percent Consolidation (%)		**Before**		**After**			0.020	0.05	876	0.88	41.9	1512	1.51	72.4	2328	2.33	111.1			
Height of Sample (inch)		1.00		1.0000			0.030	0.08	1032	1.03	49.4	1860	1.86	89.1	2916	2.92	139.1			
Diameter of Sample (inch)		2.42		2.42			0.040	0.10	1116	1.12	53.4	2076	2.08	99.4	3312	3.31	158.0			
Dial Reading-Consolidation (inch)							0.050	0.13	1176	1.18	56.3	2220	2.22	106.3	3612	3.61	172.3			
Weight of Soil + Ring (gm)		190.51					0.060	0.15	1200	1.20	57.5	2316	2.32	110.9	3840	3.84	183.2			
Weight of Ring (gm)		43.41					0.070	0.18	1200	1.20	57.5	2352	2.35	112.6	3972	3.97	189.5			
Weight of Wet Soil + Cont. (gm)				147.76			0.080	0.20	1188	1.19	56.9	2364	2.36	113.2	4068	4.07	194.1			
Weight of Dry Soil + Cont. (gm)				115.69			0.090	0.23	1176	1.18	56.3	2364	2.36	113.2	4116	4.12	196.3			
Weight of Cont. (gm) **No.**				3.63			0.100	0.25	1164	1.16	55.7	2340	2.34	112.0	4140	4.14	197.5			
Moisture Content (%)				28.62			0.110	0.28	1140	1.14	54.6	2292	2.29	109.7	4128	4.13	196.9			
Wet Density (pcf / kN/m^3)		121.83	19.18				0.120	0.30	1116	1.12	53.4	2244	2.24	107.4	4104	4.10	195.8			
Dry Density (pcf / kN/m^3)		94.72	14.91				0.130	0.33	1104	1.10	52.9	2184	2.18	104.6	4068	4.07	194.1			
Percent Saturation (%)	99.85		**File No. :**	615510 2			0.140	0.36	1080	1.08	51.7	2124	2.12	101.7	4008	4.01	191.2			
Prepared By : RJ	**Date :** 05/04/07		**Normal Stress**				0.150	0.38	1068	1.07	51.1	2076	2.08	99.4	3948	3.95	188.3			
Tested By : RJ	**Date :** 05/04/07		**3.00**	(ksf)			0.160	0.41	1032	1.03	49.4	2004	2.00	96.0	3900	3.90	186.0			
Percent Consolidation (%)		**Before**		**After**			0.170	0.43	1008	1.01	48.3	1944	1.94	93.1	3840	3.84	183.2			
Height of Sample (inch)		1.00		1.0000			0.180	0.46	972	0.97	46.5	1872	1.87	89.6	3780	3.78	180.3			
Diameter of Sample (inch)		2.42		2.42			0.190	0.48	948	0.95	45.4	1824	1.82	87.3	3720	3.72	177.5			
Dial Reading-Consolidation (inch)							0.200	0.51	924	0.92	44.2	1776	1.78	85.0	3660	3.66	174.6			
Weight of Soil + Ring (gm)		190.18					0.210	0.53	912	0.91	43.7	1752	1.75	83.9	3600	3.60	171.7			
Weight of Ring (gm)		43.55					0.220	0.56	900	0.90	43.1	1716	1.72	82.2	3552	3.55	169.4			
Weight of Wet Soil + Cont. (gm)				147.63			0.230	0.58	900	0.90	43.1	1716	1.72	82.2	3492	3.49	166.6			
Weight of Dry Soil + Cont. (gm)				114.85			0.240	0.61	900	0.90	43.1	1716	1.72	82.2	3420	3.42	163.1			
Weight of Cont. (gm) **No.**				3.65			0.250	0.64	912	0.91	43.7	1728	1.73	82.7	3396	3.40	162.0			
Moisture Content (%)				29.48			0.260	0.66	900	0.90	43.1	1704	1.70	81.6	3360	3.36	160.3			
Wet Density (pcf / kN/m^3)		121.44	19.12				0.270	0.69	912	0.91	43.7	1716	1.72	82.2	3324	3.32	158.6			
Dry Density (pcf / kN/m^3)		93.79	14.76				0.280	0.71	912	0.91	43.7	1692	1.69	81.0	3300	3.30	157.4			
Percent Saturation (%)	98.10		**File No. :**	615510 3			0.290	0.74	912	0.91	43.7	1716	1.72	82.2	3288	3.29	156.8			
Prepared By : RJ	**Date :** 05/04/07		**Normal Stress**				0.300	0.76	924	0.92	44.2	1716	1.72	82.2	3300	3.30	157.4			
Tested By : RJ	**Date :** 05/04/07		**6.00**	(ksf)			0.310	0.79	912	0.91	43.7	1716	1.72	82.2	3300	3.30	157.4			
Percent Consolidation (%)		**Before**		**After**			0.320	0.81	924	0.92	44.2	1716	1.72	82.2	3324	3.32	158.6			
Height of Sample (inch)		1.00		1.0000			0.330	0.84	924	0.92	44.2	1716	1.72	82.2	3360	3.36	160.3			
Diameter of Sample (inch)		2.42		2.42			0.340	0.86	924	0.92	44.2	1716	1.72	82.2	3384	3.38	161.4			
Dial Reading-Consolidation (inch)							0.350	0.89	924	0.92	44.2	1728	1.73	82.7	3408	3.41	162.6			
Weight of Soil + Ring (gm)		189.43					0.360	0.91	936	0.94	44.8	1728	1.73	82.7	3468	3.47	165.4			
Weight of Ring (gm)		43.48					0.370	0.94	936	0.94	44.8	1728	1.73	82.7	3492	3.49	166.6			
Weight of Wet Soil + Cont. (gm)				146.31			0.380	0.97	924	0.92	44.2	1716	1.72	82.2	3492	3.49	166.6			
Weight of Dry Soil + Cont. (gm)				114.19			0.390	0.99	924	0.92	44.2	1740	1.74	83.3	3516	3.52	167.7			
Weight of Cont. (gm) **No.**				3.63			0.400	1.02	924	0.92	44.2	1728	1.73	82.7	3528	3.53	168.3			
Moisture Content (%)				29.05				0.00												
Wet Density (pcf / kN/m^3)		120.88	19.03					0.00												
Dry Density (pcf / kN/m^3)		93.67	14.74					0.00												
Strength (ksf)	(kPa)	(ksf)	(kPa)	(ksf)	(kPa)			0.00												
Peak 1.20	57.46	2.36	113.19	4.14	198.22			0.00												
Ultimate 0.90	43.09	1.69	81.01	3.29	157.43			0.00												



Ultimate : ○	Shear Type :	Inundated	Undisturbed	Peak : ●



Boring No. : 06-9		**Strength Intercept (C) :**	0.31	(ksf)		0.10	(ksf)	
Sample No. : D-5			14.94	(kPa)	**Peak**	4.88	(kPa)	**Ultimate**
Depth (ft/m) : 25.0	7.63	**Friction Angle (ϕ) :**	32.80	Degree		27.96	Degree	
Description : Sand with Silt (SP-SM)						**Shear Rate** (inch/minute) :		0.02

SYMBOL	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	DRY DENSITY (kN/m^3)	VOID RATIO	NORMAL STRESS (ksf)	NORMAL STRESS (kPa)	PEAK STRESS (ksf)	PEAK STRESS (kPa)	ULTIMATE STRESS (ksf)	ULTIMATE STRESS (kPa)
●	28.62	94.72	14.91	0.78	1.50	71.82	1.20	57.46	0.90	43.09
◆	29.48	93.79	14.76	0.80	3.00	143.64	2.36	113.19	1.69	81.01
▲	29.05	93.67	14.74	0.80	6.00	287.28	4.14	198.22	3.29	157.43

Earth Mechanics, Inc.
Geotechnical and Earthquake Engineering

Antioch Bridge

DIRECT SHEAR TEST (ASTM D-3080)

Project No. : 06-155 **Date :** 05/04/07

Figure No. :

DIRECT SHEAR TEST

ASTM D-3080-90

Project No. : 06-155 **Project Name :** BATA/Antioch Bridge

Boring No. : 06-9			Saturated		Field Moisture	x	Inundated	**Specific Gravity** (Assumed) :	2.70
Sample No. : D-11		x	Undisturbed		Remolded		Consolidated-Drained	**Shear Rate** (inch/min) :	0.02
Depth (ft/m) :	55.0 16.78	x	Shear Once		Reshear		Residual	**Data File Number :**	615511
Description :	Sand with Silt (SP-SM)								

Percent Saturation (%)	100.88	**File No. :**	615511 1																	
Prepared By : RJ	**Date :** 05/06/07																			
Tested By : RJ	**Date :** 05/06/07																			
Computed By : LCC	**Date :** 05/08/07																			
Checked By :	**Date :**																			
Percent Consolidation (%)		**Before**		**After**																
Height of Sample (inch)		1.00		1.0000																
Diameter of Sample (inch)		2.42		2.42																
Dial Reading-Consolidation (inch)																				
Weight of Soil + Ring (gm)		189.95																		
Weight of Ring (gm)		43.33																		
Weight of Wet Soil + Cont. (gm)				147.05																
Weight of Dry Soil + Cont. (gm)				113.85																
Weight of Cont. (gm) **No.**				3.64																
Moisture Content (%)				30.12																
Wet Density (pcf / kN/m³)		121.43	19.11																	
Dry Density (pcf / kN/m³)		93.32	14.69																	
Percent Saturation (%)	108.44	**File No. :**	615511 2																	
Prepared By : RJ	**Date :** 05/06/07	**Normal Stress**																		
Tested By : RJ	**Date :** 05/06/07	**5.00**	(ksf)																	
Percent Consolidation (%)		**Before**		**After**																
Height of Sample (inch)		1.00		1.0000																
Diameter of Sample (inch)		2.42		2.42																
Dial Reading-Consolidation (inch)																				
Weight of Soil + Ring (gm)		194.63																		
Weight of Ring (gm)		43.54																		
Weight of Wet Soil + Cont. (gm)				152.56																
Weight of Dry Soil + Cont. (gm)				117.87																
Weight of Cont. (gm) **No.**				3.63																
Moisture Content (%)				30.37																
Wet Density (pcf / kN/m³)		125.14	19.70																	
Dry Density (pcf / kN/m³)		95.99	15.11																	
Percent Saturation (%)	100.79	**File No. :**	615511 3																	
Prepared By : RJ	**Date :** 05/06/07	**Normal Stress**																		
Tested By : RJ	**Date :** 05/06/07	**10.00**	(ksf)																	
Percent Consolidation (%)		**Before**		**After**																
Height of Sample (inch)		1.00		1.0000																
Diameter of Sample (inch)		2.42		2.42																
Dial Reading-Consolidation (inch)																				
Weight of Soil + Ring (gm)		190.29																		
Weight of Ring (gm)		43.39																		
Weight of Wet Soil + Cont. (gm)				147.61																
Weight of Dry Soil + Cont. (gm)				114.55																
Weight of Cont. (gm) **No.**				3.62																
Moisture Content (%)				29.80																
Wet Density (pcf / kN/m³)		121.67	19.15																	
Dry Density (pcf / kN/m³)		93.73	14.75																	

Strength	(ksf)	(kPa)	(ksf)	(kPa)	(ksf)	(kPa)
Peak	1.93	92.50	3.71	177.54	6.90	330.32
Ultimate	1.48	70.67	2.82	135.02	5.84	279.76

Shear Deflection (inch)	(mm)	**Normal Stress (psf/ksf/kPa)** 2500	2.50	119.7	5000	5.0	239.4	10000	10.0	478.8
		Shear Stress (psf/ksf/kPa)								
0.000	0.00	0.0	0.0	0.0	0.00	0.0	0.00	0.0	0.0	0.0
0.010	0.03	900	0.90	43.1	1188	1.19	56.9	2076	2.08	99.0
0.020	0.05	1296	1.30	62.1	1860	1.86	89.1	3348	3.35	159.7
0.030	0.08	1560	1.56	74.7	2400	2.40	114.9	4284	4.28	204.4
0.040	0.10	1728	1.73	82.7	2820	2.82	135.0	5064	5.06	241.6
0.050	0.13	1836	1.84	87.9	3144	3.14	150.5	5627	5.63	268.4
0.060	0.15	1884	1.88	90.2	3372	3.37	161.5	6059	6.06	289.0
0.070	0.18	1908	1.91	91.4	3528	3.53	168.9	6395	6.40	305.1
0.080	0.20	1932	1.93	92.5	3612	3.61	172.9	6635	6.64	316.5
0.090	0.23	1920	1.92	91.9	3672	3.67	175.8	6779	6.78	323.4
0.100	0.25	1908	1.91	91.4	3708	3.71	177.5	6863	6.86	327.4
0.110	0.28	1884	1.88	90.2	3696	3.70	177.0	6899	6.90	329.1
0.120	0.30	1860	1.86	89.1	3684	3.68	176.4	6899	6.90	329.1
0.130	0.33	1824	1.82	87.3	3648	3.65	174.7	6875	6.88	328.0
0.140	0.36	1788	1.79	85.6	3612	3.61	172.9	6827	6.83	325.7
0.150	0.38	1740	1.74	83.3	3564	3.56	170.6	6803	6.80	324.5
0.160	0.41	1692	1.69	81.0	3540	3.54	169.5	6731	6.73	321.1
0.170	0.43	1608	1.61	77.0	3480	3.48	166.6	6671	6.67	318.2
0.180	0.46	1560	1.56	74.7	3420	3.42	163.7	6599	6.60	314.8
0.190	0.48	1524	1.52	73.0	3384	3.38	162.0	6515	6.52	310.8
0.200	0.51	1500	1.50	71.8	3336	3.34	159.7	6407	6.41	305.6
0.210	0.53	1488	1.49	71.2	3288	3.29	157.4	6275	6.28	299.3
0.220	0.56	1476	1.48	70.7	3264	3.26	156.3	6143	6.14	293.0
0.230	0.58	1488	1.49	71.2	3204	3.20	153.4	5999	6.00	286.2
0.240	0.61	1488	1.49	71.2	3156	3.16	151.1	5927	5.93	282.7
0.250	0.64	1488	1.49	71.2	3108	3.11	148.8	5879	5.88	280.4
0.260	0.66	1500	1.50	71.8	3048	3.05	145.9	5843	5.84	278.7
0.270	0.69	1500	1.50	71.8	2988	2.99	143.1	5843	5.84	278.7
0.280	0.71	1512	1.51	72.4	2928	2.93	140.2	5843	5.84	278.7
0.290	0.74	1512	1.51	72.4	2892	2.89	138.5	5867	5.87	279.9
0.300	0.76	1524	1.52	73.0	2856	2.86	136.7	5891	5.89	281.0
0.310	0.79	1524	1.52	73.0	2844	2.84	136.2	5891	5.89	281.0
0.320	0.81	1524	1.52	73.0	2844	2.84	136.2	5915	5.92	282.2
0.330	0.84	1524	1.52	73.0	2832	2.83	135.6	5939	5.94	283.3
0.340	0.86	1524	1.52	73.0	2820	2.82	135.0	5963	5.96	284.4
0.350	0.89	1524	1.52	73.0	2832	2.83	135.6	5951	5.95	283.9
0.360	0.91	1512	1.51	72.4	2844	2.84	136.2	5963	5.96	284.4
0.370	0.94	1524	1.52	73.0	2856	2.86	136.7	5987	5.99	285.6
0.380	0.97	1524	1.52	73.0	2892	2.89	138.5	5987	5.99	285.6
0.390	0.99	1524	1.52	73.0	2916	2.92	139.6	6011	6.01	286.7
0.400	1.02	1512	1.51	72.4	2940	2.94	140.8	6011	6.01	286.7
	0.00									
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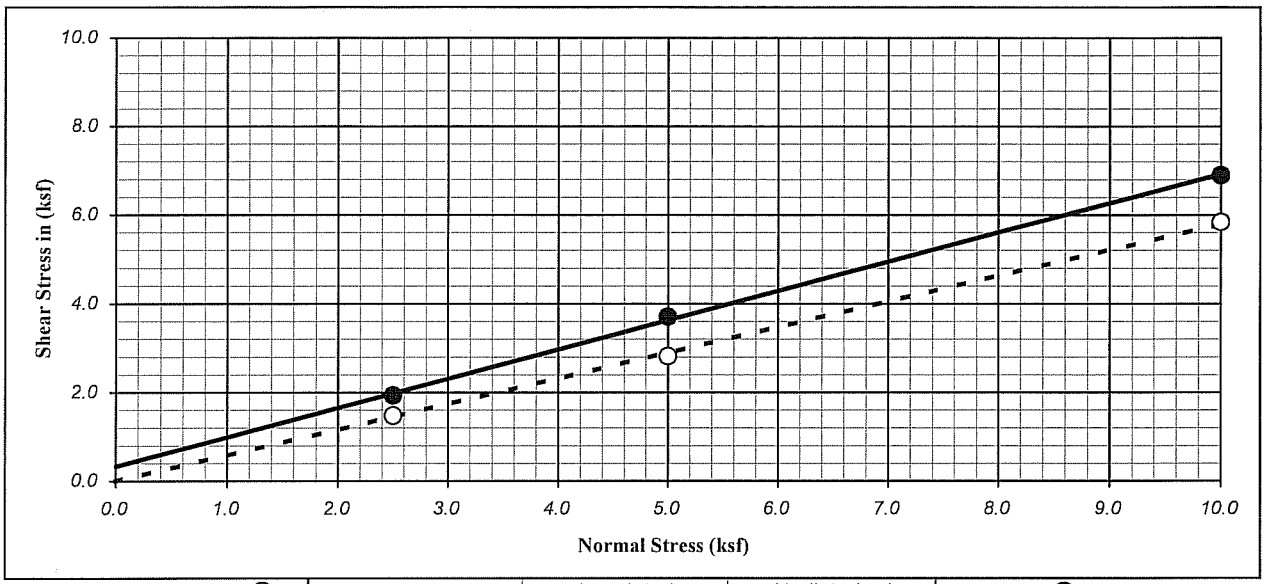
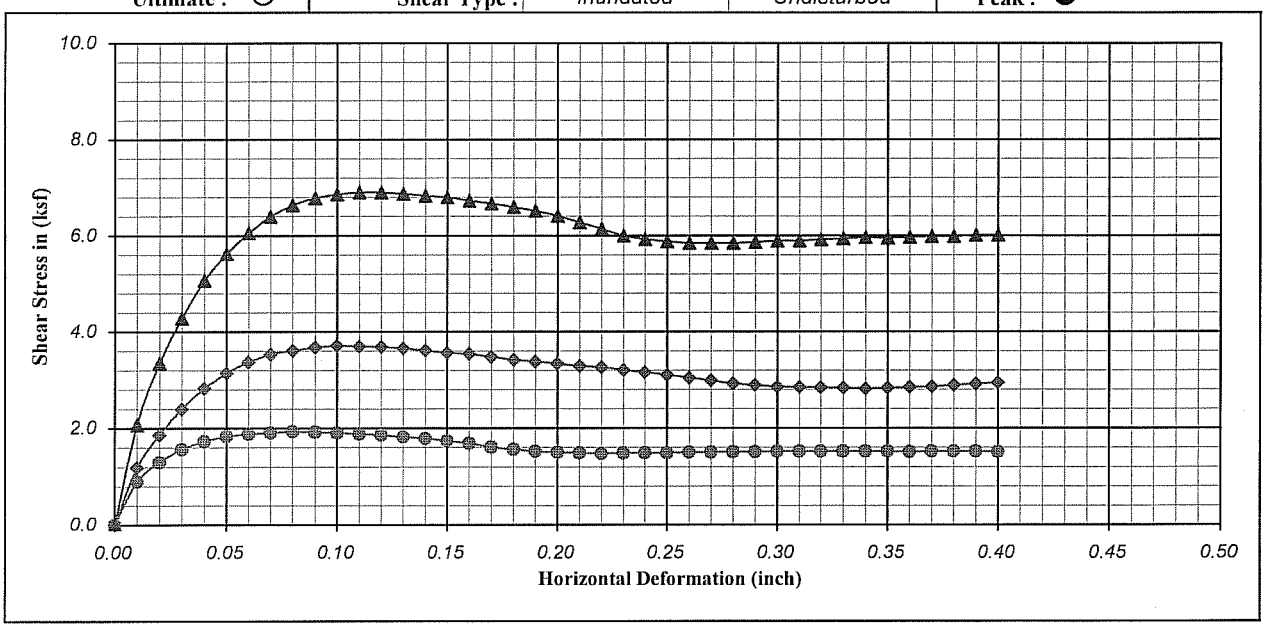


Ultimate : ○	Shear Type :	Inundated	Undisturbed	Peak : ●



Boring No. : 06-9		**Strength Intercept (C) :**	0.34	(ksf)	**Peak**	0.00	(ksf)	**Ultimate**
Sample No. : D-11			16.11	(kPa)		0.00	(kPa)	
Depth (ft/m) : 55.0	16.78	**Friction Angle (ϕ) :**	33.38	Degree		30.14	Degree	
Description : Sand with Silt (SP-SM)						**Shear Rate** (inch/minute) :		0.02

SYMBOL	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	DRY DENSITY (kN/m^3)	VOID RATIO	NORMAL STRESS (ksf)	NORMAL STRESS (kPa)	PEAK STRESS (ksf)	PEAK STRESS (kPa)	ULTIMATE STRESS (ksf)	ULTIMATE STRESS (kPa)
●	30.12	93.32	14.69	0.81	2.50	119.70	1.93	92.50	1.48	70.67
◆	30.37	95.99	15.11	0.76	5.00	239.40	3.71	177.54	2.82	135.02
▲	29.80	93.73	14.75	0.80	10.00	478.80	6.90	330.32	5.84	279.76

Earth Mechanics, Inc.
Geotechnical and Earthquake Engineering

Antioch Bridge

DIRECT SHEAR TEST (ASTM D-3080)

Project No. : 06-155 | **Date :** 05/06/07

Figure No. :

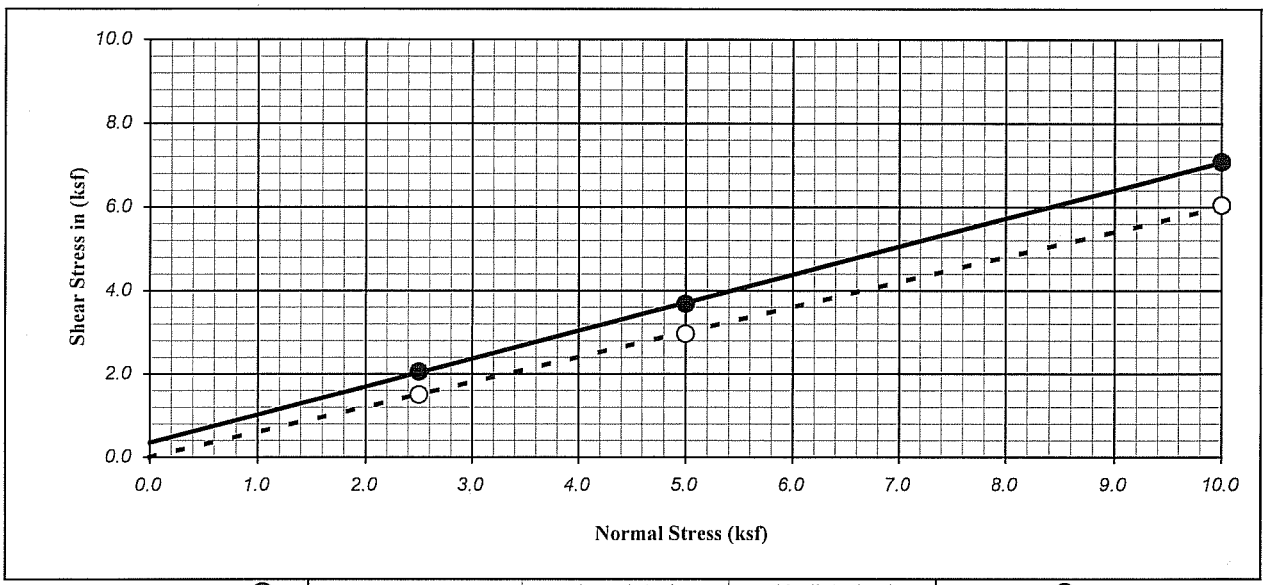
DIRECT SHEAR TEST

ASTM D-3080-90

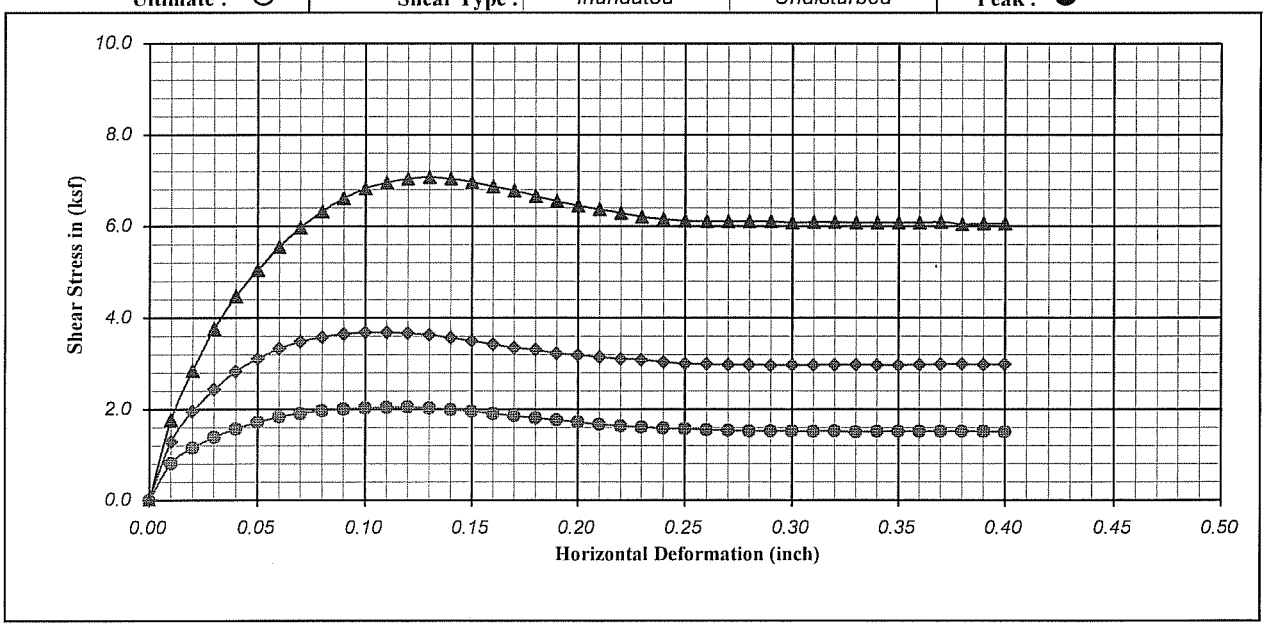
Project No. : 06-155 **Project Name :** BATA/Antioch Bridge

Boring No. : 06-10			Saturated		Field Moisture	x	Inundated	**Specific Gravity** (Assumed) :	2.70
Sample No. : D-11		x	Undisturbed		Remolded		Consolidated-Drained	**Shear Rate** (inch/min) :	0.02
Depth (ft/m) :	55.5 16.93	x	Shear Once		Reshear		Residual	**Data File Number :**	615513
Description :	Sand with Silt (SP-SM)								

Percent Saturation (%)	105.85		**File No. :**	615513 1			**Shear Deflection**		**Normal Stress (psf/ksf/kPa)**													
Prepared By : RJ	**Date :** 05/06/07		**Normal Stress**						2500	2.50	119.7	5000	5.0	239.4	10000	10.0	478.8					
Tested By : RJ	**Date :** 05/06/07						(inch)	(mm)	**Shear Stress (psf/ksf/kPa)**													
Computed By : LCC	**Date :** 5/8//07		**2.50**	(ksf)			0.000	0.00	0.0	0.0	0.0	0.00	0.0	0.00	0.0	0.0	0.0					
Checked By :	**Date :**						0.010	0.03	804	0.80	38.5	1284	1.28	61.5	1764	1.76	84.1					
Percent Consolidation (%)		**Before**		**After**			0.020	0.05	1152	1.15	55.2	1956	1.96	93.7	2844	2.84	135.7					
Height of Sample (inch)		1.00		1.0000			0.030	0.08	1392	1.39	66.6	2436	2.44	116.6	3756	3.76	179.2					
Diameter of Sample (inch)		2.42		2.42			0.040	0.10	1572	1.57	75.3	2832	2.83	135.6	4476	4.48	213.5					
Dial Reading-Consolidation (inch)							0.050	0.13	1716	1.72	82.2	3108	3.11	148.8	5040	5.04	240.4					
Weight of Soil + Ring (gm)		184.16					0.060	0.15	1836	1.84	87.9	3324	3.32	159.2	5555	5.56	265.0					
Weight of Ring (gm)		42.84					0.070	0.18	1908	1.91	91.4	3480	3.48	166.6	5975	5.98	285.0					
Weight of Wet Soil + Cont. (gm)				145.30			0.080	0.20	1968	1.97	94.2	3576	3.58	171.2	6323	6.32	301.6					
Weight of Dry Soil + Cont. (gm)				105.09			0.090	0.23	2004	2.00	96.0	3648	3.65	174.7	6611	6.61	315.4					
Weight of Cont. (gm) No.				3.62			0.100	0.25	2028	2.03	97.1	3684	3.68	176.4	6827	6.83	325.7					
Moisture Content (%)				39.63			0.110	0.28	2040	2.04	97.7	3684	3.68	176.4	6959	6.96	332.0					
Wet Density (pcf / kN/m^3)		117.04	18.42				0.120	0.30	2052	2.05	98.2	3660	3.66	175.2	7043	7.04	336.0					
Dry Density (pcf / kN/m^3)		83.83	13.19				0.130	0.33	2028	2.03	97.1	3624	3.62	173.5	7079	7.08	337.7					
Percent Saturation (%)	102.36		**File No. :**	615513 2			0.140	0.36	1992	1.99	95.4	3564	3.56	170.6	7043	7.04	336.0					
Prepared By : RJ	**Date :** 05/06/07		**Normal Stress**				0.150	0.38	1956	1.96	93.7	3492	3.49	167.2	6971	6.97	332.5					
Tested By : RJ	**Date :** 05/06/07		**5.00**	(ksf)			0.160	0.41	1908	1.91	91.4	3420	3.42	163.7	6875	6.88	328.0					
Percent Consolidation (%)		**Before**		**After**			0.170	0.43	1860	1.86	89.1	3348	3.35	160.3	6779	6.78	323.4					
Height of Sample (inch)		1.00		1.0000			0.180	0.46	1812	1.81	86.8	3300	3.30	158.0	6659	6.66	317.6					
Diameter of Sample (inch)		2.42		2.42			0.190	0.48	1764	1.76	84.5	3228	3.23	154.6	6551	6.55	312.5					
Dial Reading-Consolidation (inch)							0.200	0.51	1716	1.72	82.2	3192	3.19	152.8	6455	6.46	307.9					
Weight of Soil + Ring (gm)		189.57					0.210	0.53	1668	1.67	79.9	3144	3.14	150.5	6371	6.37	303.9					
Weight of Ring (gm)		45.38					0.220	0.56	1632	1.63	78.1	3108	3.11	148.8	6287	6.29	299.9					
Weight of Wet Soil + Cont. (gm)				146.32			0.230	0.58	1608	1.61	77.0	3084	3.08	147.7	6203	6.20	295.9					
Weight of Dry Soil + Cont. (gm)				110.47			0.240	0.61	1584	1.58	75.8	3036	3.04	145.4	6155	6.16	293.6					
Weight of Cont. (gm) No.				3.63			0.250	0.64	1572	1.57	75.3	3000	3.00	143.6	6119	6.12	291.9					
Moisture Content (%)				33.55			0.260	0.66	1548	1.55	74.1	2988	2.99	143.1	6107	6.11	291.3					
Wet Density (pcf / kN/m^3)		119.42	18.80				0.270	0.69	1536	1.54	73.5	2976	2.98	142.5	6107	6.11	291.3					
Dry Density (pcf / kN/m^3)		89.42	14.07				0.280	0.71	1524	1.52	73.0	2976	2.98	142.5	6107	6.11	291.3					
Percent Saturation (%)	100.19		**File No. :**	615513 3			0.290	0.74	1524	1.52	73.0	2964	2.96	141.9	6107	6.11	291.3					
Prepared By : RJ	**Date :** 05/06/07		**Normal Stress**				0.300	0.76	1524	1.52	73.0	2964	2.96	141.9	6083	6.08	290.2					
Tested By : RJ	**Date :** 05/06/07		**10.00**	(ksf)			0.310	0.79	1512	1.51	72.4	2964	2.96	141.9	6095	6.10	290.7					
Percent Consolidation (%)		**Before**		**After**			0.320	0.81	1524	1.52	73.0	2976	2.98	142.5	6095	6.10	290.7					
Height of Sample (inch)		1.00		1.0000			0.330	0.84	1500	1.50	71.8	2976	2.98	142.5	6083	6.08	290.2					
Diameter of Sample (inch)		2.42		2.42			0.340	0.86	1512	1.51	72.4	2964	2.96	141.9	6083	6.08	290.2					
Dial Reading-Consolidation (inch)							0.350	0.89	1512	1.51	72.4	2964	2.96	141.9	6083	6.08	290.2					
Weight of Soil + Ring (gm)		188.87					0.360	0.91	1512	1.51	72.4	2976	2.98	142.5	6083	6.08	290.2					
Weight of Ring (gm)		45.17					0.370	0.94	1512	1.51	72.4	2988	2.99	143.1	6095	6.10	290.7					
Weight of Wet Soil + Cont. (gm)				145.09			0.380	0.97	1512	1.51	72.4	2988	2.99	143.1	6047	6.05	288.5					
Weight of Dry Soil + Cont. (gm)				110.35			0.390	0.99	1512	1.51	72.4	2976	2.98	142.5	6059	6.06	289.0					
Weight of Cont. (gm) No.				3.64			0.400	1.02	1500	1.50	71.8	2988	2.99	143.1	6059	6.06	289.0					
Moisture Content (%)				32.56				0.00														
Wet Density (pcf / kN/m^3)		119.02	18.73					0.00														
Dry Density (pcf / kN/m^3)		89.79	14.13					0.00														
Strength	(ksf) (kPa)	(ksf)	(kPa)	(ksf)	(kPa)			0.00														
Peak	2.05 98.25	3.68	176.39	7.08	338.94			0.00														
Ultimate	1.50 71.82	2.96	141.92	6.05	289.53			0.00														



Ultimate : ○	Shear Type :	Inundated	Undisturbed	Peak : ●



Boring No. : 06-10		**Strength Intercept (C) :**	0.35	(ksf)		0.00	(ksf)	
Sample No. : D-11			16.97	(kPa)	**Peak**	0.00	(kPa)	**Ultimate**
Depth (ft/m) : 55.5	16.93	**Friction Angle (ϕ) :**	33.88	Degree		31.06	Degree	
Description : Sand with Silt (SP-SM)						**Shear Rate** (inch/minute) :		0.02

SYMBOL	MOISTURE CONTENT (%)	DRY DENSITY (pcf)	DRY DENSITY (kN/m^3)	VOID RATIO	NORMAL STRESS (ksf)	NORMAL STRESS (kPa)	PEAK STRESS (ksf)	PEAK STRESS (kPa)	ULTIMATE STRESS (ksf)	ULTIMATE STRESS (kPa)
●	39.63	83.83	13.19	1.01	2.50	119.70	2.05	98.25	1.50	71.82
◆	33.55	89.42	14.07	0.89	5.00	239.40	3.68	176.39	2.96	141.92
▲	32.56	89.79	14.13	0.88	10.00	478.80	7.08	338.94	6.05	289.53

Earth Mechanics, Inc.
Geotechnical and Earthquake Engineering

Antioch Bridge

DIRECT SHEAR TEST (ASTM D-3080)

Project No. : 06-155 | **Date :** 05/06/07 | Figure No. :

MEASUREMENT OF SOIL CORROSIVITY

Project No.	: 06-155	Project Name : BATA/ Antioch Bridge			
Boring No.	: 06-1	Depth (ft/m) :	5.0		
Sample No.	: S-1	Description : Olive Brown, CLAY w/ sand, CL			

**** Sample for Corrosivity tests must screen through No. 8 Sieve*

Measurement of Soil Resistivity (ASTM G-57-78 / CT-643)

Test Standard		ASTM	X	CAL. TRAN.	Wt of Wet Soil + Cont.(gm)		205.73	Weight of Total
Soil Box Diamension (cm)		22.86 X 3.81 X 2.54		15.31 X 10.04 X4.41	Wt of Dry Soil + Cont.(gm)		182.97	Sample for Test (gm)
(L X W X H) / (inch)		9.0 X 1.5 X 1.0		6.04X 3.95 X 1.74	Wt. of Cont. No.	1	57.24	75.41
Soil Box Constant(C)		1.0		6.72	Setup Moisture Content(%)	81.9	18.10	

Trial	Resistivity Meter Reading (ohm-cm)							
	As received	1	2	3	4	5		
Water added	0.0	14.89	8.14				Prepared By : M.T.	Date : 03/27/07
Meter reading	1K x 2.9	1K x 1.2	1K x 1.4				Tested By : M.T.	Date : 03/27/07
Resistivity	2900	1200	1400				Calculated By : M.T.	Date : 03/27/07
							Checked By : R.Y	Date : 3-30-07
							Minimum Resistivity :	1200

Measurement of Soil pH (ASTM G-51-77 / CT-643)

Weight 30 gm soil sample and add 30 ml distilled water, stir to a soil slurry and settle at least 1hr.

Prepared By	: M.T.	Date : 03/27/07	Time :	12:35	Beaker No. :	19	pH Reading			
Tested By	: M.T.	Date : 03/28/07	Weigh of Wetsoil (gm)			30.07	Trial	1	2	3	Average
Calculated By	: M.T.	Date : 03/28/07	Distilled Water added (ml)			30.06	Test Time	14:30	14:45	15:00	
Checked By	: R.Y	Date : 3-30-07	Moisture Content (%)			18.10	Reading	7.85	7.85	7.87	7.86

Measurement of Soil Soluble Sulfate Content (CT - 417)

Weight 100.0 gm of sample soil & add 300 ml. of distilled water. Stopper and shake well. Allow to settle overnight. Prepare two 30 (ml.) of water layer into a 150 (ml.) beaker, dilute to 100 (ml.), add 5 (ml.) conditioning reagent. Turbidity Blank - Adjust the stirrer to the maximum speed, add 1 spoonfull Barium Chloride & start timing. Stir for exactly 1 minute.

Flask No. : 36		Prepared By : M.T.	Date : 03/27/07
Weight of Soil (gm) : 100.03		Tested By : M.T.	Date : 03/28/07
Distilled Water (ml.) : 300.04		Calculated By : M.T.	Date : 03/28/07
Shaking at : 12:25		Checked By : R.Y	Date : 3-30-07
Reshaking at : 13:25			

Total Water Sample Prepared	60.02	With BaCL		1	< Beaker Number >			2	Blank
Distilled Water added (ml)	200.02			100.02	Tested Sample Volume			100.00	
Time Intervals	0:00:00	0:00:30	0:01:00	0:01:30	0:02:00	0:02:30	0:03:00	0:04:00	Maximum
With BaCL (time) 16:26:00	16:30:00	16:30:30	16:31:00	16:31:30	16:32:00	16:32:30	16:33:00	16:34:00	
Turbidity with BaCL (NTV)		33.6	33.5	33.6	33.5	33.5	33.5	33.4	33.6
Blank (time) 16:22:00	16:26:00	16:26:30	16:27:00	16:27:30	16:28:00	16:28:30	16:29:00	16:30:00	
Turbidity Blank (NTV)		1.85	1.84	1.85	1.84	1.84	1.84	1.88	1.88
Difference (ppm)									31.72
SO_4 (from graph) (ppm)									70

Measurement of Soil Chloride Content (CT - 422)

*1. Weight 100.0 gm sample soil & add 300 ml. of distilled water. Stopper and shake vigorously for 20 seconds, reshaking after one hour and let it settle over night. 2. Pour 30 ml aliquot of filtered solution into a 150 ml beaker, then check pH. If pH is in the range 6 through 8, go to step 4. If ph below 6, add Sodium Hydroxide and if above 8, add Acetic Acid to adjust to the range. 4. Add two drops of Potassium Chromate solution before titrate with Silver Nitrate and change color from Yellow to Red. ** If the titration is over 30 ml., take a smaller sample. Dilute any smaller sample to about 50 ml..*

Flask No. : 36		Prepared By : M.T.	Date : 03/27/07
Wt. of Soil (gm) : 100.03		Tested By : M.T.	Date : 03/28/07
Distilled Water (ml.) : 300.04		Calculated By : M.T.	Date : 03/28/07
Shaking at : 12:25		Checked By : R.Y	Date : 3-30-07
Reshaking at : 13:25		Vaccum & Filter at :	
Remark :			

Titration of (I ml.) Sample Diluted to (F ml.)	29	< Beaker No.		38		
Total Sample Prepared :	Initial	Final	Total	Initial	Final	Total
Sample Volume (ml)	30.01			30.07		
pH of Liquid Sample	7.14			7.17		
Sodium Hydroxide added (ml)	-	-	-	-	-	-
Acetic Acid added (ml)	-	-	-	-	-	-
Silver Nitrate added (ml)	5.0	6.3	1.3	6.3	7.7	1.4
ppm CL= 100x(ml of Sil.Ni.-0.2 ml blank)F/I			110			120
Moisture - Free CL = ppm CL X 100 / (100 - w)			134			147

Average
1.35
115
140

MEASUREMENT OF SOIL CORROSIVITY

Project No. : 06-155	Project Name : BATA/ Antioch Bridge		
Boring No. : 06-2	Depth (ft/m) :	15.0	
Sample No. : S-3	Description :	Dk Grey, LEAN CLAY, w/many Peat (CL)	

*** *Sample for Corrosivity tests must screen through No. 8 Sieve*

Measurement of Soil Resistivity (ASTM G-57-78 / CT-643)

Test Standard	ASTM	X	CAL. TRAN.	Wt of Wet Soil + Cont.(gm)		209.38	Weight of Total
Soil Box Diamension (cm)	22.86 X 3.81 X 2.54		15.31 X 10.04 X4.41	Wt of Dry Soil + Cont.(gm)		140.09	Sample for Test (gm)
(L X W X H) / (inch)	9.0 X 1.5 X 1.0		6.04X 3.95 X 1.74	Wt. of Cont. No.	6	57.20	75.28
Soil Box Constant(C)	1.0		6.72	Setup Moisture Content(%)	16.41	83.59	

Trial	Resistivity Meter Reading (ohm-cm)						Prepared By : M.T.	Date : 03/27/07
	As received	1	2	3	4	5	Tested By : M.T.	Date : 03/27/07
Water added	0.0	9.15					Calculated By : M.T.	Date : 03/27/07
Meter reading	100x5.2	100x5.2					Checked By : R.S.	Date : 3/30/07
Resistivity	520	520					Minimum Resistivity :	520

Measurement of Soil pH (ASTM G-51-77 / CT-643)

Weight 30 gm soil sample and add 30 ml distilled water, stir to a soil slurry and settle at least 1hr.

Prepared By	: M.T.	Date : 03/27/07	Time :	12:50	Beaker No. :	26	pH Reading			
Tested By	: M.T.	Date : 03/27/07	Weigh of Wetsoil (gm)			30.03	Trial	1	2	3	Average
Calculated By	: M.T.	Date : 03/27/07	Distilled Water added (ml)			30.07	Test Time	15:15	15:30	15:45	
Checked By	: R.S.	Date : 3-30-07	Moisture Content (%)			83.59	Reading	5.26	5.27	5.27	5.27

Measurement of Soil Soluble Sulfate Content (CT - 417)

Weight 100.0 gm of sample soil & add 300 ml. of distilled water. Stopper and shake well. Allow to settle overnight. Prepare two 30 (ml.) of water layer into a 150 (ml.) beaker, dilute to 100 (ml.), add 5 (ml.) conditioning reagent. Turbidity Blank - Adjust the stirrer to the maximum speed, add 1 spoonfull Barium Chloride & start timing. Stir for exactly 1 minute.

Flask No. : 33	Prepared By : M.T.	Date : 03/27/07
Weight of Soil (gm) : 100.05	Tested By : M.T.	Date : 03/28/07
Distilled Water (ml.) : 300.09	Calculated By : M.T.	Date : 03/28/07
Shaking at : 12:40	Checked By : R.S.	Date : 3-30-07
Reshaking at : 13:40		

Total Water Sample Prepared	60.06	With BaCL		3	< Beaker Number >			4	Blank
Distilled Water added (ml)	200.09			100.02	Tested Sample Volume			100.07	
Time Intervals	0:00:00	0:00:30	0:01:00	0:01:30	0:02:00	0:02:30	0:03:00	0:04:00	Maximum
With BaCL (time)	16:38:00	16:38:30	16:39:00	16:39:30	16:40:00	16:40:30	16:41:00	16:42:00	
Turbidity with BaCL (NTV)		337	340	337	334	330	328	324	340
Blank (time) 16:30:30	16:34:00	16:34:30	16:35:00	16:35:30	16:36:00	16:36:30	16:37:00	16:38:00	
Turbidity Blank (NTV)		1.48	1.48	1.48	1.47	1.47	1.46	1.47	1.48
Difference (ppm)									338.5
SO_4 (from graph) (ppm)									750

Measurement of Soil Chloride Content (CT - 422)

*1. Weight 100.0 gm sample soil & add 300 ml. of distilled water. Stopper and shake vigorously for 20 seconds, reshaking after one hour and let it settle over night. 2. Pour 30 ml aliquot of filtered solution into a 150 ml beaker, then check pH. If pH is in the range 6 through 8, go to step 4. If ph below 6, add Sodium Hydroxide and if above 8, add Acetic Acid to adjust to the range. 4. Add two drops of Potassium Chromate solution before titrate with Silver Nitrate and change color from Yellow to Red. ** If the titration is over 30 ml., take a smaller sample. Dilute any smaller sample to about 50 ml..*

Flask No. : 33	Prepared By : M.T.	Date : 03/27/07
Wt. of Soil (gm) : 100.05	Tested By : M.T.	Date : 03/28/07
Distilled Water (ml.) : 300.09	Calculated By : M.T.	Date : 03/28/07
Shaking at : 12:40	Checked By : R.S.	Date : 3-30-07
Reshaking at : 13:40	Vaccum & Filter at :	
Remark :		

Titration of (I ml.) Sample Diluted to (F ml.)	10	< Beaker No.		>	24	
Total Sample Prepared :	Initial	Final	Total	Initial	Final	Total	
Sample Volume (ml)	30.07			30.05			
pH of Liquid Sample	6.05			6.01			
Sodium Hydroxide added (ml)	-	-	-	-	-	-	
Acetic Acid added (ml)	-	-	-	-	-	-	Average
Silver Nitrate added (ml)	7.7	18.8	11.1	18.8	30.0	11.2	11.15
ppm CL= 100x(ml of Sil.Ni.-0.2 ml blank)*F/I			1090			1100	1095
Moisture - Free CL = ppm CL X 100 / (100 - w)			6642			6703	6673

MEASUREMENT OF SOIL CORROSIVITY

Project No. : 06-155	Project Name : BATA/ Antioch Bridge				
Boring No. : 06-6	Depth (ft/m) :	6.0			
Sample No. : D-1	Description :	Black, LEAN CLAY, w/ many Rat (CL)			

**** Sample for Corrosivity tests must screen through No. 8 Sieve*

Measurement of Soil Resistivity (ASTM G-57-78 / CT-643)

Test Standard	ASTM	X	CAL. TRAN.	Wt of Wet Soil + Cont.(gm)		147.95	Weight of Total
Soil Box Diamension (cm)	22.86 X 3.81 X 2.54		15.31 X 10.04 X4.41	Wt of Dry Soil + Cont.(gm)		84.35	Sample for Test (gm)
(L X W X H) / (inch)	9.0 X 1.5 X 1.0		6.04X 3.95 X 1.74	Wt. of Cont. No.	33	58.11	75.84
Soil Box Constant(C)	1.0		6.72	Setup Moisture Content(%)		242.38	

Trial	Resistivity Meter Reading (ohm-cm)						Prepared By : M.T.	Date : 03/27/07
	As received	1	2	3	4	5	Tested By : M.T.	Date : 03/27/07
Water added	0.0	6.09	3.03				Calculated By : M.T.	Date : 03/27/07
Meter reading	1Kx1.2	1Kx1.1	1Kx1.2				Checked By : R.Y.	Date : 3-30-07
Resistivity	1200	1100	1200				Minimum Resistivity :	1100

Measurement of Soil pH (ASTM G-51-77 / CT-643)

Weight 30 gm soil sample and add 30 ml distilled water, stir to a soil slurry and settle at least 1hr.

						pH Reading				
Prepared By	: M.T.	Date : 03/27/07	Time : 13:40	Beaker No. :	34	Trial	1	2	3	Average
Tested By	: M.T.	Date : 03/27/07	Weigh of Wetsoil (gm)		30.00	Test Time	16:00	16:15	16:30	
Calculated By	: M.T.	Date : 03/27/07	Distilled Water added (ml)		30.09	Reading	6.06	6.05	6.05	6.05
Checked By	: R.Y.	Date : 3-30-07	Moisture Content (%)		242.38					

Measurement of Soil Soluble Sulfate Content (CT - 417)

Weight 100.0 gm of sample soil & add 300 ml. of distilled water. Stopper and shake well. Allow to settle overnight. Prepare two 30 (ml.) of water layer into a 150 (ml.) beaker, dilute to 100 (ml.), add 5 (ml.) conditioning reagent. Turbidity Blank - Adjust the stirrer to the maximum speed, add 1 spoonfull Barium Chloride & start timing. Stir for exactly 1 minute.

Flask No. : 11	Prepared By : M.T.	Date : 03/27/07
Weight of Soil (gm) : 100.02	Tested By : M.T.	Date : 03/28/07
Distilled Water (ml.) : 300.07	Calculated By : M.T.	Date : 03/28/07
Shaking at : 13:30	Checked By : R.Y.	Date : 3-30-07
Reshaking at : 14:30		

Total Water Sample Prepared	60.08	With BaCL		5	< Beaker Number >			6	Blank
Distilled Water added (ml)	200.05			100.01	Tested Sample Volume			100.04	
Time Intervals	0:00:00	0:00:30	0:01:00	0:01:30	0:02:00	0:02:30	0:03:00	0:04:00	Maximum
With BaCL (time) 16:42:00	16:46:00	16:46:30	16:47:00	16:47:30	16:48:00	16:48:30	16:49:00	16:50:00	
Turbidity with BaCL (NTV)		65.0	65.9	65.6	65.1	63.9	62.7	62.2	65.9
Blank (time) 16:38:00	16:42:00	16:42:30	16:43:00	16:43:30	16:44:00	16:44:30	16:45:00	16:46:00	
Turbidity Blank (NTV)		6.72	6.74	6.66	6.67	6.50	6.51	6.33	6.74
Difference (ppm)									59.16
SO_4 (from graph) (ppm)									130

Measurement of Soil Chloride Content (CT - 422)

*1. Weight 100.0 gm sample soil & add 300 ml. of distilled water. Stopper and shake vigorously for 20 seconds, reshaking after one hour and let it settle over night. 2. Pour 30 ml aliquot of filtered solution into a 150 ml beaker, then check pH. If pH is in the range 6 through 8, go to step 4. If ph below 6, add Sodium Hydroxide and if above 8, add Acetic Acid to adjust to the range. 4. Add two drops of Potassium Chromate solution before titrate with Silver Nitrate and change color from Yellow to Red. ** If the titration is over 30 ml., take a smaller sample. Dilute any smaller sample to about 50 ml..*

Flask No. : 11	Prepared By : M.T.	Date : 03/27/07
Wt. of Soil (gm) : 100.02	Tested By : M.T.	Date : 03/28/07
Distilled Water (ml.) : 300.07	Calculated By : M.T.	Date : 04/28/07
Shaking at : 13:30	Checked By : R.Y.	Date : 4-16-07
Reshaking at : 14:30	Vaccum & Filter at :	
Remark :		

Titration of (I ml.) Sample Diluted to (F ml.)	25	< Beaker No.			> 39	
Total Sample Prepared :	Initial	Final	Total	Initial	Final	Total
Sample Volume (ml)	30.09			30.09		
pH of Liquid Sample	6.43			6.54		
Sodium Hydroxide added (ml)	-	-	-	-	-	-
Acetic Acid added (ml)	-	-	-	-	-	-
Silver Nitrate added (ml)	30.0	35.7	5.7	35.7	41.4	5.7
ppm CL= 100x(ml of Sil.Ni.-0.2 ml blank)*F/I						
Moisture - Free CL = ppm CL X 100 / (100 - w)						

Average 5.7

> 1333

MEASUREMENT OF SOIL CORROSIVITY

Project No. : 06-155	Project Name : BATA/ Antioch Bridge		
Boring No. : 06-6	Depth (ft/m) :	36.0	
Sample No. : S-7	Description :	Bluish Gray, LEAN CLAY w/ sand (CL)	

*** Sample for Corrosivity tests must screen through No. 8 Sieve

Measurement of Soil Resistivity (ASTM G-57-78 / CT-643)

Test Standard	ASTM	X	CAL. TRAN.	Wt of Wet Soil + Cont.(gm)		232.68	Weight of Total
Soil Box Diamension(cm)	22.86 X 3.81 X 2.54		15.31 X 10.04 X4.41	Wt of Dry Soil + Cont.(gm)		187.94	Sample for Test (gm)
(L X W X H) /(inch)	9.0 X 1.5 X 1.0		6.04X 3.95 X 1.74	Wt. of Cont. No.	36	58.08	74.50
Soil Box Constant(C)	1.0		6.72	Setup Moisture Content(%)	65.55	34.45	

Trial	Resistivity Meter Reading (ohm-cm)						Prepared By : M.T.	Date : 03/27/07
	As received	1	2	3	4	5	Tested By : M.T.	Date : 03/27/07
Water added	0.0	4.70	3.77				Calculated By : M.T.	Date : 03/27/07
Meter reading	100x9.1	100x7.5	100x7.7				Checked By : R.Y	Date : 3-30-07
Resistivity	910	750	770				Minimum Resistivity :	750

Measurement of Soil pH (ASTM G-51-77 / CT-643)

Weight 30 gm soil sample and add 30 ml distilled water, stir to a soil slurry and settle at least 1hr.

						pH Reading				
Prepared By	: M.T.	Date : 03/27/07	Time : 13:55	Beaker No. :	13	Trial	1	2	3	Average
Tested By	: M.T.	Date : 03/28/07	Weigh of Wetsoil(gm)		30.09	Test Time	16:45	17:00	17:15	
Calculated By	: M.T.	Date : 03/28/07	Distilled Water added (ml)		30.09	Reading	6.50	6.49	6.51	6.50
Checked By	: R.Y	Date : 3-30-07	Moisture Content (%)		34.45					

Measurement of Soil Soluble Sulfate Content (CT - 417)

Weight 100.0 gm of sample soil & add 300 ml. of distilled water. Stopper and shake well. Allow to settle overnight. Prepare two 30 (ml.) of water layer into a 150 (ml.) beaker, dilute to 100 (ml.), add 5 (ml.) conditioning reagent. Turbidity Blank - Adjust the stirrer to the maximum speed, add 1 spoonfull Barium Chloride & start timing. Stir for exactly 1 minute.

Flask No. : 10		Prepared By : M.T.	Date : 03/27/07
Weight of Soil (gm) : 100.09		Tested By : M.T.	Date : 03/28/07
Distilled Water (ml.) : 300.09		Calculated By : M.T.	Date : 03/28/07
Shaking at : 13:45		Checked By : R.Y	Date : 3-30-07
Reshaking at : 14:45			

Total Water Sample Prepared	60.04	With BaCL		7	< Beaker Number >			8	Blank
Distilled Water added (ml)	200.06			100.02	Tested Sample Volume			100.04	
Time Intervals	0:00:00	0:00:30	0:01:00	0:01:30	0:02:00	0:02:30	0:03:00	0:04:00	Maximum
With BaCL (time) 16:50:00	16:54:00	16:54:30	16:55:00	16:55:30	16:56:00	16:56:30	16:57:00	16:58:00	
Turbidity with BaCL (NTV)		21.3	21.2	21.3	21.3	21.2	21.2	21.1	21.3
Blank (time) 16:46:00	16:50:00	16:50:30	16:51:00	16:51:30	16:52:00	16:52:30	16:53:00	16:54:00	
Turbidity Blank (NTV)		3.46	3.42	3.40	3.40	3.39	3.41	3.40	3.46
Difference (ppm)									17.84
SO_4 (from graph) (ppm)									40

Measurement of Soil Chloride Content (CT - 422)

*1. Weight 100.0 gm sample soil & add 300 ml. of distilled water. Stopper and shake vigorously for 20 seconds, reshaking after one hour and let it settle over night. 2. Pour 30 ml aliquot of filtered solution into a 150 ml beaker, then check pH. If pH is in the range 6 through 8, go to step 4. If ph below 6, add Sodium Hydroxide and if above 8, add Acetic Acid to adjust to the range. 4. Add two drops of Potassium Chromate solution before titrate with Silver Nitrate and change color from Yellow to Red. ** If the titration is over 30 ml., take a smaller sample. Dilute any smaller sample to about 50 ml..*

Flask No. : 10		Prepared By : M.T.	Date : 03/27/07
Wt. of Soil (gm) : 100.09		Tested By : M.T.	Date : 03/28/07
Distilled Water (ml.) : 300.09		Calculated By : M.T.	Date : 03/28/07
Shaking at : 13:45		Checked By : R.Y	Date : 3-30-07
Reshaking at : 14:45		Vaccum & Filter at :	
Remark :			

Titration of (I ml.) Sample Diluted to (F ml.)	16	< Beaker No.			28	
Total Sample Prepared :	Initial	Final	Total	Initial	Final	Total	
Sample Volume (ml)	30.00			30.05			
pH of Liquid Sample	6.65			6.72			
Sodium Hydroxide added (ml)	-	-	-	-	-	-	
Acetic Acid added (ml)	-	-	-	-	-	-	
Silver Nitrate added (ml)	41.4	47.7	6.3	47.7	54.0	6.3	Average 6.3
ppm CL= 100x(ml of Sil.Ni.-0.2 ml blank)*F/I			610			610	610
Moisture - Free CL = ppm CL X 100 / (100 - w)			931			931	931

MEASUREMENT OF SOIL CORROSIVITY

Project No. : 06-155	Project Name : BATA/ Antioch Bridge		
Boring No. : 06-7	Depth (ft/m) :	40	
Sample No. : S-1	Description :	BLACK, LEAN CLAY w/ many Peat (CL)	CL w/ Peat

*** *Sample for Corrosivity tests must screen through No. 8 Sieve*

Measurement of Soil Resistivity (ASTM G-57-78 / CT-643)

Test Standard	ASTM	X	CAL. TRAN.	Wt of Wet Soil + Cont.(gm)	192.73	Weight of Total
Soil Box Diamension (cm)	22.86 X 3.81 X 2.54		15.31 X 10.04 X4.41	Wt of Dry Soil + Cont.(gm)	81.04	Sample for Test(gm)
(L X W X H) /(inch)	9.0 X 1.5 X 1.0		6.04X 3.95 X 1.74	Wt. of Cont. No. 6	57.21	62.23
Soil Box Constant(C)	1.0		6.72	Setup Moisture Content(%)	468.69	

Trial	Resistivity Meter Reading (ohm-cm)							
	As received	1	2	3	4	5		
Water added	0.0	9.29	7.27				Prepared By : M.T.	Date : 05/03/07
Meter reading	100x3.4	100x2.7	100x2.7				Tested By : M.T.	Date : 05/04/07
Resistivity	340	270	270				Calculated By : M.T.	Date : 05/04/07
							Checked By : R.Y	Date : 5-7-07
							Minimum Resistivity :	270

Measurement of Soil pH (ASTM G-51-77 / CT-643)

Weight 30 gm soil sample and add 30 ml distilled water, stir to a soil slurry and settle at least 1hr.

Prepared By : M.T.	Date :	Time : 15:05	Beaker No. : 25	5.29 pH Reading					
Tested By : M.T.	Date :	Weigh of Wetsoil (gm)	30.02	Trial	1	2	3	Average	
Calculated By : M.T.	Date :	Distilled Water added (ml)	30.07	Test Time	17:30	17:45	18:00		
Checked By : R.Y	Date : 5-7-07	Moisture Content(%)	468.69	Reading	5.19	5.18	5.17	5.18	

Measurement of Soil Soluble Sulfate Content (CT - 417)

Weight 100.0 gm of sample soil & add 300 ml. of distilled water. Stopper and shake well. Allow to settle overnight. Prepare two 30 (ml.) of water layer into a 150 (ml.) beaker, dilute to 100 (ml.), add 5 (ml.) conditioning reagent. Turbidity Blank - Adjust the stirrer to the maximum speed, add 1 spoonfull Barium Chloride & start timing. Stir for exactly 1 minute.

Flask No. : 33	Prepared By : M.T.	Date : 05/03/07
Weight of Soil (gm) : 100.05	Tested By : M.T.	Date : 05/04/07
Distilled Water (ml.) : 300.07	Calculated By : M.T.	Date : 05/07/07
Shaking at : 14:55	Checked By : R.Y	Date : 5-7-07
Reshaking at : 15:55		

Total Water Sample Prepared	60.00	With BaCL		7	< Beaker Number >			8	Blank
Distilled Water added (ml)	200.03			100.03	Tested Sample Volume			100.00	
Time Intervals	0:00:00	0:00:30	0:01:00	0:01:30	0:02:00	0:02:30	0:03:00	0:04:00	Maximum
With BaCL (time)	17:34:00	17:34:30	17:35:00	17:35:30	17:36:00	17:36:30	17:37:00	17:38:00	
Turbidity with BaCL (NTV)		221	219	217	217	216	212	206	221
Blank (time)	17:30:00	17:30:30	17:31:00	17:31:30	17:32:00	17:32:30	17:33:00	17:34:00	
Turbidity Blank (NTV)		1.96	1.95	1.95	1.94	1.95	1.95	1.93	1.96
Difference (ppm)									219.04
SO_4 (from graph) (ppm)									490

Measurement of Soil Chloride Content (CT - 422)

*1. Weight 100.0 gm sample soil & add 300 ml. of distilled water. Stopper and shake vigorously for 20 seconds, reshaking after one hour and let it settle over night. 2. Pour 30 ml aliquot of filtered solution into a 150 ml beaker, then check pH. If pH is in the range 6 through 8, go to step 4. If ph below 6, add Sodium Hydroxide and if above 8, add Acetic Acid to adjust to the range. 4. Add two drops of Potassium Chromate solution before titrate with Silver Nitrate and change color from Yellow to Red. ** If the titration is over 30 ml., take a smaller sample. Dilute any smaller sample to about 50 ml..*

Flask No. : 33	Prepared By : M.T.	Date : 05/03/07
Wt. of Soil (gm) : 100.05	Tested By : M.T.	Date : 05/04/07
Distilled Water (ml) : 300.07	Calculated By : M.T.	Date : 05/07/07
Shaking at : 14:55	Checked By : R.Y	Date : 5-7-07
Reshaking at : 15:55	Vaccum & Filter at :	
Remark :		

Titration of (I ml.) Sample Diluted to (F ml.)	36	< Beaker No. >			40	
Total Sample Prepared :	Initial	Final	Total	Initial	Final	Total	
Sample Volume (ml)	30.05			30.01			
pH of Liquid Sample	6.46			6.47			
Sodium Hydroxide added (ml)	-	-	-	-	-	-	
Acetic Acid added (ml)	-	-	-	-	-	-	Average
Silver Nitrate added (ml)	33.9	41.7	7.8	41.7	49.3	7.6	7.7
ppm CL= 100x(ml of Sil.Ni.-0.2 ml blank)*F/I			760			740	750
Moisture - Free CL = ppm CL X 100 / (100 - w)			>3562			>3468	>3515

MEASUREMENT OF SOIL CORROSIVITY

Project No. : 06-155	Project Name : BATA/ Antioch Bridge		
Boring No. : 66-7	Depth (ft/m) :	24.0	
Sample No. : D-5	Description :	DK Gray, LEAN CLAY w/ many Peat (CL)	

**** Sample for Corrosivity tests must screen through No. 8 Sieve*

Measurement of Soil Resistivity (ASTM G-57-78 / CT-643)

Test Standard	ASTM	X	CAL. TRAN.	Wt of Wet Soil + Cont.(gm)		162.52	Weight of Total
Soil Box Diamension (cm)	22.86 X 3.81 X 2.54		15.31 X 10.04 X4.41	Wt of Dry Soil + Cont.(gm)		107.02	Sample for Test (gm)
(L X W X H) / (inch)	9.0 X 1.5 X 1.0		6.04X 3.95 X 1.74	Wt. of Cont. No.	9	57.65	74.47
Soil Box Constant(C)	1.0		6.72	Setup Moisture Content(%)		112.42	

Trial	Resistivity Meter Reading (ohm-cm)						
	As received	1	2	3	4	5	
Water added	0.0	3.90	2.57				
Meter reading	100x5.9	100 x 5.4	100 x 5.4				
Resistivity	590	540	540				

Prepared By : M.T.	Date : 05/03/07
Tested By : M.T.	Date : 05/04/07
Calculated By : M.T.	Date : 05/04/07
Checked By : R.Y	Date : 5-7-07
Minimum Resistivity :	540

Measurement of Soil pH (ASTM G-51-77 / CT-643)

Weight 30 gm soil sample and add 30 ml distilled water, stir to a soil slurry and settle at least 1hr.

Prepared By	: M.T.	Date :	Time :	14:40	Beaker No. :	10	pH Reading			
Tested By	: M.T.	Date :	Weigh of Wetsoil (gm)			30.03	Trial	1	2	3	Average
Calculated By	: M.T.	Date :	Distilled Water added (ml)			30.05	Test Time	16:00	16:15	16:30	
Checked By	: R.Y	Date : 5-7-07	Moisture Content (%)			112.42	Reading	5.38	5.39	5.39	5.39

Measurement of Soil Soluble Sulfate Content (CT - 417)

Weight 100.0 gm of sample soil & add 300 ml. of distilled water. Stopper and shake well. Allow to settle overnight. Prepare two 30 (ml.) of water layer into a 150 (ml.) beaker, dilute to 100 (ml.), add 5 (ml.) conditioning reagent. Turbidity Blank - Adjust the stirrer to the maximum speed, add 1 spoonfull Barium Chloride & start timing. Stir for exactly 1 minute.

Flask No. : 10		Prepared By : M.T.	Date : 05/03/07
Weight of Soil (gm) : 100.01		Tested By : M.T.	Date : 05/04/07
Distilled Water (ml.) : 300.05		Calculated By : M.T.	Date : 05/07/07
Shaking at : 14:30		Checked By : R.Y	Date : 5-7-07
Reshaking at : 15:30			

Total Water Sample Prepared	60.05	With BaCL		3	< Beaker Number >			4	Blank
Distilled Water added (ml)	200.05			100.00	Tested Sample Volume			100.05	
Time Intervals	0:00:00	0:00:30	0:01:00	0:01:30	0:02:00	0:02:30	0:03:00	0:04:00	Maximum
With BaCL (time) 17:14:00	17:18:00	17:18:30	17:19:00	17:19:30	17:20:00	17:20:30	17:21:00	17:22:00	
Turbidity with BaCL (NTV)		244	242	242	242	241	241	240	244
Blank (time) 17:10:00	17:14:00	17:14:30	17:15:00	17:15:30	17:16:00	17:16:30	17:17:00	17:18:00	
Turbidity Blank (NTV)		1.33	1.31	1.33	1.32	1.32	1.33	1.33	1.33
Difference (ppm)									242.67
SO_4 (from graph) (ppm)									520

Measurement of Soil Chloride Content (CT - 422)

*1. Weight 100.0 gm sample soil & add 300 ml. of distilled water. Stopper and shake vigorously for 20 seconds, reshaking after one hour and let it settle over night. 2. Pour 30 ml aliquot of filtered solution into a 150 ml beaker, then check pH. If pH is in the range 6 through 8, go to step 4. If ph below 6, add Sodium Hydroxide and if above 8, add A cetic A cid to adjust to the range. 4. Add two drops of Potassium Chromate solution before titrate with Silver Nitrate and change color from Yellow to Red. ** If the titration is over 30 ml., take a smaller sample. Dilute any smaller sample to about 50 ml..*

Flask No. : 10		Prepared By : M.T.	Date : 05/03/07
Wt. of Soil (gm) : 100.01		Tested By : M.T.	Date : 05/04/07
Distilled Water (ml.) : 300.05		Calculated By : M.T.	Date : 05/07/07
Shaking at : 14:30		Checked By : R.Y	Date : 5-7-07
Reshaking at : 15:30		Vaccum & Filter at :	
Remark :			

Titration of (I ml.) Sample Diluted to (F ml.)	11	< Beaker No. >		26		
Total Sample Prepared :	Initial	Final	Total	Initial	Final	Total
Sample Volume (ml)	30.05			30.09		
pH of Liquid Sample	6.09			6.03		
Sodium Hydroxide added (ml)	-	-	-	-	-	-
Acetic Acid added (ml)	-	-	-	-	-	-
Silver Nitrate added (ml)	12.6	15.1	2.5	15.1	17.6	2.5
ppm CL= 100x(ml of Sil.Ni.-0.2 ml blank)F/I			230			230
Moisture - Free CL = ppm CL X 100 / (100 - w)			259			259

	Average
	2.5
	230
	259

MEASUREMENT OF SOIL CORROSIVITY

Project No. : 06-155	Project Name : BATA/ Antioch Bridge		
Boring No. : 06-8	Depth (ft/m) :	6.0	
Sample No. : S-2	Description :	Dk Brown, LEAN CLAY w/ Organic (CL)	

**** Sample for Corrosivity tests must screen through No. 8 Sieve*

Measurement of Soil Resistivity (ASTM G-57-78 / CT-643)

Test Standard	ASTM	X	CAL. TRAN.	Wt of Wet Soil + Cont.(gm)		216.41	Weight of Total
Soil Box Diamension (cm)	22.86 X 3.81 X 2.54		15.31 X 10.04 X4.41	Wt of Dry Soil + Cont.(gm)		165.57	Sample for Test (gm)
(L X W X H) / (inch)	9.0 X 1.5 X 1.0		6.04 X 3.95 X 1.74	Wt. of Cont. No.	4	58.97	77.31
Soil Box Constant(C)	1.0		6.72	Setup Moisture Content(%)	52.31	47.69	

Trial	Resistivity Meter Reading (ohm-cm)							
	As received	1	2	3	4	5		
Water added	0.0	3.09	2.18				Prepared By : M.T.	Date : 04/05/07
Meter reading	1Kx 1.7	1Kx1.6	1Kx1.6				Tested By : M.T.	Date : 04/05/07
Resistivity	1700	1600	1600				Calculated By : M.T.	Date : 04/05/07
							Checked By : R.Y	Date : 4-8-07
							Minimum Resistivity :	1600

Measurement of Soil pH (ASTM G-51-77 / CT-643)

Weight 30 gm soil sample and add 30 ml distilled water, stir to a soil slurry and settle at least 1hr.

Prepared By	: M.T.	Date : 04/05/07	Time :	10.00	Beaker No. :	13	pH Reading			
Tested By	: M.T.	Date : 04/06/07	Weigh of Wetsoil (gm)			30.05	Trial	1	2	3	Average
Calculated By	: M.T.	Date : 04/06/07	Distilled Water added (ml)			30.09	Test Time	17:45	18:00	18:15	
Checked By	: R.Y	Date : 4-8-07	Moisture Content(%)			47.69	Reading	6.12	6.12	6.11	6.12

Measurement of Soil Soluble Sulfate Content (CT - 417)

Weight 100.0 gm of sample soil & add 300 ml. of distilled water. Stopper and shake well. Allow to settle overnight. Prepare two 30 (ml.) of water layer into a 150 (ml.) beaker, dilute to 100 (ml.), add 5 (ml.) conditioning reagent. Turbidity Blank - Adjust the stirrer to the maximum speed, add 1 spoonfull Barium Chloride & start timing. Stir for exactly 1 minute.

Flask No. : 8	Prepared By : M.T.	Date : 04/05/07
Weight of Soil (gm) : 100.09	Tested By : M.T.	Date : 04/07/07
Distilled Water (ml.) : 300.06	Calculated By : M.T.	Date : 04/07/07
Shaking at : 0950	Checked By : R.Y	Date : 4-8-07
Reshaking at : 1050		

Total Water Sample Prepared	60.07	With BaCL		1	< Beaker Number >			2	Blank
Distilled Water added (ml)	200.07			100.00	Tested Sample Volume			100.07	
Time Intervals	0:00:00	0:00:30	0:01:00	0:01:30	0:02:00	0:02:30	0:03:00	0:04:00	Maximum
With BaCL (time) 10:58:00	11:00:00	11:00:30	11:01:00	11:01:30	11:02:00	11:02:30	11:03:00	11:04:00	
Turbidity with BaCL (NTV)		128	128	128	128	128	128	128	128
Blank (time) 10:52:00	10:56:00	10:56:30	10:57:00	10:57:30	10:58:00	10:58:30	10:59:00	11:00:00	
Turbidity Blank (NTV)		65.7	65.7	65.8	65.8	65.8	65.8	65.7	65.8
Difference (ppm)									62.2
SO_4 (from graph) (ppm)									140

Measurement of Soil Chloride Content (CT - 422)

*1. Weight 100.0 gm sample soil & add 300 ml. of distilled water. Stopper and shake vigorously for 20 seconds, reshaking after one hour and let it settle over night. 2. Pour 30 ml aliquot of filtered solution into a 150 ml beaker, then check pH. If pH is in the range 6 through 8, go to step 4. If ph below 6, add Sodium Hydroxide and if above 8, add Acetic Acid to adjust to the range. 4. Add two drops of Potassium Chromate solution before titrate with Silver Nitrate and change color from Yellow to Red. ** If the titration is over 30 ml., take a smaller sample. Dilute any smaller sample to about 50 ml..*

Flask No. : 8	Prepared By : M.T.	Date : 04/05/07
Wt. of Soil (gm) : 100.09	Tested By : M.T.	Date : 04/07/07
Distilled Water (ml) : 300.06	Calculated By : M.T.	Date : 04/07/07
Shaking at : 0950	Checked By : R.Y	Date : 4-8-07
Reshaking at : 1050	Vaccum & Filter at :	
Remark :		

Titration of (I ml.) Sample Diluted to (F ml.)	10	< Beaker No.			> 24		
Total Sample Prepared :	Initial	Final	Total	Initial	Final	Total	
Sample Volume (ml)	30.07			30.02			
pH of Liquid Sample	6.51			6.57			
Sodium Hydroxide added (ml)	-	-	-	-	-	-	
Acetic Acid added (ml)	-	-	-	-	-	-	
Silver Nitrate added (ml)	5.0	6.7	1.7	6.7	8.5	1.8	Average 1.75
ppm CL= 100x(ml of Sil.Ni.-0.2 ml blank)F/I			150			160	155
Moisture - Free CL = ppm CL X 100 / (100 - w)			287			306	296

MEASUREMENT OF SOIL CORROSIVITY

Project No. : 06-155	Project Name : BATA/ Antioch Bridge		
Boring No. : 06-8	Depth (ft/m) :	26.0	
Sample No. : S-6	Description :	Dk Gray, SILTY CLAY (CL-ML)	

**** Sample for Corrosivity tests must screen through No. 8 Sieve*

Measurement of Soil Resistivity (ASTM G-57-78 / CT-643)

Test Standard	ASTM	X	CAL. TRAN.	Wt of Wet Soil + Cont.(gm)		216.64	Weight of Total
Soil Box Diamension (cm)	22.86 X 3.81 X 2.54		15.31 X 10.04 X4.41	Wt of Dry Soil + Cont.(gm)		148.54	Sample for Test (gm)
(L X W X H) / (inch)	9.0 X 1.5 X 1.0		6.04X 3.95 X 1.74	Wt. of Cont. No.	1	57.24	76.07
Soil Box Constant(C)	1.0		6.72	Setup Moisture Content(%)	2541	74.59	

Trial	Resistivity Meter Reading (ohm-cm)						Prepared By : M.T.	Date : 04/04/07
	As received	1	2	3	4	5	Tested By : M.T.	Date : 04/05/07
Water added	0.0	5.09	3.55				Calculated By : M.T.	Date : 04/05/07
Meter reading	1Kx1.3	1Kx1.2	1Kx1.2				Checked By : R.Y	Date : 4/8/07
Resistivity	1300	1200	1200				Minimum Resistivity :	1200

Measurement of Soil pH (ASTM G-51-77 / CT-643)

Weight 30 gm soil sample and add 30 ml distilled water, stir to a soil slurry and settle at least 1hr.

Prepared By	: M.T.	Date : 04/05/07	Time :	10:10	Beaker No. :	26	pH Reading			
Tested By	: M.T.	Date : 04/06/07	Weigh of Wetsoil (gm)			30.05	Trial	1	2	3	Average
Calculated By	: M.T.	Date : 04/06/07	Distilled Water added (ml)			30.09	Test Time	18:30	18:45	19:00	
Checked By	: R.Y	Date : 4/8/07	Moisture Content(%)			74.59	Reading	5.59	5.59	5.58	5.59

Measurement of Soil Soluble Sulfate Content (CT - 417)

Weight 100.0 gm of sample soil & add 300 ml. of distilled water. Stopper and shake well. Allow to settle overnight. Prepare two 30 (ml.) of water layer into a 150 (ml.) beaker, dilute to 100 (ml.), add 5 (ml.) conditioning reagent. Turbidity Blank - Adjust the stirrer to the maximum speed, add 1 spoonfull Barium Chloride & start timing. Stir for exactly 1 minute.

Flask No. : 37	Prepared By : M.T.	Date : 04/05/07
Weight of Soil (gm) : 100.09	Tested By : M.T.	Date : 04/07/07
Distilled Water (ml.) : 300.02	Calculated By : M.T.	Date : 04/07/07
Shaking at : 10:00	Checked By :	Date :
Reshaking at : 1100		

Total Water Sample Prepared	60.07	With BaCL		3	< Beaker Number >			4	Blank
Distilled Water added (ml)	200.02			100.00	< Tested Sample Volume >			100.02	
Time Intervals	0:00:00	0:00:30	0:01:00	0:01:30	0:02:00	0:02:30	0:03:00	0:04:00	Maximum
With BaCL (time) 11:04:00	11:08:00	11:08:30	11:09:00	11:09:30	11:10:00	11:10:30	11:11:00	11:12:00	
Turbidity with BaCL (NTV)		48.3	48.5	48.6	48.4	48.3	48.0	47.7	48.6
Blank (time) 11:00:00	11:04:00	11:04:30	11:05:00	11:05:30	11:06:00	11:06:30	11:07:00	11:08:00	
Turbidity Blank (NTV)		7.09	7.15	7.06	7.07	6.99	7.03	6.94	7.15
Difference (ppm)									41.45
SO_4 (from graph) (ppm)									95

Measurement of Soil Chloride Content (CT - 422)

*1. Weight 100.0 gm sample soil & add 300 ml. of distilled water. Stopper and shake vigorously for 20 seconds, reshaking after one hour and let it settle over night. 2. Pour 30 ml aliquot of filtered solution into a 150 ml beaker, then check pH. If pH is in the range 6 through 8, go to step 4. If ph below 6, add Sodium Hydroxide and if above 8, add Acetic Acid to adjust to the range. 4. Add two drops of Potassium Chromate solution before titrate with Silver Nitrate and change color from Yellow to Red. ** If the titration is over 30 ml., take a smaller sample. Dilute any smaller sample to about 50 ml..*

Flask No. : 37	Prepared By : M.T.	Date : 04/05/07
Wt. of Soil (gm) : 100.09	Tested By : M.T.	Date : 04/07/07
Distilled Water (ml) : 300.02	Calculated By : M.T.	Date : 04/07/07
Shaking at : 1000	Checked By : R.Y	Date : 4/8/07
Reshaking at : 11:00	Vaccum & Filter at :	
Remark :		

Titration of (1 ml.) Sample Diluted to (F ml.)	11	< Beaker No. >		29			
Total Sample Prepared :	Initial	Final	Total	Initial	Final	Total	
Sample Volume (ml)	30.06			30.04			
pH of Liquid Sample	6.64			6.65			
Sodium Hydroxide added (ml)	-	-	-	-	-	-	
Acetic Acid added (ml)	-	-	-	-	-	-	
Silver Nitrate added (ml)	8.5	10.0	1.5	10.0	11.5	1.5	Average 1.5
ppm CL= 100x(ml of Sil.Ni.-0.2 ml blank)F/I			130			130	130
Moisture - Free CL = ppm CL X 100 / (100 - w)			512			512	512

MEASUREMENT OF SOIL CORROSIVITY

Project No. : 06-155	Project Name : BATA/ Antioch Bridge		
Boring No. : 06-9	Depth (ft/m) :		5.0
Sample No. : D-1	Description :	BLACK, LEAN CL w/ non-plastic CL-CL w/ Peat	

**** Sample for Corrosivity tests must screen through No. 8 Sieve*

Measurement of Soil Resistivity (ASTM G-57-78 / CT-643)

Test Standard	ASTM	X	CAL. TRAN.	Wt of Wet Soil + Cont.(gm)		133.49	Weight of Total
Soil Box Diamension (cm)	22.86 X 3.81 X 2.54		15.31 X 10.04 X4.41	Wt of Dry Soil + Cont.(gm)		87.02	Sample for Test (gm)
(L X W X H) / (inch)	9.0 X 1.5 X 1.0		6.04X 3.95 X 1.74	Wt. of Cont. No.	16	57.41	72.54
Soil Box Constant(C)	1.0		6.72	Setup Moisture Content(%)		156.94	

Trial	Resistivity Meter Reading (ohm-cm)							
	As received	1	2	3	4	5		
Water added	0.0	7.63	5.17	3.89	2.99		Prepared By : M.T.	Date : 05/03/07
Meter reading	1K x 1.1	100x7.9	100x7.1	100x6.9	100x6.9		Tested By : M.T.	Date : 05/04/07
Resistivity	1100	790	710	690	690		Calculated By : M.T.	Date : 05/04/07
							Checked By : R.Y	Date : 5-7-07
							Minimum Resistivity :	690

Measurement of Soil pH (ASTM G-51-77 / CT-643)

Weight 30 gm soil sample and add 30 ml distilled water, stir to a soil slurry and settle at least 1hr.

Prepared By	: M.T.	Date : 05/03/07	Time :	14:55	Beaker No. :	19	pH Reading			
Tested By	: M.T.	Date : 05/04/07	Weigh of Wetsoil (gm)			30.03	Trial	1	2	3	Average
Calculated By	: M.T.	Date : 05/04/07	Distilled Water added (ml)			30.02	Test Time	16:45	17:00	17:15	
Checked By	: R.Y	Date : 5-7-07	Moisture Content(%)			15694	Reading	5.69	5.71	5.71	5.70

Measurement of Soil Soluble Sulfate Content (CT - 417)

Weight 100.0 gm of sample soil & add 300 ml. of distilled water. Stopper and shake well. Allow to settle overnight. Prepare two 30 (ml.) of water layer into a 150 (ml.) beaker, dilute to 100 (ml.), add 5 (ml.) conditioning reagent. Turbidity Blank - Adjust the stirrer to the maximum speed, add 1 spoonfull Barium Chloride & start timing. Stir for exactly 1 minute.

Flask No. : 40	Prepared By : M.T.	Date : 05/03/07
Weight of Soil (gm) : 100.01	Tested By : M.T.	Date : 05/04/07
Distilled Water (ml.) : 300.05	Calculated By : M.T.	Date : 05/07/07
Shaking at : 14:45	Checked By : R.Y	Date : 5-7-07
Reshaking at : 15:45		

Total Water Sample Prepared	60.08	With BaCL		5	< Beaker Number >			6	Blank
Distilled Water added (ml)	200.05			200.02	Tested Sample Volume			209.03	
Time Intervals	0:00:00	0:00:30	0:01:00	0:01:30	0:02:00	0:02:30	0:03:00	0:04:00	Maximum
With BaCL (time) 17:22:00	17:26:00	17:26:30	17:27:00	17:27:30	17:28:00	17:28:30	17:29:00	17:30:00	
Turbidity with BaCL (NTV)		157	155	154	154	154	152	150	157
Blank (time) 17:18:00	17:22:00	17:22:30	17:23:00	17:23:30	17:24:00	17:24:30	17:25:00	17:26:00	
Turbidity Blank (NTV)		2.35	2.35	2.37	2.37	2.35	2.35	2.34	2.37
Difference (ppm)									154.63
SO_4 (from graph) (ppm)									340

Measurement of Soil Chloride Content (CT - 422)

*1. Weight 100.0 gm sample soil & add 300 ml. of distilled water. Stopper and shake vigorously for 20 seconds, reshaking after one hour and let it settle over night. 2. Pour 30 ml aliquot of filtered solution into a 150 ml beaker, then check pH. If pH is in the range 6 through 8, go to step 4. If ph below 6, add Sodium Hydroxide and if above 8, add A cetic Acid to adjust to the range. 4. Add two drops of Potassium Chromate solution before titrate with Silver Nitrate and change color from Yellow to Red. ** If the titration is over 30 ml., take a smaller sample. Dilute any smaller sample to about 50 ml..*

Flask No. : 40	Prepared By : M.T.	Date : 05/03/07
Wt. of Soil (gm) : 100.01	Tested By : M.T.	Date : 05/04/07
Distilled Water (ml) : 300.05	Calculated By : M.T.	Date : 05/07/07
Shaking at : 14.45	Checked By : R.Y.	Date : 5-7-07
Reshaking at : 15.45	Vaccum & Filter at :	
Remark :		

Titration of (I ml.) Sample Diluted to (F ml.)	15	< Beaker No. >		16		
Total Sample Prepared :	Initial	Final	Total	Initial	Final	Total
Sample Volume (ml)	30.05			30.07		
pH of Liquid Sample	6.67			6.32		
Sodium Hydroxide added (ml)	-	-	-	-	-	-
Acetic Acid added (ml)	-	-	-	-	-	-
Silver Nitrate added (ml)	17.6	25.8	8.2	25.8	33.9	8.1
ppm CL= 100x(ml of Sil.Ni.-0.2 ml blank)*F/I			800			790
Moisture - Free CL = ppm CL X 100 / (100 - w)			1256			1240

Average
8.15
795
1248

MEASUREMENT OF SOIL CORROSIVITY

Project No. : 06-155	Project Name : BATA/ Antioch Bridge		
Boring No. : 06 – 10	Depth (ft/m) :	10.5	
Sample No. : S-2	Description :	DK Gray, LEAN CLAY w/ Peat (CL)	

*** *Sample for Corrosivity tests must screen through No. 8 Sieve*

Measurement of Soil Resistivity (ASTM G-57-78 / CT-643)

Test Standard	ASTM	X	CAL. TRAN.	Wt of Wet Soil + Cont.(gm)		211.71	Weight of Total
Soil Box Diamension (cm)	22.86 X 3.81 X 2.54		15.31 X 10.04 X4.41	Wt of Dry Soil + Cont.(gm)		157.73	Sample for Test (gm)
(L X W X H) / (inch)	9.0 X 1.5 X 1.0		6.04X 3.95 X 1.74	Wt. of Cont. No.	6	57.20	76.45
Soil Box Constant (C)	1.0		6.72	Setup Moisture Content (%)	46.3	53.70	

Trial	Resistivity Meter Reading (ohm-cm)						
	As received	1	2	3	4	5	
Water added	0.0	3.93					
Meter reading	100 X 8.1	100X8.2					
Resistivity	810	820					

Prepared By : M.T.	Date : 04/05/07
Tested By : M.T.	Date : 04/05/07
Calculated By : M.T.	Date : 04/05/07
Checked By : RY	Date : 4-8-07
Minimum Resistivity :	810

Measurement of Soil pH (ASTM G-51-77 / CT-643)

Weight 30 gm soil sample and add 30 ml distilled water, stir to a soil slurry and settle at least 1hr.

Prepared By	: M.T.	Date : 04/05/07	Time :	10:20	Beaker No. : 39
Tested By	: M.T.	Date : 04/06/07	Weigh of Wetsoil (gm)		30.07
Calculated By	: M.T.	Date : 04/06/07	Distilled Water added (ml)		30.07
Checked By	: RY	Date : 4-8-07	Moisture Content (%)		53.70

6.15 pH Reading

Trial	1	2	3	Average
Test Time	19:15	19:30	19:45	
Reading	6.15	6.16	6.16	6.16

Measurement of Soil Soluble Sulfate Content (CT - 417)

Weight 100.0 gm of sample soil & add 300 ml. of distilled water. Stopper and shake well. Allow to settle overnight. Prepare two 30 (ml.) of water layer into a 150 (ml.) beaker, dilute to 100 (ml.), add 5 (ml.) conditioning reagent. Turbidity Blank - Adjust the stirrer to the maximum speed, add 1 spoonfull Barium Chloride & start timing. Stir for exactly 1 minute.

Flask No. : 3		Prepared By : M.T.	Date : 04/05/07
Weight of Soil (gm) : 100.07		Tested By : M.T.	Date : 04/07/07
Distilled Water (ml.) : 300.02		Calculated By : M.T.	Date : 04/07/07
Shaking at : 10:10		Checked By :	Date :
Reshaking at : 11:10			

Total Water Sample Prepared	60.09	With BaCL		5	< Beaker Number >			6	Blank
Distilled Water added (ml)	200.07			100.07	Tested Sample Volume			100.00	
Time Intervals	0:00:00	0:00:30	0:01:00	0:01:30	0:02:00	0:02:30	0:03:00	0:04:00	Maximum
With BaCL (time) 11:12:00	11:16:00	11:16:30	11:17:00	11:17:30	11:18:00	11:18:30	11:19:00	11:20:00	
Turbidity with BaCL (NTV)		93.4	93.6	93.4	93.2	93.2	92.7	92.7	93.6
Blank (time) 11:08:00	11:12:00	11:12:30	11:13:00	11:13:30	11:14:00	11:14:30	11:15:00	11:16:00	
Turbidity Blank (NTV)		24.2	24.2	24.2	24.1	24.2	24.1	24.1	24.2
Difference (ppm)									69.4
SO_4 (from graph) (ppm)									155

Measurement of Soil Chloride Content (CT - 422)

*1. Weight 100.0 gm sample soil & add 300 ml. of distilled water. Stopper and shake vigorously for 20 seconds, reshaking after one hour and let it settle over night. 2. Pour 30 ml aliquot of filtered solution into a 150 ml beaker, then check pH. If pH is in the range 6 through 8, go to step 4. If ph below 6, add Sodium Hydroxide and if above 8, add Acetic Acid to adjust to the range. 4. Add two drops of Potassium Chromate solution before titrate with Silver Nitrate and change color from Yellow to Red. ** If the titration is over 30 ml., take a smaller sample. Dilute any smaller sample to about 50 ml..*

Flask No. : 3		Prepared By : M.T.	Date : 04/05/07
Wt. of Soil (gm) : 100.07		Tested By : M.T.	Date : 04/07/07
Distilled Water (ml.) : 300.02		Calculated By : M.T.	Date : 04/07/07
Shaking at : 16:10		Checked By : RY	Date : 4-8-07
Reshaking at : 11:10		Vaccum & Filter at :	

Remark :

Titration of (I ml.) Sample Diluted to (F ml.)	19	< Beaker No.			40	
Total Sample Prepared :	Initial	Final	Total	Initial	Final	Total	
Sample Volume (ml)	30.04			30.06			
pH of Liquid Sample	6.81			6.87			
Sodium Hydroxide added (ml)	-	-	-	-	-	-	
Acetic Acid added (ml)	-	-	-	-	-	-	
Silver Nitrate added (ml)	11.5	15.8	4.3	15.8	20.0	4.2	Average 4.25
ppm CL= 100x(ml of Sil.Ni.-0.2 ml blank)F/I			410			400	405
Moisture - Free CL = ppm CL X 100 / (100 - w)			886			864	875

Figure G-1: Antioch Toll Bridge

Figure G-2: Representative Soil Column at Antioch Toll Bridge

Figure G-3: Representative Soil Column at Antioch Toll Bridge

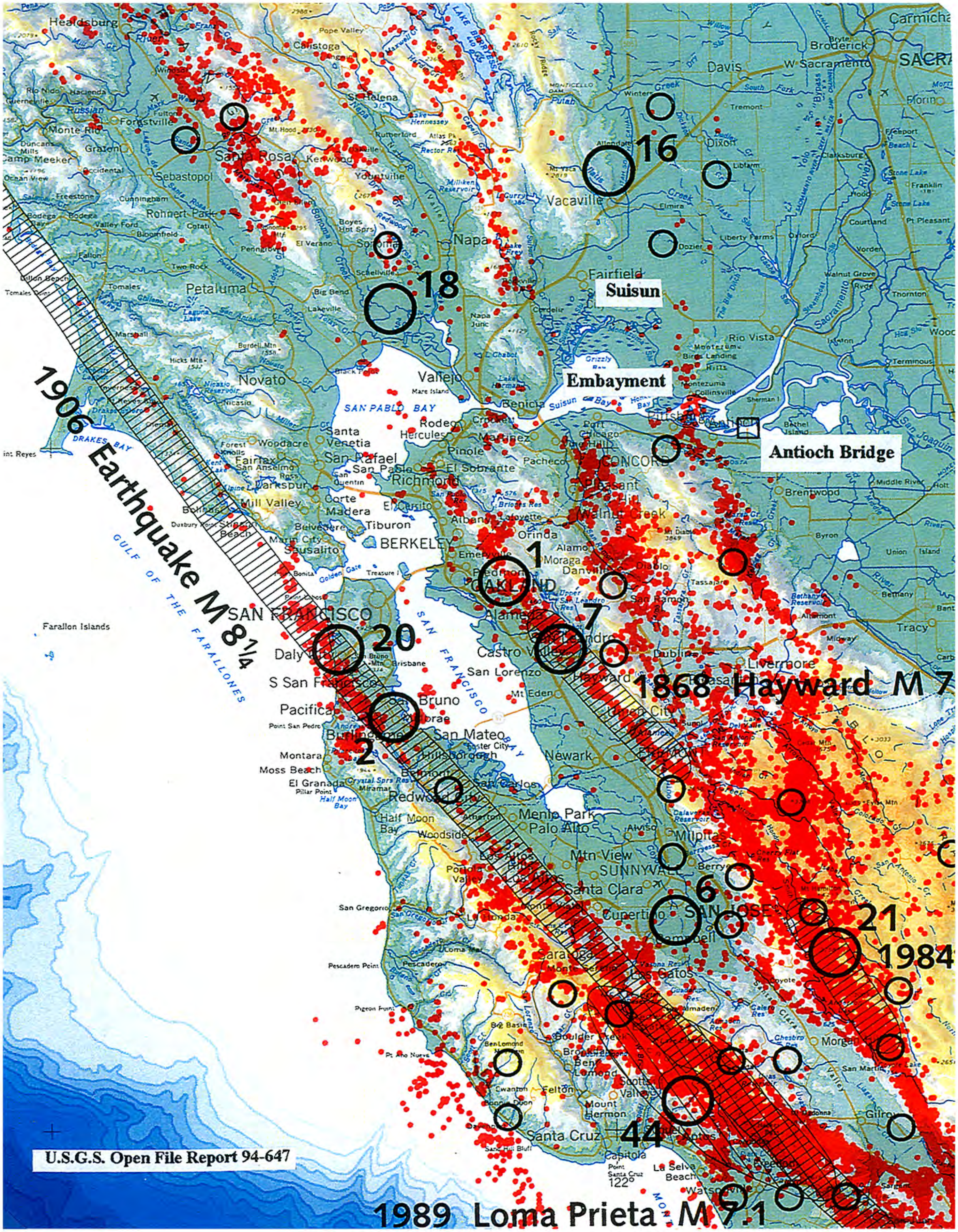
Figure G-4: Mobile B-80 Drill Rig on the *Quin Delta*

Figure G-5: ***Quin Delta***

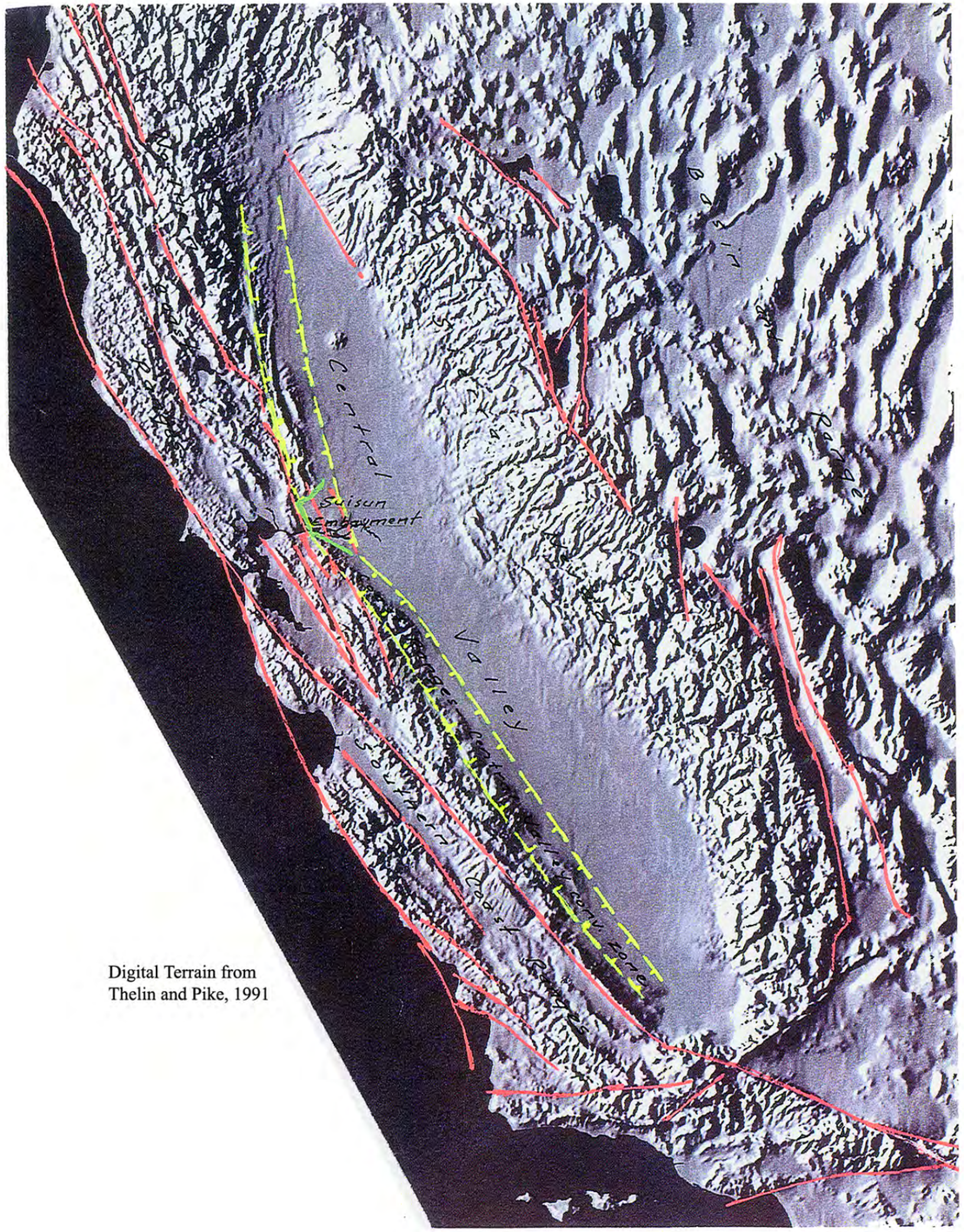
Figure G-6: P- and S-Wave Logging by GEOVision

Figure G-7: Drilling and CPT Operations at Antioch Toll Bridge

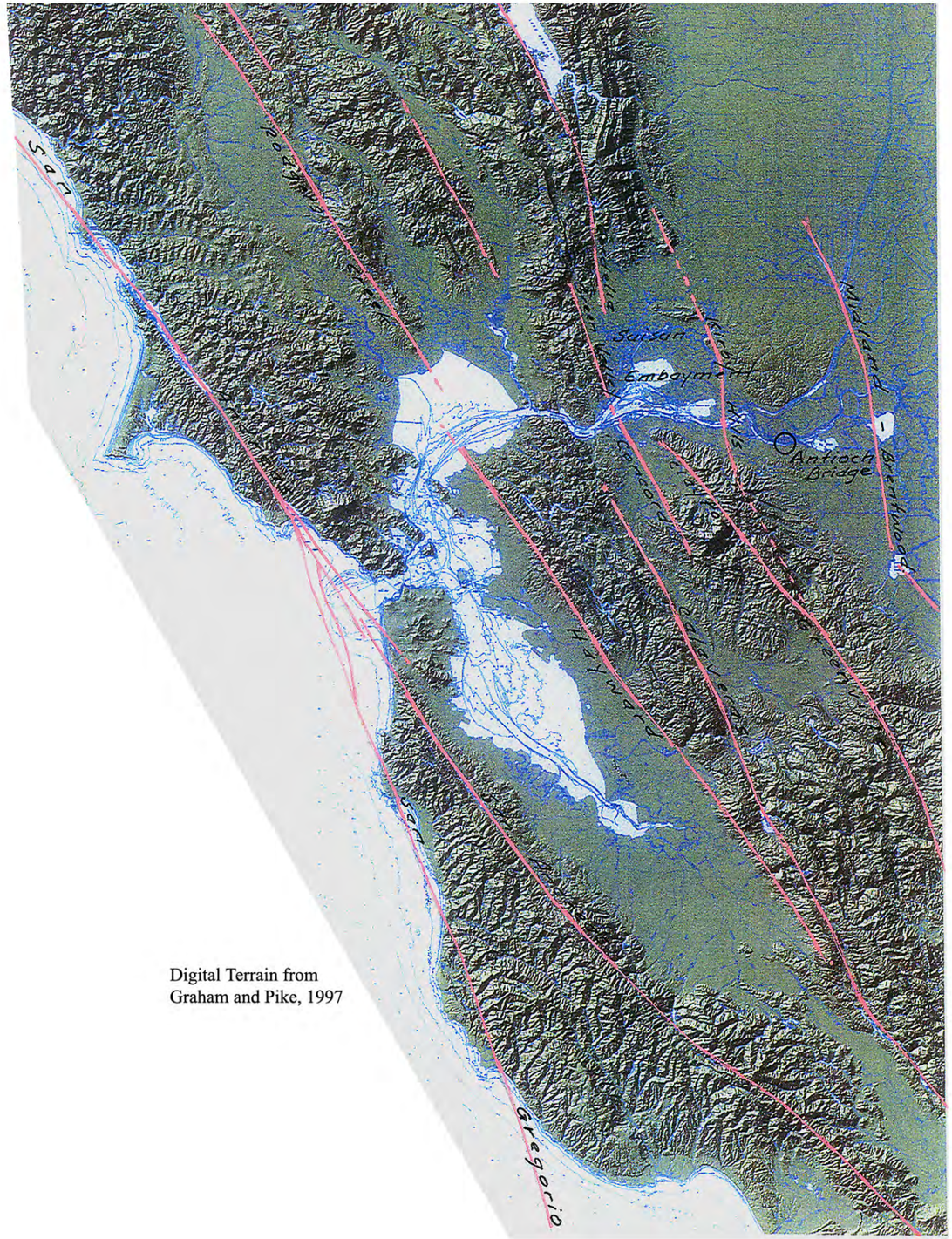
Figure G-8: Drilling and CPT Operations at Antioch Toll Bridge



Earthquake Epicenters, 1836-1994 and Selected Late Quaternary Faults Figure 1

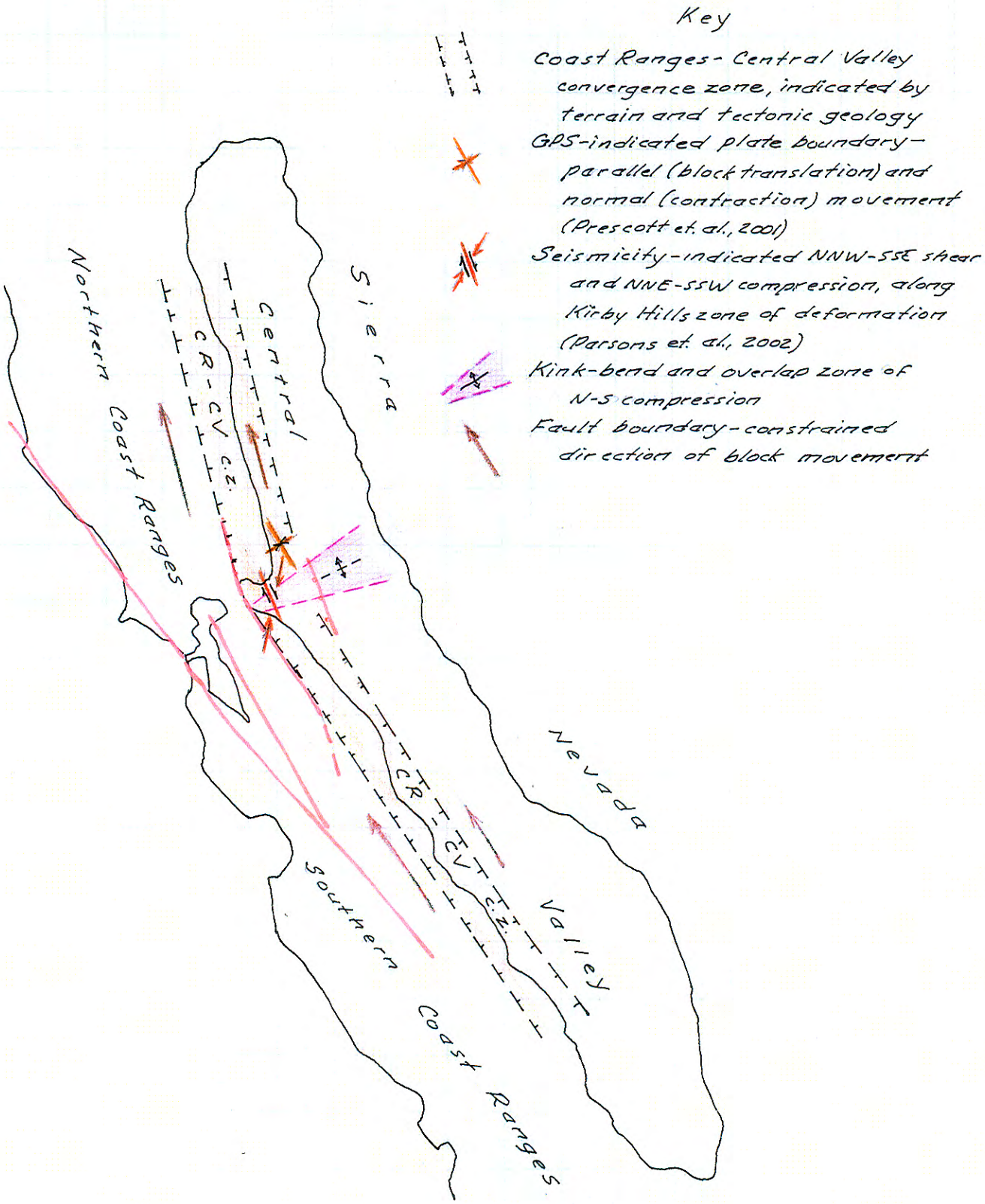


Digital Terrain from
Thelin and Pike, 1991

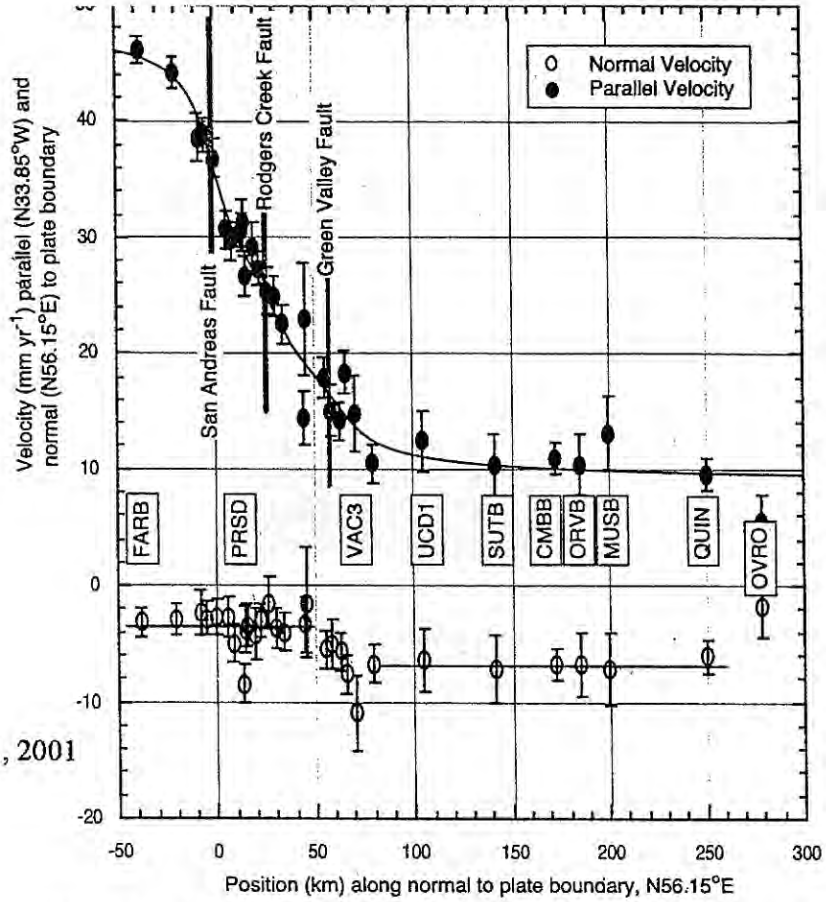


Digital Terrain from
Graham and Pike, 1997

Regional Terrain, Principal late Quaternary Faults and Coast Ranges-Central Valley convergence zone Figure 2



Conditions Driving Tectonism In the Suisun Embayment Region Figure 3



from Prescott et. al., 2001

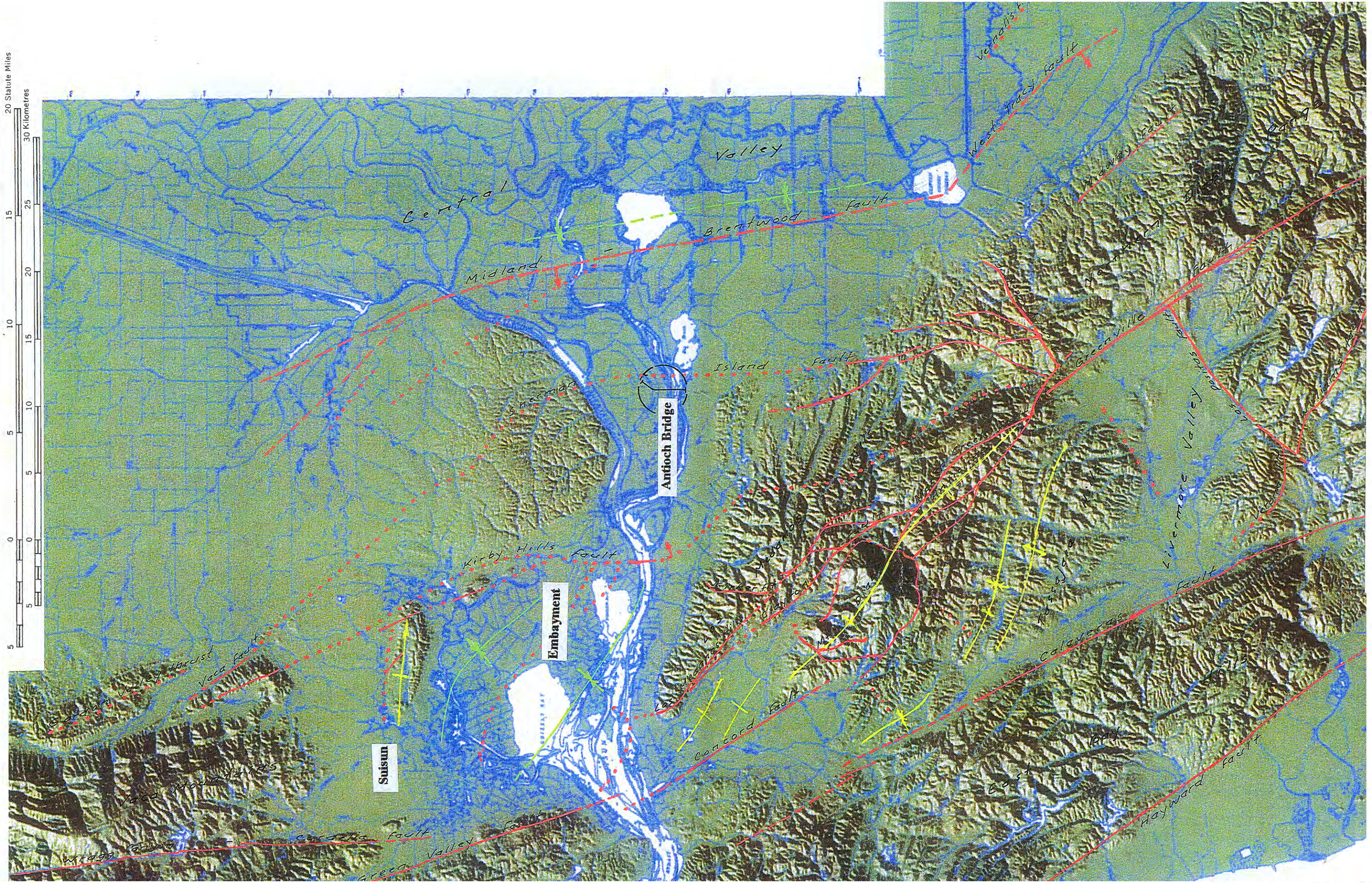
Figure 5. Plot of the motion of stations resolved into components parallel and normal to the observed direction of Pacific-North America motion (N33.85°W). Solid dots indicate the motion parallel to the direction of plate motion. Open dots indicate the motion normal to the direction of plate motion. The Pacific plate is at the left; the Sierra Nevada plate is at the right. The smooth curve through the fault-parallel component is the deformation predicted by the best fitting model (Table 3). Error bars indicate 2 σ errors.

Table 1. Stations, Locations, Observation Histories, and Velocities[a]

Station	Latitude,	Longitude,	History			ITRF97		NoAm		1-σ	
	°N	°E	N	First	Last	V_n	V_e	V_n	V_e	S_n	S_e
1395	38° 05' 14.309"	-122° 48' 45.515"	9	1993	1998	14.2	-33.3	29.1	-22.8	0.8	0.8
ADOO	38° 14' 11.117"	-122° 31' 38.880"	8	1993	1998	3.9	-27.5	18.7	-16.9	0.8	0.8
AIRR	38° 13' 23.463"	-122° 27' 20.416"	9	1993	1998	1.7	-26.4	16.5	-15.8	0.8	0.8
CAML	38° 25' 00.047"	-121° 59' 40.950"	8	1993	1998	-9.6	-22.1	5.0	-11.4	0.9	0.9
CMBB	38° 02' 03.035"	-120° 23' 09.736"	340	1994	2000	-8.9	-22.6	5.2	-11.7	0.7	0.7
CORD	38° 11' 09.568"	-122° 35' 43.022"	15	1993	1998	6.2	-28.3	21.0	-17.7	0.7	0.8
DEAL	38° 15' 28.123"	-122° 20' 16.712"	5	1996	1998	3.6	-24.6	18.3	-14.0	2.5	2.3
FARB	37° 41' 49.941"	-123° 00' 02.747"	378	1994	2000	21.7	-38.7	36.6	-28.3	0.6	0.6
GAME	38° 21' 02.466"	-122° 10' 30.879"	8	1994	1998	-6.1	-23.3	8.6	-12.6	0.8	0.9
GORR	38° 19' 52.242"	-122° 06' 52.579"	11	1993	1998	-3.7	-27.3	11.0	-16.6	0.9	0.9
HAGG	38° 19' 25.960"	-122° 15' 33.123"	8	1993	1998	-2.9	-25.1	11.8	-14.5	0.8	0.8
HENN	38° 16' 59.542"	-122° 21' 42.303"	5	1993	1996	-4.6	-21.4	10.1	-10.8	1.2	1.2
MADI	38° 18' 45.383"	-122° 12' 11.486"	7	1994	1998	-5.0	-23.3	9.7	-12.6	1.1	1.1
MOLA	37° 56' 47.667"	-122° 25' 11.717"	228	1994	2000	7.1	-30.3	21.9	-19.8	1.1	1.1
MUSB	37° 10' 11.788"	-119° 18' 33.653"	128	1997	2000	-7.0	-24.0	6.9	-13.2	1.6	1.6
NAVY	37° 48' 35.855"	-122° 21' 58.158"	10	1993	1998	5.5	-28.2	20.2	-17.7	0.9	0.9
NICC	38° 05' 33.552"	-122° 44' 11.547"	8	1993	1998	9.2	-29.8	24.0	-19.3	0.8	0.8
ORVB	39° 33' 16.660"	-121° 30' 01.039"	185	1996	2000	-9.6	-22.4	4.9	-11.4	1.4	1.4
OVRO	37° 13' 55.167"	-118° 17' 00.863"	10	1994	1998	-10.0	-15.5	3.6	-4.5	1.1	1.4
PBL1	37° 51' 10.993"	-122° 25' 08.199"	236	1995	2000	5.8	-34.5	20.6	-24.0	0.9	0.9
PRH2	38° 04' 46.957"	-122° 52' 07.415"	13	1993	1998	15.8	-34.5	30.7	-24.0	0.8	0.8
PRH3	37° 59' 47.059"	-123° 00' 53.653"	20	1993	1998	20.2	-37.5	35.1	-27.0	0.7	0.7
PRNC	38° 06' 12.694"	-122° 56' 11.747"	12	1993	1996	15.9	-33.9	30.8	-23.4	1.0	1.0
PRSD	37° 48' 19.092"	-122° 27' 18.254"	21	1993	1998	7.1	-31.2	21.9	-20.7	0.8	0.8
QUIN	39° 58' 28.396"	-120° 56' 39.933"	304	1994	2000	-9.7	-21.6	4.6	-10.4	0.7	0.7
SUTB	39° 12' 21.012"	-121° 49' 14.148"	161	1997	2000	-10.1	-22.6	4.5	-11.7	1.4	1.4
TIBB	37° 53' 27.146"	-122° 26' 51.356"	297	1994	2000	9.1	-31.1	23.9	-20.6	1.1	1.1
UCBK	37° 52' 18.435"	-122° 15' 54.543"	7	1993	1998	5.6	-25.9	20.3	-15.4	1.0	1.1
UCD1	38° 32' 10.464"	-121° 45' 04.424"	138	1996	2000	-7.9	-23.0	6.7	-12.2	1.3	1.3
VAC3	38° 23' 52.358"	-122° 06' 10.514"	11	1995	1998	-8.4	-28.0	6.2	-17.3	1.7	1.6

Motion of GPS stations along a transedt between the Pacific coast and the Sierra Nevada near the latitude of the Suisun Embayment

Figure 4



Terrain and Faults, Suisun Embayment and Antioch Bridge Area Figure 5

Epicenters

2000-2004
MAG
0.0 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.0
5.1 - 6.0

1990-2000
MAG
0.0 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.0
5.1 - 6.0

1980-1990
MAG
0.0 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.0
5.1 - 6.0
6.1 - 6.5

1970-1980
MAG
0.0 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.0
5.1 - 6.0

1960-1970
MAG
0.0 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.0
5.1 - 6.0

1950-1960
MAG
0.0 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.0
5.1 - 6.0

1940-1950
MAG
0.0 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.0
5.1 - 6.0

Pre-1940
MAG
0.0 - 2.0
2.1 - 3.0
3.1 - 4.0
4.1 - 5.0
5.1 - 6.0
6.1 - 6.6

Antioch Bridge

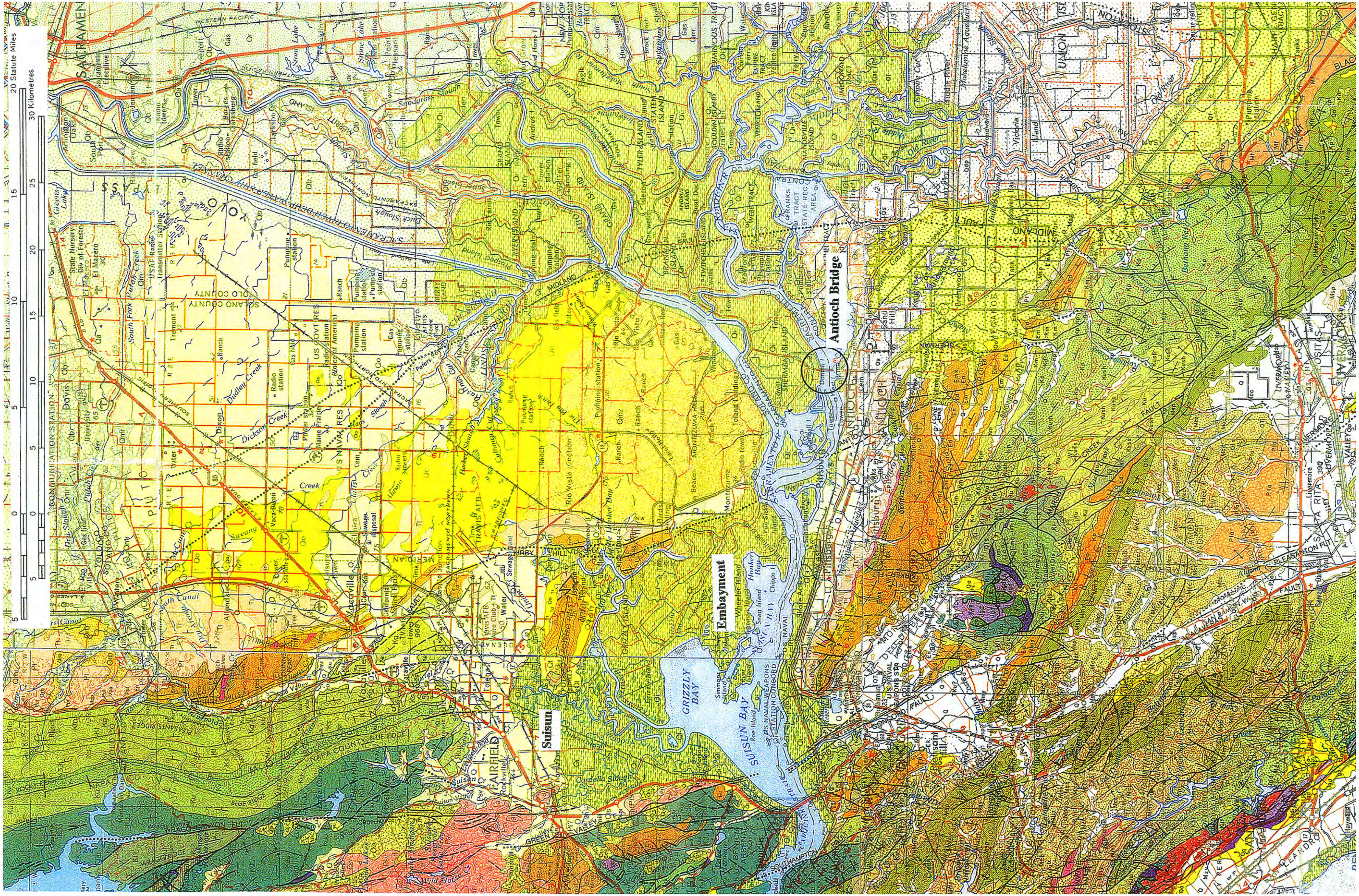
5 0 5 10 15 20 Statute Miles

5 0 5 10 15 20 25 30 Kilometres

Seismicity and Digital Terrain Source:
University of Nevada, Reno
Seismological Laboratory

Terrain, Faults and Earthquake Epicenters, 1934-2005

Figure 6



Surface Geology of Suisun Embayment and Vicinity Figure 7

Figure 9

Coast Ranges - Central Valley convergence zone
(Prescott et. al. (2001)

Suisun Embayment | Montezuma Hills uplift | Central Valley

Western Los Medanos Hills | Grizzly-Suisun Bays downwarp | Antioch Bridge | Central Valley downwarp

0 — 10 — 20 — 30

Depth in Kilometers

Ku | Tu | Concord | Los Medanos Hills det. thrust | F(?) Tectonic wedge | Kl(?) | Kirby Hills | Montezuma Hills-Antioch detachment thrust | Kl | Stewart 2s | Midland / Brentwood | Sierran Basement

Subsurface geology modified from:
Weber Band, 1998
WLA, 1998.
Hoffman 1992
Walter et. al., 1998

Subsurface geology of Central Valley based on Wagner et. al. 1987

Downdip Midland - Brentwood fault based on NCEDC (2006) (See Fig 15)

Kirby Hills Fault, crustal section, and seismicity based on Parsons et. al. 2002 (See Figure 13)

Moho

Geologic Units

Tu	Tertiary and Quaternary
Ku	Upper Cretaceous
Kl	Lower Cretaceous
F	Franciscan (?)
B	Sierran Basement
M	Mantle

Geology between Kirby Hills and Midland-Brentwood faults based on AAPG-Pac. Sect. MP-41 (1992), Weber Band (1998) and Parsons et. al (2002) (See Figures 8 and 13)

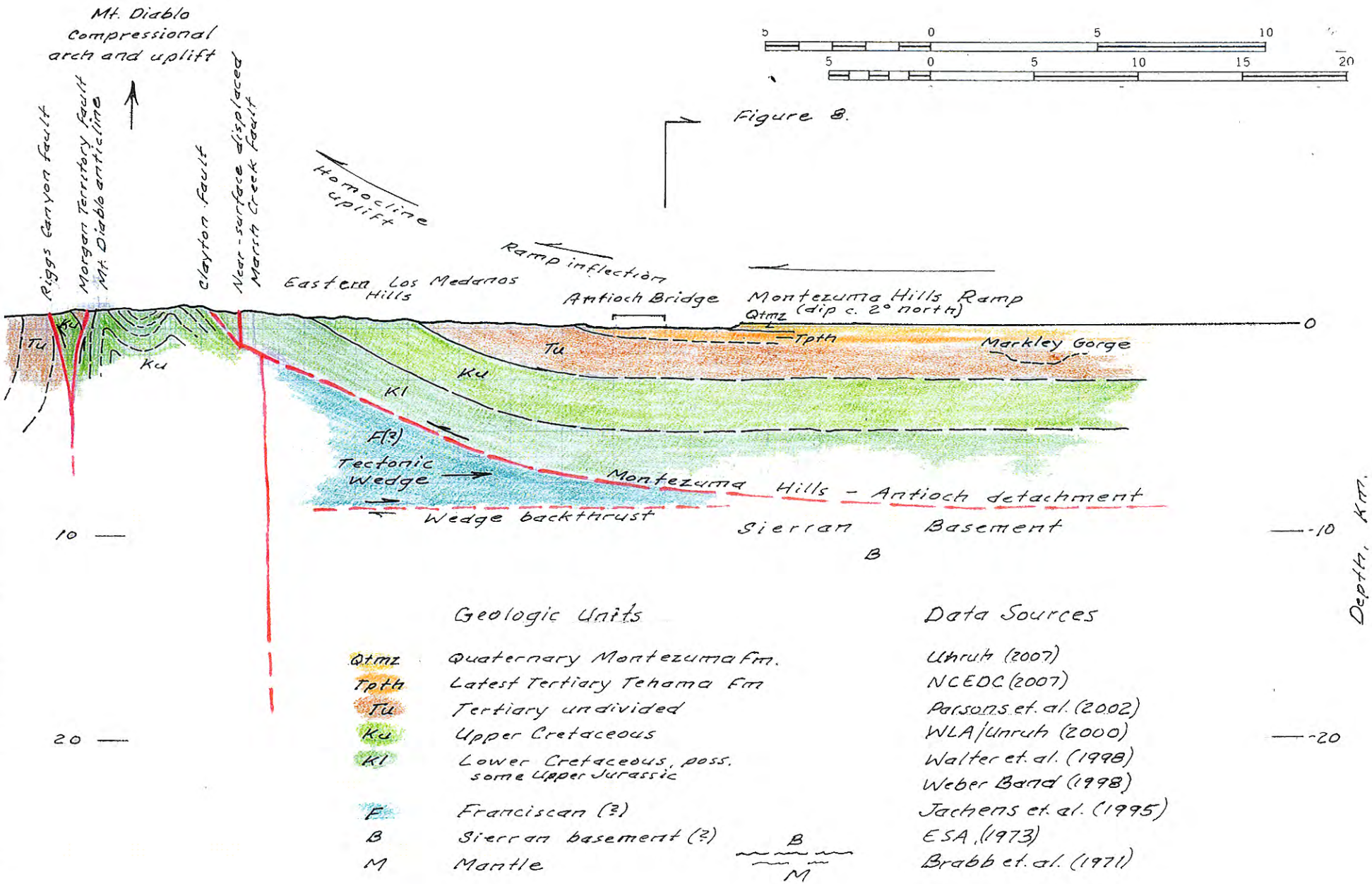
Cross Section Profile location shown on Figures 17 and 19

Data Sources

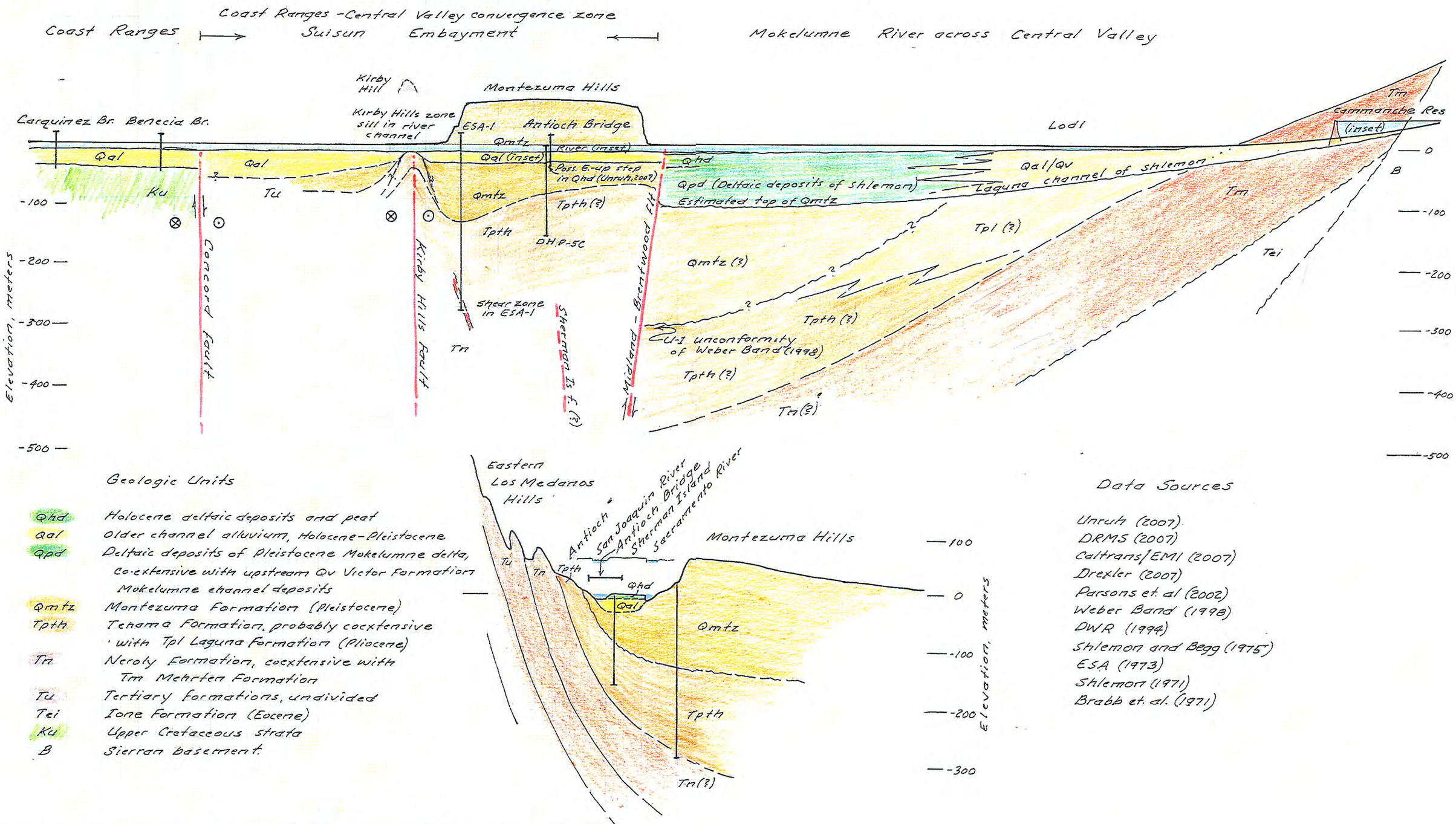
NCEDC (2006) plotted by Merriam (2007)
Parsons et. al. (2002)
Prescott et. al. (2001)
WLA (1998)
Weber Band (1998)
Walter et. al. (1998)
Jachens et. al. (1995)
Hoffman (1992)
AAPG Pac. Sect. (1992)
Wagner et. al (1987)

5 0 5 10 15 20 Statute Miles
5 0 5 10 15 20 25 30 Kilometres

Cross Section Profile, Central Valley to Western Los Medanos Hills Figure 8

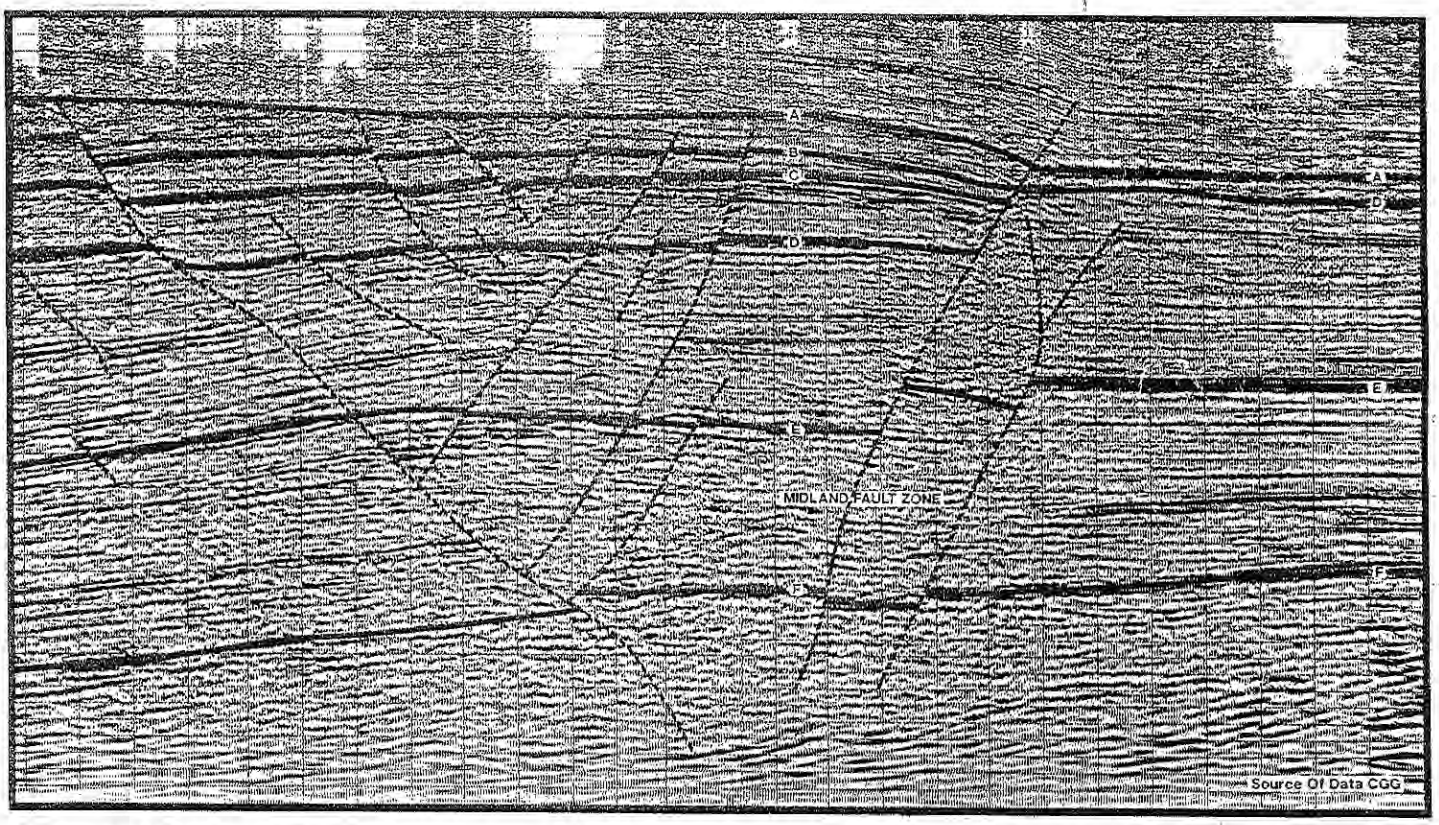


Cross Section Profile, Montezuma Hills through Los Medanos Hills Figure 9



Cross Section Profiles of Late Quaternary Geology, Lower Mokelumne and Lower Sacramento/San Joaquin River Figure 10

Antioch Bridge



11a. AAPG/Pac. Sect. 1992

S

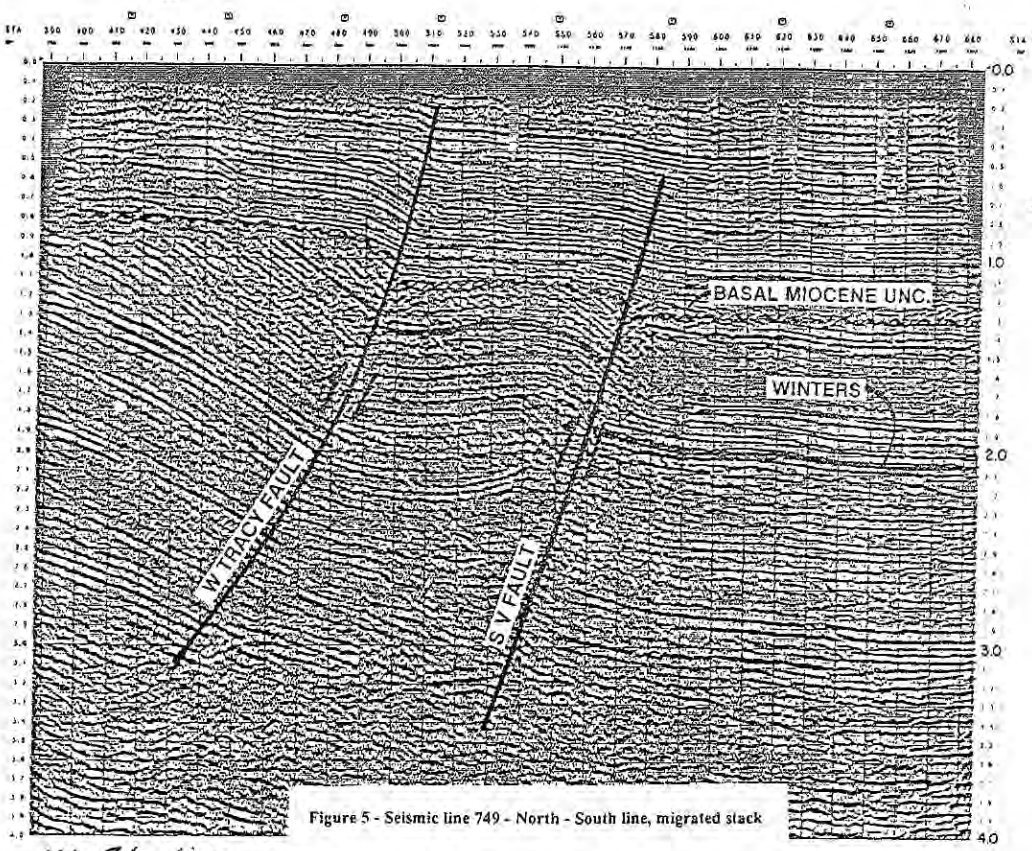


Figure 5 - Seismic line 749 - North - South line, migrated stack

11b. Sterling, 1992

Seismic Reflection Images of the Montezuma Hills-Midland-Brentwood fault, and West Tracy fault Figure 11

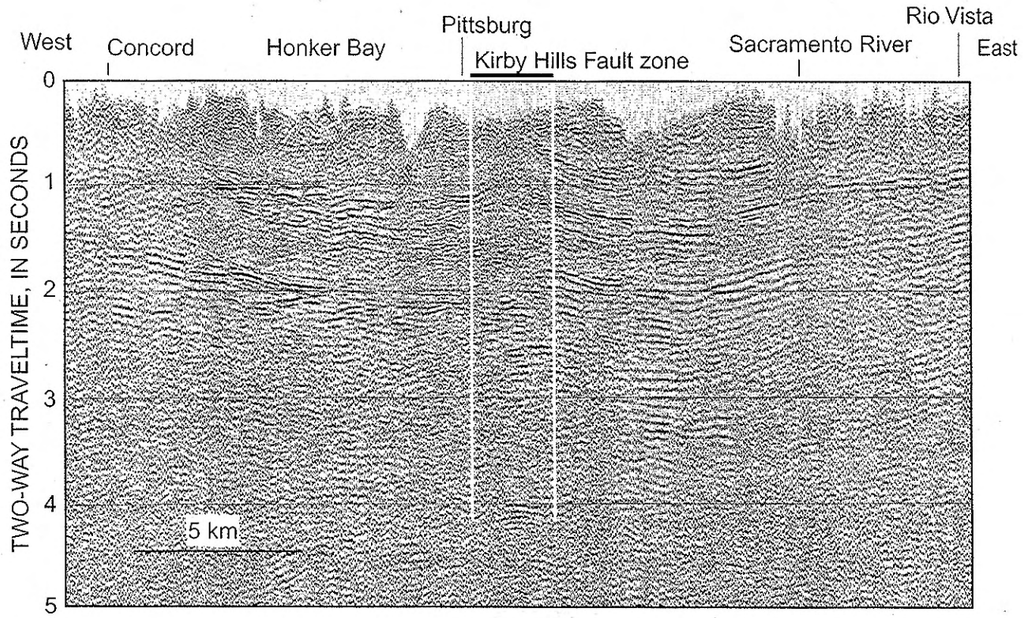


Figure 8.—Multichannel seismic-reflection profile across the Kirby Hills Fault zone (figs. 1, 4). Deformed rocks associated with fault zone are imaged from near surface to about 3-s two-way traveltime (~6–9-km depth). Heavy black line, Kirby Hills Fault zone as mapped by higher-resolution methods.

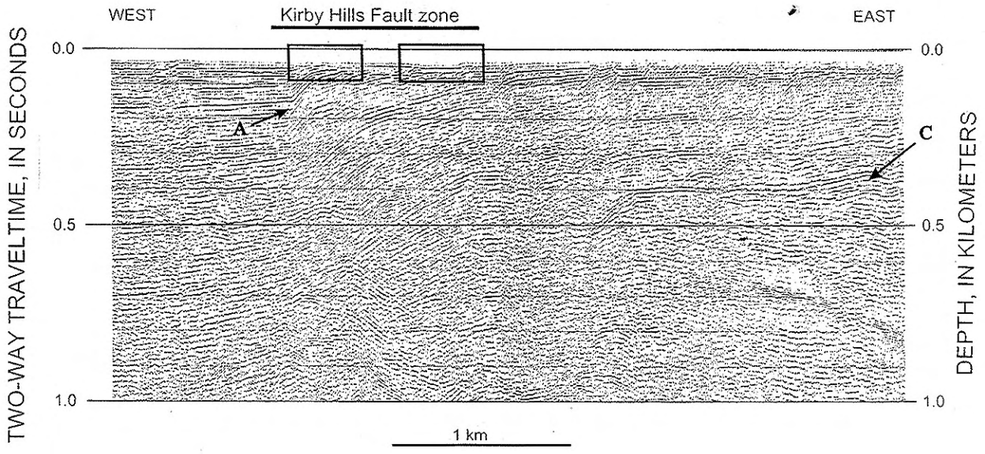


Figure 7.—Intermediate-resolution seismic-reflection profiles across the Kirby Hills Fault zone (figs. 1, 4), documenting an abrupt deformational front, east of which reflections are abruptly folded in an eastward-vergent geometry. Although this folding extends to at least 600-m depth, no fault-plane reflections are evident. Without clear images of fault plane, it is difficult to constrain style of faulting, whether fault-bend folding or fault-propagation folding. Boxes show locations of high-resolution profiles in figure 6.

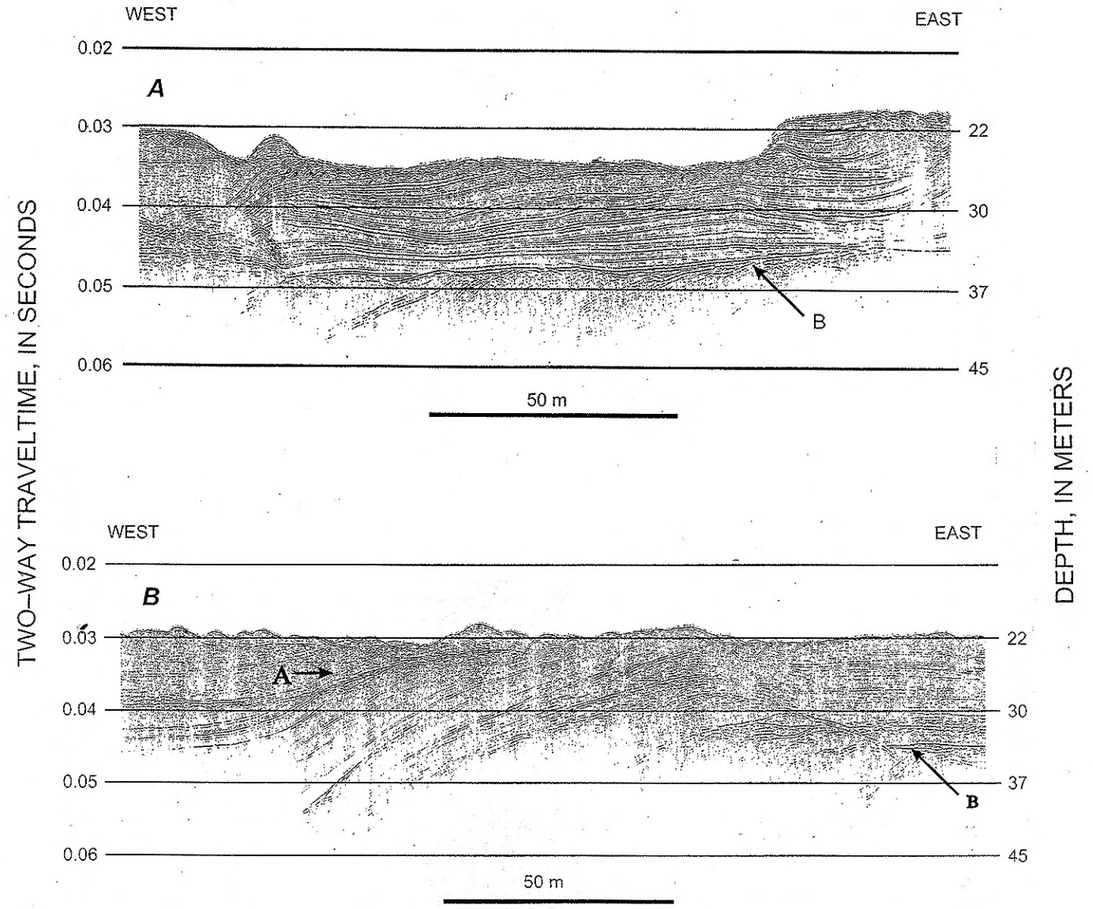


Figure 5.—Ultra-high-resolution seismic-reflection profiles gathered east (*A*) and west (*B*) of the Kirby Hills Fault zone (figs. 1, 4), showing significant deformation of youngest sedimentary rocks in fault zone. Approximately 200-m gap separates the two profiles, both of which fall within the 1-km-wide Kirby Hills Fault zone (fig. 4). Reflectors A and B are unconformities.

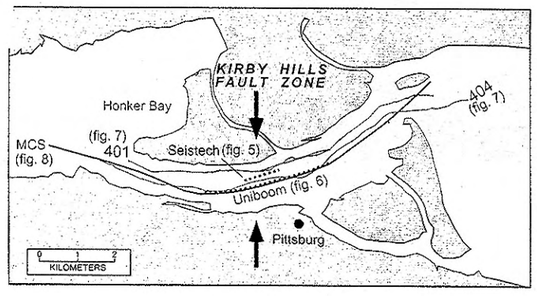
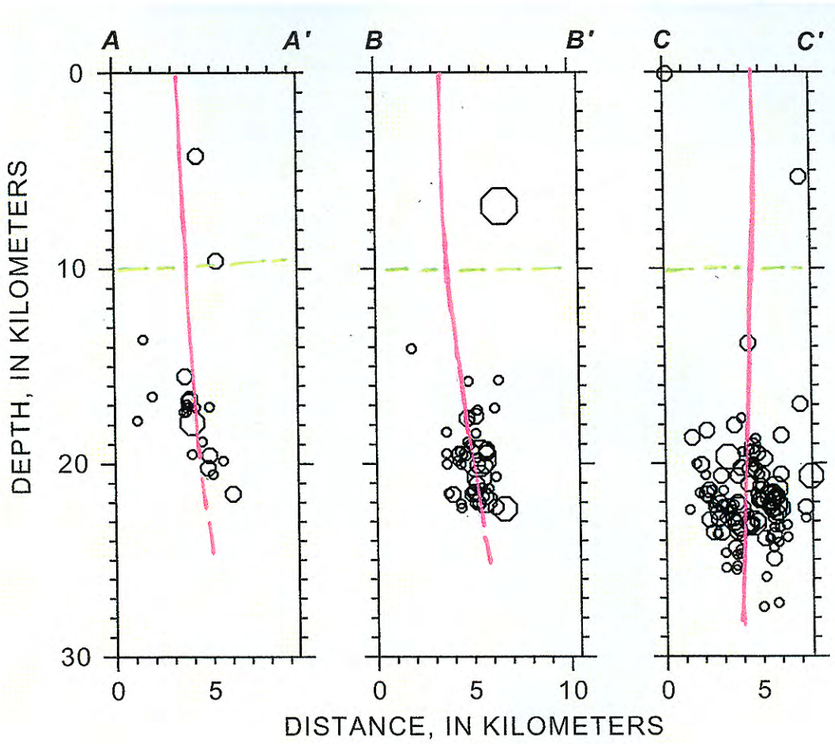
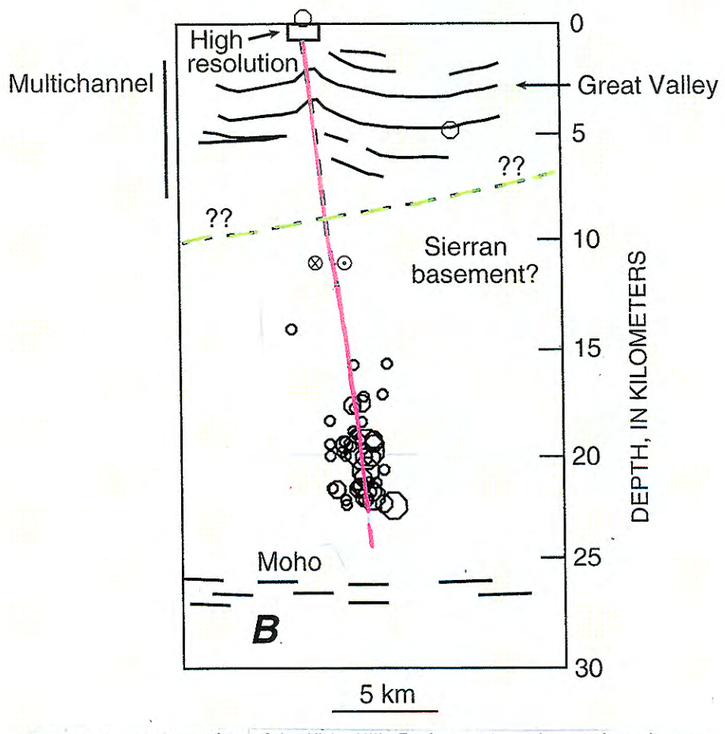


Figure 4.—Study area of the Kirby Hills Fault zone (see fig. 1 for location). Marine profiles of various resolutions shown in figures 5 through 8 were gathered along heavy black line. Fault zone is ~1 km wide and is centered over arrows.





Schematic interpretation of the Kirby Hills Fault zone based on various data constraints.

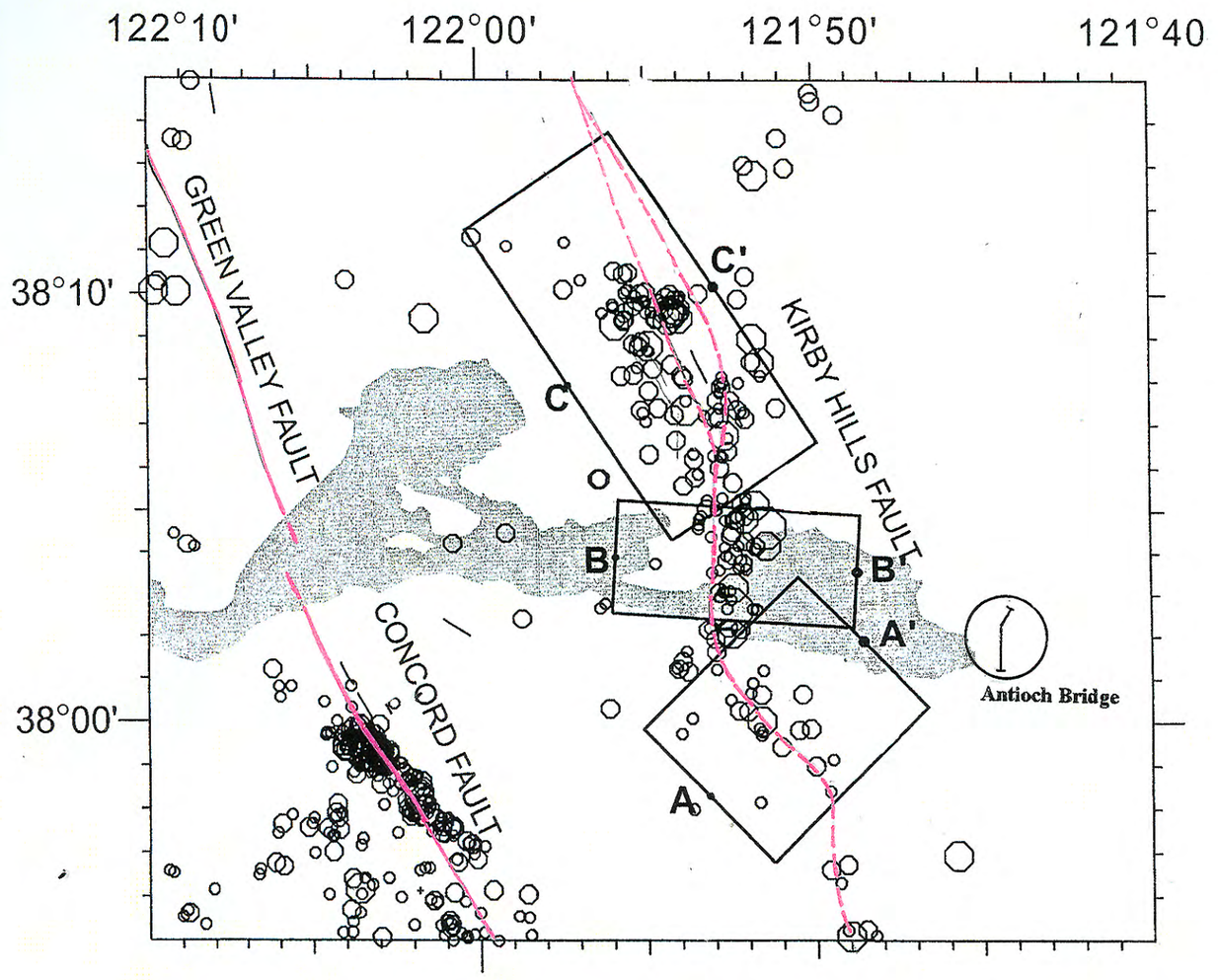
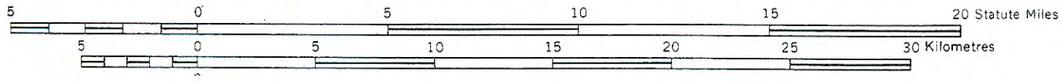


Figure 9.—Kirby Hills Fault zone (see figs. 1, 4 for location). *A*, linear trend of seismicity extending southward from where fault is mapped by marine investigations suggests that fault is ~50 km long. *B*, Depth cross sections of hypocenters, illustrating deep seismicity associated with the Kirby Hills Fault zone that extends to base of crust.



Figures modified from Parsons et. al., 2002

Map and Profiles Showing Seismicity Associated with the Kirby Hills fault

Figure 13

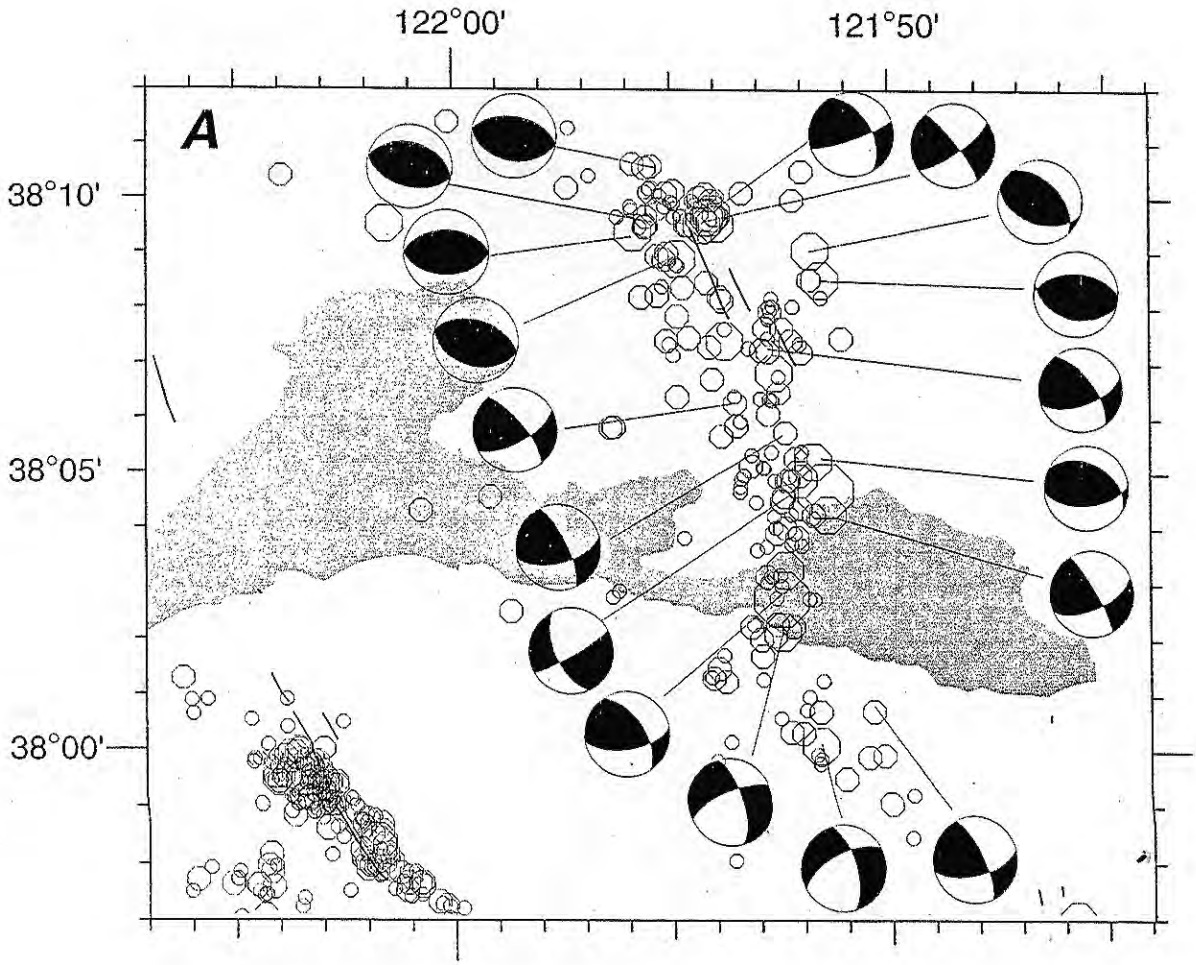
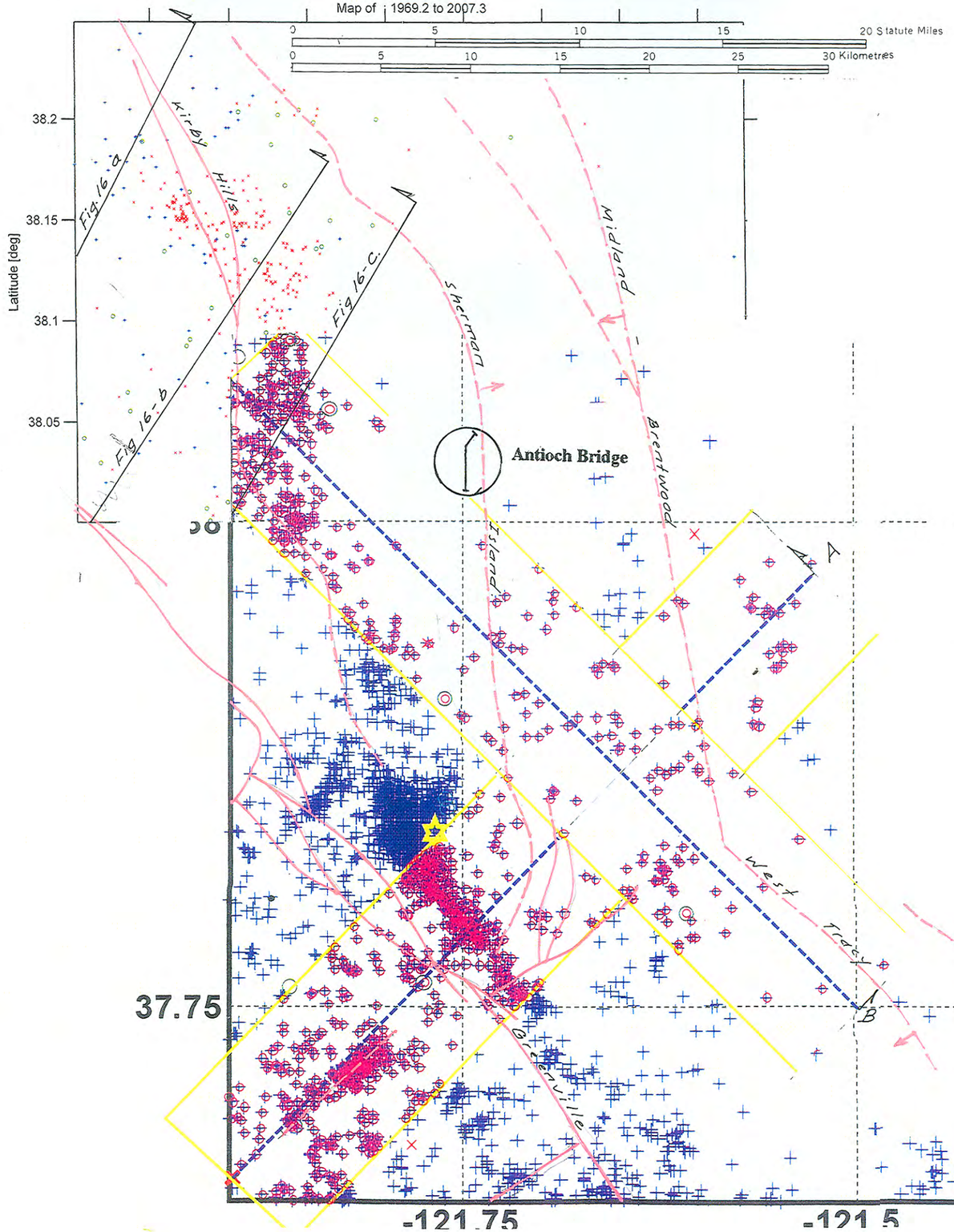
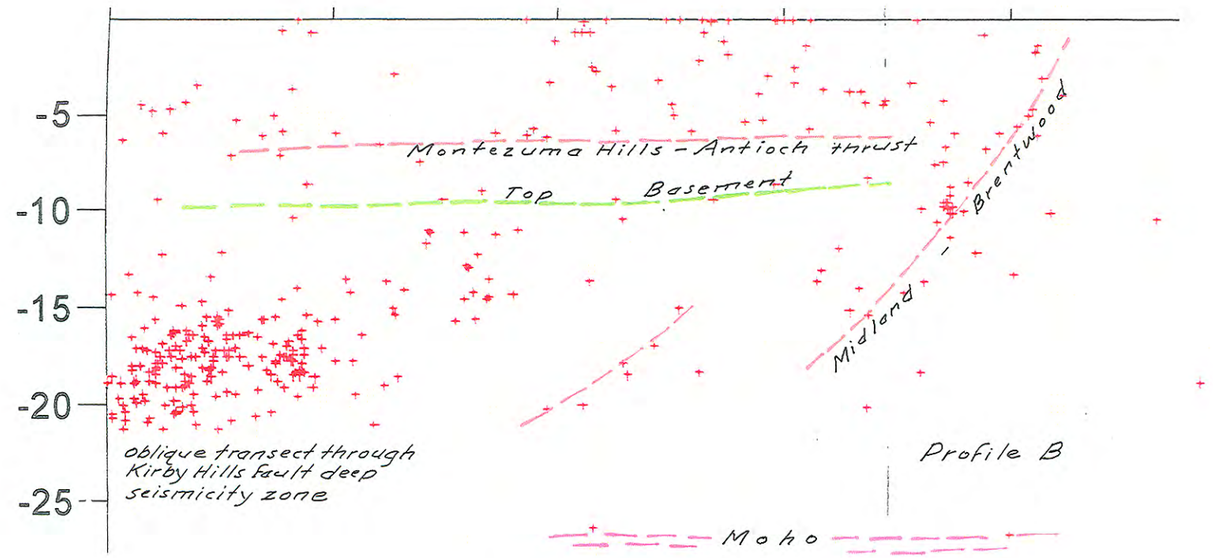


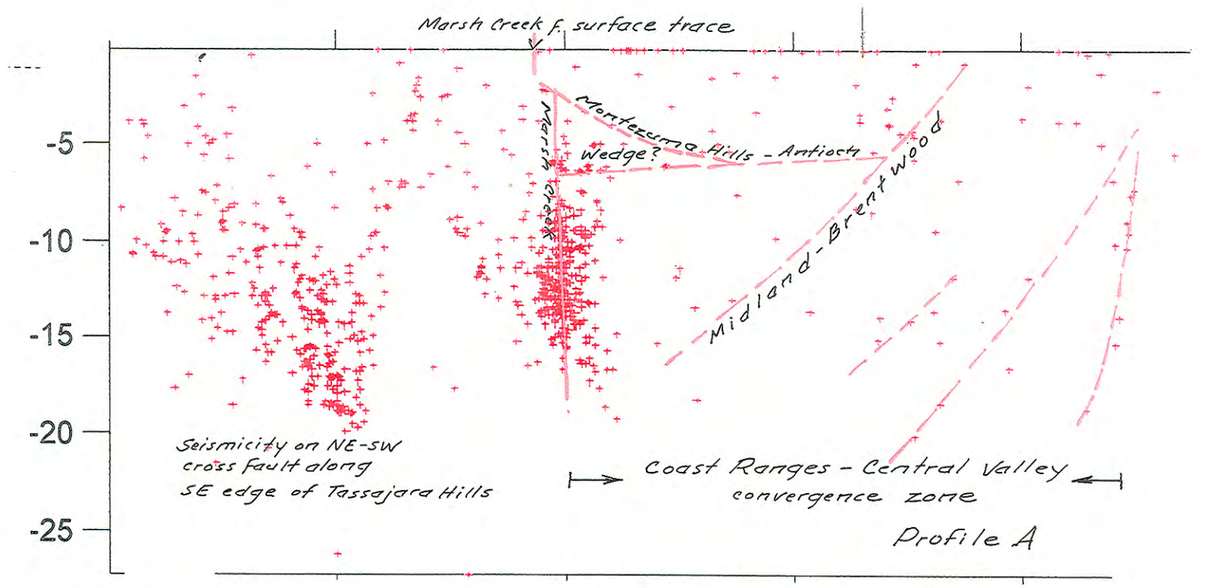
Figure 10.—Kirby Hills Fault zone (see figs. 1, 4 for location). *A*, Focal mechanisms of seismicity associated with zone. All mechanisms have at least 40 first-motion observations. Motion is predominantly right-lateral strike-slip on northwest-oriented faults, but thrust faulting also occurs on west-northwest-oriented planes north of the Sacramento River.

Figure modified from
Parsons et. al., 2002

Focal Mechanisms of Seismicity Associated with the Kirby Hills Fault Zone Figure 14







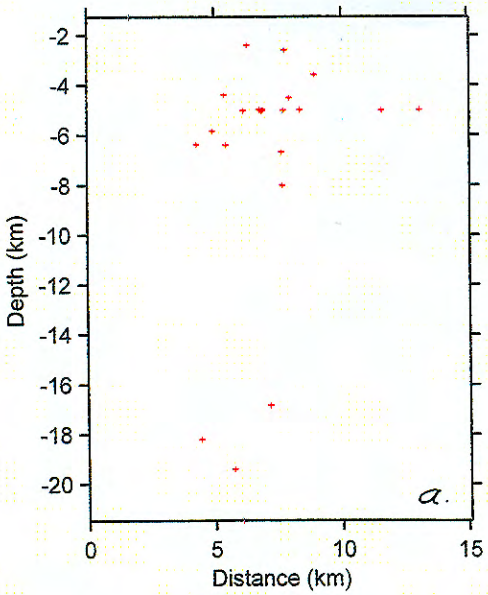
Seismicity Data Source

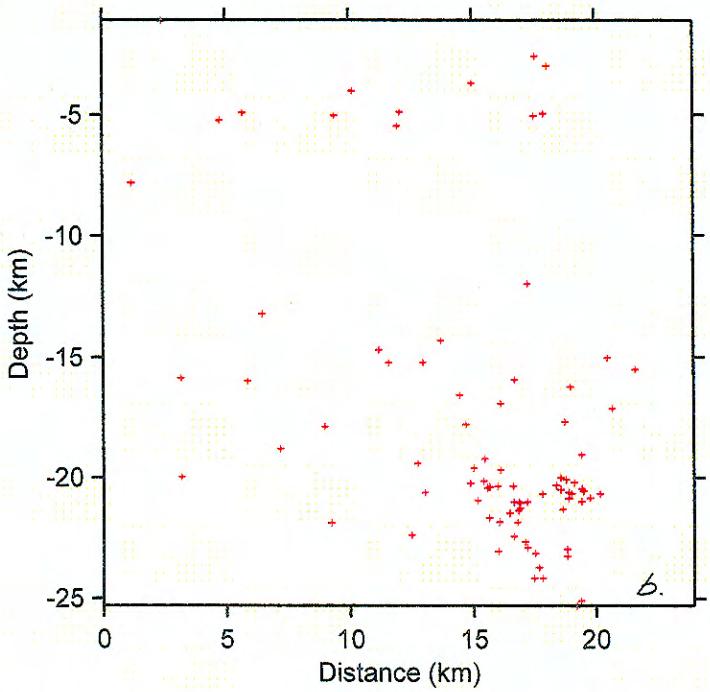
Northern California Earthquake Data Center (NCEDC)

- **Northern California Seismic Network**
- **U.S. Geological Survey Menlo Park**
- **Berkeley Seismological Laboratory, University of California, Berkeley**

Plotted by M. Merriam, C.E.G. using ZMAP system

Map Showing Seismicity in the Suisun Embayment and Brentwood-Los Medanos Hills-Northern Diablo Range Region, with Profiles of Hpocenters in the Brentwood-Los Medanos Hills Region Figure 15





Seismicity Data Source

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- **Northern California Seismic Network**
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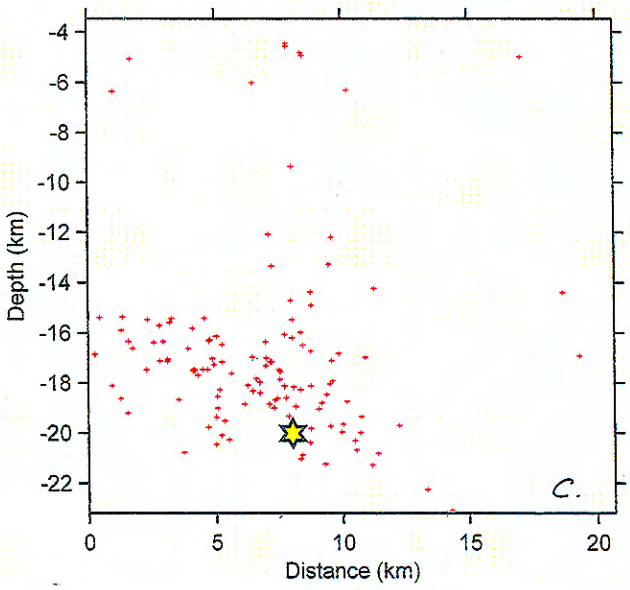
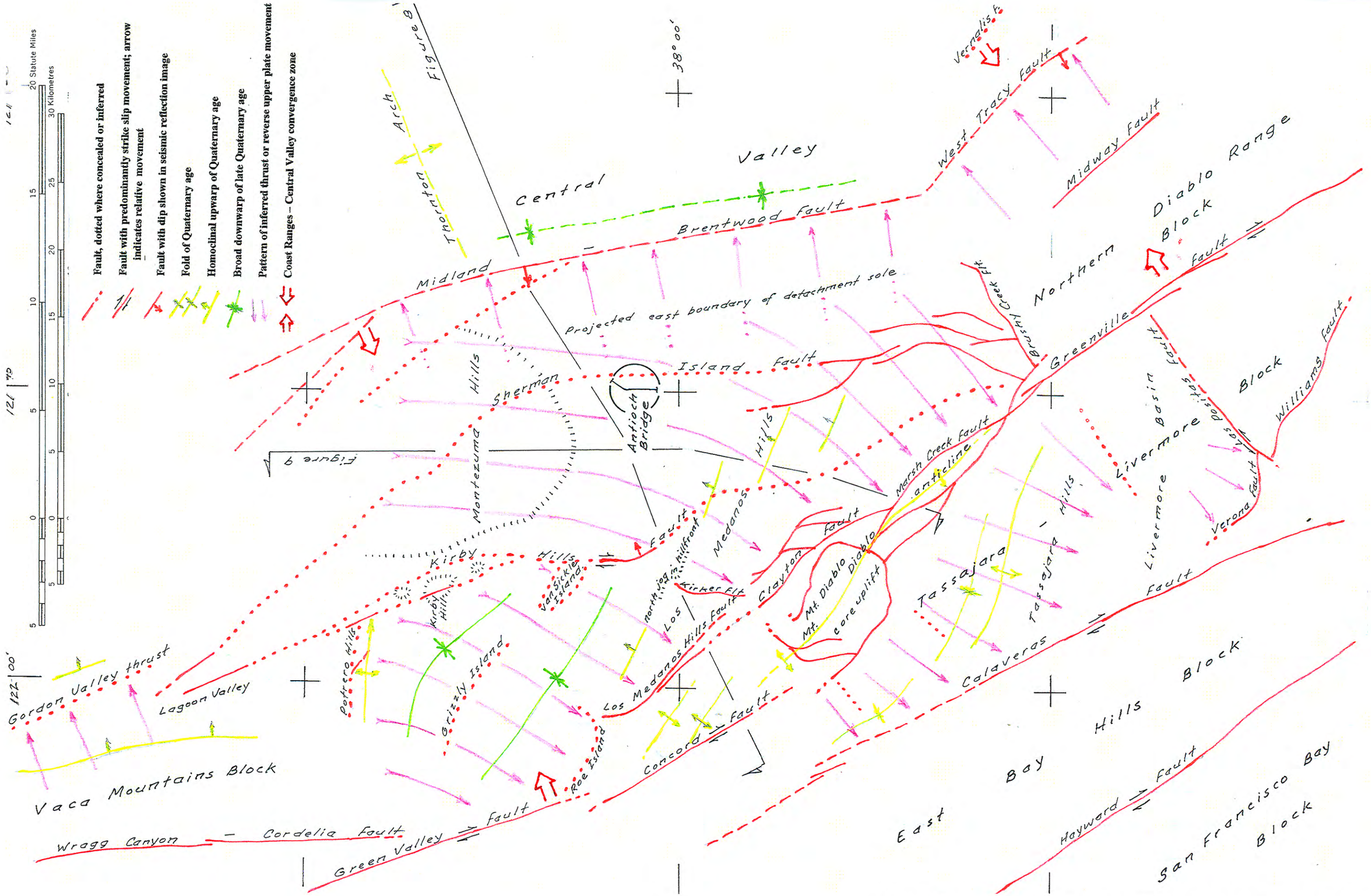
- **Berkeley Seismological Laboratory, University of California, Berkeley**

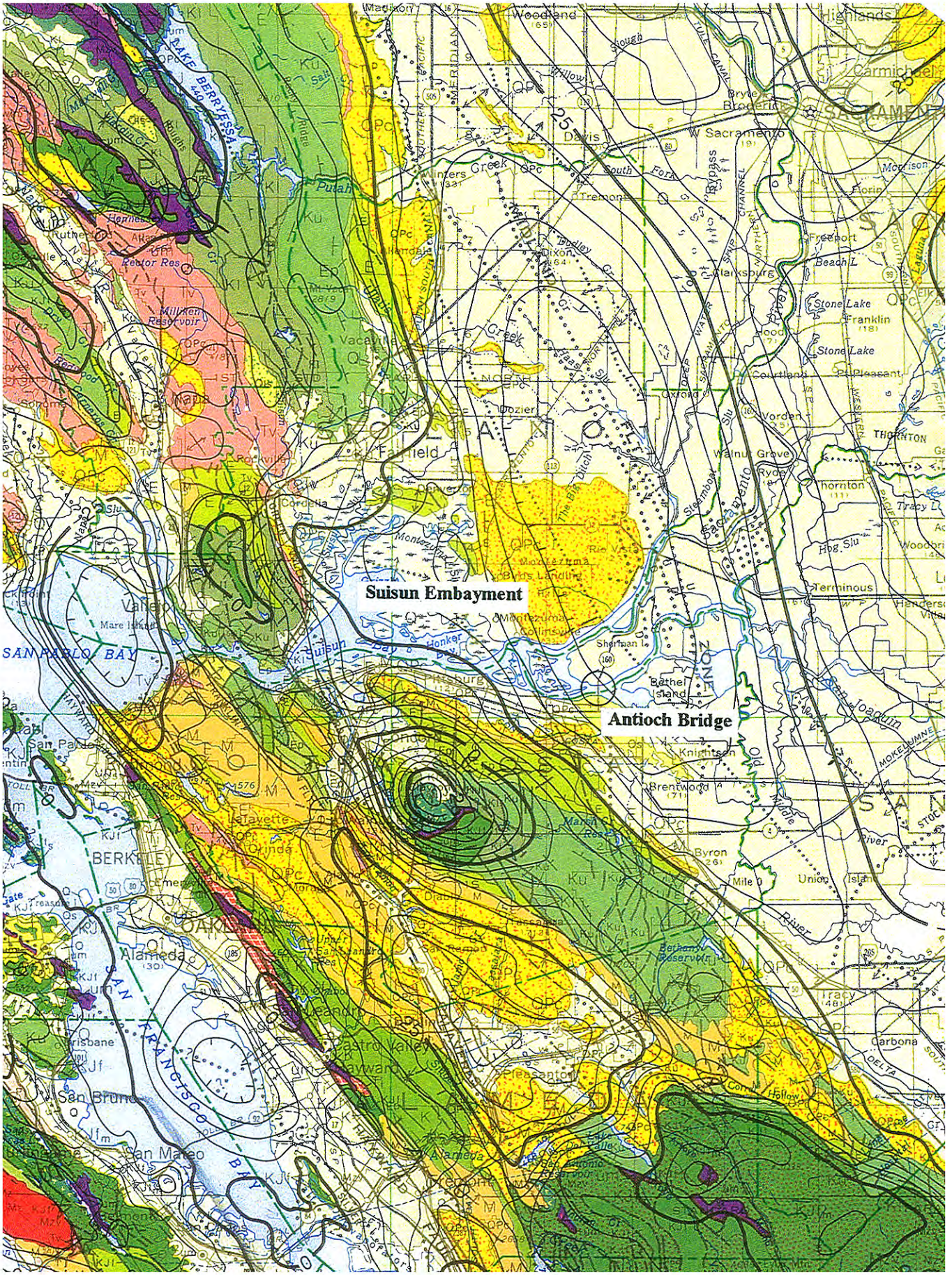
Plotted by M. Merriam, C.E.G. using ZMAP system



Profiles of Hypocenters in teh Potrero Hills-Kirby Hill Area Figure 16

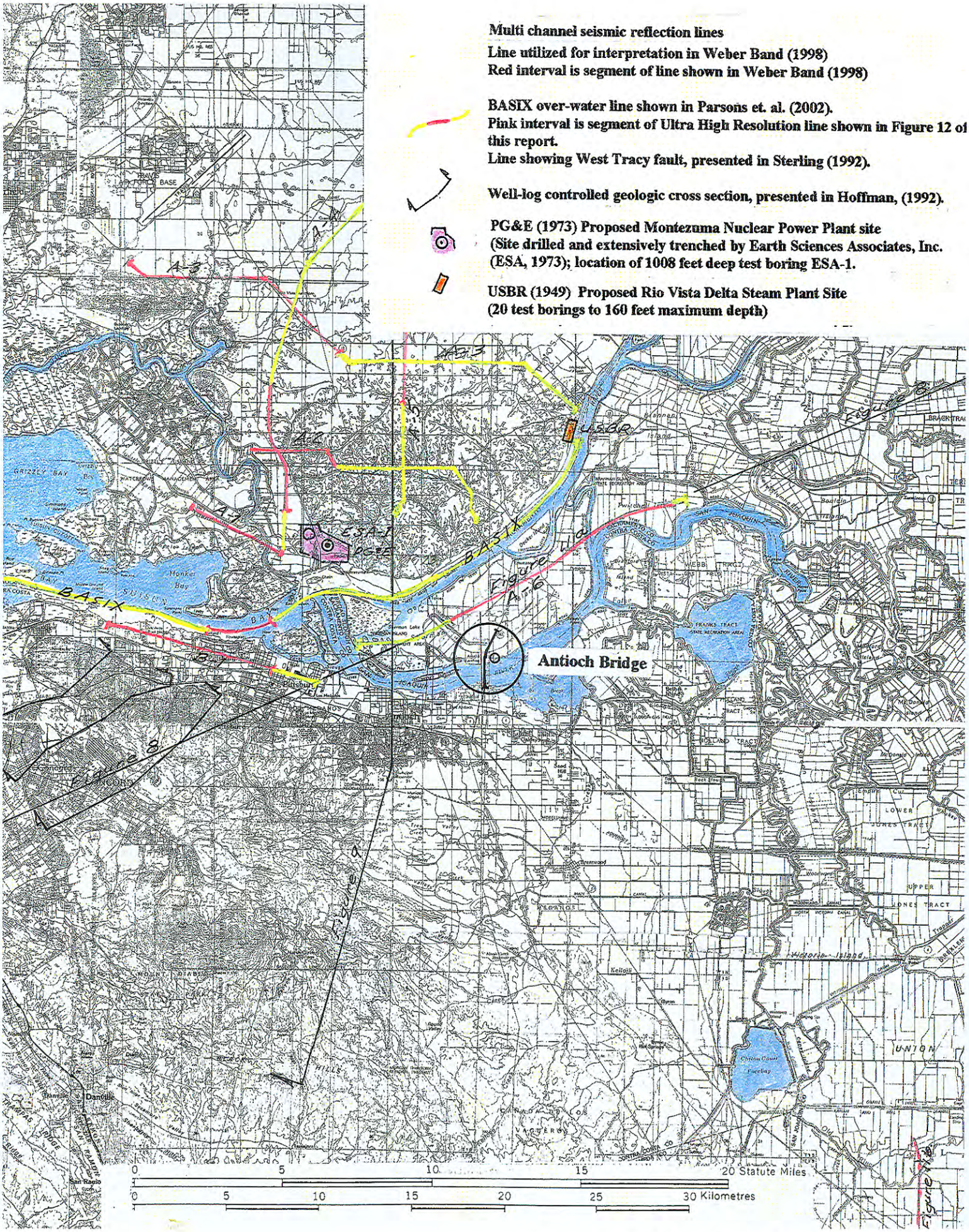


Late Quaternary Tectonics of the Suisun Embayment and Vicinity Figure 17



Map from Roberts et. al., 1990

Isostatic Residual Gravity in the Suisun Embayment Region Figure 18



Exploration and Key Features Map Figure 19

Introduction

Based on our review of current literature and references cited in Mualchin, 1996, we do not believe that the Antioch fault satisfies the Caltrans' Seismic Hazard Map selection criteria for inclusion as a seismic source. The Caltrans' Seismic Hazard Map is currently under review and an updated map is due out later this year or in early 2008. Martha Merriam, a Caltrans engineering geologist working on the map review, has confirmed that the Antioch fault will not be included in the updated map (Merriam, 2007). We agree that it is appropriate for Caltrans to remove the Antioch fault from the Seismic Hazard Map.

Reference and Literature Review

In order to fully appreciate why the Antioch fault should not be considered as a seismic source, it is necessary to understand how the Antioch fault came to be included in the 1996 Caltrans Seismic Hazard Map. Mualchin (1996) cited the following sources as references for the Antioch fault:

1. Hart, E.W., Bryant, W.A., Smith, T.C., Bedrossian, T.L., and Smith, D.P., 1981, Summary report: Fault evaluation program 1979-1980 area (southern San Francisco bay region): California Department of Conservation, Division of Mines and Geology Open-File Report 81-3SF.
2. Hart, E.W., Bryant, W.A., and Smith, T.C., 1983, Summary report: Fault evaluation program 1981-1982 area (northern Coast Range region): California Department of Conservation, Division of Mines and Geology Open-File Report 83-10SF.
3. Mualchin L., and Jones, A.L., 1992, Peak Acceleration from Maximum Credible Earthquakes in California: California Department of Conservation, Division of Mines and Geology Open-File Report 92-01.
4. Jennings, C.W., 1994, Fault Activity Map of California and Adjacent Areas: California Department of Conservation, Division of Mines and Geology, Geologic Data Map No. 6.

In the first reference, Hart, et al., 1981, the Antioch fault is shown on Plate 1 as a previously established Alquist-Priolo Special Studies Zone. However, due to limitations of time and resources, not every Alquist-Priolo Special Studies Zone in the study region was formally evaluated at that time. The Antioch fault was not evaluated during the 1979-1980 study, nor is there any discussion of the Antioch fault in the report. When Hart's 1981 report was published, the Antioch fault was considered to be an active fault by the California Division of Mines and Geology.

For the second reference, Hart, et al., 1983, the 1981-1982 study area covered by the report included only the following counties: Colusa, Del Norte, Glenn, Humboldt, Lake, Marin, Mendocino, Napa, Shasta, Siskiyou, Solano, Sonoma, Tehama, and Trinity counties. The Antioch fault, as shown on the 1996 Caltrans California Seismic Hazard Map, lies entirely within Contra Costa County, which was not included in the 1981-1982 study area. This reference has no relevancy for the Antioch fault.

The third reference, Mualchin and Jones, 1992, relied on the California Division of Geology and

Mines' (CDMG) (now known as the California Geological Survey) characterization of the Antioch fault as a "sufficiently active" and "well-defined" fault in accordance with the Alquist-Priolo Special Studies Zones Act for its inclusion as a seismic source. This characterization, based on a single map (Burke and Helley, 1973), was revisited in the CDMG's 1991 Fault Evaluation Report FER-228 (Wills, 1991). As a result of the evaluation report, the Antioch North and Antioch South Official Maps of Special Studies Zones were withdrawn effective July 1, 1993. The Fault Evaluation Report FER-228 is reproduced in its entirety in Appendix A.

The final reference, Jennings (1994), is cited as the primary source for all faults on 1996 Caltrans Seismic Hazard Map by Mualchin. Jennings shows the Antioch fault as a Quaternary, but not a Holocene, active fault. Jennings cites 4 sources for the Antioch fault:

1. Bortugno, E.J., McJunkin, R.D., and Wagner, D.L., 1991, Map showing recency of faulting, San Francisco-San Jose quadrangle, California, 1:250,000: Department of Conservation, Division of Mines and Geology Regional Geologic Map Series, Map 5A, Sheet 5.
2. Burke, D. B., and Helley, E.J., 1973, Map showing evidence for recent faulting in the vicinity of Antioch, Contra Costa County, California, U.S. Geological Survey Miscellaneous Field Studies Map MF-533.
3. Helley, E.J., and Herd, D.G., 1977, Map showing faults with Quaternary displacement, northeastern San Francisco Bay region, California: U.S. Geological Survey Miscellaneous Field Studies Map MF-881.
4. Wills, C.J., 1991, Fault evaluation report FER-228, the Antioch fault, Contra Costa County, California, California Department of Conservation, Division of Mines and Geology.

Bortugno et al (1991) and Helley and Herd (1977) both relied directly on Burke and Helley's (1973) characterization of the Antioch fault. Only Wills (1991) conducted new field studies on the Antioch fault. Given the contradictions between Wills' and Burke and Helley's findings, Jennings chose a conservative approach and shows the Antioch fault as an inferred Quaternary fault (Figure 1). In explanatory text accompanying the map, Jennings (1994) states, " As with the 1975 *Fault Map of California*, a conservative approach was followed for this new edition—we felt it is better to show those faults where evidence is questionable rather than to ignore them. Hence, some questionable faults may have been included as long as they are based on some reasonable data."

The Antioch fault was formerly thought to be an active fault based solely on the evidence for creep presented by Burke and Helley (1973). Burke and Helley documented evidence at 29 sites that they believed were indicative of active creep and Holocene displacement. In 1991, the CDMG conducted a thorough evaluation of the Antioch fault (Wills, 1991 and 1992). The evaluation included a detailed review of Burke and Helley's map and each of their 29 "actively creeping" sites that were the basis for the Antioch fault's inclusion as an Alquist-Priolo Special Studies Zone, review of numerous regional and site-specific fault studies, aerial photography analysis, surficial mapping, and trenching.

The evaluation of Burke and Helley's "actively creeping" sites found no evidence of active creep

or Holocene movement. Trenching conducted by the CDMG directly across the mapped trace of the fault and through Pliocene to early Pleistocene-aged units did not reveal any evidence of a fault. No geomorphic evidence for active faulting was found. Reviews of previous site-specific fault studies did not uncover compelling evidence of active faulting. On the basis of Wills' findings, it was recommended that the Special Studies Zones of the Antioch North and Antioch South Quadrangles be withdrawn. The Fault Evaluation Report FER-228 was not considered by Mualchin when the Antioch fault was included as a seismic source in 1992 or 1996.

Additionally, San Francisco State University's 20-year Fault Creep Monitoring Project has found no significant movement on the Antioch fault (Galehouse and Lienkemper, 2003 and Galehouse, 2002). The average rate of movement at a site monitored for 19.8 years, and adjacent to an "active creep" site of Burke and Helley, was virtually zero. The rate of movement at a second site monitored for 7.6 years was about 1 mm/year. These findings provide additional support to Wills' conclusions. The findings of the Creep Monitoring Project were not considered by Mualchin when the Antioch fault was included as a seismic source in 1992 or 1996.

For the purposes of the Caltrans California Seismic Hazard Map (Mualchin, 1996) the following general criteria (with some exceptions) were used to select faults:

1. "late Quaternary" and younger displacement,
2. fault length greater than or equal to 10 km,
3. fault located in, or adjacent to, California, and
4. occurrence of historic earthquakes.

Given the current understanding of the nature of the Antioch fault, we do not believe that the Antioch fault sufficiently satisfies these inclusion criteria.

It is assumed that, as Jennings (1994) is used a primary source, Mualchin has also adopted Jennings' definition of "late Quaternary". For the purpose of classifying faults, Jennings (1994) defined the "late Quaternary" as the time period between the Holocene/Pleistocene boundary (10,000 years before present) and approximately 700,000 years before present. However, the "late Quaternary" is an informal and vague geochronological category, undefined by the North American Commission on Stratigraphic Nomenclature (NACSN, 2005) or the International Commission on Stratigraphy (Ogg, 2004). The only formally defined subdivisions of the Quaternary period are the Holocene (present to 10,000 years ago) and the Pleistocene (10,000 to 1.6 million years ago) epochs. The term "late Quaternary" does not have a commonly accepted definition in professional practice.

The Antioch fault does not display any evidence of Holocene faulting. However, along the Antioch fault trace, there are offsets in Miocene-age bedrock. When those offsets occurred has not been definitively established. From Wills (1991):

> "According to Burke and Helley (1973), the Antioch fault offsets the contact between the Miocene Neroly and Cierbo Formations by 1000 feet (about 300 m) right-laterally (Figure 2). DWR (1978) remapped this locality and excavated several trenches across the fault. DWR could verify no more than 46 m of right-lateral offset.

> A long-term slip-rate can be calculated from the offset of these late Miocene units. 300 meters of right-lateral offset (Burke and Helley, 1973) in approximately 10 million years since the deposition of the Neroly Formation (Creely and others, 1982; Graham and others, 1983) yields an average slip-rate since Miocene time of 0.03 mm/yr. The alternative, lesser offset of 46 m (DWR, 1978) yields an average slip-rate of 0.005 mm/yr."

These long-term slip-rates are very low and, when considered in conjunction with bedrock offsets on the nearby Davis fault, suggest that perhaps the Antioch fault was only active sometime between the Eocene and late Miocene (Wills, 1991). Therefore, the Antioch fault does not appear to satisfy the requirement for "late Quaternary" and younger displacement.

The second requirement of Mualchin is that the fault length be at least 10 km in length. The reason for this requirement is due to the relationship between fault length and the size of an earthquake a fault is capable of generating (Wells and Coppersmith, 1994). The 10 km length "correspond(s) to the maximum random earthquake (M6) in California, capable of generating the smallest peak accelerations of interest (at about 10 km from the fault) in this project" (Mualchin, 1996). Depending on the reference source, the length of the Antioch fault varies between 3 and 15 km. Mualchin assigned the Antioch fault a maximum credible earthquake magnitude of 6.75. Using the commonly accepted empirical relationship of Wells and Coppersmith, a magnitude of 6.75 would correspond to a surface rupture length of about 27-28 km, almost twice the greatest length given for the Antioch fault.

As shown on Alquist-Priolo Special Studies maps prior to July 1993, the Antioch fault is approximately 13 km in length. On the 1996 Caltrans Seismic Hazard Map, the Antioch fault is shown as approximately 15 km in length. In Jennings (1994), the inferred length of the Antioch fault is approximately 12 km. In the CDMG fault evaluation report, Wills (1991) reported that the "Antioch fault can be traced as a fault in bedrock for approximately two miles, from Roosevelt Lane to north of Lone Tree Way in Antioch." Wills (1991) further states, "Consultants have not found the fault south of Lone Tree Way. The connection mapped between the Antioch fault and the Davis fault apparently does not exist." Based on trenching performed by the CDMG and others, the Antioch fault does not appear to satisfy the requirement of a minimum length of 10 km.

The fourth requirement of Mualchin is the occurrence of historical earthquakes. Mualchin includes those faults that, while they may not have verifiable late Quaternary displacement, are associated with historical seismicity. Examining a map of historical seismicity, the mapped Antioch fault is located within a less active belt of seismicity extending from the west side of the San Joaquin Valley, through the Antioch area and northward through the Sacramento Valley. To the west of the Antioch fault is a trend of deep (>15-20km), right-lateral, oblique and reverse earthquakes. This trend is not at the same location or orientation as the mapped Antioch fault. Historical earthquakes in the Antioch area include the 1965 M4.9 and 1889 M6 earthquakes. The 1965 quake occurred on a northwest-trending fault plane at a depth of about 15 km (McEvilley and Casaday, 1967). Aftershocks of the 1965 quake define a north-northeast trending fault zone, inconsistent with first-motion studies. The 1889 earthquake caused small

fissures to appear along the Main Street (since renamed to I Street) of Antioch. This street crosses a filled slough and the fissures may only represent fill settlement (Wills, 1991). There is no evidence to indicate that this earthquake occurred on the Antioch fault and may have occurred on a nearby fault such as the Pittsburg-Kirby Hills fault. The Antioch fault has not definitively satisfied the requirement of historical earthquakes.

Conclusions

The Antioch fault's inclusion in the 1992 version of the Caltrans' Seismic Hazard Map was based on its incorrect characterization as an active fault by the California Geological Survey (then known as the California Division of Mines and Geology, CDMG). It appears that the CDMG's later removal of the Antioch fault as an Alquist-Priolo Special Studies Zone was not considered when the 1996 version of the Caltrans' Seismic Hazard Map was prepared. Given our increased understanding of the nature of the Antioch fault, it is appropriate that Caltrans will not include the Antioch fault as a seismic source in the updated Seismic Hazard Map due out later this year or in early 2008.

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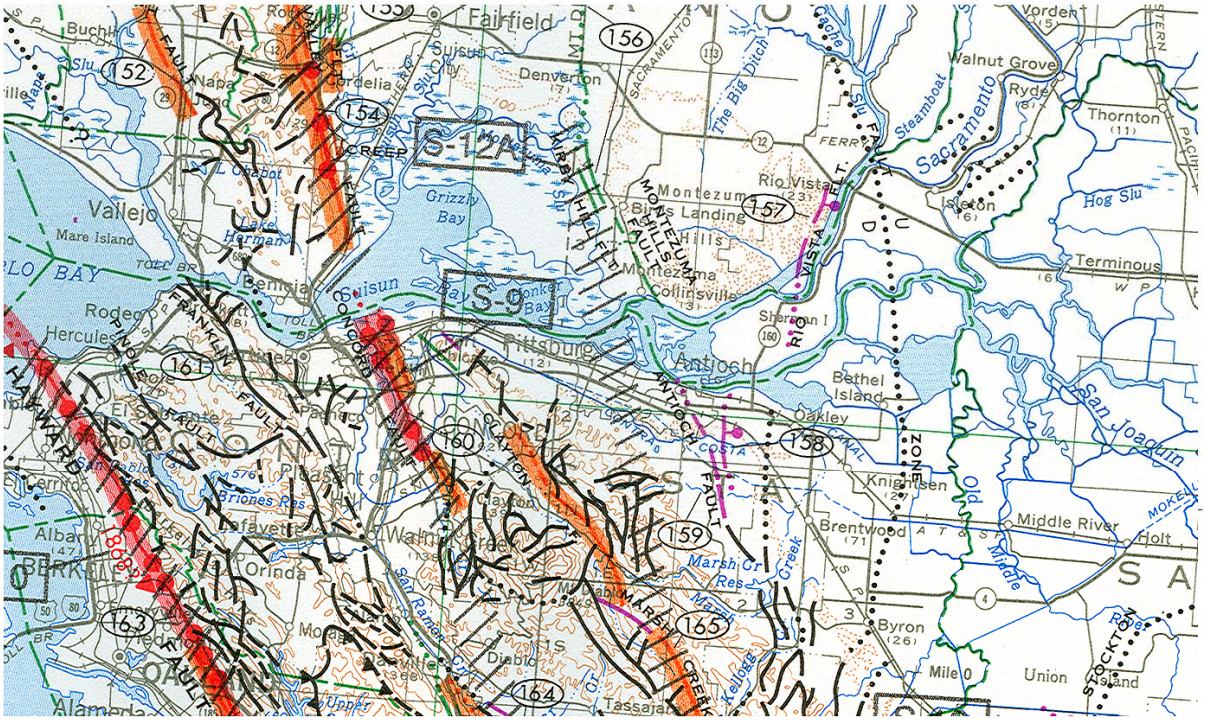

10 0 10 20 30 40 50 Miles

10 0 10 20 30 40 50 60 Kilometers

Geologic Time Scale			Years Before Present (Approx.)	Fault Symbol	Recency of Movement	DESCRIPTION ON LAND	DESCRIPTION OFFSHORE
Quaternary	Late Quaternary	Historic				Displacement during historic time (e.g. San Andreas fault 1906). Includes areas of known fault creep.	
		Holocene	200			Displacement during Holocene time.	Fault offsets seafloor sediments or strata of Holocene age.
		Pleistocene	10,000			Faults showing evidence of displacement during late Quaternary time.	Fault cuts strata of Pleistocene age.
	Early Quaternary		700,000			Undivided Quaternary faults – most faults in this category show evidence of displacement during the last 1,600,000 years; possible exceptions are faults which displace rocks of undifferentiated Plio-Pleistocene age.	Fault cuts strata of Quaternary age.
			1,600,000			Late Cenozoic faults within the Sierra Nevada, including parts of, but not restricted to, the Foothills fault system. These faults may have been active in Quaternary time.	
Pre-Quaternary			4.5 billion (Age of earth)			Faults without recognized Quaternary displacement or showing evidence of no displacement during Quaternary time. Not necessarily inactive. Pre-Quaternary faults not shown in Nevada and Oregon.	Fault cuts strata of Pliocene or older age.

Figure 1. Antioch fault as shown in Jennings (1994)

Appendix A. Fault Evaluation Report FER-228, the Antioch fault, Contra Costa County, California, California Department of Conservation, Division of Mines and Geology

CALIFORNIA DIVISION OF MINES AND GEOLOGY
FAULT EVALUATION REPORT FER-228

The Antioch fault, Contra Costa County, California

by

Christopher J. Wills
Associate Geologist
November 6, 1991

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INTRODUCTION

The Antioch fault was first mapped by Burke and Helley (1973) as an active, creeping fault. Based solely on the data shown on this map, it was included within an Alquist-Priolo Special Studies Zone in 1976. Since that time, numerous consulting geologists have investigated the fault but none have found convincing evidence for Holocene offset.

The continuing inability of consulting geologists to find evidence for Holocene offset on the Antioch fault suggests that the fault may not be "sufficiently active and well defined" (Hart, 1990) for zoning under the Alquist-Priolo Act. Available published and unpublished reports have been reviewed for this study.

GEOLOGIC SETTING

The Antioch area is located on the eastern margin of the Coast Ranges adjacent to the Sacramento-San Joaquin delta. Bedrock of the area consists of north-dipping Eocene through Pliocene sedimentary rocks. Resistant beds, mostly sandstones, of these rocks form east-west strike ridges in the hills south of Antioch. Surface mapping (Colburn, 1961; Brabb and others, 1971; Dibblee, 1981) and correlation of subsurface units in the Brentwood oil field (Ditzler and Vaughan, 1964) show that the bedrock forms a north-dipping homoclinal sequence. This sequence is cut by faults that trend north and northwest.

The youngest of the bedrock units, a poorly bedded nonmarine conglomerate, siltstone and sandstone, has been assigned to the Wolfskill Formation (Brabb and others, 1971) or the Tehama Formation (Burke and Helley, 1973). This unit overlies the 4.5-million-year-old Lawlor Tuff, and contains the 3.3-million-year-old Putah Tuff (Sarna-Wojcicki, 1976).

The older parts of Antioch are built on an alluvial plain composed of horizontally bedded sand and silty sand mapped as "older sediments" (Burke and Helley, 1973) or "older alluvium," (Atwater, 1982). The alluvium is overlain by eolian sand of the upper Modesto Formation east of Antioch. Radiocarbon dating shows that the Modesto Formation is younger than about 40,000 years and older than about 10,000 years (Atwater, 1981; Marchand and Aldwardt, 1981); therefore the older alluvium of the Antioch area must be of latest Pleistocene age or older.

The soils formed on the Antioch alluvial plain also suggest a late Pleistocene surface. These soils, mapped as the Ambrose clay loam (Carpenter and Crosby, 1939) or the Rincon clay loam (Welch, 1977), are described as having a well developed Bt horizon with extremely hard angular blocky structure and many clay films. This soil was described for this report near the Antioch fault in Antioch (see soil descriptions, Appendix A). The thickness and development of its B horizon suggest that the soil took more than 10,000 years to form.

Minor streams draining north to the San Joaquin River have dissected the Antioch alluvial plain. One of these streams, which reached the San Joaquin River between J and L Streets in Antioch, formed a channel now filled with up to 50 feet of bay mud, peat and marsh deposits (Diablo Soils Engineers, 1980; Harding Lawson Associates,1977,1986a). The depth of soft sediments in this channel and adjacent to the San Joaquin River suggest that the channel was graded to a level about 50 feet lower than the present elevation of the San Joaquin River.

The current river elevation at Antioch is only about 5 feet above sea level, therefore the low river base level must have coincided with a low sea level stand. Since the most recent low stand was about 22,000 years ago, the stream channel must be approximately 22,000 years old. By the law of superposition, the Antioch alluvial plain must be older than the channel incised into it. Additionally, the marsh deposits now filling the stream channel probably were deposited in Holocene time as sea level approached its present elevation.

THE ANTIOCH FAULT

Regional Studies

South of Antioch, north- to northwest-trending faults have been mapped at the surface (Colburn, 1961; Brabb and others, 1971; Dibblee, 1981) and by correlation of subsurface units in the Brentwood oil field (Ditzler and Vaughan, 1964). These maps show right-lateral separation of north-dipping sedimentary units across these faults (Figure 2). This sense of separation is consistent with normal, down-to-the-east, or right-lateral offset. Ditzler and Vaughan (1964) present a structure contour map based on oil well data that shows three faults in about the same position and orientation as the Davis fault of Colburn (1961) and Brabb and others (1971). One of these faults offsets both limbs of a minor fold right-laterally by about the same amount, suggesting that the displacement is predominantly right-lateral. Another, parallel fault has predominantly normal offset.

Burke and Helley (1973) proposed that a previously unmapped fault explained the alignment of parts of the Davis fault, another bedrock fault in Antioch, the linear ridge of Fraser Shoal in the San Joaquin River, and the linear west edge of the Montezuma

Hills. They show a single, straight, N30°W-trending fault cutting Tertiary sedimentary rocks in the hills south of Antioch and a zone of "anomalous features" in the City of Antioch that they thought could be due to fault creep. They proposed that creep displacement had occurred on this fault in the very recent past, possibly triggered by a series of small earthquakes in 1965. Although Burke and Helley did not formally name this fault, it quickly became known as the Antioch fault by consultants and others working in the area (Burkland and Associates, 1975; DWR, 1978).

The "Antioch fault" commonly referred to in recent studies and in this report includes this new fault mapped by Burke and Helley (1973) and those parts of the Davis fault south of the junction of the two faults (Figure 2). This usage probably came about because Burke and Helley noted evidence for recent movement on the Antioch fault and parts of the Davis fault and because the Alquist-Priolo Special Studies Zones Maps (CDMG, 1976a,b) show only those traces, which appear to form a single fault (Figure 3). The trace of the Antioch fault referred to in this report also includes a line drawn down the center of Burke and Helley's "zone of anomalous features" by CDMG on the Antioch North quadrangle. This part of the trace was drawn for zoning purposes and does not nessecarily reflect field observations.

Assuming that the offset on the Antioch and Davis faults is purely right-lateral, as suggested by Burke and Helley (1973), total offset can be measured at several locations. The apparent right-lateral offset of Eocene beds across the Davis fault is approximately 1200 m. (Brabb and others, 1971; Burke and Helley, 1973)(Figure 2). According to Burke and Helley (1973), the Antioch fault offsets the contact between the Miocene Neroly and Cierbo Formations by 1000 feet (about 300 m) right-laterally (Figure 2). DWR (1978) remapped this locality and excavated several trenches across the fault. DWR could verify no more than 46 m of right-lateral offset.

A long-term slip-rate can be calculated from the offset of these late Miocene units. 300 meters of right-lateral offset (Burke and Helley, 1973) in approximately 10 million years since the deposition of the Neroly Formation (Creely and others, 1982; Graham and others, 1983) yields an average slip-rate since Miocene time of 0.03 mm/yr. The alternative, lesser offset of 46 m (DWR, 1978) yields an average slip-rate of 0.005 mm/yr.

The average slip-rates calculated above are unusually low for an active fault in the San Andreas fault system. They suggest that the Antioch fault was active for only a short period. The proposed post-Miocene offset of 300 m could accumulate in only 300,000 years at the low (for the San Andreas fault system) slip rate of 1 mm/yr. It is then important to determine if the fault was active primarily in the Miocene (as tentatively proposed by

DWR, 1978), or has formed recently and is still active (as Burke and Helley's creep data suggest).

Total displacement of bedrock units of different ages should reflect the age of displacement on the fault. As noted above, Eocene rocks are offset across the Davis fault about 1200 m. Miocene rocks are offset a total of about half that amount; 300 meters across the Antioch fault and 360 m across the Davis fault according to Burke and Helley (1973). Much of the movement therefore appears to have occurred between Eocene and late Miocene times.

Evidence for creep

Burke and Helley's (1973) conclusion that the Antioch fault is creep-active led the Division of Mines and Geology to issue Alquist-Priolo Special Studies Zones maps of the Antioch North and Antioch South quadrangles in 1976 (CDMG, 1976a;1976b). Zones established in 1976 were based on more permissive criteria than the current standard of "sufficiently active and well defined" (Hart, 1990). Nevertheless, the Antioch fault probably would not have been zoned if it were not for the probable creep reported by Burke and Helley.

Because Burke and Helley's (1973) evidence for fault creep is the critical data for active faulting in Antioch, each of their localities was revisited in 1991. Burke and Helley's observations at each of their 29 sites are listed verbatim below. Field observations by this writer in May and June 1991 follow each of Burke and Helley's descriptions in small type (see Figure 2 for locations):

1. Distorted railroad sidings; main-line tracks seemingly undisturbed.

   This site has been modified substantially since Burke and Helley's observation: all the sidings have been removed, leaving only the main line. The main line does appear to be slightly deflected right laterally at the projection of K Street. This site corresponds to the eastern edge of an old slough, filled with very soft bay mud, peat and artificial fill. Settlement of the soft sediments toward the San Joaquin River could produce a right lateral deflection.

2. Right-lateral offsets on curbs on both sides of street. Horizontal displacements of 2 mm on north side, 7 mm on south. No walks on street.

   Some settlement and cracking of curbs was noted on the north side of 2nd Street between J and K Streets. There is no systematic offset of curbs or walks.

3. No offset fractures on 1970 walks and curbs.

   No evidence for faulting noted.

4. Zone of thoroughly fractured asphalt in street trending N20W. Undisturbed 1973 walk and curb on extension of zone on east side of street.

   This is along the old slough. Drilling on the west side of the street (Diablo Soils Engineers, 1980) penetrated about 12 feet of fill over about 12 feet of bay mud and peat. The drill stem sank through the bay mud and peat under its own weight. This area is obviously highly prone to settlement and associated cracking.

5. Fractures but no offsets between joints on old curbs on both sides of street. Newer walks undisturbed.

This is at edge of old slough, cracking is probably due to settlement. No evidence for faulting observed.

6. Dirt road with no walks or curbs.

No evidence for faulting.

7. Right-lateral offsets on old curbs on both sides of street. Horizontal displacement of 4 mm on north side, 2 mm on south. Walks recently replaced and undisturbed.

This is at edge of old slough, at the base of a sinuous scarp. Curbs with minor (<5 mm) deflections noted on 4/15/91. They are probably due to settlement.

8. Right-lateral offset of 2 mm on old curb on north side of street; no disturbance in younger (1966?) walk. Right-lateral offset of 12 mm along joint on old curb on south side aligned with 2 mm offset between joints on old walk.

There are no curbs or walkways in this block. Examination of aerial photographs shows that there were no curbs or walkways in this block in 1950 or 1973 (USDA, 1950; Pacific Resources Inc, 1973; Cartwright Aerial Surveys, 1973). This locality may have been mislocated by Burke and Helley (1973).

9. Two fractures with 1 mm of right-lateral offset each on old curb on north side of street; new walk undisturbed. One fracture but no lateral offsets between joints on old curb on south side; new walk undisturbed.

Random minor right-lateral and left-lateral deflections observed.

10. East-west buckle with about 15 cm of relief on west side of road with joint on crest. Old curb and asphalt-covered concrete street are buckled, but new walk undisturbed. Buckle dies out eastward, and east side of street is unaffected.

No buckle of this size or unusual cracks in old curbs and gutters or street. Perhaps this refers to a minor buckle with less than 2 cm relief (possible typo on MF 533, maybe it should read 15 mm relief).

11. East-west buckle with about 2 cm relief on east side of street in walk and curb with numerous patchwork repairs; joint on crest. Buckle dies out westward, and west side of street is unaffected.

Walkways have been replaced adjacent to 809 H Street, no cracks suggestive of faulting were observed.

12. Broad east-west buckle with about 3 cm of relief on walk and curb on east side of street.

Settlement of curbs and minor cracks in this area, buckle not verified.

13. Patchwork repair of curbs with many fractures of inconsistent offset in older portions. No offsets on more uniform younger walks.

Random minor cracks in old curbs and sidewalks.

14. Patchwork repair of walks and curbs. No obvious buckles unrelated to tree root growth.

Random minor cracks, buckles clearly related to tree roots.

15. No offset fractures between joints; inconsistent small offsets along joints.

Random minor cracks.

16. Right-lateral offset of 5 mm and other slight left- and right-lateral offsets on old curb on north side of street. Right-lateral offset of 3 mm on old curb on south side. Numerous left- and right-lateral offsets on walks on both sides of streets.

Curb on N side of 12th Street has been replaced adjacent to two trees.

17. Three offset fractures on 1948 curb on north side of street: 5 mm right-lateral with adjacent undisturbed young walk; 1 mm right-lateral with adjacent 1948 walk similarly offset 2 mm; 2 mm left-lateral with adjacent 1948 walk undisturbed. Three right-lateral offsets of 1,2, and 3 mm and two left-lateral offsets of 1 and 3 mm on 1948 walk and curb on south side.

15 mm right-lateral offset of curb on north side of street adjacent to 418 W 13th Street does not extend into walk or street. 2 mm right-lateral on crack about 50 feet to east near transverse cracks in walk and street, no cracking in curbs directly across street.

18. Open cracks as much as 1 cm wide in north and east walls of cafeteria and generally northwest-southeast fractures in floor with extension and relative down-drop to the northeast of about 5 mm.

No fault found in trenching by Woodward-Clyde Consultants (1975). Examination of surrounding streets at that time by WCC (1975; A. Ridley p.c. 1991) and Earl W. Hart of CDMG (p.c. 1991) could not confirm any systematic offsets or deformation of streets. Distress to building is thought to be due to expansive soil.

19. Right-lateral offset of 7 mm on pre-1965 curb on south side of street adjacent to undisturbed 1966 walk; undisturbed 1966 repair patch in walk and curb on north side.

Curb on south side of street noted is still apparently offset about 7 mm. It does not align with any cracks in walkway or street. No faults found in trenching on N side of 18th Street by Kaldveer Associates (1989).

20. Numerous fractures with no offsets or with right-lateral offsets of less than 2 mm in 1957 walks and younger (but pre-1965) curbs. Fractures on north side of street occur largely in western part of area; fractures on south side occur largely in eastern part.

No evidence for faulting observed.

21. Thoroughly disturbed old walks, curbs, and asphalt-covered concrete street with many large trees. No obvious anomalous offsets or buckles.

No evidence for faulting observed.

22. Fractures with no offsets or with right-lateral offsets of less than 2 mm on old curb on north side of street; undisturbed new curb. Undisturbed new walk and curb on south side.

No evidence for faulting observed.

23. No obvious distortion of railroad tracks, although much of the original siding has been removed.

No evidence for faulting observed. Burkland and Associates (1975) and Kneupfer (1977) note several cracks in concrete walls to E which have minor right-lateral offsets. None extend into adjacent pavement.

24. Right-lateral offset of 2 mm and left-lateral offset of 1 mm on pre-1960 curb on north side of street; undisturbed 1972 walk. Two right-lateral offsets on south side: 5 mm offset on pre-1960 curb with undisturbed new walk; 2 mm on pre-1960 curb, walk, and low retaining wall.

No unusual cracks or offsets in curbs constructed in the early 1950's, walks dating from the late 1950's or in street. The "low retaining wall" is apparently an old brick planter with many random cracks.

25. Largely new undisturbed construction. Many large trees near remaining older construction; no obvious anomalous offsets or buckles.

Burkland and Associates (1975) and Kneupfer (1977) noted cracks in curbs and a scarplet in a street in this area. Their conclusions will be discussed in more detail below.

26. East-west buckles in early-1960's walks and curbs with about 2 cm of relief.

No unusual cracks in old sidewalks curbs or street.

27. Two left-lateral offsets of less than 1 mm on early-1960's walk and curb on north side of street. Right-lateral offset of 8 mm on similar walk and curb on south side.

Darwin Myers and Associates (1981) also noted these cracks in the curbs as well as distress to the adjacent house on the north side of the street and distress to two houses and a retaining wall to the southeast. Field checking for this report revealed no consistent sense of cracking or zone of cracks. Cracks do not suggest right-lateral displacement, they may be due to expansive soils.

28. On north side, canal lining bulged inward about 4 cm and left-laterally offset about 5 mm. On south side where drain pipe enters canal, lining bulged inward about 5 cm.

Bulges and left-lateral offset verified, all appear to be larger than described by Burke and Helley. No right-lateral offset observed.

29. Indistinct, east-facing step in alluvium no more than 15 cm high. Stream channel on higher, western side entrenched to level of eastern side.

Site was investigated and trenched by DWR (1978) who verified fault in bedrock and probable fault in 100,000 to 200,000 year old alluvial material, Fault did not cut alluvial material estimated to be 50,000 to 70,000 years old. Scarp could not be verified by DWR (1978).

Of the 29 sites where Burke and Helley (1973) describe evidence for creep (Figure 2), seven sites (3,5,6,14,15,23 & 25) provide no evidence of ground deformation of any kind. Eleven sites (10,11,12,13,18,19,21,22,26,28 & 29) provide evidence of some

type of ground deformation but not right-lateral offset. Most are easily explained by expansive soils or settlement. Eleven sites (1,2,4,7,8,9,16,17,19,24 & 27) suggest possible right-lateral offsets. Of these, sites 1,2,4,7,8 & 9 are within or along the margin of an old slough which contains very soft sediment that is prone to settlement. The remaining five sites (16,17,19,24 and 27), record only minor, isolated, right-lateral offsets of curbs, sidewalks or planters. No consistent offsets in nearby curbs, linear zones of cracks, or en echelon cracks in pavement were found. None of the minor offsets that could be relocated have grown significantly in the 18 years since they were noted by Burke and Helley.

As part of his measurements of creep on Bay Area faults, J.S. Galehouse of San Francisco State University, has repeatedly surveyed two arrays across the Antioch Fault. One of these, adjacent to site 26 of Burke and Helley, has shown no systematic movement in more than 10 years of monitoring. The other, in the bedrock hills near Lone Tree Way, may have had very slight right-lateral slip across it, but the amount of movement is within the possible measurement error. Galehouse (1990) concludes that "not much, if any, net slip" has occurred on the Antioch fault at the two monitoring sites.

Geomorphic expression

Geomorphic evidence for faulting along the trace of the Antioch fault was interpreted on aerial photographs and checked in the field. Aerial photographs of 1:27,000 scale, and 1:20,000 scale, taken by the USDA in 1939 and 1950 respectively, were used for the entire area. Aerial photographs of 1:12,000 scale taken by Cartwright Aerial Surveys (1973) were also consulted at the Contra Costa County Community Development Department. Field checking of geomorphic features was done in conjunction with field checking of creep localities and geologic exposures in April and May 1991. Geomorphic features will be described from northwest to southeast.

The "zone of anomalous features" mapped by Burke and Helley (1973), reaches the San Joaquin River in a low-lying area on the west side of downtown Antioch. This low area is an old slough, now largely filled in, that follows a meandering northerly course between H and K Streets (locality 1, Figure 3). The slough is apparent on the USGS 7½ minute Antioch North quadrangle (1953) as a series of artificial closed depressions (bounded by slightly raised streets) from the San Joaquin River to south of 10th Street. It is also apparent as a swampy, sparsely developed area on 1939 and 1950 aerial photographs. The meandering, northerly course of the slough indicates that its location is not controlled by the northwest-trending Antioch fault.

The mapped trace of the Antioch fault crosses the east bank of the slough at a low angle. It then crosses the alluvial plain upon which much of Antioch is built. No geomorphic features suggestive of active faulting were observed along the mapped trace of the Antioch fault on this alluvial plain. Since the geologic relationships, geomorphic setting and soils development on this alluvial plain indicate that it is of late Pleistocene age (Atwater, 1982 and discussion above), the lack of any geomorphic expression of faulting suggests that no Holocene faulting has occurred.

Tonal lineaments on the Antioch alluvial plain were observed on the 1939 USDA photos. These vague lineaments are northeast of the trace of the Antioch fault and trend more westerly than the fault (locality 2, Figure 3). They are defined on the aerial photographs by a change in color of the vegetation and possibly in the soil. This contrast could be due to differences in soil composition or soil moisture. The tonal lineaments do not form a narrow zone or pattern that suggests faulting nor are they associated with any topographic features that suggest faulting. They are roughly parallel to the belt of late Pleistocene dunes of the Modesto Formation east of Antioch (Atwater, 1982) and may be due to variations in eolian sand content in the soil.

South of the Antioch alluvial plain, the trace of the Antioch fault passes into an area underlain by a north-dipping homoclinal sequence of Pliocene Tehama Formation and older bedrock units. This area is characterized by low, rolling hills underlain by relatively resistant bedrock and broad valleys underlain by less resistant bedrock. Hills underlain by the Tehama Formation and the Miocene Neroly and Cierbo Formations are typically rounded, with broad flat tops and steep sides. They reach an elevation of up to 220 feet (up to about 100 feet above the surrounding valleys).

The Antioch fault passes through the northernmost hills without any distinctive geomorphic features along its projected trace. At one locality within the hills, however, (locality 3, Figure 3) a relatively linear southwest-facing hill front and swale follow the mapped trace of the fault. These features are not linear in detail; the hill front is marked by several projections and reentrants and the swale is somewhat sinuous.

South of the Contra Costa Canal, a resistant "spine" of calcite cemented fault breccia marks the trace of the fault along the crests of three linear ridges (Burke and Helley, 1973) (locality 4, figure 3). This "spine" apparently projected several feet above the surrounding hill crests before the area was graded (photograph in Kneupfer, 1977, p. 33).

In order for the fault breccia to be expressed as a spine along linear ridges, it must be more resistant to erosion than the

surrounding bedrock. This seems inconsistent with recent faulting that would fragment the calcite, making it more susceptible to dissolution and erosion. If the calcite cementing was fragmented by recent fault movement, the fault breccia would form a series of topographically low areas, features such as linear valleys, saddles and side-hill benches typical of active faults.

The linear spine of calcite-cemented fault breccia is not unique to the mapped trace of the Antioch fault. Other similar features were noted on aerial photographs in the same area (Cartwright Aerial Surveys, 1973). One tonal lineament along the crest of a line of hills trends approximately N30°E and appears to be a conjugate shear to the N30°W Antioch fault (Figure 3).

Tonal lineaments are evident south of the linear fault breccia outcrops. One tonal lineament follows the mapped trace of the fault north of Lone Tree Way (locality 5, Figure 3). Other short northwest-trending tonal lineaments are evident in the surrounding area. No geomorphic features that suggest recent faulting were found south of Lone Tree Way except a set of sharp tonal lineaments that nearly coincide with the mapped trace of the fault east of Deer Valley Road (locality 6, Figure 3). This line is a crude oil pipeline (Soil Foundation Systems, 1989). Other straight, parallel, tonal lineaments are probably access roads.

Geomorphic features formed by erosion along a bedrock fault are found along the portion of the Antioch fault that had been mapped as the Davis fault (Brabb and others, 1971). These features include truncated ridges, scarps in bedrock, and saddles (Figure, 3). No geomorphic features that suggest Holocene displacement could be found.

In summary, geomorphic evidence for the Antioch fault is either completely lacking (on the alluvial plain and south of Lone Tree Way), weakly suggestive of faulting (a somewhat linear hill front and swales) or contrary to what is expected along an active fault (fault breccia that is more resistant to erosion than the surrounding bedrock). The Davis fault is clearly defined by fault line scarps, saddles and truncated ridges typical of a fault in bedrock. The strongest geomorphic evidence for recent faulting consists of a roughly linear swale and hill slope on the Antioch fault, neither of which is as sharp or as linear in detail as similar features along active faults.

Site-specific fault studies

Numerous consulting geologists have studied parcels along the Antioch fault in compliance with the Alquist-Priolo Act. Other geologists have investigated portions of the Antioch fault for evaluations of existing or proposed dams. Many of these sites have been re-examined in the field for this study and one trench

has been excavated and logged to re-evaluate an earlier study. These studies are described below from northwest to southeast. They are also summarized in the same order in Table 1. Outlines of the areas studied and trench locations are plotted on Plate 1. For ease of reference, the number of each of these reports in the DMG files is listed in the text and on Table 1 and shown on Plate 1.

Slough Area

Consultants reports near the northeast end of the Antioch fault (North of 4th Street and West of J Street) document the presence of soft sediment and artificial fill in the old slough. None have found any fault related features (Harding Lawson Associates, 1977 (AP-405), 1983 (AP-1567), 1986a (AP-1945), 1989 (AP-1107); Woodward-Clyde Consultants, 1979 (AP-1107); Western Geological Consultants, 1979 (C-559); Diablo Soils Engineers, 1980 (AP-1415); Darwin Myers Associates, 1980 (AP-1415)). Boring logs in these reports show that the soft fill and marsh deposits adjacent to the deformed railroad tracks is up to 40 feet deep (Harding Lawson Associates, 1986a (AP-1945)) (locality 7, Plate 1). They also show that the deposits are soft and prone to settlement. Diablo Soils Engineers (1980) (AP-1415) logged two borings where, after drilling through the upper 12 feet of fill, the drill stem sank under its own weight for another 12 feet through soft bay mud and peat (locality 8, Plate 1).

Alluvial Plain

Consultants reports for properties east of the slough and south to 20th Street describe trenches in older alluvium of the Antioch alluvial plain. No consultants found faults in this area (Harding Lawson Associates, 1976 (AP-337), 1986b (AP-1387), 1986c (AP-1946), 1988 (AP-2222); Darwin Myers Associates, 1981 (AP-1387); Hallenbeck-McKay and Associates, 1978 (AP-765); Western Geological Consultants, 1989 (AP-2363); Engeo, 1982 (AP-1474); Woodward-Clyde Consultants, 1975 (C-89); Kaldveer Associates, 1989 (C-772)).

Of particular importance among these reports are the reports by Woodward-Clyde Consultants (1975)(C-89) and Kaldveer Associates (1989)(C-772). WCC investigated damage to the multi-purpose building at John C. Fremont School (locality 9, Plate 1) (Site 18 of Burke and Helley). Their trenching found no evidence for faulting and they concluded that the damage to the building was probably due to expansive soils. Kaldveer Associates investigated the adjacent Antioch Junior High School property. Their trenches were more than 600 feet long and crossed the center of the Alquist-Priolo zone (locality 10, Plate 1). They found no evidence for faulting in old alluvium. Their trenching demonstrates that no Holocene faulting has occurred on the trace of the Antioch fault shown on the Special Studies Zones Map at this location. The lack of evidence for faulting in this trench or any trenching study to the north, and the lack of geomorphic

expression, suggest that the Antioch fault does not offset the alluvium north of 20th Street (where Burke and Helley described 22 of their 29 "creep" localities).

South of 20th Street, Engeo (1978)(AP-758), Western Geological Consultants (1979)(C-558) and Abel Soares and Associates (1979)(AP-1416) did not find evidence for faults in trenches. Engeo noted cracks in curbs and sidewalks in two locations (locality 11, Plate 1). These cracks roughly coincide with the trace of the Antioch fault shown on the Special Studies Zones map (CDMG 1976a), prompting Engeo to speculate that they could be due to fault creep. When this site was field checked, minor right-lateral offset of curbs along east-west expansion joints was noted at one location, left-lateral offset of a curb on a north-south expansion joint was noted at the other. Right-lateral displacement on a N30°W fault would cause right-lateral displacements on north-trending joints and compression or left-lateral displacements on east-west joints. The offset curbs in this area are not consistent with right-lateral creep on the Antioch fault. The displacements are probably due to expansive soil or other non-tectonic causes.

Burkland and Associates (1975)(AP-811) investigated a group of sites along A Street south of the Southern Pacific Railroad (Plate 1). They reported evidence for creep and exposures of faults in two trenches (Figure 4). These features define a zone that is east of, and parallel to, the fault zone plotted on the Special Studies Zones Map (locality 12, Plate 1). Their evidence for creep consists of cracks with right-lateral offsets in two low retaining walls and in three curbs, and deflection of the Southern Pacific Railroad tracks. A scarplet in a street was also noted along the same alignment. These sites were checked by this writer and Glenn Borchardt of CDMG on April 15 and May 1, 1991 and the cracks were verified. However, cracks in the retaining walls typically had more displacement near the top of the wall than near the base and did not have systematic right-lateral or left-lateral displacements. The cracks also did not appear to be confined to a narrow zone. Cracks in curbs at three street corners could not be traced into adjacent walkways or pavement. Curbs across the streets from the damaged curbs, on the projection of the fault trace, were not offset. The "scarplet in street" appears to be the east side of a small drainage swale that drains to the north. It is a very broad low feature that rises less than five feet over a width of more than 200 feet. On 1950 aerial photographs (USDA, 1950), a north-draining swale at about this location appears to be a tributary to a larger drainage that drains to the northeast. There does not appear to be any relation between the swale and the projected fault zone.

The trenches by Burkland and Associates (1975) (locations shown on Figure 4) exposed southeast- dipping siltstones and sandstones

identified as the "Tehema" (sic) Formation. In trench 3, bedding within the Tehama Formation is shown as offset. In Trench 2 the contact between the Tehama Formation and the overlying soil is shown as offset. In both trenches, faults were traced to the surface through the "dark brown to brown residual soil" and the "highly expansive" upper topsoil layer. The faults are shown on the trench log as a zone of "highly sheared clay and/or bedrock material." Murray Levish, the geologist who supervised the project for Burkland and Associates, recalls that the fault zone extended to the ground surface and thinks there may have been vertical offset of the topsoil, although his memory is not as clear on this point (M. Levish, p.c. 1991).

These soils trenched by Burkland and Associates (1975)(AP-811) appear to be the youngest materials displaced by the Antioch fault. Trench logs show a fault, drafted as a solid line, extending from the bedrock to the ground surface (Figure 5). However, the existence of shears extending through the topsoil to the ground surface is not consistent with expansive soils on a site that had been developed as an orchard (USDA aerial photographs 1939, 1950) or had once had a farmhouse and several outbuildings on it (Mr. Ralph Garrow Sr., p.c. 1991). All this activity would tend to obscure or destroy evidence for faulting in the topsoil. No evidence of surface disturbance was noted by Burkland and Associates (1975) on most of the site.

There is an apparent conflict between the geologic relationships shown on the trench logs by Burkland and Associates (1975) and what is expected at a site with expansive soils that had been previously developed. In an attempt to resolve this apparent conflict, this writer contacted the landowner and the City of Antioch and arranged for a trench to be excavated adjacent to Trench 2 of Burkland and Associates.

On June 10, 1991, a City of Antioch, Department of Public Works backhoe excavated a 65 foot long trench 9 feet deep parallel to, and about 5 feet north of, Trench 2 (locality 13, Plate 1). This trench was located to cross the faults logged by Burkland and Associates (1975) and was carefully logged by this writer, with the assistance of Glenn Borchardt, Earl W. Hart and William A. Bryant of the Division of Mines and Geology. Glenn Borchardt also described the soil profile in detail. After the trench was logged, it was examined by several other geologists including Murray Levish, who supervised the original trenching for Burkland and Associates, David Schwartz of the USGS, Todd Nelson, former Contra Costa County Geologist, and Bob Wright, who investigated the Antioch fault for a study of Contra Loma Dam (ESA, 1982).

Despite careful logging and examination of the trenches by numerous geologists, no faults or fault-related features were identified. The units exposed in the trench consisted of, from top to bottom, a well developed soil profile with Ap (disturbed),

A and Bt horizons (see soil description 2, Appendix A), a layer of alluvial sand, locally containing small channels of coarse sand and pebbles, and a massive, pervasively fractured mudstone. These units are continuous across the trench except minor variations in thickness and the pinching out of the sand, which seems to occupy a broad channel (see trench log, Figure 5).

A soil profile about 1.5 m thick is developed on the silty clay alluvium and the stratified "bedrock" at the site. It includes a B1t horizon with blocky structure, a B2t horizon with prismatic structure, and a Btkc with minute calcite concretions disseminated through it (see soil description 2, Appendix A). The thickness of the soil profile, the development of prismatic structure with clay films on the ped faces and the presence of a k (caliche) horizon together indicate that this is not a recently developed soil.

According to Glenn Borchardt, DMG soil scientist, this well-developed soil horizon could form in as little as 10,000 years under ideal conditions, but is much more likely to be between 20,000 and 50,000 years old.

The alluvial sand and the mudstone interfinger between stations 8 and 9 in the trench, indicating that they are of roughly the same age. The mudstone is probably not a late Quaternary alluvial unit because it is lithified, pervasively fractured, and only a small remnant of the original bedding is still apparent. Since the mudstone is probably part of the Tehama Formation, both it and the overlying sand are probably of Pliocene to early Pleistocene age.

None of the units exposed in the trench, which range in age from Pliocene or early Pleistocene to late Pleistocene are offset. Thus, no active fault exists where Burkland and Associates (1975) mapped it. Figure 5 compares the trench log by Burkland and Associates with the trench log described for this study. It is possible that Burkland and Associates observed vertical caliche stringers in the sand or vertical ped surfaces in the prismatic soil horizon (B2t) and mistakenly attributed these features to faulting.

Bedrock Hills

South of State Highway 4, Western Geological Consultants (1979 (AP-1417), 1988 (AP-2337), 1989 (AP-2271)); Converse Consultants (1984)(AP-1638); Darwin Myers Associates (1981)(AP-1419); and Burkland and Associates (1977)(AP-443) have investigated a scattered group of sites within the Special Studies Zone. None of the sites are across the mapped trace of the Antioch fault and none of these consultants found faults. Following construction of a shopping center on the site studied by Converse Consultants (1984)(AP-1638), other geologists have noted faults in the Tehama Formation in a cut slope (T. Nelson, p.c. 1991)(locality 14,

Plate 1). These faults were briefly examined on May 8, 1991. They offset the Tehama Formation but do not appear to extend into the overlying alluvium.

Along the trace of the Antioch fault to the southeast, large residential tracts have been developed. Before development, an engineering geologist investigated the Antioch fault on each of these tracts (Burkland and Associates, 1974 (AP-802, also filed as C-64); Burkland and Associates and Harlan Engineers, 1973 (AP-336); Purcell, Rhoades Associates, 1978 (AP-849); Earth Systems Consultants, 1979 (AP-1106); Kaldveer and Associates, 1988a,b (AP-2247); Darwin Myers Associates, 1983 (AP-1626); Berlogar, Long and Associates, 1979 (AP-1105); Berlogar Geotechnical Consultants, 1986 (AP-1953); Terrasearch, 1988 (AP-2517); Soil Foundation Systems, 1988 (AP-2169), 1989 (AP-1976); Engeo, 1987 (AP-1976), 1984 (AP-1771)). These reports cover a continuous three-mile-long section of the Antioch fault except a gap at the Contra Costa Canal.

Most consultants report a narrow zone of faults in bedrock between Roosevelt Lane and Lone Tree Way (plate 1). This narrow zone of northwest-trending bedrock faults disappears south of Lone Tree Way. Consultants were unable to find evidence for any faulting along Burke and Helley's mapped trace of the Antioch fault between Lone Tree Way and the Davis fault.

Trenching at one locality (Earth Systems Consultants, 1979, AP-1106) (locality 15, Plate 1) uncovered what was thought was conclusive evidence for faulting of the soil. Two trenches revealed a fault in bedrock that could be traced into the overlying soils. In one trench the fault offsets the contact between two horizontal silty clay units and reportedly continued to the ground surface. In the other trench, the fault did not extend through the upper soil horizon. These soils are probably relict soils, formed by in-place weathering of the bedrock, because they are on the crest and upper slopes of a hill. Faults in these soils could have formed after the soil or could be "inherited" from the bedrock. It is not conclusive evidence of recent faulting.

A cut slope near this site was also discussed and photographed by Kneupfer (1977) and logged by Earth Science Associates (1982)(locality 16, Plate 1). Two north-trending normal faults bound a broad, shallow graben in the Tehama Formation with younger deposits downfaulted in the center. The age of these younger deposits, described as "dark grey, sandy organic soil and colluvium" (ESA, 1982), is not known. Displacement of the base of this colluvium suggests late Quaternary faulting but the location of the graben on the crest of a hill and lack of surface expression of the faults suggest that the offset has not occurred in Holocene time. The relationship of these faults to the Antioch fault is also unclear. They trend northerly to slightly

east of north, rather than N30°W as the Antioch fault has been mapped. Thus, although late Quaternary displacement may have occurred on these faults, it is not clear if this suggests Quaternary offset on the Antioch fault.

To the south, Burkland and Associates and Harlan Engineers (1973) (AP-336) and Kaldveer Associates (1988a,b)(AP-2247) investigated the area where the mapped trace of the fault follows a somewhat linear hill-front and swale. These geologists found faults in the bedrock. They inferred recent movement on these faults based on steps in the bedrock-soil contact and soil filled fissures along bedrock fault zones. Kaldveer and Associates (1988a) noted that the faults extend through the bedrock and the overlying sandy clay. The sandy clay unit is laterally gradational with a silty sand that contains relict "bedrock-like" fabric (Kaldveer and Associates, 1988a, p.5) and therefore may be a relict soil formed by in-place weathering of the bedrock. Faults in this relict soil may be inherited from the bedrock and may represent faulting before the formation of the soil.

Glenn Borchardt of the CDMG examined the soil in the trenches by Kaldveer Associates and noted a well developed B horizon with clay-films and weathering rinds on clasts. He estimated the soil to be of pre-Holocene age (G. Borchardt personal communication to Kaldveer Associates, 1988). Earl W. Hart also examined these trenches on the same day. He noted that the soil horizon was not clearly faulted (E.W. Hart, p.c. 1991).

South of the Contra Costa Canal, DWR (1978) and Berlogar, Long and Associates (1979)(AP-1105) investigated the fault (locality 17, Plate 1). This site was chosen by DWR (1978) for trenching because of the prominent ridges of calcite-cemented fault breccia mapped in the area by Burke and Helley (1973).

DWR (1978) noted steps in the bedrock-soil contact and soil filled fissures along faults in a zone 8 m wide. A fault plane in bedrock trended N30°W and had horizontal striations on its surface. DWR recognized that all but the upper, 6-inch-thick A horizon has formed by in-place weathering of the bedrock to form AC and Cca horizons. Their soils consultant, Dr. E.L. Begg of U.C. Davis, estimated the age of the soils to be 50,000 to 70,000 years based on the development of a "distinct zone of lime accumulation" and a "weak argillic horizon." Although DWR was able to find no evidence for faulting of this soil, they noted that such evidence could have been destroyed by burrowing animals.

Berlogar, Long and Associates (1979)(AP-1105) trenched the same feature in the same area as DWR (1978) and also noted numerous soil-filled fissures and steps in the bedrock-soil contact. In contrast to DWR, who recognized that these features can form by differential soil development or the action of burrowing animals;

Berlogar, Long and Associates reported that these represent (tectonic) "disturbance of the surface soil."

Other studies to the south also report steps in the bedrock-soil contact and soil-filled fissures along the fault (Berlogar Geotechnical Consultants, 1986 (AP-1953); Terrasearch, 1988 (AP-2517)). Neither of these studies found shears in the soil or offset soil horizons. Most steps in the bedrock-soil contact are probably caused by differential soil development. Thin soil over sandstone across a fault from thicker soil over siltstone (Terrasearch, 1988, Trench 1 for example) probably forms because siltstone has higher clay content. Siltstone will form thicker soils where sandstone may form only a weak, thin soil. Also, burrowing animals make more and deeper burrows in soil that is easier to excavate, leading to deeper soils over softer bedrock and in fault zones. In a few cases, however, trenches showing thick soils on one side of a fault do not have a contrasting bedrock across the fault (Terrasearch 1988, Trench 2 for example) and are not easily explained by differential soil development. It is possible, therefore, that some faulting has occurred within the time of soil formation.

South of Lone Tree Way, Soil Foundation Systems (1988) (AP-2169) found a fault in bedrock east of Burke and Helley's trace that trends northerly away from the mapped Antioch fault. They did not find evidence of any faults in bedrock along the Antioch fault of Burke and Helley (1973). DWR (1978) also could not verify the Antioch fault in this area, based on their surface mapping. Farther south, Purcell Rhoades Associates (1982, trench logs included in Soils Foundation Systems, 1988) and Soils Foundation Systems (1988,1989)(AP-2169, AP-1976) excavated trenches across much of the Special Studies Zone and found no faults.

Near the south end of the Special Studies Zone, DWR (1978) investigated the Davis fault of Brabb and others (1971) near site 29 of Burke and Helley (1973)(locality 18, Plate 1). DWR could not verify the small scarp in alluvium noted by Burke and Helley. They did, however, verify a bedrock fault in the adjacent hills. DWR found "some features which could be interpreted as being caused by fault movement" in soil that they correlated with the 200,000-year-old middle Riverbank Formation of the San Joaquin Valley. DWR could find no evidence of faulting in younger soils. They concluded that no surface displacement on the Davis fault had occurred in at least the last 50,000 years.

SEISMICITY

The Antioch fault is located at the eastern edge of the seismically active area associated with the San Andreas fault system (Hill and others, 1990, figure 5.6). It is within a less active belt of seismicity extending from the west side of the San Joaquin Valley, through the Antioch area and northward through

the Sacramento Valley (Eaton, 1986). This zone has been called the Coast Ranges-Sierran Block boundary zone (Wong and others, 1988). Studies of microseismicity in the Montezuma Hills and Antioch segments of this zone show that right-lateral, oblique and reverse or thrust earthquakes have occurred. These earthquakes are unusually deep, with the majority occurring below 20 km (Wong and others, 1988; Wong and Biggar, 1989).

The largest instrumentally recorded earthquake seems to fit the pattern defined by the microseismicity. In 1965 a magnitude 4.9 event with a right-lateral focal mechanism occurred on a northwest-trending fault plane at a depth of about 15 km (McEvilly and Casaday, 1967). Aftershocks of this earthquake define a north-northeast-trending fault zone, not consistent with the northwest-trending focal plane defined by first-motion studies (McEvilly and Casaday, 1967).

The largest historic earthquake in the Antioch area occurred on May 19, 1889, and had an estimated magnitude of 6.0 (Toppozada, 1981). "Two small fissures were opened in the earth on Main Street" (San Francisco Chronicle, May 20, 1889, p.8) leading to speculation that this earthquake may have caused surface rupture on the Antioch fault (Toppozada, 1981; Wong and others, 1988). Main Street of 1889 has since been renamed I Street and is a north-south street that crosses the filled slough just west of downtown Antioch. The fissures caused by the 1889 earthquake may represent settlement of the soft fill and marsh deposits in the slough, rather than fault rupture.

CONCLUSIONS

The Antioch fault was thought to be active based on the evidence for creep assembled by Burke and Helley (1973). This evidence can be explained by settlement of marsh deposits and fill in a slough, expansive soils, and random cracking of concrete pavement over time.

There is no geomorphic evidence for Holocene movement on the fault. Instead, the only distinctive geomorphic feature along the fault, a ridge of calcite-cemented fault breccia, seems to contradict active faulting.

The Antioch fault can be traced as a fault in bedrock for approximately two miles, from Roosevelt Lane to north of Lone Tree Way in Antioch. The fault does not offset the late Pleistocene alluvium of the Antioch alluvial plain. Trenching by Kaldveer Associates (1989) and numerous other consultants found no evidence for faulting. A trench where evidence for active faulting was reported (Burkland and Asssociates, 1975) has been re-opened. They apparently mistakenly identified vertical caliche stringers and vertical soil structure as fault features.

Many consultants have found permissive evidence for active faulting such as steps in the bedrock-soil contact and soil-filled fissures. A small graben bounded by faults that offset Quaternary alluvium and colluvium (Earth Science Associates, 1982)(Locality 16, Plate 1) may represent late Quaternary faulting. The faults at this locality are not the Antioch fault, however, although they could be splays off the main fault. The lack of any geomorphic expression of the faults in this area suggests the faulting has not occurred in Holocene time.

Consultants have not found the fault south of Lone Tree Way. The connection mapped between the Antioch fault and the Davis fault apparently does not exist. The Davis fault is defined by a series of tonal lineaments and fault-line scarps along a bedrock fault. DWR (1978) found evidence that displacement on the fault has occurred in the last 200,000 years. The fault is overlain by soils that are at least 50,000 years old.

RECOMMENDATIONS

The Antioch fault should not be zoned for special studies. The existing Special Studies Zones maps of the Antioch North and Antioch South Quadrangles should be withdrawn.

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I have reviewed the report and agree with the recommendations.

Earl W. Hart
11/21/91

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APPENDIX 1, SOIL DESCRIPTIONS

Soil Description 1. Abbreviations and definitions are given in Soil Survey Staff (1951;1975)

North facing road cut exposure along 7th Street 50 feet east of H Street and west facing road cut exposure along H Street 50 feet south of 7th, Antioch, California at 38° 00' 47" north latitude, 121° 48' 50" west longitude and ≈31 feet elevation. The landform is a gently north-sloping slightly dissected alluvial plain. Soil is formed on silty alluvium. Description by Glenn Borchardt and C.J. Wills, May 1, 1991.

A1: 0-9 cm. dark brown (10YR3/3m) silt loam; massive structure; many very fine dendritic roots; few very fine pores; clear smooth boundary.

A2: 9-45 cm. dark brown (10YR3/3m) silt loam; medium, moderate, granular structure; many very fine dendritic roots; many medium and fine pores. pH 6.1; gradual smooth boundary.

A3: 45-70 cm. dark brown (10YR3/3m) silt loam; moderate, medium granular structure; common fine roots, few medium roots, common fine pores, few medium pores, gradual smooth boundary.

A4: 70-115 cm. dark brown (10YR3/3m) silt loam; weak moderate subangular blocky structure; common fine and medium roots; gradual smooth boundary.

B1: 115-130 cm. dark yellowish brown (10YR4/4m,6/4d) clay loam; strong moderate angular blocky structure; sticky and slightly plastic when wet, friable when moist, slightly hard when dry; common very fine pores; pH 6.8; clear smooth boundary.

B2: 130-151 cm. dark yellowish brown (10YR4/4m,6/4d) clay loam; strong coarse angular blocky structure; sticky and slightly plastic when wet, firm when moist, slightly hard when dry; many very fine pores; pH 6.8; clear smooth boundary.

Bt3: 151-166 cm. yellowish brown (10YR5/4m,6/4d) sandy clay loam; strong moderate angular blocky structure; sticky and slightly plastic when wet, firm when moist, hard when dry; some fine roots; pH 6.6; clear smooth boundary.

Bk: 166-191 cm. dark yellowish brown (10YR4/4m,6/4d) sandy clay loam; strong moderate angular blocky structure; slightly sticky and slightly plastic when wet, very firm when moist, very hard when dry; 1.0-cm diameter sandy clay loam filled trace fossils (usually vertical but occasionally horizontal) coated with thin (<0.5 mm) films of caliche; violent effervescence in HCl; pH 6.7; clear smooth boundary.

2Bk1: 191-235 cm. yellowish brown (10YR5/8m,5/4d) loamy sand; strong moderate angular blocky structure; non-sticky and non-plastic when wet, very firm when moist, very hard when dry; continuous white (10YR8/2d7/2m) carbonate filaments on fractures and edges of trace fossils; pH 6.6; gradual wavy boundary.

2Bk2: 235-275 cm. yellowish brown (10YR5/4m,6/4d) loamy sand; strong moderate angular blocky structure; non-sticky and non-plastic when wet, very firm when moist, very hard when dry; continuous carbonate filaments on fractures and edges of burrows to 1 mm thick; gradual boundary.

2Bqj: 235-300 cm. dark yellowish brown (10YR4/4m,6/4d) sand; single grain structure; wet non-sticky and non-plastic, moist friable, dry loose; nodules cemented with silica (?) no effervescence in HCl, pH 8.5.

Soil Description 2. Abbreviations and definitions are given in Soil Survey Staff (1951;1975)

Trench on Garrow property approximately 5 feet north of trench by Burkland and Associates (1975) east of A Street between East Madill and Bryan Streets, Antioch, California at 38° 00' 01" north latitude, 121° 48' 20" west longitude and ≈45 feet elevation. The landform is a gently north-sloping slightly dissected alluvial plain. Soil is formed on silty alluvium. Description by Glenn Borchardt, June 11 and 12, 1991.

Ap: 0-22 cm. grayish brown to very dark grayish brown (10YR5/2d,3/2m) clay loam; massive structure; slightly sticky and plastic when wet, friable when moist, very hard when dry; few medium dendritic roots, few medium tubular pores; compacted; contains fill in upper part; pH 7.0, 390 µS; abrupt smooth boundary.

A: 22-60 cm. grayish brown to very dark grayish brown (10YR5/2d,3/2m) silty clay loam; medium moderate granular, medium strong subangular blocky and medium weak angular blocky structure; slightly sticky and plastic when wet, friable when moist, hard when dry; common fine dendritic roots, few medium tubular pores, common fine tubular pores; pH 6.1, 330 µS; clear smooth boundary.

B1t: 60-96 cm. brown to dark brown (10YR5/3d,3/3m) silty clay; medium strong angular blocky to coarse strong angular blocky structure; sticky and plastic when wet, very firm when moist, very hard when dry; common fine dendritic roots, few medium tubular pores, common fine tubular pores; pH 6.4, 410 µS; gradual wavy boundary.

B2t: 96-117 cm. yellowish brown to dark brown (10YR5/4d,4/3m) clay; medium strong prismatic to coarse strong prismatic structure; sticky and very plastic when wet, very firm when moist, very hard when dry; few very fine tubular pores; continuous thin clay films on peds; pH 7.0, 925µS; clear wavy boundary.

Btkc: 117-140 cm. dark brown to dark yellowish brown (10YR4/3d,4/4m) clay loam; medium strong prismatic to coarse strong prismatic structure; sticky and very plastic when wet, very firm when moist, very hard when dry; few very fine tubular pores; continuous thin clay films on peds, dark brown clay films on sides of peds; pH 7.5, 1280 µS; broken wavy boundary.

2BCtk: 140-196 cm. very pale brown to yellowish brown (10YR7/4d,5/4m) loamy sand; massive to medium weak subangular blocky structure; nonsticky and nonplastic when wet, loose when moist, hard when dry; brown (7.5YR4/4m,5/4d) clay films on discontinuous vertical surfaces; few vertical 15-mm diameter trace fossils; pH 7.7, 1410 µS; broken wavy boundary.

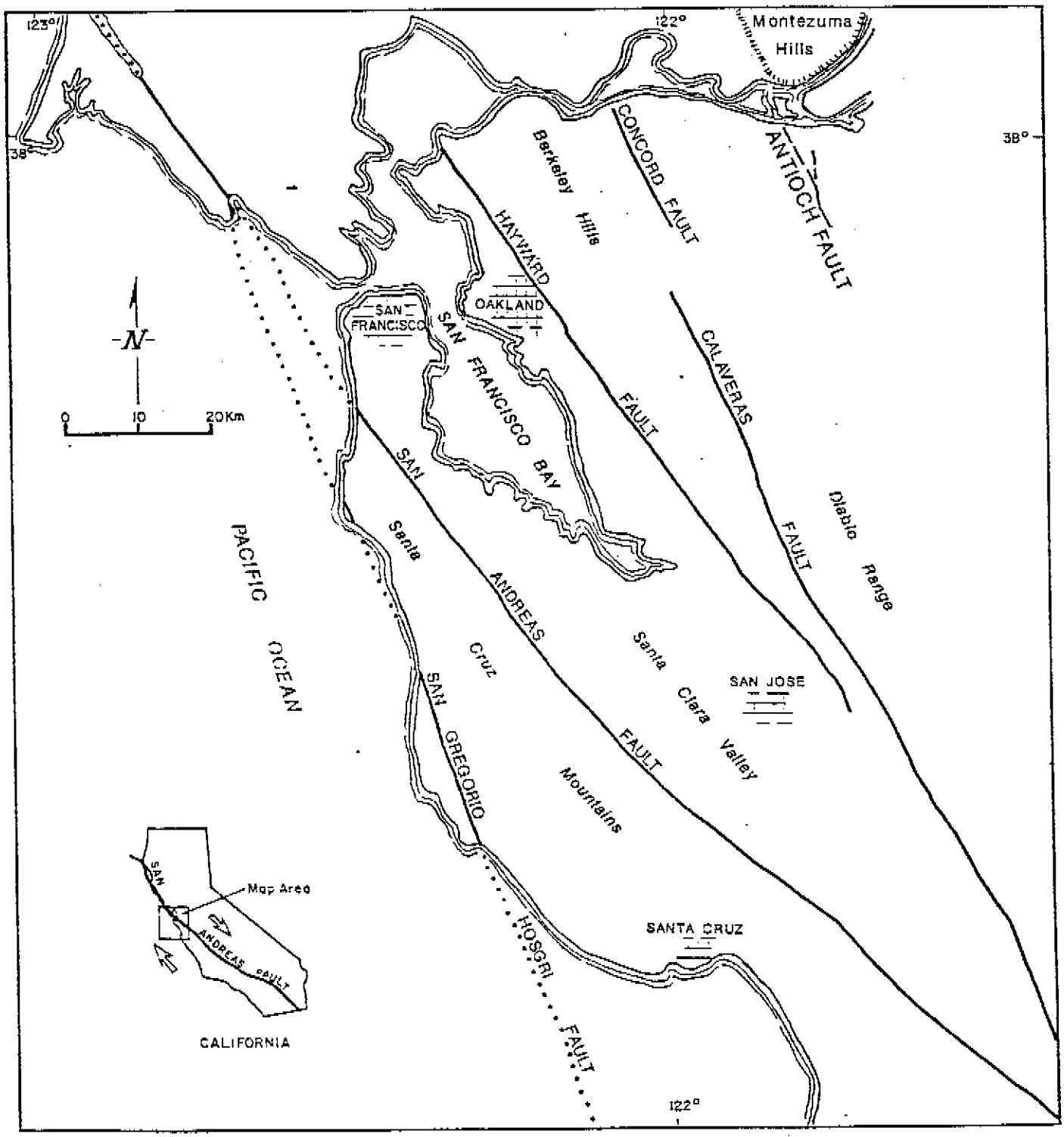
3BCtk: 196-255 cm. very pale brown (10YR7/4d,7/4m) clay loam; medium strong angular blocky structure; sticky and very plastic when wet, friable when moist, very hard when dry; calcite in pores and on ped faces; many thin clay films (7.5YR4/4m) coating pores; manganese oxide coating clay films in pores, some clay films over manganese oxide; pH 7.6, >1990 µS.

TABLE 1: Site specific geological reports within the Special Studies Zone on the Antioch fault divided into geologic areas and listed from northwest to southeast. See Plate 1 for locations of sites and trenches.

FILE #	CONSULTANT, DATE	TRENCH ?	FAULT FOUND ?	COMMENTS
Slough Area				
AP-1567	Harding Lawson, 1983	no	no	Borings only
AP-1107	Woodward Clyde, 1979, Harding Lawson, 1989	no	no	WCC Report is review and reconnaisance only, Harding Lawson report is soils report only.
AP-1945	Harding Lawson, 1986	no	no	Borings only
AP-405	Harding Lawson, 1977	yes	no	Trench 10 feet deep in horizontally bedded alluvium. Up to 5 feet of dark brown plastic clay at east end of trench. Edge of old slough?
C-559	Western Geo Consultants, 1979	no	no	Literature review only
AP-1415	Diablo Soils Engineers, 1980; D. Myers, 1980	yes	no	Inconclusive trenching in deep fill and marsh deposits borings show fill and marsh deposits to 25 feet.
Alluvial Plain				
AP-337	Harding Lawson, 1976	yes	no	12' deep building excavation in horizontally bedded alluvium
AP-2222	Harding Lawson, 1988	no	no	Site "shadowed" by report AP-1387 see below
AP-1387	D. Myers, 1981; Harding Lawson, 1981	yes	no	Trenches up to 7 feet deep to unfaulted carbonate cemented alluvium
AP-1946	Harding Lawson, 1986	yes	no	Trenches 7 feet deep in horizontally bedded alluvium
AP-765	Hallenbeck-McKay, 1978	yes	no	Trenches 12 feet deep in horizontally bedded alluvium
AP-1474	Engeo, 1982	yes	no	Trench 7 feet deep in horizontally bedded alluvium
AP-2363	Western Geo Consultants, 1989	no	no	Literature review only
C-89	Woodward Clyde Consultants, 1975	yes	no	Damage to building cited by Burke and Helley as evidence for creep is concluded to be due to expansive soils.
C-772	Kaldveer & Associates, 1989	yes	no	Trenches up to 620 feet long, 10 feet deep across center of SSZ found continuous, horizontally bedded Pleistocene alluvium, no faults
AP-758	Engeo, 1978	yes	no	Trenches 9 feet deep in horizontally bedded alluvium. "tenuous" evidence for creep noted adjacent to site.
AP-1416	A. Soares, 1979	yes	no	Trenches 9 feet deep in horizontally bedded alluvium
C-558	Western Geo Consultants, 1979	yes	no	Trench 8 feet deep in horizontally bedded alluvium

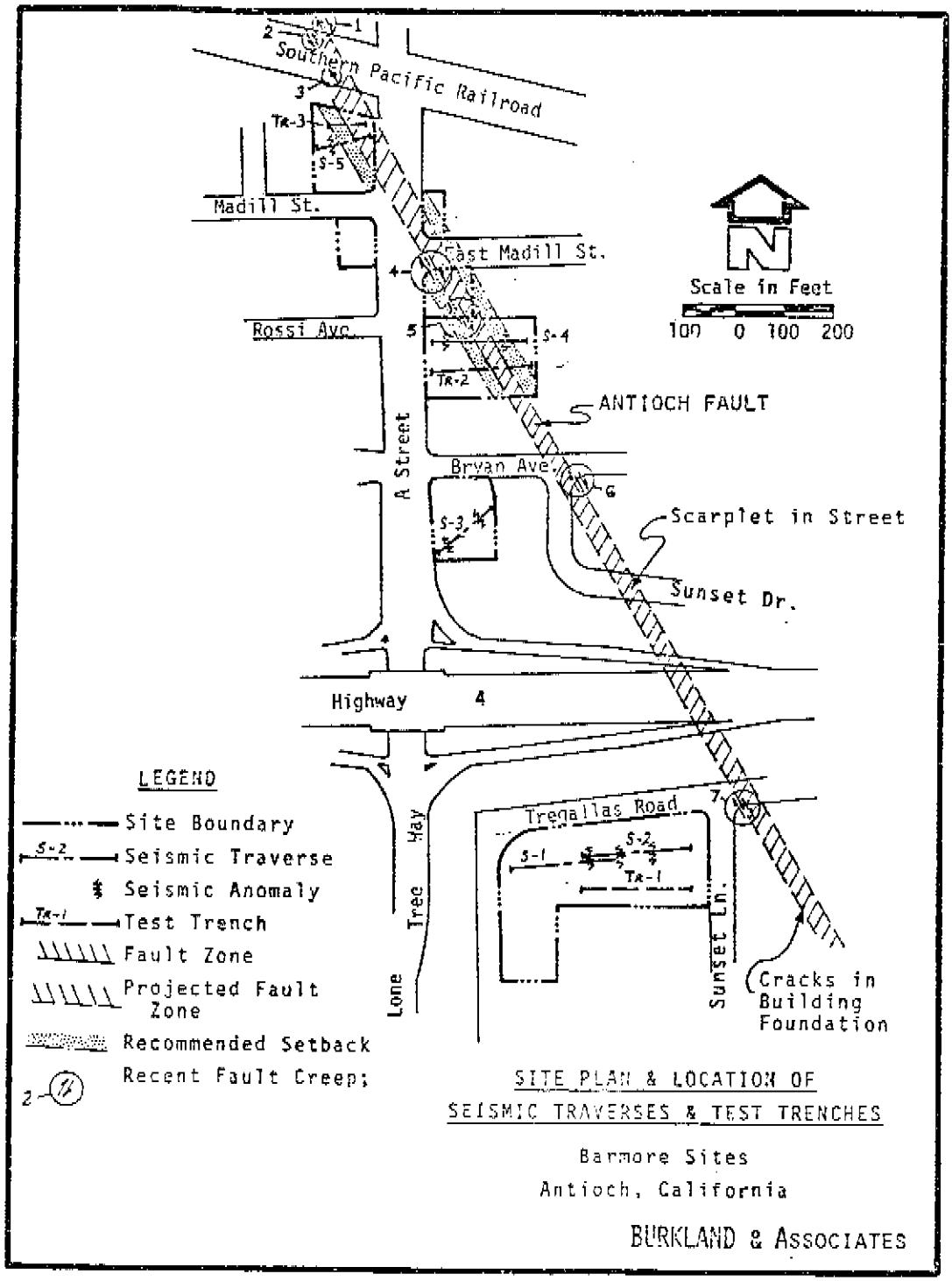
TABLE 1: Site specific geological reports within the Special Studies Zone on the Antioch fault divided into geologic areas and listed from northwest to southeast. See Plate 1 for locations of sites and trenches. (continued)

FILE #	CONSULTANT, DATE	TRENCH ?	FAULT FOUND ?	COMMENTS
AP-811	Burkland & Associates, 1975	yes	yes	Faults shown to ground surface through "expansive sandy clay" soil. Evidence for creep noted at several localities
AP-724	Harding Lawson, 1978	yes	no	Small site adjacent to site of AP-811
Bedrock Hills				
AP-1417	Western Geo Consultants, 1979	no	no	Literature review and reconnaisance only
AP-2271	Western Geo Consultants, 1989	yes	no	Trench 8 feet deep in horizontally bedded alluvium
AP-1638	Converse Consultants, 1984	no	no	Monitoring of excavation during excavation recommended, no record of this in file.
AP-2337	Western Geo Consultants, 1988	yes	no	5-7 foot deep trench in alluvium and bedrock
AP-1419	D. Myers, 1981	no	yes?	"Distress" evidence for creep? mapped along a fault to west of site
AP-443	Burkland & Associates, 1977	yes	no	Cut slope logged, log of cut slope missing from report in file
AP-849	Purcell, Rhoades, 1978	yes	no	Trench 5-12 feet deep or to bedrock
AP-802, C-64	Burkland & Associates, 1974	yes	yes	Offset of bedrock-alluvium contact
AP-1106	Earth Systems Consultants, 1979	yes	yes	Fault to ground surface, report area overlaps AP-802
AP-336	Burkland & Associates, 1974	yes	yes	Faults in bedrock possibly extending into soils. Consultant reports that EBMUD has had no damage to their aqueduct since it was installed in 1925
AP-2247	Kaldveer & Associates, 1988	yes	yes	Faults in bedrock reportedly create steps in bedrock-alluvium contact and have soil filled fissures along bedrock faults. soil not clearly offset. overlaps AP-336
AP-1626	D.Myers, 1983	yes	no	Trenches to bedrock, no faults found
AP-1105	Berlogar-Long, 1979	yes	yes	Faults in bedrock offset bedrock-alluvium contact.
AP-2517	Terrasearch, 1988	yes	yes	Step in bedrock-soil contact at fault, soil filled fissures along faults.
AP-1953	Berlogar,1986	yes	yes	Faults in bedrock and steps in bedrock-alluvium contact
AP-2169	Soil Foundation Systems, 1988	yes	yes	Faults in bedrock only, no faults found along trend of faults to the north. Many "trenches by others" shown on map, trench logs not provided.
AP-1976	Soil Foundation Systems, 1989; Engeo, 1987	yes	yes	Faults in bedrock only found in trenching by SFS
AP-1771	Engeo, 1984	yes	no	Property west of mapped trace of fault



FER 228, Figure 1,

Sketch map of the San Francisco Bay area showing major active faults and the Antioch fault. Modified from Wagner (1990).



FER 228, Figure 4,

Sketch map of sites investigated by Burkland and Associates (1975) showing sites where evidense for creep was found and locations of trenches.

Figure 1-1. Site Location Map and Photo

Figure 1-2. Antioch Bridge Pier Number

LEGEND

- EXISTING BOREHOLES
- EMI BOREHOLES
- EMI CPT
- BENCHMARKS

SCALE
1" = 200'

0 100 200 300 FT

REVISED 4/23/07

BORE LOCATIONS PLAN

Figure 2-1a

ANTIOCH BRIDGE - SHEET 1
SEISMIC RETROFIT PROJECT

Earth Mechanics, Inc.
Geotechnical and Earthquake Engineering

LEGEND

- EXISTING BOREHOLES
- EMI BOREHOLES
- EMI CPT
- BENCHMARKS

SCALE
1" = 200'
0 100 200 300 FT

REVISED 4/23/07

BORE LOCATIONS PLAN

Figure 2-1b

ANTIOCH BRIDGE - SHEET 2
SEISMIC RETROFIT PROJECT

Earth Mechanics, Inc.
Geotechnical and Earthquake Engineering

LEGEND

- EXISTING BOREHOLES
- EMI BOREHOLES
- EMI CPT
- BENCHMARKS

SCALE
1" = 200'

0 100 200 300 FT

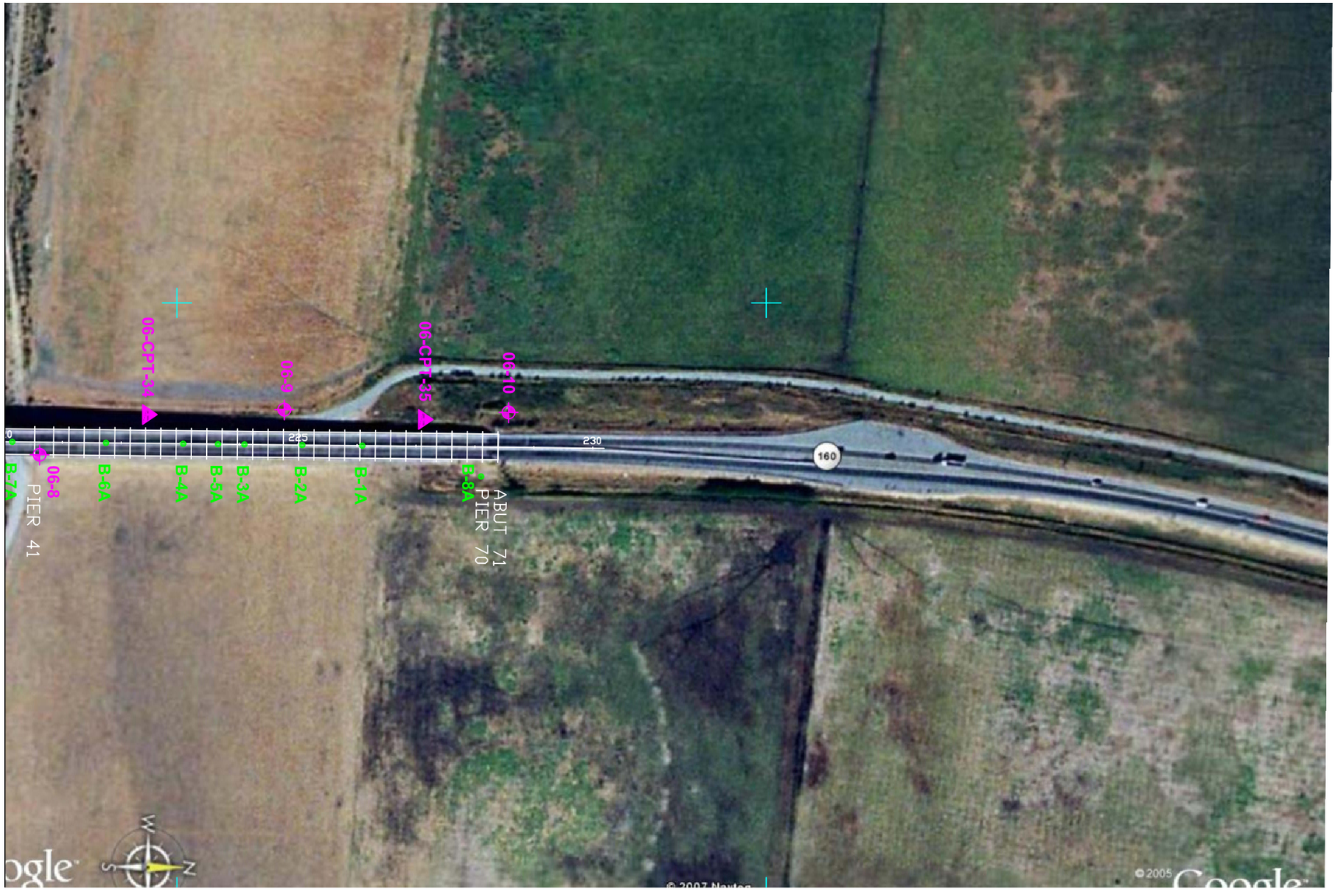
REVISED 4/23/07

BORE LOCATIONS PLAN

Figure 2-1c

ANTIOCH BRIDGE - SHEET 3
SEISMIC RETROFIT PROJECT

Earth Mechanics, Inc.
Geotechnical and Earthquake Engineering



LEGEND

- EXISTING BOREHOLES
- EMI BOREHOLES
- EMI CPT
- BENCHMARKS

SCALE
1" = 200'

0 100 200 300 FT

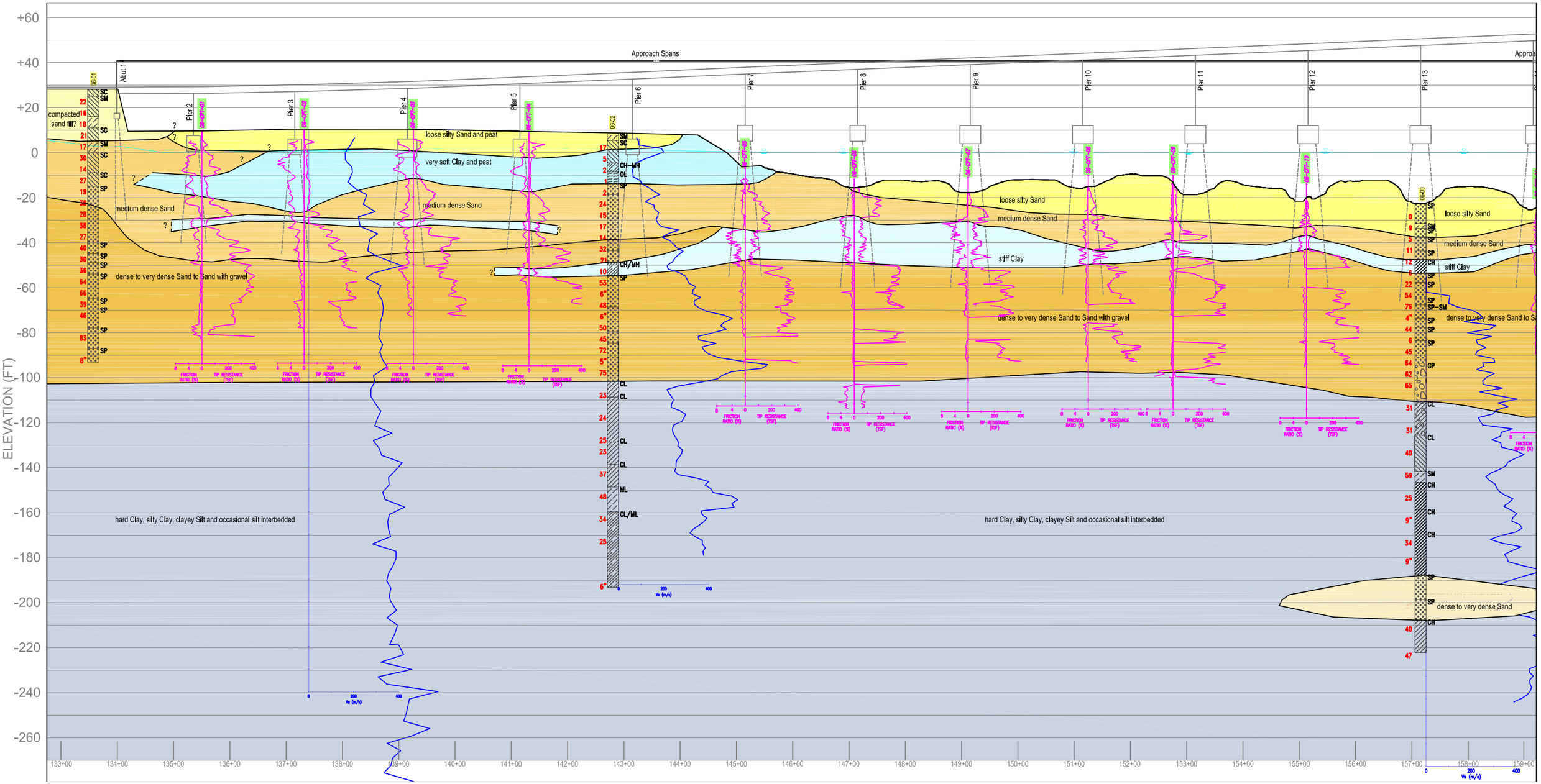
REVISED 4/23/07

BORE LOCATIONS PLAN

Figure 2-1d

ANTIOCH BRIDGE - SHEET 4
SEISMIC RETROFIT PROJECT

Earth Mechanics, Inc.
Geotechnical and Earthquake Engineering



LEGEND

- Water table
- Soil Boring with SPT blowcounts (bpf) and soil type (USCS)
- Penetrometer with driving rate (sec/ft)
- Shear wave velocity (sec/ft)
- 14" sqr. PC Piles
- 24" sqr. PC Piles
- 54" PC Piles
- 12" sqr. PC Piles
- 24" Composite Piles
- 30" Steel Pipe Piles

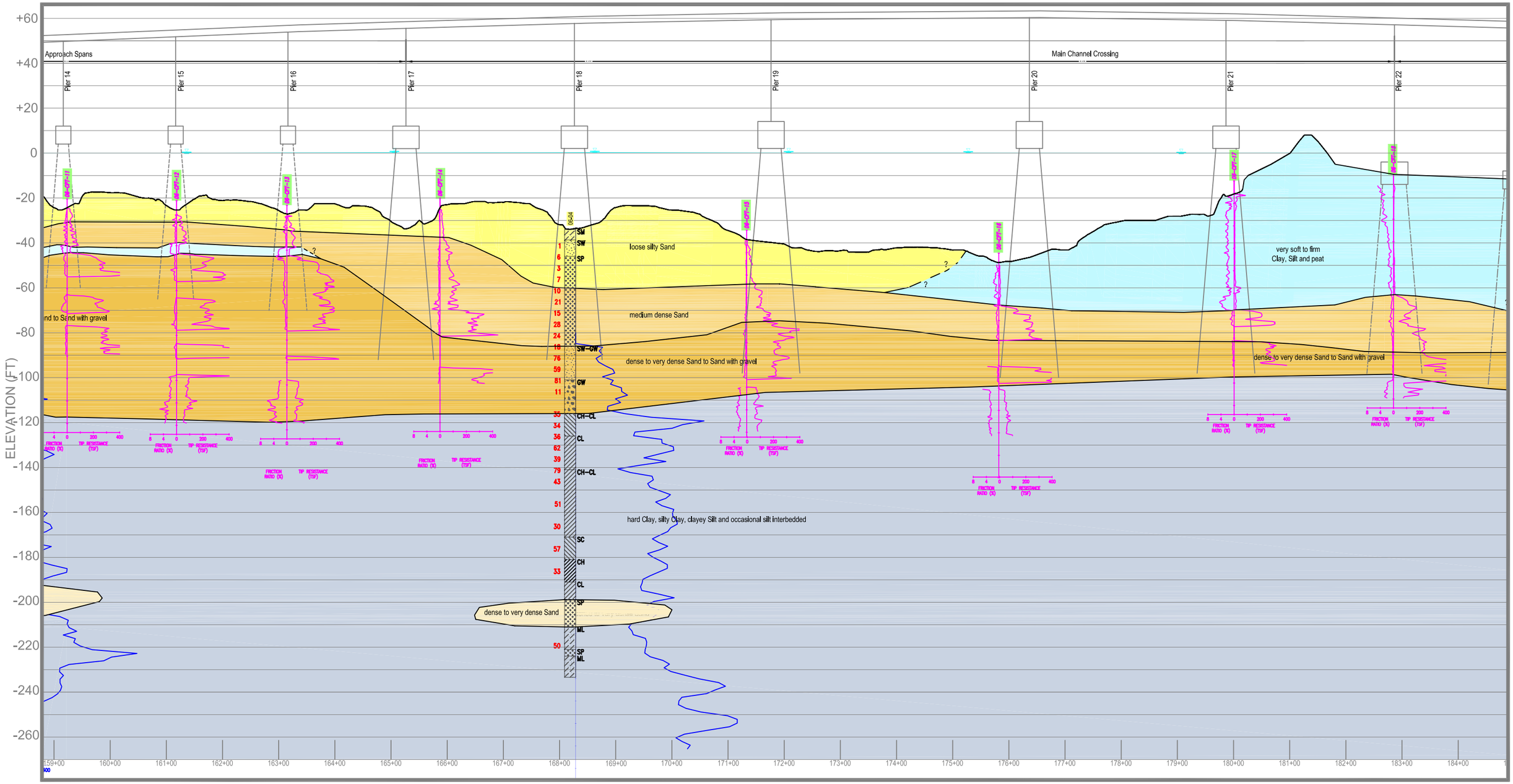
Station along ℄ Bridge

CROSS SECTION ANTIOCH BRIDGE

Figure 2-2a

- Fill
- loose silty Sand and Peat to silty Sand
- very soft to firm Clay and Peat
- medium dense Sand
- stiff Clay
- dense to very dense Sand to Sand with gravel
- hard Clay, silty Clay, clayey Silt and occasional silt interbedded

Earth Mechanics, Inc.
Geotechnical and Earthquake Engineering



LEGEND

- Water table
- Soil Boring with SPT blowcounts (bpf) and soil type (USCS)
- Penetrometer with driving rate (sec/ft)
- Shear wave velocity (sec/ft)
- 14" sqr. PC Piles
- 24" sqr. PC Piles
- 54" PC Piles
- 12" sqr. PC Piles
- 24" Composite Piles
- 30" Steel Pipe Piles

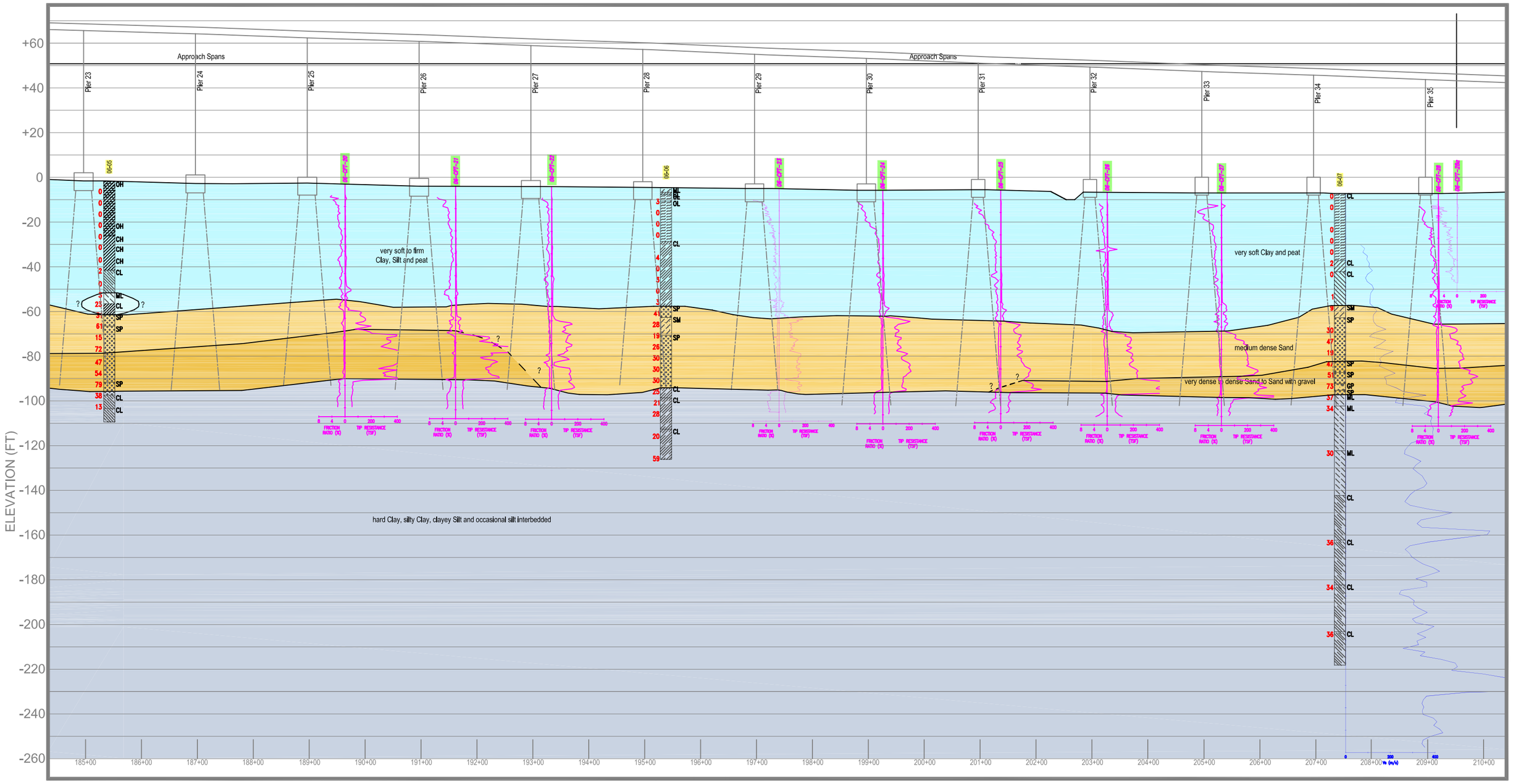
Station along ℄ Bridge

CROSS SECTION ANTIOCH BRIDGE

Figure 2-2b

- Fill
- loose silty Sand and Peat to silty Sand
- very soft to firm Clay, Silt and Peat
- medium dense Sand
- stiff Clay
- dense to very dense Sand to Sand with gravel
- hard Clay, silty Clay, clayey Silt and occasional silt interbedded

Earth Mechanics, Inc.
Geotechnical and Earthquake Engineering



LEGEND

- Water table
- Soil Boring with SPT blowcounts (bpf) and soil type (USCS)
- Penetrometer with driving rate (sec/ft)
- Shear wave velocity (sec/ft)
- 14" sqr. PC Piles
- 12" sqr. PC Piles
- 24" sqr. PC Piles
- 24" Composite Piles
- 54" PC Piles
- 30" Steel Pipe Piles

Station along ℄ Bridge

CROSS SECTION ANTIOCH BRIDGE

Figure 2-2c

- Fill
- loose silty Sand and Peat to silty Sand
- very soft to firm Clay, Silt and Peat
- medium dense Sand
- stiff Clay
- dense to very dense Sand to Sand with gravel
- hard Clay, silty Clay, clayey Silt and occasional silt interbedded

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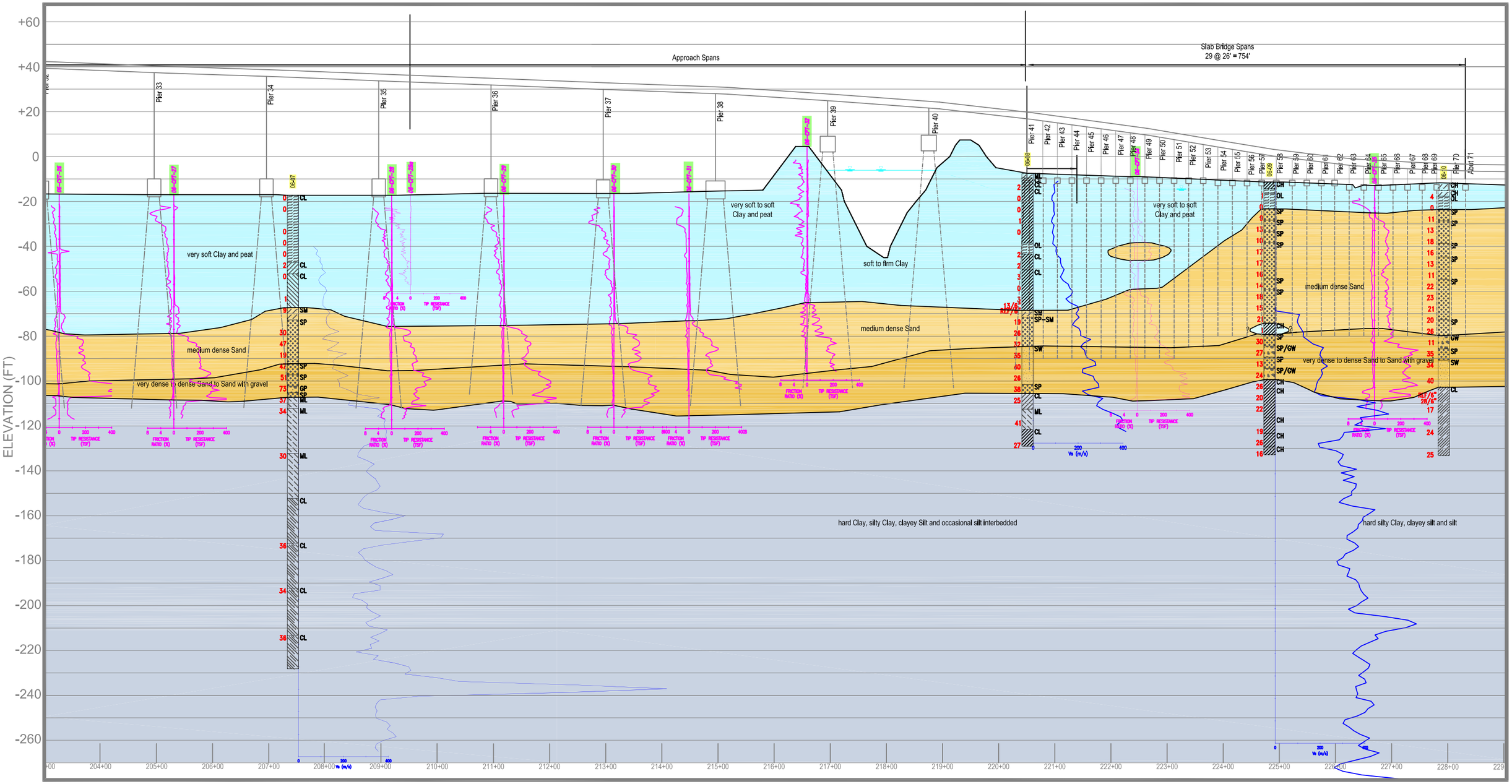

LEGEND

- Water table
- Soil Boring with SPT blowcounts (bpf) and soil type (USCS)
- Penetrometer with driving rate (sec/ft)
- Shear wave velocity (sec/ft)
- 14" sqr. PC Piles
- 24" sqr. PC Piles
- 54" PC Piles
- 12" sqr. PC Piles
- 24" Composite Piles
- 30" Steel Pipe Piles

Station along ℄ Bridge

CROSS SECTION ANTIOCH BRIDGE

Figure 2-2d

- Fill
- loose silty Sand and Peat to silty Sand
- very soft to firm Clay, Silt and Peat
- medium dense Sand
- stiff Clay
- dense to very dense Sand to Sand with gravel
- hard Clay, silty Clay, clayey Silt and occasional silt interbedded

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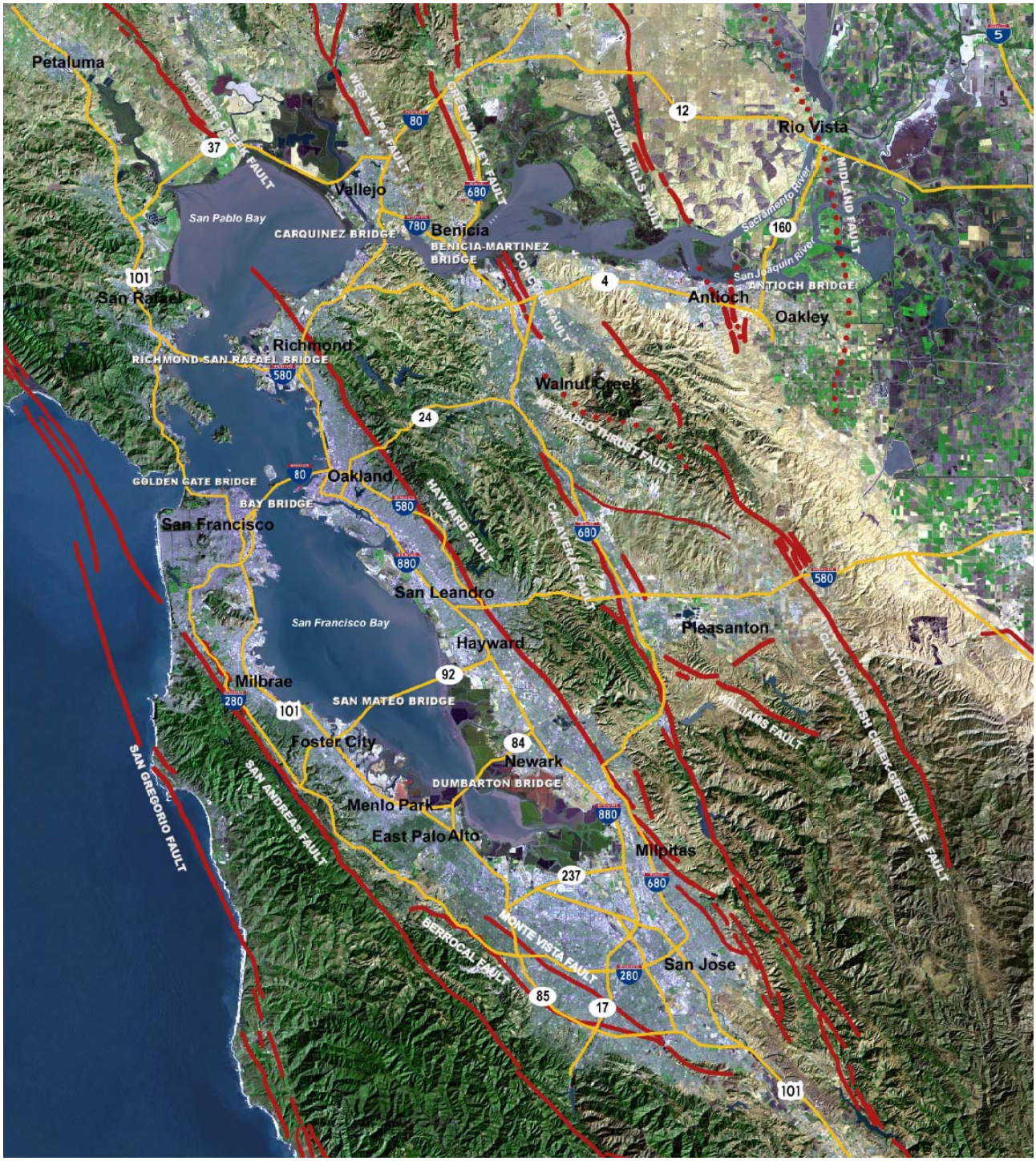
Figure 4-1. Bay Area Fault Map



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N-VALUE (EQUIV. SPT) VS. ELEVATION

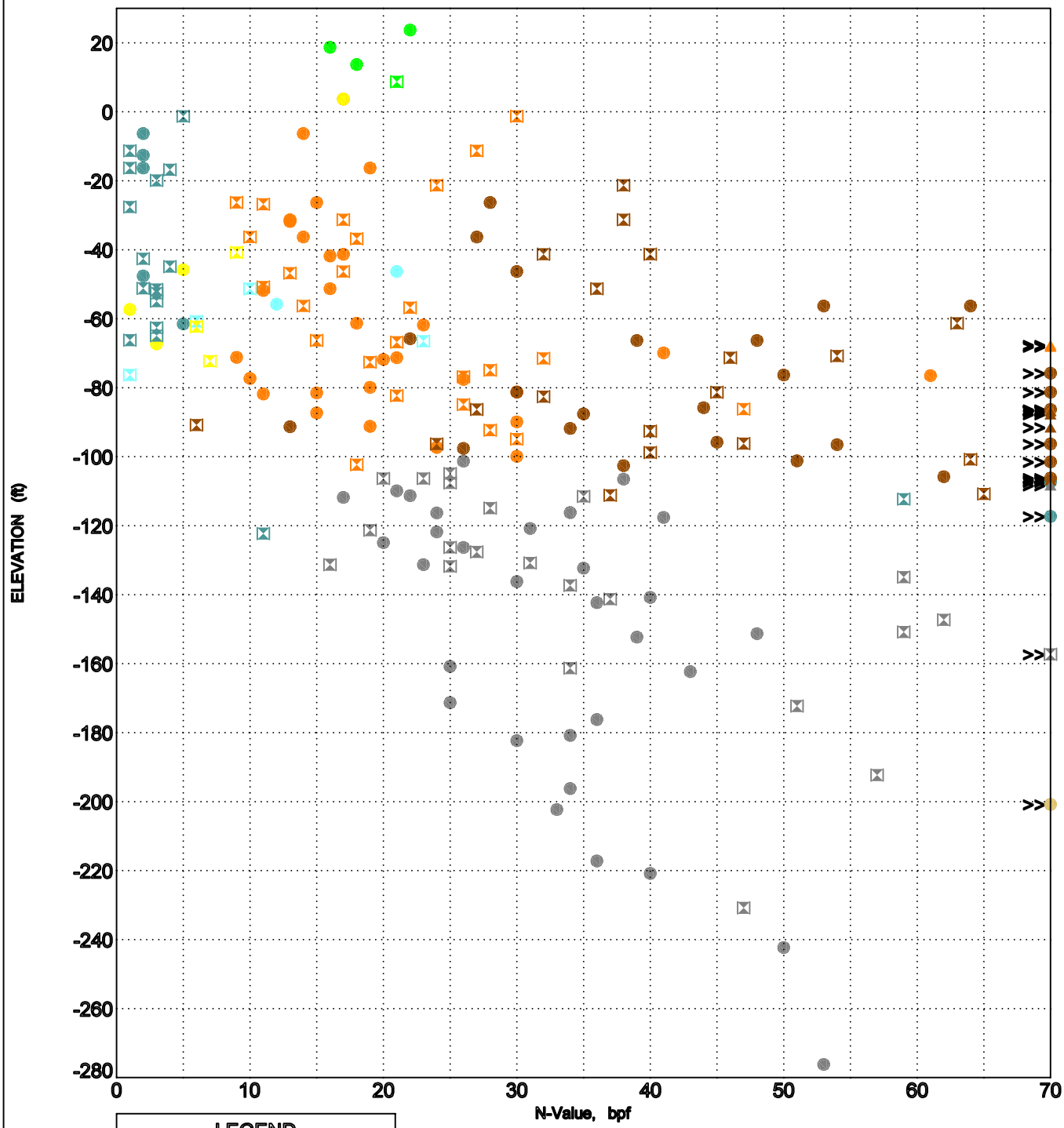
Figure 5-1

CLIENT BATA/Caltrans

PROJECT NAME Antioch Toll Bridge

PROJECT NUMBER 06-155

PROJECT LOCATION Oakley



LEGEND
● SPT N-Value
⊠ Equiv. SPT N-Value*
▲ Refusal
>> N-Value > 70

- Compacted Sand Fill
- Loose Silty Sand and Peat
- Medium Dense Sand
- Very Soft Clay and Peat
- Stiff Clay
- Dense to Very Dense Sand , w/ Gravel
- Hard Clay, Silty Clay, Clayey Silt
- Dense to Very Dense Sand

* Blowcount obtained by Modified California Sampler and converted to equivalent SPT blowcount using a Conversion Factor of 0.63.

ANTIOCH SPT N-VALUE GRAPH BORINGS 9-21-07.GPJ DAMBARTON.GDT 1/17/09

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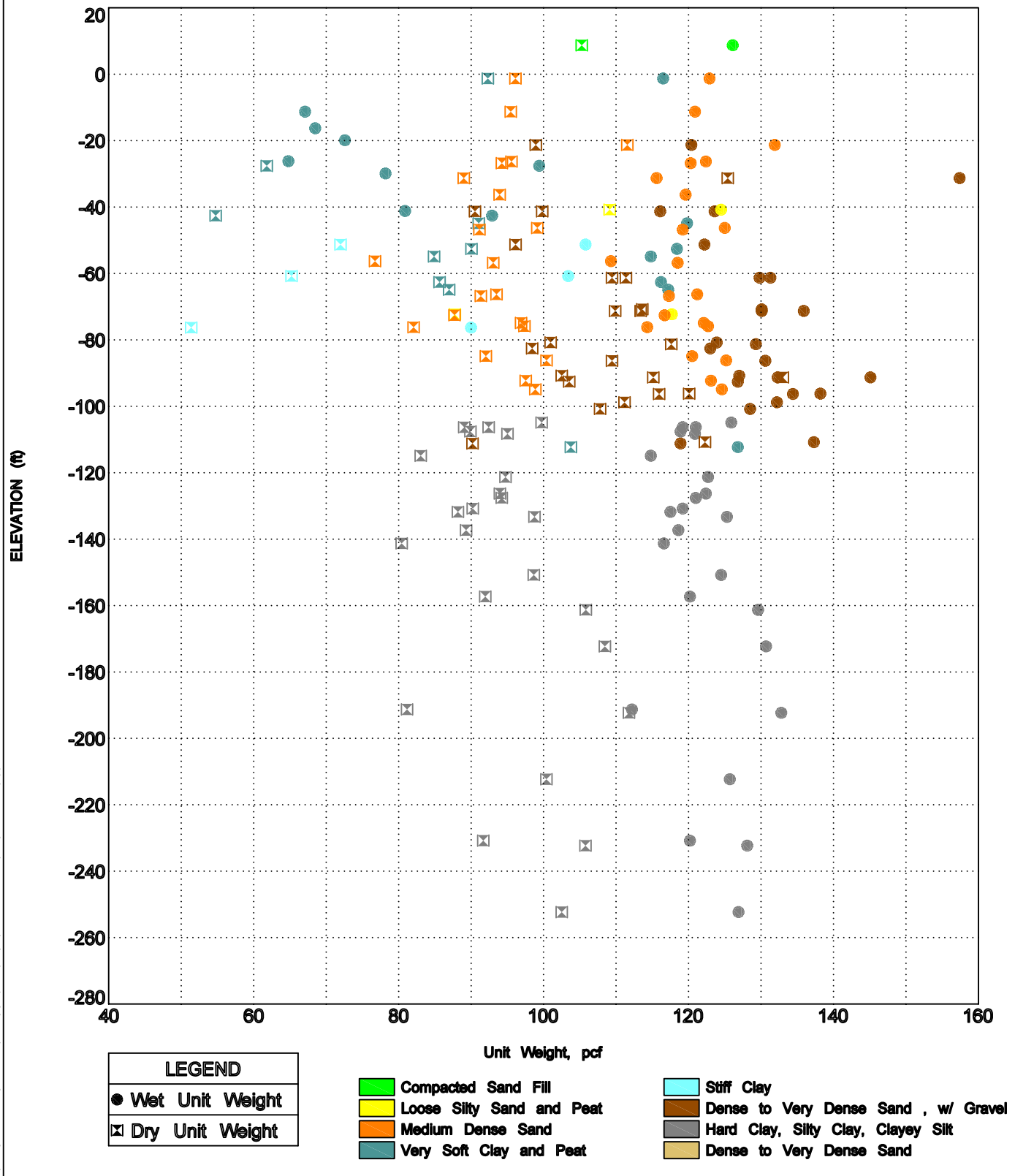
UNIT WEIGHT VERSUS ELEVATION

Figure 5-2

CLIENT _____ PROJECT NAME Antioch Toll Bridge

PROJECT NUMBER 06-155 PROJECT LOCATION Oakley



ANTIOCH UNIT WEIGHT BORINGS 9-21-07.GPJ DAMBARTON.GDT 1/15/09

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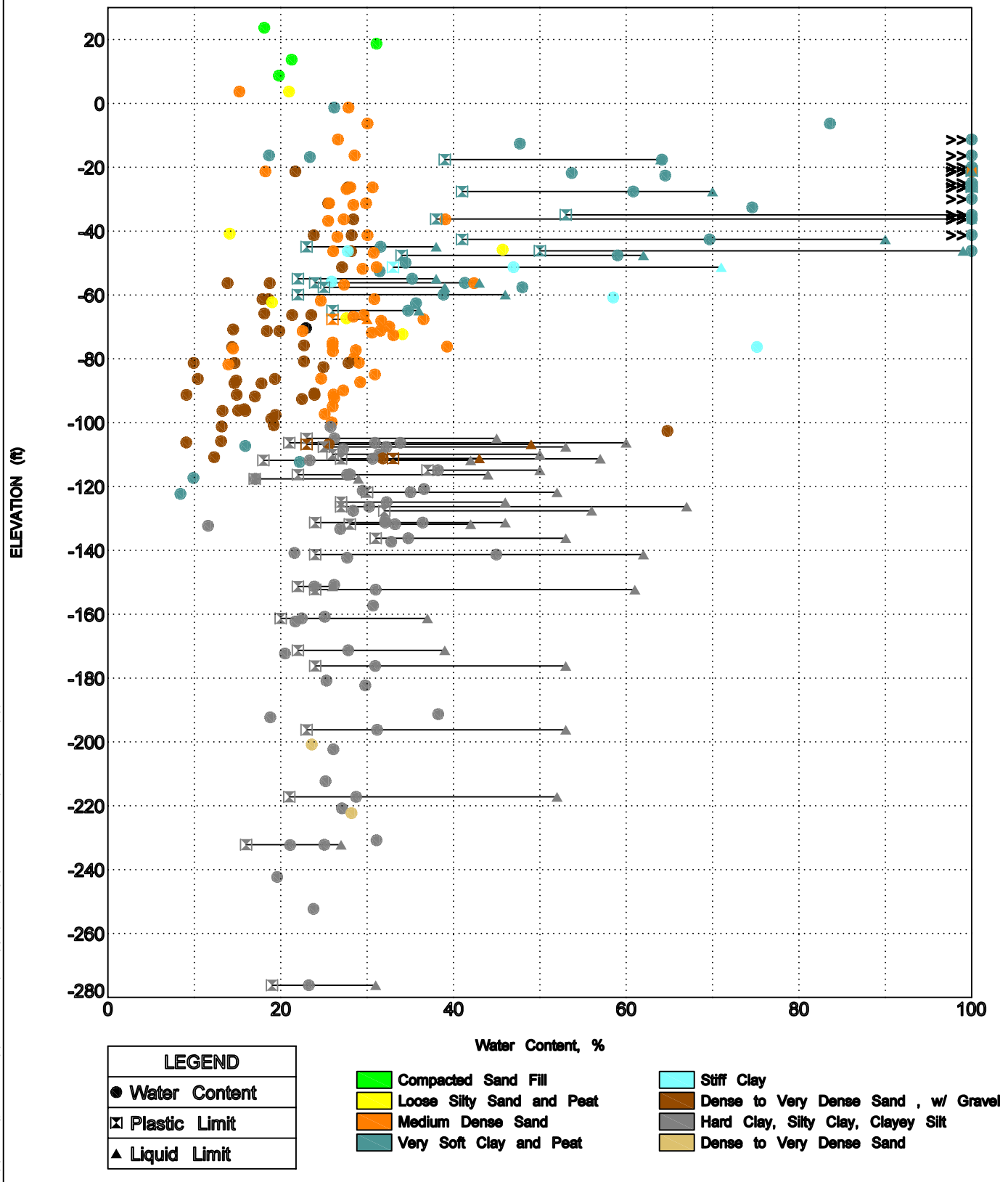
INDEX PROPERTIES VERSUS ELEVATION

Figure 5-3

CLIENT _____ PROJECT NAME Antioch Toll Bridge

PROJECT NUMBER 06-155 PROJECT LOCATION Oakley



ANTIOCH PI & WATER CONTENT BORINGS 9-21-07.GPJ DAMBARTON.GDT 1/15/09

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SHEAR STRENGTH VS. ELEVATION

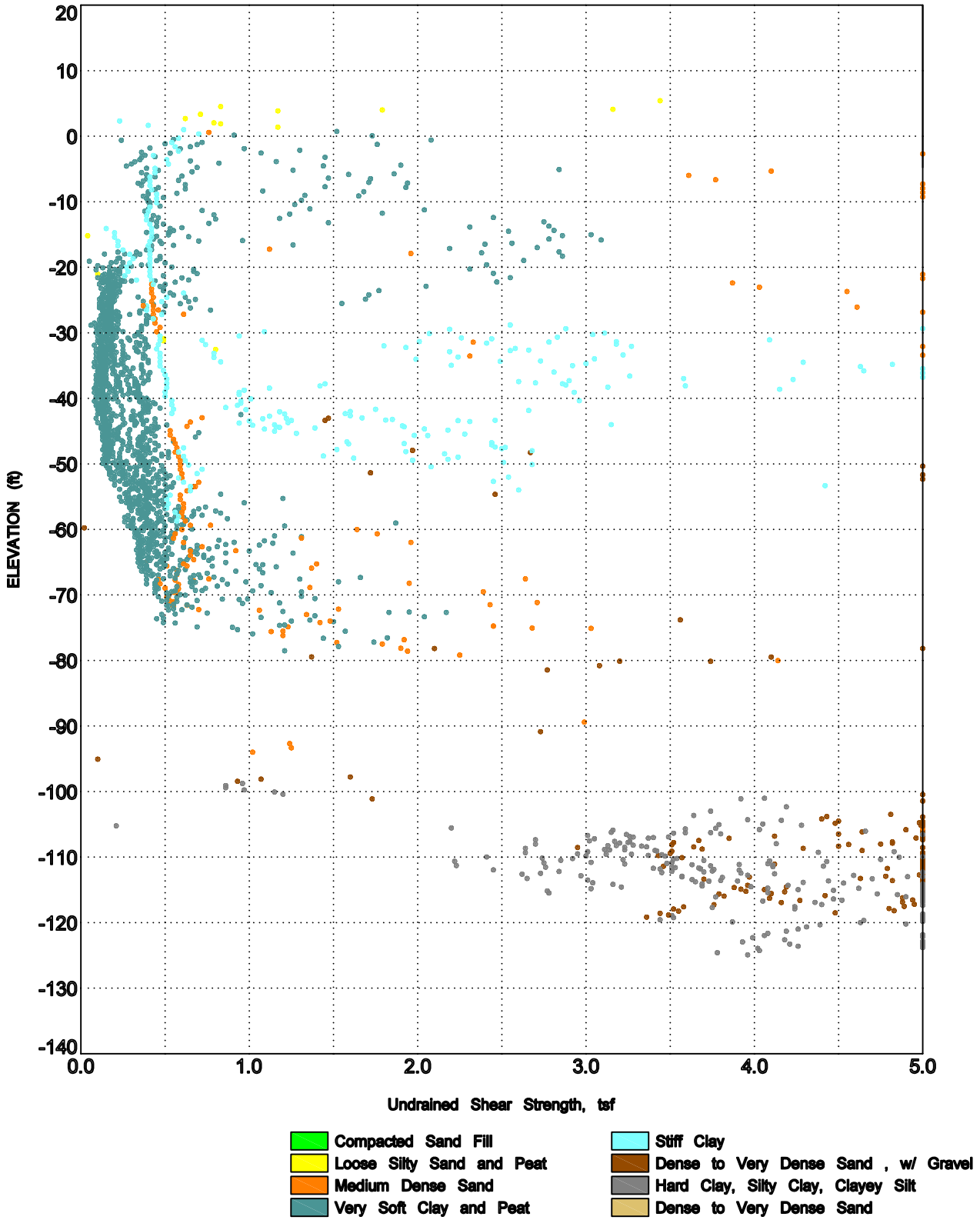
Figure 5-4

CLIENT BATA/Caltrans

PROJECT NAME Antioch Bridge Seismic Retrofit Project

PROJECT NUMBER

PROJECT LOCATION



* Undrained Shear Strength estimated from CPT test

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SHEAR WAVE VELOCITY VS. ELEVATION

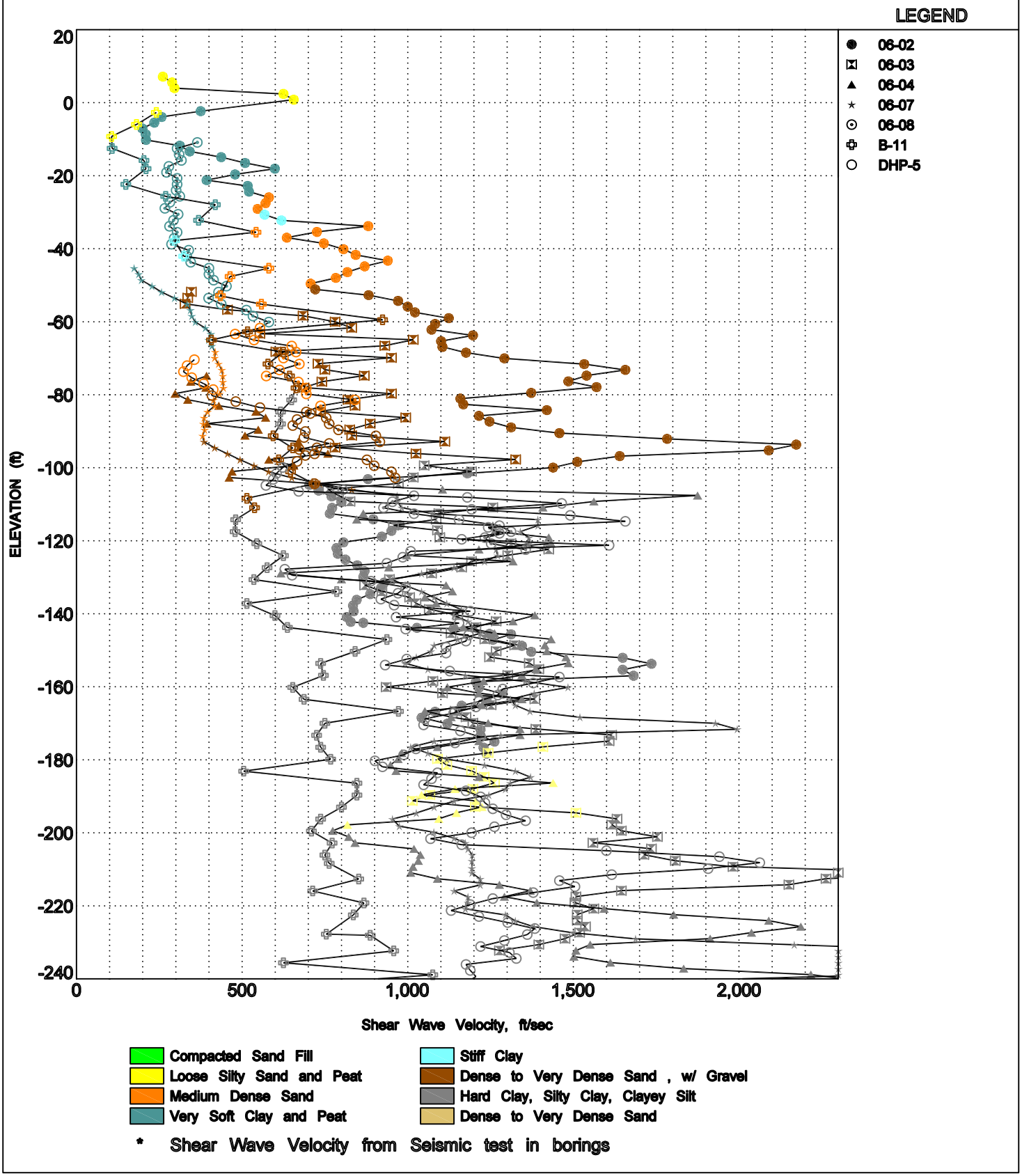
Figure 5-5

CLIENT BATA/Caltrans

PROJECT NAME Antioch Bridge Seismic Retrofit Project

PROJECT NUMBER

PROJECT LOCATION



* Shear Wave Velocity from Seismic test in borings

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SHEAR WAVE VELOCITY VS. ELEVATION

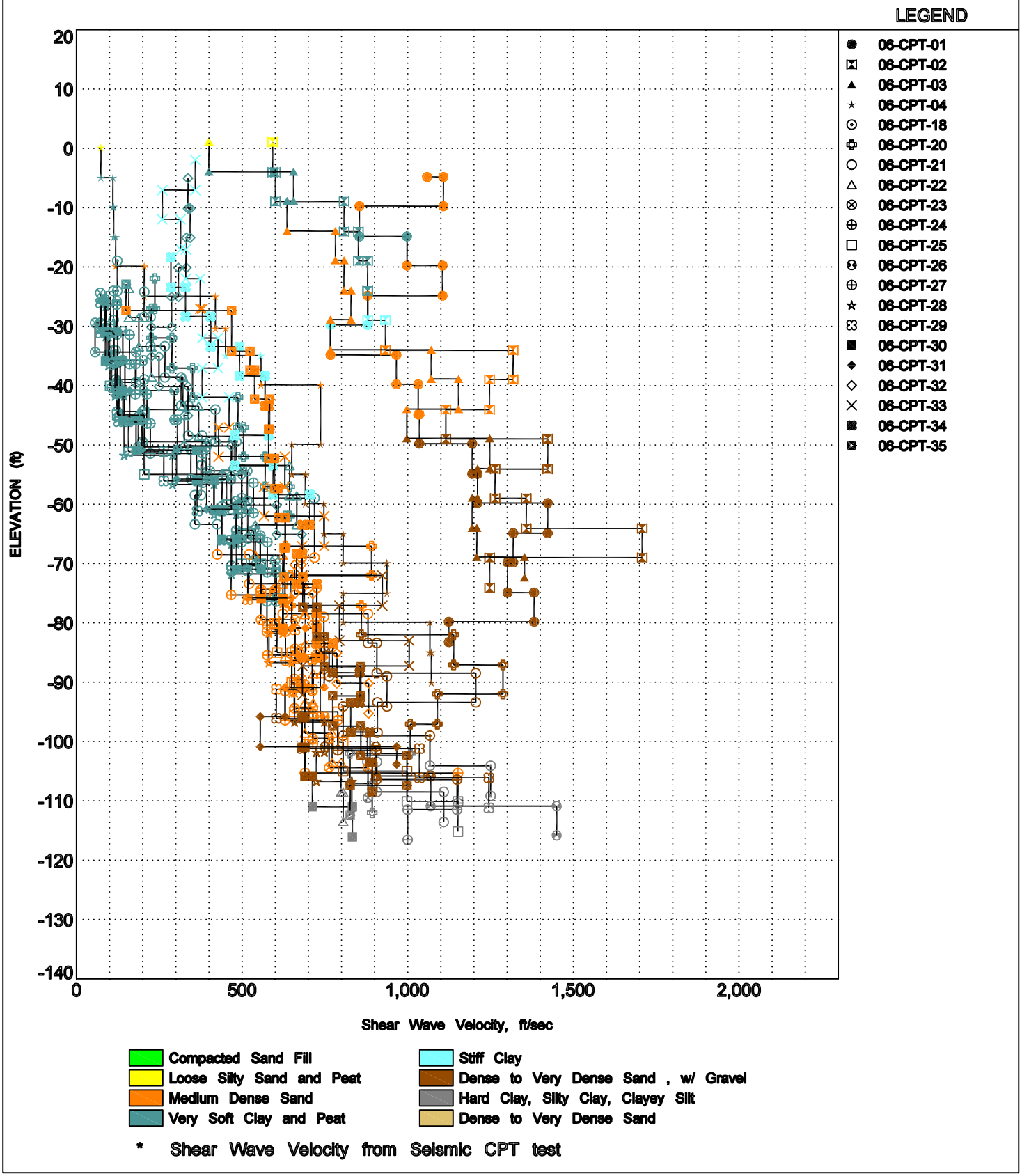
Figure 5-6

CLIENT BATA/Caltrans

PROJECT NAME Antioch Bridge Seismic Retrofit Project

PROJECT NUMBER

PROJECT LOCATION



SITE INVESTIGATION REPORT

EVALUATION OF MINING AND AGRICULTURAL CONTAMINANTS IN SURFACE SOIL ON SHERMAN ISLAND NEAR THE ANTIOCH BRIDGE

ANTIOCH BRIDGE SEISMIC RETROFIT PROJECT CONTRA COSTA AND SACRAMENTO COUNTIES, CALIFORNIA

PREPARED FOR:
CALTRANS DISTRICT 4
111 GRAND AVENUE, 14TH FLOOR
OAKLAND, CA 94612

PREPARED BY:
GEOCON CONSULTANTS, INC.
6671 BRISA STREET
LIVERMORE, CALIFORNIA

GEOCON PROJECT NO. E8435-06-18A
CALTRANS EA 04-1A5211

AUGUST 2009

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.

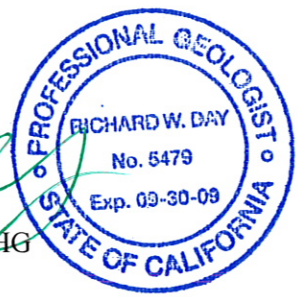
This report is not a comprehensive site characterization and should not be construed as such. The findings as presented in this report are predicated on the results of the limited sampling and laboratory testing performed. In addition, the information obtained is not intended to address potential impacts 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.

GEOCON CONSULTANTS, INC.

Lauren Vigliotti
Senior Staff Geologist

Richard Day, CEG, CHG
Regional Manager



CALIFORNIA DEPARTMENT OF TRANSPORTATION – DISTRICT 4
OFFICE OF ENVIRONMENTAL ENGINEERING

Reviewed By:	Recommended By:	Approved By:
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SITE INVESTIGATION REPORT – Evaluation of Mining and Agricultural Contaminants in Surface Soil on Sherman Island Near the Antioch Bridge

1.0 INTRODUCTION

This Site Investigation Report for the Antioch Bridge Seismic Retrofit project was prepared by Geocon Consultants, Inc. under California Department of Transportation (Caltrans) Contract No. 04A2912 and Task Order (TO) 18A1, EA 04-1A5221.

1.1 Project Description and Proposed Improvements

The site consists of areas adjacent to the Antioch Bridge located on State Route 160 (SR-160) connecting the City of Antioch in Contra Costa County, and Sherman Island in Sacramento County, California. The site location is depicted on the Vicinity Map, Figure 1. Caltrans intends to retrofit the Antioch Bridge which spans approximately two miles. The project limits extend north from Post Mile (PM) 0.8 in Contra Costa County to PM 1.3 at the border of Contra Costa and Sacramento Counties, and from PM 0 to PM 1.3 on Sherman Island in Sacramento County.

The site investigation was performed at the Temporary Access Road between Pier 22 and Pier 38, the Temporary Contractor Staging and Laydown Area, and the area below the bridge slab span, between Bent 42 and Abutment 71.

1.2 General Objectives

The purpose of the soil investigation was to evaluate the concentrations of metals and pesticides in soil associated with historic mining deposits and use of agricultural chemicals within the project area. Construction activities during site preparation may create airborne dust, which may contain potential contaminants, and therefore present a health hazard. The information obtained from this investigation will be used by Caltrans to identify health and safety concerns during proposed construction activities.

1.3 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* (May 2008), 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. ESLs are strictly risk assessment tools and "not regulatory clean up standards." The presence of a chemical at concentrations in excess of an ESL does not necessarily indicate that adverse impacts to human health or the environment are occurring; this simply indicates that a potential for adverse risk may exist and that additional evaluation is or "may be" warranted (SFRWQCB, 2008).

The following ESL tables were used for comparative purposes: Table A – Shallow Soil (≤3 meters below ground surface; bgs) – Groundwater is a Current or Potential Source of Drinking Water, and Table K-3 – Direct Exposure Soil Screening Levels, Construction/Trench Worker Exposure Scenario. The respective ESLs are listed at the end of Tables 1 and 2 for comparative purposes.

2.0 SCOPE OF SERVICES

The scope of services requested by Caltrans under TO-18A1, EA 04-1A5221 included the following:

2.1 Pre-field Activities

- Prepared a site-specific *Health and Safety Plan* to provide guidelines on the use of personal protective equipment and the health and safety procedures implemented during the field activities.
- Retained the services of Advanced Technology Laboratories (ATL), a Caltrans-approved and California-certified analytical laboratory, to perform the chemical analysis of samples.

2.2 Field Activities

The field investigation was performed on June 16, 2009, by Chris Merritt and Dave Watts of Geocon, under the responsible charge of Richard Day. Mr. Day and Mr. Merritt are Professional Geologists in the State of California. The following field activities were performed during soil sampling efforts:

- Collected 18 four-point composite surface soil samples, using hand tools, for CAM 17 metals and pesticides analysis.
- Transported samples to California-certified environmental laboratories.

3.0 INVESTIGATIVE METHODS

3.1 Sampling Procedures

A total of 72 soil sub-samples were collected from 18 locations that each comprised an approximate 20-foot diameter area. Soil sampling locations were identified by the Caltrans TO Manager as shown on the Site Plans, Figures 2-1 through 2-3.

The soil samples were collected between the ground surface and a depth of six inches using hand tools that were decontaminated between each sample location. A total of 72 sub-samples were collected into clean glass jars sealed with plastic, Teflon-lined caps. Sample containers were labeled and transported to ATL using standard chain-of-custody (COC) documentation. ATL was instructed to combine the four sub-samples collected from each location into a total of 18 composites. Soil sampling locations were back-filled to surface with soil cuttings. Groundwater was not encountered during the field activities.

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. Decontamination water was disposed to the ground surface within Caltrans right-of-way in a manner not to create runoff, away from drain inlets or potential water bodies.

3.2 Laboratory Analyses

Laboratory analyses were performed under a 48-hour turn-around-time. Reproductions of the laboratory reports and chain-of-custody documentation are presented as Appendix A. The 18 composite soil samples were analyzed for CAM17 metals according to Title 22 CCR, Environmental Protection Agency (EPA) Test Methods 6010 ICAP and 7471A, and for organochlorine pesticides using EPA Method 8081B.

3.3 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. Reproductions of laboratory reports and COC documentation are presented in Appendix A.

4.0 INVESTIGATIVE RESULTS

4.1 Subsurface Conditions

Observations during field activities indicated that surface soil at the project location generally consist of brown, gravelly sand and silt.

4.2 Laboratory Analytical Results

A summary of the laboratory analytical results for metals and pesticides are presented in Tables 1 and 2, respectively, and are summarized below:

- The following metals were not detected above their respective reporting limits (RLs) in the samples: antimony, beryllium, cadmium, selenium, silver, and thallium. Remaining CAM 17 metals were reported in the soil samples as follows:

- Arsenic concentrations ranged from 4.2 to 11 milligrams per kilogram (mg/kg)
- Barium concentrations ranged from 80 to 190 mg/kg
- Chromium concentrations ranged from 32 to 61 mg/kg
- Cobalt concentrations ranged from 6.7 to 11 mg/kg
- Copper concentrations ranged from 17 to 45 mg/kg
- Lead concentrations ranged from 7.4 to 15 mg/kg
- Mercury concentrations ranged from 0.11 to 0.41 mg/kg
- Nickel concentrations ranged from 35 to 63 mg/kg
- Vanadium concentrations ranged from 39 to 89 mg/kg
- Zinc concentrations ranged from 38 to 110 mg/kg

- The following pesticides were reported in the soil samples:
  - 4,4'-DDD concentrations ranged from 2.0 to 4.2 micrograms per kilogram (µg/kg)
  - 4,4'DDE concentrations ranged from less than (<) the RL of 2.0 to 18 µg/kg
  - 4,4'-DDT concentrations ranged from <2.0 to 29 µg/kg
  - Dieldrin above the RL in two samples, at concentrations of 2.5 µg/kg and 3.9 µg/kg

4.3 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. The data showed acceptable recoveries and relative percent differences (RPDs) for all of the analyses. 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.

5.0 CONCLUSIONS

5.1 CAM 17 Metals

The CAM 17 metals concentrations in site soil were compared to ESLs (Tables A and K-3, SFRWQCB, May 2008) and with published background levels typically present in California soils as presented in *Background Concentrations of Trace and Major Elements in California Soils* (Kearney Foundation of Soil Science, Division of Agriculture and Natural Resources, University of California, March 1996). Arsenic and vanadium were the only metals with reported concentrations greater than their respective ESL values in the soil samples collected at the site. Arsenic was detected in the samples at concentrations between 4.2 and 11 mg/kg, exceeding the residential land use ESL of 0.39 mg/kg and the commercial/industrial land use ESL of 1.6 mg/kg for shallow soil (≤3 meters; SFRWQCB, Table A). Vanadium was reported in the soil samples at concentrations between 39 mg/kg and 89 mg/kg, exceeding the residential land use ESL of 16 mg/kg for shallow soil.

The means, maximums, ESLs and published background concentrations are summarized in the table below:

Metal	Mean	Maximum	Shallow Soil Commercial/ Industrial ESL	Direct Exposure Construction Worker ESL	PUBLISHED BACKGROUND MEAN[1]	PUBLISHED BACKGROUND RANGE [1]
Arsenic	9.1	11	1.6	15	3.5	0.6 to 11.0
Vanadium	70	89	200	770	112	39 to 288

Concentrations reported in milligrams per kilogram (mg/kg)

[1] Kearney Foundation of Soil Science, March 1996

The mean and maximum values for arsenic in the soil samples collected at the Site are greater than the residential and commercial/industrial land use ESLs; however, they are less than the direct exposure ESL (Table K-3) 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.

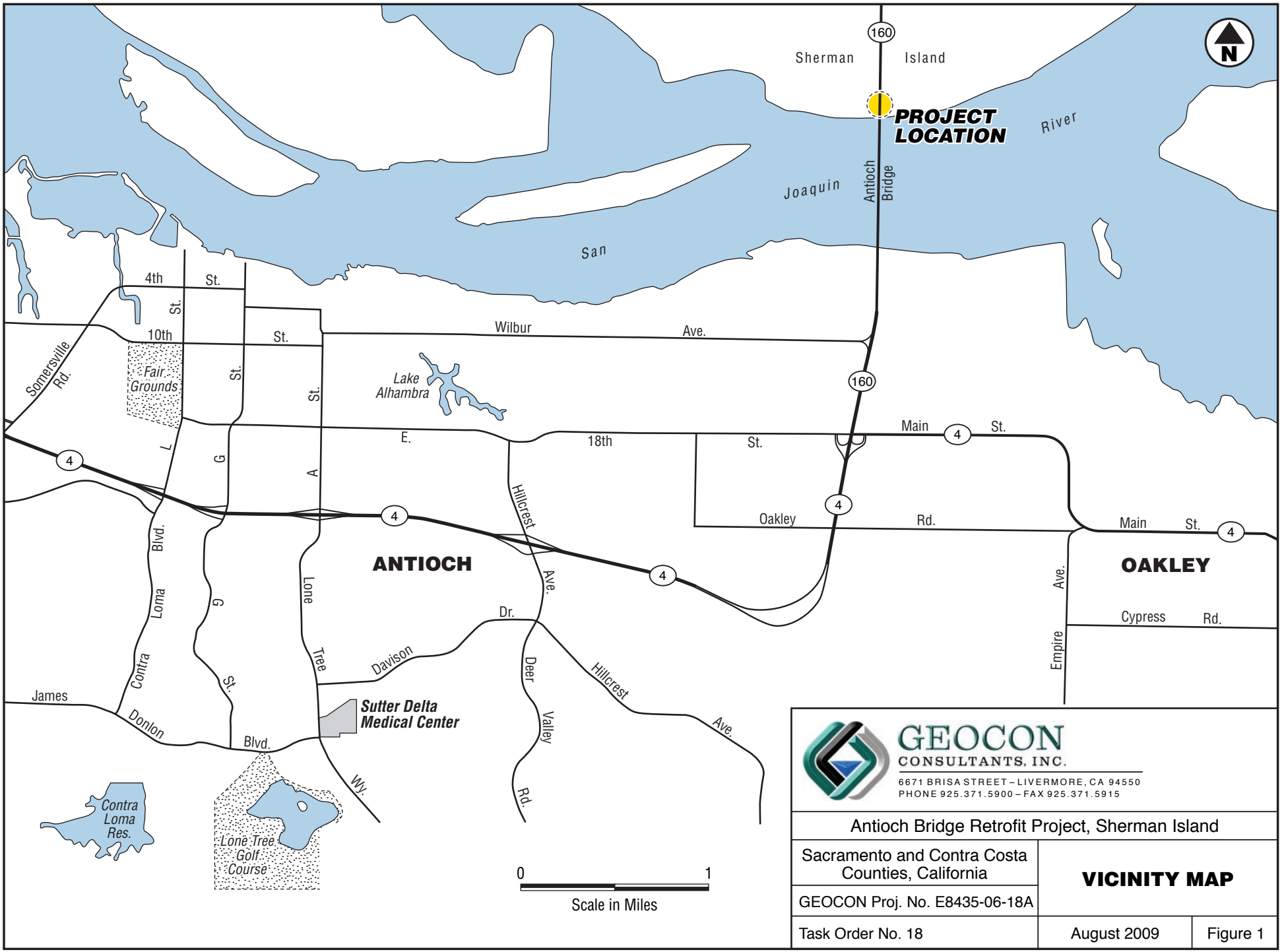
The mean and maximum values for vanadium in the soil samples collected at the site is greater than the residential land use ESL, however, they are less than the commercial/industrial land use and direct exposure ESLs, as well as the published background concentration mean.

5.2 Pesticides

The reported concentrations of pesticides in soil samples collected at the Site are less than their respective ESLs, with the exception of dieldrin. Dieldrin was reported in soil samples Comp TAR5 and Comp TAR6 at concentrations of 2.5 µg/kg and 3.9 µg/kg, respectively, exceeding the residential and commercial/industrial land use ESLs of 2.3 µg/kg. The reported concentrations are below the direct exposure ESL of 1,600 µg/kg.

5.3 Worker Protection

The contractor(s) should consider developing project-specific safe work practices to prevent or minimize worker exposure to impacted soil. The work practices should include protocols for dust control and other health and safety protocols and procedures for the handling of metals- and pesticides-impacted soil.



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Antioch Bridge Retrofit Project, Sherman Island

Sacramento and Contra Costa Counties, California

VICINITY MAP

GEOCON Proj. No. E8435-06-18A

Task Order No. 18 | August 2009 | Figure 1

LEGEND:

TAR1 ⊗ Approximate Sample Location

0 100
Scale in Feet

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Antioch Bridge Retrofit Project, Sherman Island

Sacramento and Contra Costa Counties, California

SITE PLAN

GEOCON Proj. No. E8435-06-18A

Task Order No. 18 | August 2009 | Figure 2-1

LEGEND:

TAR1 ⊗ Approximate Sample Location

0 100
Scale in Feet

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Antioch Bridge Retrofit Project, Sherman Island

Sacramento and Contra Costa Counties, California	**SITE PLAN**	
GEOCON Proj. No. E8435-06-18A		
Task Order No. 18	August 2009	Figure 2-2

LEGEND:

TAR1 ⊗ Approximate Sample Location

0 100

Scale in Feet

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Sacramento and Contra Costa Counties, California

SITE PLAN

GEOCON Proj. No. E8435-06-18A

Task Order No. 18 | August 2009 | Figure 2-3

TABLE 1
Summary of CAM17 Metals Results
Antioch Bridge Retrofit
Antioch, California

Sample ID	Antimony	Arsenic	Barium	Beryllium	Cadmium	Chromium	Cobalt	Copper	Lead	Molybdenum	Nickel	Selenium	Silver	Thallium	Vanadium	Zinc	Mercury
Comp SS1	<2.0	4.2	80	<1.0	<1.0	32	6.7	17	7.4	<1.0	39	<1.0	<1.0	<1.0	39	38	0.26
Comp SS2	<2.0	8.0	130	<1.0	<1.0	44	8.9	32	8.7	1.1	53	<1.0	<1.0	<1.0	60	110	0.12
Comp TAR1	<2.0	7.9	110	<1.0	<1.0	34	8.6	26	9.3	1.1	35	<1.0	<1.0	<1.0	49	40	0.16
Comp TAR2	<2.0	10	100	<1.0	<1.0	38	10	29	11	1.2	40	<1.0	<1.0	<1.0	59	44	0.23
Comp TAR3	<2.0	8.8	120	<1.0	<1.0	40	10	32	13	1.1	41	<1.0	<1.0	<1.0	57	61	0.26
Comp TAR4	<2.0	10	120	<1.0	<1.0	38	11	33	11	<1.0	40	<1.0	<1.0	<1.0	58	49	0.41
Comp TAR5	<2.0	8.8	100	<1.0	<1.0	33	9.0	26	9.8	<1.0	38	<1.0	<1.0	<1.0	50	40	0.23
Comp TAR6	<2.0	8.6	120	<1.0	<1.0	35	7.5	29	11	1.3	39	<1.0	<1.0	<1.0	53	46	0.17
Comp TCWA1	<2.0	8.7	170	<1.0	<1.0	59	9.1	43	13	1.1	59	<1.0	<1.0	<1.0	82	61	0.12
Comp TCWA2	<2.0	8.8	170	<1.0	<1.0	57	9.0	41	14	1.2	57	<1.0	<1.0	<1.0	77	64	0.15
Comp TCWA3	<2.0	9.5	170	<1.0	<1.0	57	9.4	42	11	1.3	58	<1.0	<1.0	<1.0	81	57	0.12
Comp TCWA4	<2.0	10	190	<1.0	<1.0	59	9.5	43	14	1.4	59	<1.0	<1.0	<1.0	84	58	0.14
Comp TCWA5	<2.0	10	190	<1.0	<1.0	61	10	45	12	1.2	63	<1.0	<1.0	<1.0	89	61	0.12
Comp TCWA6	<2.0	9.3	180	<1.0	<1.0	57	9.6	42	13	2.0	58	<1.0	<1.0	<1.0	80	65	0.13
Comp TCWA7	<2.0	10	180	<1.0	<1.0	60	10	43	12	1.2	61	<1.0	<1.0	<1.0	85	61	0.11
Comp TCWA8	<2.0	10	190	<1.0	<1.0	59	9.4	45	14	1.4	60	<1.0	<1.0	<1.0	85	57	0.14
Comp TCWA9	<2.0	10	170	<1.0	<1.0	61	11	44	12	1.3	63	<1.0	<1.0	<1.0	86	63	0.11
Comp TCWA10	<2.0	11	190	<1.0	<1.0	58	9.8	43	15	1.6	59	<1.0	<1.0	<1.0	85	59	0.14
ESLs																	
Residential Land Use	6.1	0.39	750	4.0	1.7	750	40	230	200	40	150	10	20	1.3	16	600	1.3
Comm/Ind Land Use	40	1.6	1,500	8.0	7.4	750	80	230	750	40	150	10	40	16	200	600	10
Construct/Trench Wkr	310	15	2,600	98	39	1.2E+06	94	310,000	750	3,900	260	3,900	3,900	62	770	230,000	58

Notes:

Results are shown in milligrams per kilogram (mg/kg)

Values for chromium are Chromium III, as there is no standard for total chromium

< = Analyte was not detected above the laboratory reporting limit

ESLs = Environmental Screening Levels, SFRWQCB, May 2008, Tables A and K-3

TABLE 2
Summary of Pesticides Results
Antioch Bridge Retrofit
Antioch, California

Sample ID	4,4-DDD	4,4-DDE	4,4-DDT	Dieldrin	Other Pesticides
Comp SS1	2.8	2.1	11	<2.0	ND
Comp SS2	<2.0	<2.0	3.5	<2.0	ND
Comp TAR1	<2.0	<2.0	<2.0	<2.0	ND
Comp TAR2	<2.0	<2.0	<2.0	<2.0	ND
Comp TAR3	<2.0	<2.0	<2.0	<2.0	ND
Comp TAR4	<2.0	<2.0	<2.0	<2.0	ND
Comp TAR5	<2.0	2.2	<2.0	2.5	ND
Comp TAR6	<2.0	2.3	<2.0	3.9	ND
Comp TCWA1	<2.0	18	22	<2.0	ND
Comp TCWA2	<2.0	4.9	11	<2.0	ND
Comp TCWA3	2.5	14	26	<2.0	ND
Comp TCWA4	2.0	8.5	20	<2.0	ND
Comp TCWA5	4.2	14	29	<2.0	ND
Comp TCWA6	2.0	6.8	13	<2.0	ND
Comp TCWA7	4.0	12	24	<2.0	ND
Comp TCWA8	2.1	9.2	16	<2.0	ND
Comp TCWA9	<2.0	8.3	15	<2.0	ND
Comp TCWA10	<2.0	7.1	15	<2.0	ND
ESLs					
Residential Land Use	2,400	1,700	1,700	2.3	---
Commercial/Industrial Land Use	10,000	4,000	4,000	2.3	---
Construction/Trench Worker	120,000	87,000	87,000	1,600	---

Notes:

Data are presented in micrograms per kilogram (ug/kg).

< = Analyte was not detected above the stated detection limit

ND = No analytes detected above the method detection limit

ESL = Environmental Screening Levels, SFRWQCB (May 2008), Tables A and K-3.

APPENDIX A

June 19, 2009

Dave Watts
Geocon Consultants, Inc.
6671 Brisa Street
Livermore, CA 94550

TEL: (925) 371-5900
FAX: (925) 371-5915

ELAP No.: 1838
NELAP No.: 02107CA
NEVADA.: CA-401
CSDLAC No.: 10196

Workorder No.: 105982

RE: ANTIOCH BRIDGE RETROFIT, E8435-06-18

Attention: Dave Watts

Enclosed are the results for sample(s) received on June 17, 2009 by Advanced Technology Laboratories . 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 (562)989-4045 if I can be of further assistance to your company.

Sincerely,

for Eddie F. Rodriguez
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.

CLIENT:	Geocon Consultants, Inc.	**Client Sample ID:**	Composite TAR1-A,B,C,D
Lab Order:	105982	**Collection Date:**	6/16/2009
Project:	ANTIOCH BRIDGE RETROFIT, E8435-06-	**Matrix:**	SOIL
Lab ID:	105982-073A		

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
ICP METALS						
	EPA 3050B			**EPA 6010B**		
RunID: ICP8_090618E	QC Batch: 55985			PrepDate:	6/17/2009	Analyst: **CL**
Antimony	ND	2.0		mg/Kg	1	6/18/2009 02:51 PM
Arsenic	7.9	1.0		mg/Kg	1	6/18/2009 02:51 PM
Barium	110	1.0		mg/Kg	1	6/18/2009 02:51 PM
Beryllium	ND	1.0		mg/Kg	1	6/18/2009 02:51 PM
Cadmium	ND	1.0		mg/Kg	1	6/18/2009 02:51 PM
Chromium	34	1.0		mg/Kg	1	6/18/2009 02:51 PM
Cobalt	8.6	1.0		mg/Kg	1	6/18/2009 02:51 PM
Copper	26	2.0		mg/Kg	1	6/18/2009 02:51 PM
Lead	9.3	1.0		mg/Kg	1	6/18/2009 02:51 PM
Molybdenum	1.1	1.0		mg/Kg	1	6/18/2009 02:51 PM
Nickel	35	1.0		mg/Kg	1	6/18/2009 02:51 PM
Selenium	ND	1.0		mg/Kg	1	6/18/2009 02:51 PM
Silver	ND	1.0		mg/Kg	1	6/18/2009 02:51 PM
Thallium	ND	1.0		mg/Kg	1	6/18/2009 02:51 PM
Vanadium	49	1.0		mg/Kg	1	6/18/2009 02:51 PM
Zinc	40	1.0		mg/Kg	1	6/18/2009 02:51 PM
ORGANOCHLORINE PESTICIDES BY GC/ECD						
	EPA 3550B			**EPA 8081A**		
RunID: GC9_090618A	QC Batch: 56044			PrepDate:	6/18/2009	Analyst: **HL**
4,4´-DDD	ND	2.0		µg/Kg	1	6/18/2009 10:00 PM
4,4´-DDE	ND	2.0		µg/Kg	1	6/18/2009 10:00 PM
4,4´-DDT	ND	2.0		µg/Kg	1	6/18/2009 10:00 PM
Aldrin	ND	1.0		µg/Kg	1	6/18/2009 10:00 PM
alpha-BHC	ND	1.0		µg/Kg	1	6/18/2009 10:00 PM
alpha-Chlordane	ND	1.0		µg/Kg	1	6/18/2009 10:00 PM
beta-BHC	ND	1.0		µg/Kg	1	6/18/2009 10:00 PM
Chlordane	ND	8.5		µg/Kg	1	6/18/2009 10:00 PM
delta-BHC	ND	1.0		µg/Kg	1	6/18/2009 10:00 PM
Dieldrin	ND	2.0		µg/Kg	1	6/18/2009 10:00 PM
Endosulfan I	ND	1.0		µg/Kg	1	6/18/2009 10:00 PM
Endosulfan II	ND	2.0		µg/Kg	1	6/18/2009 10:00 PM
Endosulfan sulfate	ND	2.0		µg/Kg	1	6/18/2009 10:00 PM
Endrin	ND	2.0		µg/Kg	1	6/18/2009 10:00 PM
Endrin aldehyde	ND	2.0		µg/Kg	1	6/18/2009 10:00 PM
Endrin ketone	ND	2.0		µg/Kg	1	6/18/2009 10:00 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.	**Client Sample ID:**	Composite TAR1-A,B,C,D
Lab Order:	105982	**Collection Date:**	6/16/2009
Project:	ANTIOCH BRIDGE RETROFIT, E8435-06-	**Matrix:**	SOIL
Lab ID:	105982-073A		

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
ORGANOCHLORINE PESTICIDES BY GC/ECD						
	EPA 3550B			**EPA 8081A**		
RunID: GC9_090618A	QC Batch: 56044			PrepDate:	6/18/2009	Analyst: **HL**
gamma-BHC	ND	1.0		µg/Kg	1	6/18/2009 10:00 PM
gamma-Chlordane	ND	1.0		µg/Kg	1	6/18/2009 10:00 PM
Heptachlor	ND	1.0		µg/Kg	1	6/18/2009 10:00 PM
Heptachlor epoxide	ND	1.0		µg/Kg	1	6/18/2009 10:00 PM
Methoxychlor	ND	5.0		µg/Kg	1	6/18/2009 10:00 PM
Toxaphene	ND	50		µg/Kg	1	6/18/2009 10:00 PM
Surr: Decachlorobiphenyl	62.9	20-142		%REC	1	6/18/2009 10:00 PM
Surr: Tetrachloro-m-xylene	60.1	25-115		%REC	1	6/18/2009 10:00 PM
MERCURY BY COLD VAPOR TECHNIQUE						
				EPA 7471A		
RunID: AA5_090618B	QC Batch: 55982			PrepDate:	6/17/2009	Analyst: **IL**
Mercury	0.16	0.10		mg/Kg	1	6/18/2009 12:59 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:**	Composite TAR2-A,B,C,D
Lab Order:	105982	**Collection Date:**	6/16/2009
Project:	ANTIOCH BRIDGE RETROFIT, E8435-06-	**Matrix:**	SOIL
Lab ID:	105982-074A		

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
ICP METALS						
	EPA 3050B			**EPA 6010B**		
RunID: ICP8_090618E	QC Batch: 55985			PrepDate:	6/17/2009	Analyst: **CL**
Antimony	ND	2.0		mg/Kg	1	6/18/2009 02:54 PM
Arsenic	10	1.0		mg/Kg	1	6/18/2009 02:54 PM
Barium	100	1.0		mg/Kg	1	6/18/2009 02:54 PM
Beryllium	ND	1.0		mg/Kg	1	6/18/2009 02:54 PM
Cadmium	ND	1.0		mg/Kg	1	6/18/2009 02:54 PM
Chromium	38	1.0		mg/Kg	1	6/18/2009 02:54 PM
Cobalt	10	1.0		mg/Kg	1	6/18/2009 02:54 PM
Copper	29	2.0		mg/Kg	1	6/18/2009 02:54 PM
Lead	11	1.0		mg/Kg	1	6/18/2009 02:54 PM
Molybdenum	1.2	1.0		mg/Kg	1	6/18/2009 02:54 PM
Nickel	40	1.0		mg/Kg	1	6/18/2009 02:54 PM
Selenium	ND	1.0		mg/Kg	1	6/18/2009 02:54 PM
Silver	ND	1.0		mg/Kg	1	6/18/2009 02:54 PM
Thallium	ND	1.0		mg/Kg	1	6/18/2009 02:54 PM
Vanadium	59	1.0		mg/Kg	1	6/18/2009 02:54 PM
Zinc	44	1.0		mg/Kg	1	6/18/2009 02:54 PM
ORGANOCHLORINE PESTICIDES BY GC/ECD						
	EPA 3550B			**EPA 8081A**		
RunID: GC9_090618A	QC Batch: 56044			PrepDate:	6/18/2009	Analyst: **HL**
4,4´-DDD	ND	2.0		µg/Kg	1	6/18/2009 10:28 PM
4,4´-DDE	ND	2.0		µg/Kg	1	6/18/2009 10:28 PM
4,4´-DDT	ND	2.0		µg/Kg	1	6/18/2009 10:28 PM
Aldrin	ND	1.0		µg/Kg	1	6/18/2009 10:28 PM
alpha-BHC	ND	1.0		µg/Kg	1	6/18/2009 10:28 PM
alpha-Chlordane	ND	1.0		µg/Kg	1	6/18/2009 10:28 PM
beta-BHC	ND	1.0		µg/Kg	1	6/18/2009 10:28 PM
Chlordane	ND	8.5		µg/Kg	1	6/18/2009 10:28 PM
delta-BHC	ND	1.0		µg/Kg	1	6/18/2009 10:28 PM
Dieldrin	ND	2.0		µg/Kg	1	6/18/2009 10:28 PM
Endosulfan I	ND	1.0		µg/Kg	1	6/18/2009 10:28 PM
Endosulfan II	ND	2.0		µg/Kg	1	6/18/2009 10:28 PM
Endosulfan sulfate	ND	2.0		µg/Kg	1	6/18/2009 10:28 PM
Endrin	ND	2.0		µg/Kg	1	6/18/2009 10:28 PM
Endrin aldehyde	ND	2.0		µg/Kg	1	6/18/2009 10:28 PM
Endrin ketone	ND	2.0		µg/Kg	1	6/18/2009 10:28 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.	**Client Sample ID:**	Composite TAR2-A,B,C,D
Lab Order:	105982	**Collection Date:**	6/16/2009
Project:	ANTIOCH BRIDGE RETROFIT, E8435-06-	**Matrix:**	SOIL
Lab ID:	105982-074A		

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
ORGANOCHLORINE PESTICIDES BY GC/ECD						
	EPA 3550B			**EPA 8081A**		
RunID: GC9_090618A	QC Batch: 56044			PrepDate:	6/18/2009	Analyst: **HL**
gamma-BHC	ND	1.0		µg/Kg	1	6/18/2009 10:28 PM
gamma-Chlordane	ND	1.0		µg/Kg	1	6/18/2009 10:28 PM
Heptachlor	ND	1.0		µg/Kg	1	6/18/2009 10:28 PM
Heptachlor epoxide	ND	1.0		µg/Kg	1	6/18/2009 10:28 PM
Methoxychlor	ND	5.0		µg/Kg	1	6/18/2009 10:28 PM
Toxaphene	ND	50		µg/Kg	1	6/18/2009 10:28 PM
Surr: Decachlorobiphenyl	50.5	20-142		%REC	1	6/18/2009 10:28 PM
Surr: Tetrachloro-m-xylene	51.3	25-115		%REC	1	6/18/2009 10:28 PM
MERCURY BY COLD VAPOR TECHNIQUE						
				EPA 7471A		
RunID: AA5_090618B	QC Batch: 55982			PrepDate:	6/17/2009	Analyst: **IL**
Mercury	0.23	0.10		mg/Kg	1	6/18/2009 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		

CLIENT:	Geocon Consultants, Inc.	**Client Sample ID:**	Composite TAR3-A,B,C,D
Lab Order:	105982	**Collection Date:**	6/16/2009
Project:	ANTIOCH BRIDGE RETROFIT, E8435-06-	**Matrix:**	SOIL
Lab ID:	105982-075A		

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
ICP METALS						
	EPA 3050B			**EPA 6010B**		
RunID: ICP8_090618E	QC Batch: 55985			PrepDate:	6/17/2009	Analyst: **CL**
Antimony	ND	2.0		mg/Kg	1	6/18/2009 02:56 PM
Arsenic	8.8	1.0		mg/Kg	1	6/18/2009 02:56 PM
Barium	120	1.0		mg/Kg	1	6/18/2009 02:56 PM
Beryllium	ND	1.0		mg/Kg	1	6/18/2009 02:56 PM
Cadmium	ND	1.0		mg/Kg	1	6/18/2009 02:56 PM
Chromium	40	1.0		mg/Kg	1	6/18/2009 02:56 PM
Cobalt	10	1.0		mg/Kg	1	6/18/2009 02:56 PM
Copper	32	2.0		mg/Kg	1	6/18/2009 02:56 PM
Lead	13	1.0		mg/Kg	1	6/18/2009 02:56 PM
Molybdenum	1.1	1.0		mg/Kg	1	6/18/2009 02:56 PM
Nickel	41	1.0		mg/Kg	1	6/18/2009 02:56 PM
Selenium	ND	1.0		mg/Kg	1	6/18/2009 02:56 PM
Silver	ND	1.0		mg/Kg	1	6/18/2009 02:56 PM
Thallium	ND	1.0		mg/Kg	1	6/18/2009 02:56 PM
Vanadium	57	1.0		mg/Kg	1	6/18/2009 02:56 PM
Zinc	61	1.0		mg/Kg	1	6/18/2009 02:56 PM
ORGANOCHLORINE PESTICIDES BY GC/ECD						
	EPA 3550B			**EPA 8081A**		
RunID: GC9_090618A	QC Batch: 56044			PrepDate:	6/18/2009	Analyst: **HL**
4,4´-DDD	ND	2.0		µg/Kg	1	6/18/2009 10:42 PM
4,4´-DDE	ND	2.0		µg/Kg	1	6/18/2009 10:42 PM
4,4´-DDT	ND	2.0		µg/Kg	1	6/18/2009 10:42 PM
Aldrin	ND	1.0		µg/Kg	1	6/18/2009 10:42 PM
alpha-BHC	ND	1.0		µg/Kg	1	6/18/2009 10:42 PM
alpha-Chlordane	ND	1.0		µg/Kg	1	6/18/2009 10:42 PM
beta-BHC	ND	1.0		µg/Kg	1	6/18/2009 10:42 PM
Chlordane	ND	8.5		µg/Kg	1	6/18/2009 10:42 PM
delta-BHC	ND	1.0		µg/Kg	1	6/18/2009 10:42 PM
Dieldrin	ND	2.0		µg/Kg	1	6/18/2009 10:42 PM
Endosulfan I	ND	1.0		µg/Kg	1	6/18/2009 10:42 PM
Endosulfan II	ND	2.0		µg/Kg	1	6/18/2009 10:42 PM
Endosulfan sulfate	ND	2.0		µg/Kg	1	6/18/2009 10:42 PM
Endrin	ND	2.0		µg/Kg	1	6/18/2009 10:42 PM
Endrin aldehyde	ND	2.0		µg/Kg	1	6/18/2009 10:42 PM
Endrin ketone	ND	2.0		µg/Kg	1	6/18/2009 10:42 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		

CLIENT:	Geocon Consultants, Inc.	**Client Sample ID:**	Composite TAR3-A,B,C,D
Lab Order:	105982	**Collection Date:**	6/16/2009
Project:	ANTIOCH BRIDGE RETROFIT, E8435-06-	**Matrix:**	SOIL
Lab ID:	105982-075A		

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
ORGANOCHLORINE PESTICIDES BY GC/ECD						
	EPA 3550B			**EPA 8081A**		
RunID: GC9_090618A	QC Batch: 56044			PrepDate:	6/18/2009	Analyst: **HL**
gamma-BHC	ND	1.0		µg/Kg	1	6/18/2009 10:42 PM
gamma-Chlordane	ND	1.0		µg/Kg	1	6/18/2009 10:42 PM
Heptachlor	ND	1.0		µg/Kg	1	6/18/2009 10:42 PM
Heptachlor epoxide	ND	1.0		µg/Kg	1	6/18/2009 10:42 PM
Methoxychlor	ND	5.0		µg/Kg	1	6/18/2009 10:42 PM
Toxaphene	ND	50		µg/Kg	1	6/18/2009 10:42 PM
Surr: Decachlorobiphenyl	54.0	20-142		%REC	1	6/18/2009 10:42 PM
Surr: Tetrachloro-m-xylene	55.6	25-115		%REC	1	6/18/2009 10:42 PM
MERCURY BY COLD VAPOR TECHNIQUE						
				EPA 7471A		
RunID: AA5_090618B	QC Batch: 55982			PrepDate:	6/17/2009	Analyst: **IL**
Mercury	0.26	0.10		mg/Kg	1	6/18/2009 01:02 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.	**Client Sample ID:**	Composite TAR4-A,B,C,D
Lab Order:	105982	**Collection Date:**	6/16/2009
Project:	ANTIOCH BRIDGE RETROFIT, E8435-06-	**Matrix:**	SOIL
Lab ID:	105982-076A		

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
ICP METALS						
	EPA 3050B			**EPA 6010B**		
RunID: ICP8_090618E	QC Batch: 55985			PrepDate:	6/17/2009	Analyst: **CL**
Antimony	ND	2.0		mg/Kg	1	6/18/2009 02:59 PM
Arsenic	10	1.0		mg/Kg	1	6/18/2009 02:59 PM
Barium	120	1.0		mg/Kg	1	6/18/2009 02:59 PM
Beryllium	ND	1.0		mg/Kg	1	6/18/2009 02:59 PM
Cadmium	ND	1.0		mg/Kg	1	6/18/2009 02:59 PM
Chromium	38	1.0		mg/Kg	1	6/18/2009 02:59 PM
Cobalt	11	1.0		mg/Kg	1	6/18/2009 02:59 PM
Copper	33	2.0		mg/Kg	1	6/18/2009 02:59 PM
Lead	11	1.0		mg/Kg	1	6/18/2009 02:59 PM
Molybdenum	ND	1.0		mg/Kg	1	6/18/2009 02:59 PM
Nickel	40	1.0		mg/Kg	1	6/18/2009 02:59 PM
Selenium	ND	1.0		mg/Kg	1	6/18/2009 02:59 PM
Silver	ND	1.0		mg/Kg	1	6/18/2009 02:59 PM
Thallium	ND	1.0		mg/Kg	1	6/18/2009 02:59 PM
Vanadium	58	1.0		mg/Kg	1	6/18/2009 02:59 PM
Zinc	49	1.0		mg/Kg	1	6/18/2009 02:59 PM
ORGANOCHLORINE PESTICIDES BY GC/ECD						
	EPA 3550B			**EPA 8081A**		
RunID: GC9_090618A	QC Batch: 56044			PrepDate:	6/18/2009	Analyst: **HL**
4,4´-DDD	ND	2.0		µg/Kg	1	6/18/2009 10:56 PM
4,4´-DDE	ND	2.0		µg/Kg	1	6/18/2009 10:56 PM
4,4´-DDT	ND	2.0		µg/Kg	1	6/18/2009 10:56 PM
Aldrin	ND	1.0		µg/Kg	1	6/18/2009 10:56 PM
alpha-BHC	ND	1.0		µg/Kg	1	6/18/2009 10:56 PM
alpha-Chlordane	ND	1.0		µg/Kg	1	6/18/2009 10:56 PM
beta-BHC	ND	1.0		µg/Kg	1	6/18/2009 10:56 PM
Chlordane	ND	8.5		µg/Kg	1	6/18/2009 10:56 PM
delta-BHC	ND	1.0		µg/Kg	1	6/18/2009 10:56 PM
Dieldrin	ND	2.0		µg/Kg	1	6/18/2009 10:56 PM
Endosulfan I	ND	1.0		µg/Kg	1	6/18/2009 10:56 PM
Endosulfan II	ND	2.0		µg/Kg	1	6/18/2009 10:56 PM
Endosulfan sulfate	ND	2.0		µg/Kg	1	6/18/2009 10:56 PM
Endrin	ND	2.0		µg/Kg	1	6/18/2009 10:56 PM
Endrin aldehyde	ND	2.0		µg/Kg	1	6/18/2009 10:56 PM
Endrin ketone	ND	2.0		µg/Kg	1	6/18/2009 10:56 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.	**Client Sample ID:**	Composite TAR4-A,B,C,D
Lab Order:	105982	**Collection Date:**	6/16/2009
Project:	ANTIOCH BRIDGE RETROFIT, E8435-06-	**Matrix:**	SOIL
Lab ID:	105982-076A		

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
ORGANOCHLORINE PESTICIDES BY GC/ECD						
	EPA 3550B			**EPA 8081A**		
RunID: GC9_090618A	QC Batch: 56044			PrepDate:	6/18/2009	Analyst: **HL**
gamma-BHC	ND	1.0		µg/Kg	1	6/18/2009 10:56 PM
gamma-Chlordane	ND	1.0		µg/Kg	1	6/18/2009 10:56 PM
Heptachlor	ND	1.0		µg/Kg	1	6/18/2009 10:56 PM
Heptachlor epoxide	ND	1.0		µg/Kg	1	6/18/2009 10:56 PM
Methoxychlor	ND	5.0		µg/Kg	1	6/18/2009 10:56 PM
Toxaphene	ND	50		µg/Kg	1	6/18/2009 10:56 PM
Surr: Decachlorobiphenyl	51.5	20-142		%REC	1	6/18/2009 10:56 PM
Surr: Tetrachloro-m-xylene	53.4	25-115		%REC	1	6/18/2009 10:56 PM
MERCURY BY COLD VAPOR TECHNIQUE						
				EPA 7471A		
RunID: AA5_090618B	QC Batch: 55982			PrepDate:	6/17/2009	Analyst: **IL**
Mercury	0.41	0.10		mg/Kg	1	6/18/2009 01:04 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.	**Client Sample ID:**	Composite TAR5-A,B,C,D
Lab Order:	105982	**Collection Date:**	6/16/2009
Project:	ANTIOCH BRIDGE RETROFIT, E8435-06-	**Matrix:**	SOIL
Lab ID:	105982-077A		

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
ICP METALS						
	EPA 3050B			**EPA 6010B**		
RunID: ICP8_090618E	QC Batch: 55985			PrepDate:	6/17/2009	Analyst: **CL**
Antimony	ND	2.0		mg/Kg	1	6/18/2009 03:01 PM
Arsenic	8.8	1.0		mg/Kg	1	6/18/2009 03:01 PM
Barium	100	1.0		mg/Kg	1	6/18/2009 03:01 PM
Beryllium	ND	1.0		mg/Kg	1	6/18/2009 03:01 PM
Cadmium	ND	1.0		mg/Kg	1	6/18/2009 03:01 PM
Chromium	33	1.0		mg/Kg	1	6/18/2009 03:01 PM
Cobalt	9.0	1.0		mg/Kg	1	6/18/2009 03:01 PM
Copper	26	2.0		mg/Kg	1	6/18/2009 03:01 PM
Lead	9.8	1.0		mg/Kg	1	6/18/2009 03:01 PM
Molybdenum	ND	1.0		mg/Kg	1	6/18/2009 03:01 PM
Nickel	38	1.0		mg/Kg	1	6/18/2009 03:01 PM
Selenium	ND	1.0		mg/Kg	1	6/18/2009 03:01 PM
Silver	ND	1.0		mg/Kg	1	6/18/2009 03:01 PM
Thallium	ND	1.0		mg/Kg	1	6/18/2009 03:01 PM
Vanadium	50	1.0		mg/Kg	1	6/18/2009 03:01 PM
Zinc	40	1.0		mg/Kg	1	6/18/2009 03:01 PM
ORGANOCHLORINE PESTICIDES BY GC/ECD						
	EPA 3550B			**EPA 8081A**		
RunID: GC9_090618A	QC Batch: 56044			PrepDate:	6/18/2009	Analyst: **HL**
4,4´-DDD	ND	2.0		µg/Kg	1	6/18/2009 11:11 PM
4,4´-DDE	2.2	2.0		µg/Kg	1	6/18/2009 11:11 PM
4,4´-DDT	ND	2.0		µg/Kg	1	6/18/2009 11:11 PM
Aldrin	ND	1.0		µg/Kg	1	6/18/2009 11:11 PM
alpha-BHC	ND	1.0		µg/Kg	1	6/18/2009 11:11 PM
alpha-Chlordane	ND	1.0		µg/Kg	1	6/18/2009 11:11 PM
beta-BHC	ND	1.0		µg/Kg	1	6/18/2009 11:11 PM
Chlordane	ND	8.5		µg/Kg	1	6/18/2009 11:11 PM
delta-BHC	ND	1.0		µg/Kg	1	6/18/2009 11:11 PM
Dieldrin	2.5	2.0		µg/Kg	1	6/18/2009 11:11 PM
Endosulfan I	ND	1.0		µg/Kg	1	6/18/2009 11:11 PM
Endosulfan II	ND	2.0		µg/Kg	1	6/18/2009 11:11 PM
Endosulfan sulfate	ND	2.0		µg/Kg	1	6/18/2009 11:11 PM
Endrin	ND	2.0		µg/Kg	1	6/18/2009 11:11 PM
Endrin aldehyde	ND	2.0		µg/Kg	1	6/18/2009 11:11 PM
Endrin ketone	ND	2.0		µg/Kg	1	6/18/2009 11:11 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.	**Client Sample ID:**	Composite TAR5-A,B,C,D
Lab Order:	105982	**Collection Date:**	6/16/2009
Project:	ANTIOCH BRIDGE RETROFIT, E8435-06-	**Matrix:**	SOIL
Lab ID:	105982-077A		

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
ORGANOCHLORINE PESTICIDES BY GC/ECD						
	EPA 3550B			**EPA 8081A**		
RunID: GC9_090618A	QC Batch: 56044			PrepDate:	6/18/2009	Analyst: **HL**
gamma-BHC	ND	1.0		µg/Kg	1	6/18/2009 11:11 PM
gamma-Chlordane	ND	1.0		µg/Kg	1	6/18/2009 11:11 PM
Heptachlor	ND	1.0		µg/Kg	1	6/18/2009 11:11 PM
Heptachlor epoxide	ND	1.0		µg/Kg	1	6/18/2009 11:11 PM
Methoxychlor	ND	5.0		µg/Kg	1	6/18/2009 11:11 PM
Toxaphene	ND	50		µg/Kg	1	6/18/2009 11:11 PM
Surr: Decachlorobiphenyl	56.5	20-142		%REC	1	6/18/2009 11:11 PM
Surr: Tetrachloro-m-xylene	60.5	25-115		%REC	1	6/18/2009 11:11 PM
MERCURY BY COLD VAPOR TECHNIQUE						
				EPA 7471A		
RunID: AA5_090618B	QC Batch: 55982			PrepDate:	6/17/2009	Analyst: **IL**
Mercury	0.23	0.10		mg/Kg	1	6/18/2009 01:06 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.	**Client Sample ID:**	Composite TAR6-A,B,C,D
Lab Order:	105982	**Collection Date:**	6/16/2009
Project:	ANTIOCH BRIDGE RETROFIT, E8435-06-	**Matrix:**	SOIL
Lab ID:	105982-078A		

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
ICP METALS						
	EPA 3050B			**EPA 6010B**		
RunID: ICP8_090618E	QC Batch: 55985			PrepDate:	6/17/2009	Analyst: **CL**
Antimony	ND	2.0		mg/Kg	1	6/18/2009 03:08 PM
Arsenic	8.6	1.0		mg/Kg	1	6/18/2009 03:08 PM
Barium	120	1.0		mg/Kg	1	6/18/2009 03:08 PM
Beryllium	ND	1.0		mg/Kg	1	6/18/2009 03:08 PM
Cadmium	ND	1.0		mg/Kg	1	6/18/2009 03:08 PM
Chromium	35	1.0		mg/Kg	1	6/18/2009 03:08 PM
Cobalt	7.5	1.0		mg/Kg	1	6/18/2009 03:08 PM
Copper	29	2.0		mg/Kg	1	6/18/2009 03:08 PM
Lead	11	1.0		mg/Kg	1	6/18/2009 03:08 PM
Molybdenum	1.3	1.0		mg/Kg	1	6/18/2009 03:08 PM
Nickel	39	1.0		mg/Kg	1	6/18/2009 03:08 PM
Selenium	ND	1.0		mg/Kg	1	6/18/2009 03:08 PM
Silver	ND	1.0		mg/Kg	1	6/18/2009 03:08 PM
Thallium	ND	1.0		mg/Kg	1	6/18/2009 03:08 PM
Vanadium	53	1.0		mg/Kg	1	6/18/2009 03:08 PM
Zinc	46	1.0		mg/Kg	1	6/18/2009 03:08 PM
ORGANOCHLORINE PESTICIDES BY GC/ECD						
	EPA 3550B			**EPA 8081A**		
RunID: GC9_090618A	QC Batch: 56044			PrepDate:	6/18/2009	Analyst: **HL**
4,4´-DDD	ND	2.0		µg/Kg	1	6/18/2009 11:25 PM
4,4´-DDE	2.3	2.0		µg/Kg	1	6/18/2009 11:25 PM
4,4´-DDT	ND	2.0		µg/Kg	1	6/18/2009 11:25 PM
Aldrin	ND	1.0		µg/Kg	1	6/18/2009 11:25 PM
alpha-BHC	ND	1.0		µg/Kg	1	6/18/2009 11:25 PM
alpha-Chlordane	ND	1.0		µg/Kg	1	6/18/2009 11:25 PM
beta-BHC	ND	1.0		µg/Kg	1	6/18/2009 11:25 PM
Chlordane	ND	8.5		µg/Kg	1	6/18/2009 11:25 PM
delta-BHC	ND	1.0		µg/Kg	1	6/18/2009 11:25 PM
Dieldrin	3.9	2.0		µg/Kg	1	6/18/2009 11:25 PM
Endosulfan I	ND	1.0		µg/Kg	1	6/18/2009 11:25 PM
Endosulfan II	ND	2.0		µg/Kg	1	6/18/2009 11:25 PM
Endosulfan sulfate	ND	2.0		µg/Kg	1	6/18/2009 11:25 PM
Endrin	ND	2.0		µg/Kg	1	6/18/2009 11:25 PM
Endrin aldehyde	ND	2.0		µg/Kg	1	6/18/2009 11:25 PM
Endrin ketone	ND	2.0		µg/Kg	1	6/18/2009 11:25 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		

CLIENT:	Geocon Consultants, Inc.	**Client Sample ID:**	Composite TAR6-A,B,C,D
Lab Order:	105982	**Collection Date:**	6/16/2009
Project:	ANTIOCH BRIDGE RETROFIT, E8435-06-	**Matrix:**	SOIL
Lab ID:	105982-078A		

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
ORGANOCHLORINE PESTICIDES BY GC/ECD						
	EPA 3550B			**EPA 8081A**		
RunID: GC9_090618A	QC Batch: 56044			PrepDate:	6/18/2009	Analyst: **HL**
gamma-BHC	ND	1.0		µg/Kg	1	6/18/2009 11:25 PM
gamma-Chlordane	ND	1.0		µg/Kg	1	6/18/2009 11:25 PM
Heptachlor	ND	1.0		µg/Kg	1	6/18/2009 11:25 PM
Heptachlor epoxide	ND	1.0		µg/Kg	1	6/18/2009 11:25 PM
Methoxychlor	ND	5.0		µg/Kg	1	6/18/2009 11:25 PM
Toxaphene	ND	50		µg/Kg	1	6/18/2009 11:25 PM
Surr: Decachlorobiphenyl	52.7	20-142		%REC	1	6/18/2009 11:25 PM
Surr: Tetrachloro-m-xylene	54.7	25-115		%REC	1	6/18/2009 11:25 PM
MERCURY BY COLD VAPOR TECHNIQUE						
				EPA 7471A		
RunID: AA5_090618B	QC Batch: 55982			PrepDate:	6/17/2009	Analyst: **IL**
Mercury	0.17	0.10		mg/Kg	1	6/18/2009 01:08 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.	**Client Sample ID:**	Composite SS1-A,B,C,D
Lab Order:	105982	**Collection Date:**	6/16/2009
Project:	ANTIOCH BRIDGE RETROFIT, E8435-06-	**Matrix:**	SOIL
Lab ID:	105982-079A		

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
ICP METALS						
	EPA 3050B			**EPA 6010B**		
RunID: ICP8_090618E	QC Batch: 55985			PrepDate:	6/17/2009	Analyst: **CL**
Antimony	ND	2.0		mg/Kg	1	6/18/2009 03:10 PM
Arsenic	4.2	1.0		mg/Kg	1	6/18/2009 03:10 PM
Barium	80	1.0		mg/Kg	1	6/18/2009 03:10 PM
Beryllium	ND	1.0		mg/Kg	1	6/18/2009 03:10 PM
Cadmium	ND	1.0		mg/Kg	1	6/18/2009 03:10 PM
Chromium	32	1.0		mg/Kg	1	6/18/2009 03:10 PM
Cobalt	6.7	1.0		mg/Kg	1	6/18/2009 03:10 PM
Copper	17	2.0		mg/Kg	1	6/18/2009 03:10 PM
Lead	7.4	1.0		mg/Kg	1	6/18/2009 03:10 PM
Molybdenum	ND	1.0		mg/Kg	1	6/18/2009 03:10 PM
Nickel	39	1.0		mg/Kg	1	6/18/2009 03:10 PM
Selenium	ND	1.0		mg/Kg	1	6/18/2009 03:10 PM
Silver	ND	1.0		mg/Kg	1	6/18/2009 03:10 PM
Thallium	ND	1.0		mg/Kg	1	6/18/2009 03:10 PM
Vanadium	39	1.0		mg/Kg	1	6/18/2009 03:10 PM
Zinc	38	1.0		mg/Kg	1	6/18/2009 03:10 PM
ORGANOCHLORINE PESTICIDES BY GC/ECD						
	EPA 3550B			**EPA 8081A**		
RunID: GC9_090618A	QC Batch: 56044			PrepDate:	6/18/2009	Analyst: **HL**
4,4´-DDD	2.8	2.0		µg/Kg	1	6/18/2009 11:39 PM
4,4´-DDE	2.1	2.0		µg/Kg	1	6/18/2009 11:39 PM
4,4´-DDT	11	2.0		µg/Kg	1	6/18/2009 11:39 PM
Aldrin	ND	1.0		µg/Kg	1	6/18/2009 11:39 PM
alpha-BHC	ND	1.0		µg/Kg	1	6/18/2009 11:39 PM
alpha-Chlordane	ND	1.0		µg/Kg	1	6/18/2009 11:39 PM
beta-BHC	ND	1.0		µg/Kg	1	6/18/2009 11:39 PM
Chlordane	ND	8.5		µg/Kg	1	6/18/2009 11:39 PM
delta-BHC	ND	1.0		µg/Kg	1	6/18/2009 11:39 PM
Dieldrin	ND	2.0		µg/Kg	1	6/18/2009 11:39 PM
Endosulfan I	ND	1.0		µg/Kg	1	6/18/2009 11:39 PM
Endosulfan II	ND	2.0		µg/Kg	1	6/18/2009 11:39 PM
Endosulfan sulfate	ND	2.0		µg/Kg	1	6/18/2009 11:39 PM
Endrin	ND	2.0		µg/Kg	1	6/18/2009 11:39 PM
Endrin aldehyde	ND	2.0		µg/Kg	1	6/18/2009 11:39 PM
Endrin ketone	ND	2.0		µg/Kg	1	6/18/2009 11:39 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.	**Client Sample ID:**	Composite SS1-A,B,C,D
Lab Order:	105982	**Collection Date:**	6/16/2009
Project:	ANTIOCH BRIDGE RETROFIT, E8435-06-	**Matrix:**	SOIL
Lab ID:	105982-079A		

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
ORGANOCHLORINE PESTICIDES BY GC/ECD						
	EPA 3550B			**EPA 8081A**		
RunID: GC9_090618A	QC Batch: 56044			PrepDate:	6/18/2009	Analyst: **HL**
gamma-BHC	ND	1.0		µg/Kg	1	6/18/2009 11:39 PM
gamma-Chlordane	ND	1.0		µg/Kg	1	6/18/2009 11:39 PM
Heptachlor	ND	1.0		µg/Kg	1	6/18/2009 11:39 PM
Heptachlor epoxide	ND	1.0		µg/Kg	1	6/18/2009 11:39 PM
Methoxychlor	ND	5.0		µg/Kg	1	6/18/2009 11:39 PM
Toxaphene	ND	50		µg/Kg	1	6/18/2009 11:39 PM
Surr: Decachlorobiphenyl	56.3	20-142		%REC	1	6/18/2009 11:39 PM
Surr: Tetrachloro-m-xylene	58.7	25-115		%REC	1	6/18/2009 11:39 PM
MERCURY BY COLD VAPOR TECHNIQUE						
				EPA 7471A		
RunID: AA5_090618B	QC Batch: 55982			PrepDate:	6/17/2009	Analyst: **IL**
Mercury	0.26	0.10		mg/Kg	1	6/18/2009 01:14 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:**	Composite SS2-A,B,C,D
Lab Order:	105982	**Collection Date:**	6/16/2009
Project:	ANTIOCH BRIDGE RETROFIT, E8435-06-	**Matrix:**	SOIL
Lab ID:	105982-080A		

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
ICP METALS						
	EPA 3050B			**EPA 6010B**		
RunID: ICP8_090618E	QC Batch: 55985			PrepDate: 6/17/2009	Analyst: **CL**	
Antimony	ND	2.0		mg/Kg	1	6/18/2009 03:21 PM
Arsenic	8.0	1.0		mg/Kg	1	6/18/2009 03:21 PM
Barium	130	1.0		mg/Kg	1	6/18/2009 03:21 PM
Beryllium	ND	1.0		mg/Kg	1	6/18/2009 03:21 PM
Cadmium	ND	1.0		mg/Kg	1	6/18/2009 03:21 PM
Chromium	44	1.0		mg/Kg	1	6/18/2009 03:21 PM
Cobalt	8.9	1.0		mg/Kg	1	6/18/2009 03:21 PM
Copper	32	2.0		mg/Kg	1	6/18/2009 03:21 PM
Lead	8.7	1.0		mg/Kg	1	6/18/2009 03:21 PM
Molybdenum	1.1	1.0		mg/Kg	1	6/18/2009 03:21 PM
Nickel	53	1.0		mg/Kg	1	6/18/2009 03:21 PM
Selenium	ND	1.0		mg/Kg	1	6/18/2009 03:21 PM
Silver	ND	1.0		mg/Kg	1	6/18/2009 03:21 PM
Thallium	ND	1.0		mg/Kg	1	6/18/2009 03:21 PM
Vanadium	60	1.0		mg/Kg	1	6/18/2009 03:21 PM
Zinc	110	1.0		mg/Kg	1	6/18/2009 03:21 PM
ORGANOCHLORINE PESTICIDES BY GC/ECD						
	EPA 3550B			**EPA 8081A**		
RunID: GC9_090618A	QC Batch: 56044			PrepDate: 6/18/2009	Analyst: **HL**	
4,4´-DDD	ND	2.0		µg/Kg	1	6/18/2009 11:53 PM
4,4´-DDE	ND	2.0		µg/Kg	1	6/18/2009 11:53 PM
4,4´-DDT	3.5	2.0		µg/Kg	1	6/18/2009 11:53 PM
Aldrin	ND	1.0		µg/Kg	1	6/18/2009 11:53 PM
alpha-BHC	ND	1.0		µg/Kg	1	6/18/2009 11:53 PM
alpha-Chlordane	ND	1.0		µg/Kg	1	6/18/2009 11:53 PM
beta-BHC	ND	1.0		µg/Kg	1	6/18/2009 11:53 PM
Chlordane	ND	8.5		µg/Kg	1	6/18/2009 11:53 PM
delta-BHC	ND	1.0		µg/Kg	1	6/18/2009 11:53 PM
Dieldrin	ND	2.0		µg/Kg	1	6/18/2009 11:53 PM
Endosulfan I	ND	1.0		µg/Kg	1	6/18/2009 11:53 PM
Endosulfan II	ND	2.0		µg/Kg	1	6/18/2009 11:53 PM
Endosulfan sulfate	ND	2.0		µg/Kg	1	6/18/2009 11:53 PM
Endrin	ND	2.0		µg/Kg	1	6/18/2009 11:53 PM
Endrin aldehyde	ND	2.0		µg/Kg	1	6/18/2009 11:53 PM
Endrin ketone	ND	2.0		µg/Kg	1	6/18/2009 11:53 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.	**Client Sample ID:**	Composite SS2-A,B,C,D
Lab Order:	105982	**Collection Date:**	6/16/2009
Project:	ANTIOCH BRIDGE RETROFIT, E8435-06-	**Matrix:**	SOIL
Lab ID:	105982-080A		

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
ORGANOCHLORINE PESTICIDES BY GC/ECD						
	EPA 3550B			**EPA 8081A**		
RunID: GC9_090618A	QC Batch: 56044			PrepDate:	6/18/2009	Analyst: **HL**
gamma-BHC	ND	1.0		µg/Kg	1	6/18/2009 11:53 PM
gamma-Chlordane	ND	1.0		µg/Kg	1	6/18/2009 11:53 PM
Heptachlor	ND	1.0		µg/Kg	1	6/18/2009 11:53 PM
Heptachlor epoxide	ND	1.0		µg/Kg	1	6/18/2009 11:53 PM
Methoxychlor	ND	5.0		µg/Kg	1	6/18/2009 11:53 PM
Toxaphene	ND	50		µg/Kg	1	6/18/2009 11:53 PM
Surr: Decachlorobiphenyl	55.9	20-142		%REC	1	6/18/2009 11:53 PM
Surr: Tetrachloro-m-xylene	60.0	25-115		%REC	1	6/18/2009 11:53 PM
MERCURY BY COLD VAPOR TECHNIQUE						
				EPA 7471A		
RunID: AA5_090618B	QC Batch: 55982			PrepDate:	6/17/2009	Analyst: **IL**
Mercury	0.12	0.10		mg/Kg	1	6/18/2009 01:16 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:**	Composite TCWA1-A,B,C,D
Lab Order:	105982	**Collection Date:**	6/16/2009
Project:	ANTIOCH BRIDGE RETROFIT, E8435-06-	**Matrix:**	SOIL
Lab ID:	105982-081A		

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
ICP METALS						
	EPA 3050B			**EPA 6010B**		
RunID: ICP8_090618E	QC Batch: 55985			PrepDate:	6/17/2009	Analyst: **CL**
Antimony	ND	2.0		mg/Kg	1	6/18/2009 03:24 PM
Arsenic	8.7	1.0		mg/Kg	1	6/18/2009 03:24 PM
Barium	170	1.0		mg/Kg	1	6/18/2009 03:24 PM
Beryllium	ND	1.0		mg/Kg	1	6/18/2009 03:24 PM
Cadmium	ND	1.0		mg/Kg	1	6/18/2009 03:24 PM
Chromium	59	1.0		mg/Kg	1	6/18/2009 03:24 PM
Cobalt	9.1	1.0		mg/Kg	1	6/18/2009 03:24 PM
Copper	43	2.0		mg/Kg	1	6/18/2009 03:24 PM
Lead	13	1.0		mg/Kg	1	6/18/2009 03:24 PM
Molybdenum	1.1	1.0		mg/Kg	1	6/18/2009 03:24 PM
Nickel	59	1.0		mg/Kg	1	6/18/2009 03:24 PM
Selenium	ND	1.0		mg/Kg	1	6/18/2009 03:24 PM
Silver	ND	1.0		mg/Kg	1	6/18/2009 03:24 PM
Thallium	ND	1.0		mg/Kg	1	6/18/2009 03:24 PM
Vanadium	82	1.0		mg/Kg	1	6/18/2009 03:24 PM
Zinc	61	1.0		mg/Kg	1	6/18/2009 03:24 PM
ORGANOCHLORINE PESTICIDES BY GC/ECD						
	EPA 3550B			**EPA 8081A**		
RunID: GC9_090618A	QC Batch: 56044			PrepDate:	6/18/2009	Analyst: **HL**
4,4´-DDD	ND	2.0		µg/Kg	1	6/19/2009 12:07 AM
4,4´-DDE	18	2.0		µg/Kg	1	6/19/2009 12:07 AM
4,4´-DDT	22	2.0		µg/Kg	1	6/19/2009 12:07 AM
Aldrin	ND	1.0		µg/Kg	1	6/19/2009 12:07 AM
alpha-BHC	ND	1.0		µg/Kg	1	6/19/2009 12:07 AM
alpha-Chlordane	ND	1.0		µg/Kg	1	6/19/2009 12:07 AM
beta-BHC	ND	1.0		µg/Kg	1	6/19/2009 12:07 AM
Chlordane	ND	8.5		µg/Kg	1	6/19/2009 12:07 AM
delta-BHC	ND	1.0		µg/Kg	1	6/19/2009 12:07 AM
Dieldrin	ND	2.0		µg/Kg	1	6/19/2009 12:07 AM
Endosulfan I	ND	1.0		µg/Kg	1	6/19/2009 12:07 AM
Endosulfan II	ND	2.0		µg/Kg	1	6/19/2009 12:07 AM
Endosulfan sulfate	ND	2.0		µg/Kg	1	6/19/2009 12:07 AM
Endrin	ND	2.0		µg/Kg	1	6/19/2009 12:07 AM
Endrin aldehyde	ND	2.0		µg/Kg	1	6/19/2009 12:07 AM
Endrin ketone	ND	2.0		µg/Kg	1	6/19/2009 12:07 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		

CLIENT:	Geocon Consultants, Inc.	**Client Sample ID:**	Composite TCWA1-A,B,C,D
Lab Order:	105982	**Collection Date:**	6/16/2009
Project:	ANTIOCH BRIDGE RETROFIT, E8435-06-	**Matrix:**	SOIL
Lab ID:	105982-081A		

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
ORGANOCHLORINE PESTICIDES BY GC/ECD						
	EPA 3550B			**EPA 8081A**		
RunID: GC9_090618A	QC Batch: 56044			PrepDate:	6/18/2009	Analyst: **HL**
gamma-BHC	ND	1.0		µg/Kg	1	6/19/2009 12:07 AM
gamma-Chlordane	ND	1.0		µg/Kg	1	6/19/2009 12:07 AM
Heptachlor	ND	1.0		µg/Kg	1	6/19/2009 12:07 AM
Heptachlor epoxide	ND	1.0		µg/Kg	1	6/19/2009 12:07 AM
Methoxychlor	ND	5.0		µg/Kg	1	6/19/2009 12:07 AM
Toxaphene	ND	50		µg/Kg	1	6/19/2009 12:07 AM
Surr: Decachlorobiphenyl	56.9	20-142		%REC	1	6/19/2009 12:07 AM
Surr: Tetrachloro-m-xylene	59.7	25-115		%REC	1	6/19/2009 12:07 AM
MERCURY BY COLD VAPOR TECHNIQUE						
				EPA 7471A		
RunID: AA5_090618B	QC Batch: 55982			PrepDate:	6/17/2009	Analyst: **IL**
Mercury	0.12	0.10		mg/Kg	1	6/18/2009 01:18 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		

CLIENT:	Geocon Consultants, Inc.	**Client Sample ID:**	Composite TCWA2-A,B,C,D
Lab Order:	105982	**Collection Date:**	6/16/2009
Project:	ANTIOCH BRIDGE RETROFIT, E8435-06-	**Matrix:**	SOIL
Lab ID:	105982-082A		

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
ICP METALS						
	EPA 3050B			**EPA 6010B**		
RunID: ICP8_090618E	QC Batch: 55985			PrepDate: 6/17/2009	Analyst: **CL**	
Antimony	ND	2.0		mg/Kg	1	6/18/2009 03:26 PM
Arsenic	8.8	1.0		mg/Kg	1	6/18/2009 03:26 PM
Barium	170	1.0		mg/Kg	1	6/18/2009 03:26 PM
Beryllium	ND	1.0		mg/Kg	1	6/18/2009 03:26 PM
Cadmium	ND	1.0		mg/Kg	1	6/18/2009 03:26 PM
Chromium	57	1.0		mg/Kg	1	6/18/2009 03:26 PM
Cobalt	9.0	1.0		mg/Kg	1	6/18/2009 03:26 PM
Copper	41	2.0		mg/Kg	1	6/18/2009 03:26 PM
Lead	14	1.0		mg/Kg	1	6/18/2009 03:26 PM
Molybdenum	1.2	1.0		mg/Kg	1	6/18/2009 03:26 PM
Nickel	57	1.0		mg/Kg	1	6/18/2009 03:26 PM
Selenium	ND	1.0		mg/Kg	1	6/18/2009 03:26 PM
Silver	ND	1.0		mg/Kg	1	6/18/2009 03:26 PM
Thallium	ND	1.0		mg/Kg	1	6/18/2009 03:26 PM
Vanadium	77	1.0		mg/Kg	1	6/18/2009 03:26 PM
Zinc	64	1.0		mg/Kg	1	6/18/2009 03:26 PM
ORGANOCHLORINE PESTICIDES BY GC/ECD						
	EPA 3550B			**EPA 8081A**		
RunID: GC9_090618A	QC Batch: 56044			PrepDate: 6/18/2009	Analyst: **HL**	
4,4´-DDD	ND	2.0		µg/Kg	1	6/19/2009 12:21 AM
4,4´-DDE	4.9	2.0		µg/Kg	1	6/19/2009 12:21 AM
4,4´-DDT	11	2.0		µg/Kg	1	6/19/2009 12:21 AM
Aldrin	ND	1.0		µg/Kg	1	6/19/2009 12:21 AM
alpha-BHC	ND	1.0		µg/Kg	1	6/19/2009 12:21 AM
alpha-Chlordane	ND	1.0		µg/Kg	1	6/19/2009 12:21 AM
beta-BHC	ND	1.0		µg/Kg	1	6/19/2009 12:21 AM
Chlordane	ND	8.5		µg/Kg	1	6/19/2009 12:21 AM
delta-BHC	ND	1.0		µg/Kg	1	6/19/2009 12:21 AM
Dieldrin	ND	2.0		µg/Kg	1	6/19/2009 12:21 AM
Endosulfan I	ND	1.0		µg/Kg	1	6/19/2009 12:21 AM
Endosulfan II	ND	2.0		µg/Kg	1	6/19/2009 12:21 AM
Endosulfan sulfate	ND	2.0		µg/Kg	1	6/19/2009 12:21 AM
Endrin	ND	2.0		µg/Kg	1	6/19/2009 12:21 AM
Endrin aldehyde	ND	2.0		µg/Kg	1	6/19/2009 12:21 AM
Endrin ketone	ND	2.0		µg/Kg	1	6/19/2009 12:21 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		

CLIENT:	Geocon Consultants, Inc.	**Client Sample ID:**	Composite TCWA2-A,B,C,D
Lab Order:	105982	**Collection Date:**	6/16/2009
Project:	ANTIOCH BRIDGE RETROFIT, E8435-06-	**Matrix:**	SOIL
Lab ID:	105982-082A		

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
ORGANOCHLORINE PESTICIDES BY GC/ECD						
	EPA 3550B			**EPA 8081A**		
RunID: GC9_090618A	QC Batch: 56044			PrepDate:	6/18/2009	Analyst: **HL**
gamma-BHC	ND	1.0		µg/Kg	1	6/19/2009 12:21 AM
gamma-Chlordane	ND	1.0		µg/Kg	1	6/19/2009 12:21 AM
Heptachlor	ND	1.0		µg/Kg	1	6/19/2009 12:21 AM
Heptachlor epoxide	ND	1.0		µg/Kg	1	6/19/2009 12:21 AM
Methoxychlor	ND	5.0		µg/Kg	1	6/19/2009 12:21 AM
Toxaphene	ND	50		µg/Kg	1	6/19/2009 12:21 AM
Surr: Decachlorobiphenyl	60.9	20-142		%REC	1	6/19/2009 12:21 AM
Surr: Tetrachloro-m-xylene	61.1	25-115		%REC	1	6/19/2009 12:21 AM
MERCURY BY COLD VAPOR TECHNIQUE						
				EPA 7471A		
RunID: AA5_090618B	QC Batch: 55982			PrepDate:	6/17/2009	Analyst: **IL**
Mercury	0.15	0.10		mg/Kg	1	6/18/2009 12:54 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.	**Client Sample ID:**	Composite TCWA3-A,B,C,D
Lab Order:	105982	**Collection Date:**	6/16/2009
Project:	ANTIOCH BRIDGE RETROFIT, E8435-06-	**Matrix:**	SOIL
Lab ID:	105982-083A		

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
ICP METALS						
	EPA 3050B			**EPA 6010B**		
RunID: ICP8_090618F	QC Batch: 55986			PrepDate: 6/17/2009	Analyst: **CL**	
Antimony	ND	2.0		mg/Kg	1	6/18/2009 04:33 PM
Arsenic	9.5	1.0		mg/Kg	1	6/18/2009 04:33 PM
Barium	170	1.0		mg/Kg	1	6/18/2009 04:33 PM
Beryllium	ND	1.0		mg/Kg	1	6/18/2009 04:33 PM
Cadmium	ND	1.0		mg/Kg	1	6/18/2009 04:33 PM
Chromium	57	1.0		mg/Kg	1	6/18/2009 04:33 PM
Cobalt	9.4	1.0		mg/Kg	1	6/18/2009 04:33 PM
Copper	42	2.0		mg/Kg	1	6/18/2009 04:33 PM
Lead	11	1.0		mg/Kg	1	6/18/2009 04:33 PM
Molybdenum	1.3	1.0		mg/Kg	1	6/18/2009 04:33 PM
Nickel	58	1.0		mg/Kg	1	6/18/2009 04:33 PM
Selenium	ND	1.0		mg/Kg	1	6/18/2009 04:33 PM
Silver	ND	1.0		mg/Kg	1	6/18/2009 04:33 PM
Thallium	ND	1.0		mg/Kg	1	6/18/2009 04:33 PM
Vanadium	81	1.0		mg/Kg	1	6/18/2009 04:33 PM
Zinc	57	1.0		mg/Kg	1	6/18/2009 04:33 PM
ORGANOCHLORINE PESTICIDES BY GC/ECD						
	EPA 3550B			**EPA 8081A**		
RunID: GC9_090618B	QC Batch: 56045			PrepDate: 6/18/2009	Analyst: **HL**	
4,4´-DDD	2.5	2.0		µg/Kg	1	6/19/2009 12:35 AM
4,4´-DDE	14	2.0		µg/Kg	1	6/19/2009 12:35 AM
4,4´-DDT	26	2.0		µg/Kg	1	6/19/2009 12:35 AM
Aldrin	ND	1.0		µg/Kg	1	6/19/2009 12:35 AM
alpha-BHC	ND	1.0		µg/Kg	1	6/19/2009 12:35 AM
alpha-Chlordane	ND	1.0		µg/Kg	1	6/19/2009 12:35 AM
beta-BHC	ND	1.0		µg/Kg	1	6/19/2009 12:35 AM
Chlordane	ND	8.5		µg/Kg	1	6/19/2009 12:35 AM
delta-BHC	ND	1.0		µg/Kg	1	6/19/2009 12:35 AM
Dieldrin	ND	2.0		µg/Kg	1	6/19/2009 12:35 AM
Endosulfan I	ND	1.0		µg/Kg	1	6/19/2009 12:35 AM
Endosulfan II	ND	2.0		µg/Kg	1	6/19/2009 12:35 AM
Endosulfan sulfate	ND	2.0		µg/Kg	1	6/19/2009 12:35 AM
Endrin	ND	2.0		µg/Kg	1	6/19/2009 12:35 AM
Endrin aldehyde	ND	2.0		µg/Kg	1	6/19/2009 12:35 AM
Endrin ketone	ND	2.0		µg/Kg	1	6/19/2009 12:35 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		

CLIENT:	Geocon Consultants, Inc.	**Client Sample ID:**	Composite TCWA3-A,B,C,D
Lab Order:	105982	**Collection Date:**	6/16/2009
Project:	ANTIOCH BRIDGE RETROFIT, E8435-06-	**Matrix:**	SOIL
Lab ID:	105982-083A		

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
ORGANOCHLORINE PESTICIDES BY GC/ECD						
	EPA 3550B			**EPA 8081A**		
RunID: GC9_090618B	QC Batch: 56045			PrepDate:	6/18/2009	Analyst: **HL**
gamma-BHC	ND	1.0		µg/Kg	1	6/19/2009 12:35 AM
gamma-Chlordane	ND	1.0		µg/Kg	1	6/19/2009 12:35 AM
Heptachlor	ND	1.0		µg/Kg	1	6/19/2009 12:35 AM
Heptachlor epoxide	ND	1.0		µg/Kg	1	6/19/2009 12:35 AM
Methoxychlor	ND	5.0		µg/Kg	1	6/19/2009 12:35 AM
Toxaphene	ND	50		µg/Kg	1	6/19/2009 12:35 AM
Surr: Decachlorobiphenyl	66.2	20-142		%REC	1	6/19/2009 12:35 AM
Surr: Tetrachloro-m-xylene	66.3	25-115		%REC	1	6/19/2009 12:35 AM
MERCURY BY COLD VAPOR TECHNIQUE						
				EPA 7471A		
RunID: AA5_090618C	QC Batch: 55983			PrepDate:	6/17/2009	Analyst: **IL**
Mercury	0.12	0.10		mg/Kg	1	6/18/2009 02:41 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		

CLIENT:	Geocon Consultants, Inc.	**Client Sample ID:**	Composite TCWA4-A,B,C,D
Lab Order:	105982	**Collection Date:**	6/16/2009
Project:	ANTIOCH BRIDGE RETROFIT, E8435-06-	**Matrix:**	SOIL
Lab ID:	105982-084A		

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
ICP METALS						
	EPA 3050B			**EPA 6010B**		
RunID: ICP8_090618F	QC Batch: 55986			PrepDate: 6/17/2009	Analyst: **CL**	
Antimony	ND	2.0		mg/Kg	1	6/18/2009 04:44 PM
Arsenic	10	1.0		mg/Kg	1	6/18/2009 04:44 PM
Barium	190	1.0		mg/Kg	1	6/18/2009 04:44 PM
Beryllium	ND	1.0		mg/Kg	1	6/18/2009 04:44 PM
Cadmium	ND	1.0		mg/Kg	1	6/18/2009 04:44 PM
Chromium	59	1.0		mg/Kg	1	6/18/2009 04:44 PM
Cobalt	9.5	1.0		mg/Kg	1	6/18/2009 04:44 PM
Copper	43	2.0		mg/Kg	1	6/18/2009 04:44 PM
Lead	14	1.0		mg/Kg	1	6/18/2009 04:44 PM
Molybdenum	1.4	1.0		mg/Kg	1	6/18/2009 04:44 PM
Nickel	59	1.0		mg/Kg	1	6/18/2009 04:44 PM
Selenium	ND	1.0		mg/Kg	1	6/18/2009 04:44 PM
Silver	ND	1.0		mg/Kg	1	6/18/2009 04:44 PM
Thallium	ND	1.0		mg/Kg	1	6/18/2009 04:44 PM
Vanadium	84	1.0		mg/Kg	1	6/18/2009 04:44 PM
Zinc	58	1.0		mg/Kg	1	6/18/2009 04:44 PM
ORGANOCHLORINE PESTICIDES BY GC/ECD						
	EPA 3550B			**EPA 8081A**		
RunID: GC9_090618B	QC Batch: 56045			PrepDate: 6/18/2009	Analyst: **HL**	
4,4´-DDD	2.0	2.0		µg/Kg	1	6/19/2009 01:04 AM
4,4´-DDE	8.5	2.0		µg/Kg	1	6/19/2009 01:04 AM
4,4´-DDT	20	2.0		µg/Kg	1	6/19/2009 01:04 AM
Aldrin	ND	1.0		µg/Kg	1	6/19/2009 01:04 AM
alpha-BHC	ND	1.0		µg/Kg	1	6/19/2009 01:04 AM
alpha-Chlordane	ND	1.0		µg/Kg	1	6/19/2009 01:04 AM
beta-BHC	ND	1.0		µg/Kg	1	6/19/2009 01:04 AM
Chlordane	ND	8.5		µg/Kg	1	6/19/2009 01:04 AM
delta-BHC	ND	1.0		µg/Kg	1	6/19/2009 01:04 AM
Dieldrin	ND	2.0		µg/Kg	1	6/19/2009 01:04 AM
Endosulfan I	ND	1.0		µg/Kg	1	6/19/2009 01:04 AM
Endosulfan II	ND	2.0		µg/Kg	1	6/19/2009 01:04 AM
Endosulfan sulfate	ND	2.0		µg/Kg	1	6/19/2009 01:04 AM
Endrin	ND	2.0		µg/Kg	1	6/19/2009 01:04 AM
Endrin aldehyde	ND	2.0		µg/Kg	1	6/19/2009 01:04 AM
Endrin ketone	ND	2.0		µg/Kg	1	6/19/2009 01:04 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		

CLIENT:	Geocon Consultants, Inc.	**Client Sample ID:**	Composite TCWA4-A,B,C,D
Lab Order:	105982	**Collection Date:**	6/16/2009
Project:	ANTIOCH BRIDGE RETROFIT, E8435-06-	**Matrix:**	SOIL
Lab ID:	105982-084A		

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
ORGANOCHLORINE PESTICIDES BY GC/ECD						
	EPA 3550B			**EPA 8081A**		
RunID: GC9_090618B	QC Batch: 56045			PrepDate:	6/18/2009	Analyst: **HL**
gamma-BHC	ND	1.0		µg/Kg	1	6/19/2009 01:04 AM
gamma-Chlordane	ND	1.0		µg/Kg	1	6/19/2009 01:04 AM
Heptachlor	ND	1.0		µg/Kg	1	6/19/2009 01:04 AM
Heptachlor epoxide	ND	1.0		µg/Kg	1	6/19/2009 01:04 AM
Methoxychlor	ND	5.0		µg/Kg	1	6/19/2009 01:04 AM
Toxaphene	ND	50		µg/Kg	1	6/19/2009 01:04 AM
Surr: Decachlorobiphenyl	62.4	20-142		%REC	1	6/19/2009 01:04 AM
Surr: Tetrachloro-m-xylene	62.0	25-115		%REC	1	6/19/2009 01:04 AM
MERCURY BY COLD VAPOR TECHNIQUE						
				EPA 7471A		
RunID: AA5_090618C	QC Batch: 55983			PrepDate:	6/17/2009	Analyst: **IL**
Mercury	0.14	0.10		mg/Kg	1	6/18/2009 02:43 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		

CLIENT:	Geocon Consultants, Inc.	**Client Sample ID:**	Composite TCWA5-A,B,C,D
Lab Order:	105982	**Collection Date:**	6/16/2009
Project:	ANTIOCH BRIDGE RETROFIT, E8435-06-	**Matrix:**	SOIL
Lab ID:	105982-085A		

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
ICP METALS						
	EPA 3050B			**EPA 6010B**		
RunID: ICP8_090618F	QC Batch: 55986			PrepDate: 6/17/2009	Analyst: **CL**	
Antimony	ND	2.0		mg/Kg	1	6/18/2009 04:46 PM
Arsenic	10	1.0		mg/Kg	1	6/18/2009 04:46 PM
Barium	190	1.0		mg/Kg	1	6/18/2009 04:46 PM
Beryllium	ND	1.0		mg/Kg	1	6/18/2009 04:46 PM
Cadmium	ND	1.0		mg/Kg	1	6/18/2009 04:46 PM
Chromium	61	1.0		mg/Kg	1	6/18/2009 04:46 PM
Cobalt	10	1.0		mg/Kg	1	6/18/2009 04:46 PM
Copper	45	2.0		mg/Kg	1	6/18/2009 04:46 PM
Lead	12	1.0		mg/Kg	1	6/18/2009 04:46 PM
Molybdenum	1.2	1.0		mg/Kg	1	6/18/2009 04:46 PM
Nickel	63	1.0		mg/Kg	1	6/18/2009 04:46 PM
Selenium	ND	1.0		mg/Kg	1	6/18/2009 04:46 PM
Silver	ND	1.0		mg/Kg	1	6/18/2009 04:46 PM
Thallium	ND	1.0		mg/Kg	1	6/18/2009 04:46 PM
Vanadium	89	1.0		mg/Kg	1	6/18/2009 04:46 PM
Zinc	61	1.0		mg/Kg	1	6/18/2009 04:46 PM
ORGANOCHLORINE PESTICIDES BY GC/ECD						
	EPA 3550B			**EPA 8081A**		
RunID: GC9_090618B	QC Batch: 56045			PrepDate: 6/18/2009	Analyst: **HL**	
4,4´-DDD	4.2	2.0		µg/Kg	1	6/19/2009 01:18 AM
4,4´-DDE	14	2.0		µg/Kg	1	6/19/2009 01:18 AM
4,4´-DDT	29	2.0		µg/Kg	1	6/19/2009 01:18 AM
Aldrin	ND	1.0		µg/Kg	1	6/19/2009 01:18 AM
alpha-BHC	ND	1.0		µg/Kg	1	6/19/2009 01:18 AM
alpha-Chlordane	ND	1.0		µg/Kg	1	6/19/2009 01:18 AM
beta-BHC	ND	1.0		µg/Kg	1	6/19/2009 01:18 AM
Chlordane	ND	8.5		µg/Kg	1	6/19/2009 01:18 AM
delta-BHC	ND	1.0		µg/Kg	1	6/19/2009 01:18 AM
Dieldrin	ND	2.0		µg/Kg	1	6/19/2009 01:18 AM
Endosulfan I	ND	1.0		µg/Kg	1	6/19/2009 01:18 AM
Endosulfan II	ND	2.0		µg/Kg	1	6/19/2009 01:18 AM
Endosulfan sulfate	ND	2.0		µg/Kg	1	6/19/2009 01:18 AM
Endrin	ND	2.0		µg/Kg	1	6/19/2009 01:18 AM
Endrin aldehyde	ND	2.0		µg/Kg	1	6/19/2009 01:18 AM
Endrin ketone	ND	2.0		µg/Kg	1	6/19/2009 01:18 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		

CLIENT:	Geocon Consultants, Inc.	**Client Sample ID:**	Composite TCWA5-A,B,C,D
Lab Order:	105982	**Collection Date:**	6/16/2009
Project:	ANTIOCH BRIDGE RETROFIT, E8435-06-	**Matrix:**	SOIL
Lab ID:	105982-085A		

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
ORGANOCHLORINE PESTICIDES BY GC/ECD						
	EPA 3550B			**EPA 8081A**		
RunID: GC9_090618B	QC Batch: 56045			PrepDate:	6/18/2009	Analyst: **HL**
gamma-BHC	ND	1.0		µg/Kg	1	6/19/2009 01:18 AM
gamma-Chlordane	ND	1.0		µg/Kg	1	6/19/2009 01:18 AM
Heptachlor	ND	1.0		µg/Kg	1	6/19/2009 01:18 AM
Heptachlor epoxide	ND	1.0		µg/Kg	1	6/19/2009 01:18 AM
Methoxychlor	ND	5.0		µg/Kg	1	6/19/2009 01:18 AM
Toxaphene	ND	50		µg/Kg	1	6/19/2009 01:18 AM
Surr: Decachlorobiphenyl	49.4	20-142		%REC	1	6/19/2009 01:18 AM
Surr: Tetrachloro-m-xylene	50.6	25-115		%REC	1	6/19/2009 01:18 AM
MERCURY BY COLD VAPOR TECHNIQUE						
				EPA 7471A		
RunID: AA5_090618C	QC Batch: 55983			PrepDate:	6/17/2009	Analyst: **IL**
Mercury	0.12	0.10		mg/Kg	1	6/18/2009 02:45 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.	**Client Sample ID:**	Composite TCWA6-A,B,C,D
Lab Order:	105982	**Collection Date:**	6/16/2009
Project:	ANTIOCH BRIDGE RETROFIT, E8435-06-	**Matrix:**	SOIL
Lab ID:	105982-086A		

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
ICP METALS						
	EPA 3050B			**EPA 6010B**		
RunID: ICP8_090618F	QC Batch: 55986			PrepDate: 6/17/2009	Analyst: **CL**	
Antimony	ND	2.0		mg/Kg	1	6/18/2009 04:49 PM
Arsenic	9.3	1.0		mg/Kg	1	6/18/2009 04:49 PM
Barium	180	1.0		mg/Kg	1	6/18/2009 04:49 PM
Beryllium	ND	1.0		mg/Kg	1	6/18/2009 04:49 PM
Cadmium	ND	1.0		mg/Kg	1	6/18/2009 04:49 PM
Chromium	57	1.0		mg/Kg	1	6/18/2009 04:49 PM
Cobalt	9.6	1.0		mg/Kg	1	6/18/2009 04:49 PM
Copper	42	2.0		mg/Kg	1	6/18/2009 04:49 PM
Lead	13	1.0		mg/Kg	1	6/18/2009 04:49 PM
Molybdenum	2.0	1.0		mg/Kg	1	6/18/2009 04:49 PM
Nickel	58	1.0		mg/Kg	1	6/18/2009 04:49 PM
Selenium	ND	1.0		mg/Kg	1	6/18/2009 04:49 PM
Silver	ND	1.0		mg/Kg	1	6/18/2009 04:49 PM
Thallium	ND	1.0		mg/Kg	1	6/18/2009 04:49 PM
Vanadium	80	1.0		mg/Kg	1	6/18/2009 04:49 PM
Zinc	65	1.0		mg/Kg	1	6/18/2009 04:49 PM
ORGANOCHLORINE PESTICIDES BY GC/ECD						
	EPA 3550B			**EPA 8081A**		
RunID: GC9_090618B	QC Batch: 56045			PrepDate: 6/18/2009	Analyst: **HL**	
4,4´-DDD	2.0	2.0		µg/Kg	1	6/19/2009 01:32 AM
4,4´-DDE	6.8	2.0		µg/Kg	1	6/19/2009 01:32 AM
4,4´-DDT	13	2.0		µg/Kg	1	6/19/2009 01:32 AM
Aldrin	ND	1.0		µg/Kg	1	6/19/2009 01:32 AM
alpha-BHC	ND	1.0		µg/Kg	1	6/19/2009 01:32 AM
alpha-Chlordane	ND	1.0		µg/Kg	1	6/19/2009 01:32 AM
beta-BHC	ND	1.0		µg/Kg	1	6/19/2009 01:32 AM
Chlordane	ND	8.5		µg/Kg	1	6/19/2009 01:32 AM
delta-BHC	ND	1.0		µg/Kg	1	6/19/2009 01:32 AM
Dieldrin	ND	2.0		µg/Kg	1	6/19/2009 01:32 AM
Endosulfan I	ND	1.0		µg/Kg	1	6/19/2009 01:32 AM
Endosulfan II	ND	2.0		µg/Kg	1	6/19/2009 01:32 AM
Endosulfan sulfate	ND	2.0		µg/Kg	1	6/19/2009 01:32 AM
Endrin	ND	2.0		µg/Kg	1	6/19/2009 01:32 AM
Endrin aldehyde	ND	2.0		µg/Kg	1	6/19/2009 01:32 AM
Endrin ketone	ND	2.0		µg/Kg	1	6/19/2009 01:32 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		

CLIENT:	Geocon Consultants, Inc.	**Client Sample ID:**	Composite TCWA6-A,B,C,D
Lab Order:	105982	**Collection Date:**	6/16/2009
Project:	ANTIOCH BRIDGE RETROFIT, E8435-06-	**Matrix:**	SOIL
Lab ID:	105982-086A		

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
ORGANOCHLORINE PESTICIDES BY GC/ECD						
	EPA 3550B			**EPA 8081A**		
RunID: GC9_090618B	QC Batch: 56045			PrepDate:	6/18/2009	Analyst: **HL**
gamma-BHC	ND	1.0		µg/Kg	1	6/19/2009 01:32 AM
gamma-Chlordane	ND	1.0		µg/Kg	1	6/19/2009 01:32 AM
Heptachlor	ND	1.0		µg/Kg	1	6/19/2009 01:32 AM
Heptachlor epoxide	ND	1.0		µg/Kg	1	6/19/2009 01:32 AM
Methoxychlor	ND	5.0		µg/Kg	1	6/19/2009 01:32 AM
Toxaphene	ND	50		µg/Kg	1	6/19/2009 01:32 AM
Surr: Decachlorobiphenyl	52.9	20-142		%REC	1	6/19/2009 01:32 AM
Surr: Tetrachloro-m-xylene	54.0	25-115		%REC	1	6/19/2009 01:32 AM
MERCURY BY COLD VAPOR TECHNIQUE						
				EPA 7471A		
RunID: AA5_090618C	QC Batch: 55983			PrepDate:	6/17/2009	Analyst: **IL**
Mercury	0.13	0.10		mg/Kg	1	6/18/2009 02:47 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.	**Client Sample ID:**	Composite TCWA7-A,B,C,D
Lab Order:	105982	**Collection Date:**	6/16/2009
Project:	ANTIOCH BRIDGE RETROFIT, E8435-06-	**Matrix:**	SOIL
Lab ID:	105982-087A		

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
ICP METALS						
	EPA 3050B			**EPA 6010B**		
RunID: ICP8_090618F	QC Batch: 55986			PrepDate: 6/17/2009	Analyst: **CL**	
Antimony	ND	2.0		mg/Kg	1	6/18/2009 04:51 PM
Arsenic	10	1.0		mg/Kg	1	6/18/2009 04:51 PM
Barium	180	1.0		mg/Kg	1	6/18/2009 04:51 PM
Beryllium	ND	1.0		mg/Kg	1	6/18/2009 04:51 PM
Cadmium	ND	1.0		mg/Kg	1	6/18/2009 04:51 PM
Chromium	60	1.0		mg/Kg	1	6/18/2009 04:51 PM
Cobalt	10	1.0		mg/Kg	1	6/18/2009 04:51 PM
Copper	43	2.0		mg/Kg	1	6/18/2009 04:51 PM
Lead	12	1.0		mg/Kg	1	6/18/2009 04:51 PM
Molybdenum	1.2	1.0		mg/Kg	1	6/18/2009 04:51 PM
Nickel	61	1.0		mg/Kg	1	6/18/2009 04:51 PM
Selenium	ND	1.0		mg/Kg	1	6/18/2009 04:51 PM
Silver	ND	1.0		mg/Kg	1	6/18/2009 04:51 PM
Thallium	ND	1.0		mg/Kg	1	6/18/2009 04:51 PM
Vanadium	85	1.0		mg/Kg	1	6/18/2009 04:51 PM
Zinc	61	1.0		mg/Kg	1	6/18/2009 04:51 PM
ORGANOCHLORINE PESTICIDES BY GC/ECD						
	EPA 3550B			**EPA 8081A**		
RunID: GC9_090618B	QC Batch: 56045			PrepDate: 6/18/2009	Analyst: **HL**	
4,4´-DDD	4.0	2.0		µg/Kg	1	6/19/2009 01:46 AM
4,4´-DDE	12	2.0		µg/Kg	1	6/19/2009 01:46 AM
4,4´-DDT	24	2.0		µg/Kg	1	6/19/2009 01:46 AM
Aldrin	ND	1.0		µg/Kg	1	6/19/2009 01:46 AM
alpha-BHC	ND	1.0		µg/Kg	1	6/19/2009 01:46 AM
alpha-Chlordane	ND	1.0		µg/Kg	1	6/19/2009 01:46 AM
beta-BHC	ND	1.0		µg/Kg	1	6/19/2009 01:46 AM
Chlordane	ND	8.5		µg/Kg	1	6/19/2009 01:46 AM
delta-BHC	ND	1.0		µg/Kg	1	6/19/2009 01:46 AM
Dieldrin	ND	2.0		µg/Kg	1	6/19/2009 01:46 AM
Endosulfan I	ND	1.0		µg/Kg	1	6/19/2009 01:46 AM
Endosulfan II	ND	2.0		µg/Kg	1	6/19/2009 01:46 AM
Endosulfan sulfate	ND	2.0		µg/Kg	1	6/19/2009 01:46 AM
Endrin	ND	2.0		µg/Kg	1	6/19/2009 01:46 AM
Endrin aldehyde	ND	2.0		µg/Kg	1	6/19/2009 01:46 AM
Endrin ketone	ND	2.0		µg/Kg	1	6/19/2009 01:46 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		

CLIENT:	Geocon Consultants, Inc.	**Client Sample ID:**	Composite TCWA7-A,B,C,D
Lab Order:	105982	**Collection Date:**	6/16/2009
Project:	ANTIOCH BRIDGE RETROFIT, E8435-06-	**Matrix:**	SOIL
Lab ID:	105982-087A		

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
ORGANOCHLORINE PESTICIDES BY GC/ECD						
	EPA 3550B			**EPA 8081A**		
RunID: GC9_090618B	QC Batch: 56045			PrepDate:	6/18/2009	Analyst: **HL**
gamma-BHC	ND	1.0		µg/Kg	1	6/19/2009 01:46 AM
gamma-Chlordane	ND	1.0		µg/Kg	1	6/19/2009 01:46 AM
Heptachlor	ND	1.0		µg/Kg	1	6/19/2009 01:46 AM
Heptachlor epoxide	ND	1.0		µg/Kg	1	6/19/2009 01:46 AM
Methoxychlor	ND	5.0		µg/Kg	1	6/19/2009 01:46 AM
Toxaphene	ND	50		µg/Kg	1	6/19/2009 01:46 AM
Surr: Decachlorobiphenyl	61.5	20-142		%REC	1	6/19/2009 01:46 AM
Surr: Tetrachloro-m-xylene	59.6	25-115		%REC	1	6/19/2009 01:46 AM
MERCURY BY COLD VAPOR TECHNIQUE						
				EPA 7471A		
RunID: AA5_090618C	QC Batch: 55983			PrepDate:	6/17/2009	Analyst: **IL**
Mercury	0.11	0.10		mg/Kg	1	6/18/2009 02:49 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:**	Composite TCWA8-A,B,C,D
Lab Order:	105982	**Collection Date:**	6/16/2009
Project:	ANTIOCH BRIDGE RETROFIT, E8435-06-	**Matrix:**	SOIL
Lab ID:	105982-088A		

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
ICP METALS						
	EPA 3050B			**EPA 6010B**		
RunID: ICP8_090618F	QC Batch: 55986			PrepDate: 6/17/2009	Analyst: **CL**	
Antimony	ND	2.0		mg/Kg	1	6/18/2009 04:54 PM
Arsenic	10	1.0		mg/Kg	1	6/18/2009 04:54 PM
Barium	190	1.0		mg/Kg	1	6/18/2009 04:54 PM
Beryllium	ND	1.0		mg/Kg	1	6/18/2009 04:54 PM
Cadmium	ND	1.0		mg/Kg	1	6/18/2009 04:54 PM
Chromium	59	1.0		mg/Kg	1	6/18/2009 04:54 PM
Cobalt	9.4	1.0		mg/Kg	1	6/18/2009 04:54 PM
Copper	45	2.0		mg/Kg	1	6/18/2009 04:54 PM
Lead	14	1.0		mg/Kg	1	6/18/2009 04:54 PM
Molybdenum	1.4	1.0		mg/Kg	1	6/18/2009 04:54 PM
Nickel	60	1.0		mg/Kg	1	6/18/2009 04:54 PM
Selenium	ND	1.0		mg/Kg	1	6/18/2009 04:54 PM
Silver	ND	1.0		mg/Kg	1	6/18/2009 04:54 PM
Thallium	ND	1.0		mg/Kg	1	6/18/2009 04:54 PM
Vanadium	85	1.0		mg/Kg	1	6/18/2009 04:54 PM
Zinc	57	1.0		mg/Kg	1	6/18/2009 04:54 PM
ORGANOCHLORINE PESTICIDES BY GC/ECD						
	EPA 3550B			**EPA 8081A**		
RunID: GC9_090618B	QC Batch: 56045			PrepDate: 6/18/2009	Analyst: **HL**	
4,4´-DDD	2.1	2.0		µg/Kg	1	6/19/2009 02:00 AM
4,4´-DDE	9.2	2.0		µg/Kg	1	6/19/2009 02:00 AM
4,4´-DDT	16	2.0		µg/Kg	1	6/19/2009 02:00 AM
Aldrin	ND	1.0		µg/Kg	1	6/19/2009 02:00 AM
alpha-BHC	ND	1.0		µg/Kg	1	6/19/2009 02:00 AM
alpha-Chlordane	ND	1.0		µg/Kg	1	6/19/2009 02:00 AM
beta-BHC	ND	1.0		µg/Kg	1	6/19/2009 02:00 AM
Chlordane	ND	8.5		µg/Kg	1	6/19/2009 02:00 AM
delta-BHC	ND	1.0		µg/Kg	1	6/19/2009 02:00 AM
Dieldrin	ND	2.0		µg/Kg	1	6/19/2009 02:00 AM
Endosulfan I	ND	1.0		µg/Kg	1	6/19/2009 02:00 AM
Endosulfan II	ND	2.0		µg/Kg	1	6/19/2009 02:00 AM
Endosulfan sulfate	ND	2.0		µg/Kg	1	6/19/2009 02:00 AM
Endrin	ND	2.0		µg/Kg	1	6/19/2009 02:00 AM
Endrin aldehyde	ND	2.0		µg/Kg	1	6/19/2009 02:00 AM
Endrin ketone	ND	2.0		µg/Kg	1	6/19/2009 02:00 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		

CLIENT:	Geocon Consultants, Inc.	**Client Sample ID:**	Composite TCWA8-A,B,C,D
Lab Order:	105982	**Collection Date:**	6/16/2009
Project:	ANTIOCH BRIDGE RETROFIT, E8435-06-	**Matrix:**	SOIL
Lab ID:	105982-088A		

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
ORGANOCHLORINE PESTICIDES BY GC/ECD						
	EPA 3550B			**EPA 8081A**		
RunID: GC9_090618B	QC Batch: 56045			PrepDate:	6/18/2009	Analyst: **HL**
gamma-BHC	ND	1.0		µg/Kg	1	6/19/2009 02:00 AM
gamma-Chlordane	ND	1.0		µg/Kg	1	6/19/2009 02:00 AM
Heptachlor	ND	1.0		µg/Kg	1	6/19/2009 02:00 AM
Heptachlor epoxide	ND	1.0		µg/Kg	1	6/19/2009 02:00 AM
Methoxychlor	ND	5.0		µg/Kg	1	6/19/2009 02:00 AM
Toxaphene	ND	50		µg/Kg	1	6/19/2009 02:00 AM
Surr: Decachlorobiphenyl	51.4	20-142		%REC	1	6/19/2009 02:00 AM
Surr: Tetrachloro-m-xylene	52.8	25-115		%REC	1	6/19/2009 02:00 AM
MERCURY BY COLD VAPOR TECHNIQUE						
				EPA 7471A		
RunID: AA5_090618C	QC Batch: 55983			PrepDate:	6/17/2009	Analyst: **IL**
Mercury	0.14	0.10		mg/Kg	1	6/18/2009 02:51 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.	**Client Sample ID:**	Composite TCWA9-A,B,C,D
Lab Order:	105982	**Collection Date:**	6/16/2009
Project:	ANTIOCH BRIDGE RETROFIT, E8435-06-	**Matrix:**	SOIL
Lab ID:	105982-089A		

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
ICP METALS						
	EPA 3050B			**EPA 6010B**		
RunID: ICP8_090618F	QC Batch: 55986			PrepDate: 6/17/2009	Analyst: **CL**	
Antimony	ND	2.0		mg/Kg	1	6/18/2009 04:56 PM
Arsenic	10	1.0		mg/Kg	1	6/18/2009 04:56 PM
Barium	170	1.0		mg/Kg	1	6/18/2009 04:56 PM
Beryllium	ND	1.0		mg/Kg	1	6/18/2009 04:56 PM
Cadmium	ND	1.0		mg/Kg	1	6/18/2009 04:56 PM
Chromium	61	1.0		mg/Kg	1	6/18/2009 04:56 PM
Cobalt	11	1.0		mg/Kg	1	6/18/2009 04:56 PM
Copper	44	2.0		mg/Kg	1	6/18/2009 04:56 PM
Lead	12	1.0		mg/Kg	1	6/18/2009 04:56 PM
Molybdenum	1.3	1.0		mg/Kg	1	6/18/2009 04:56 PM
Nickel	63	1.0		mg/Kg	1	6/18/2009 04:56 PM
Selenium	ND	1.0		mg/Kg	1	6/18/2009 04:56 PM
Silver	ND	1.0		mg/Kg	1	6/18/2009 04:56 PM
Thallium	ND	1.0		mg/Kg	1	6/18/2009 04:56 PM
Vanadium	86	1.0		mg/Kg	1	6/18/2009 04:56 PM
Zinc	63	1.0		mg/Kg	1	6/18/2009 04:56 PM
ORGANOCHLORINE PESTICIDES BY GC/ECD						
	EPA 3550B			**EPA 8081A**		
RunID: GC9_090618B	QC Batch: 56045			PrepDate: 6/18/2009	Analyst: **HL**	
4,4´-DDD	ND	2.0		µg/Kg	1	6/19/2009 02:15 AM
4,4´-DDE	8.3	2.0		µg/Kg	1	6/19/2009 02:15 AM
4,4´-DDT	15	2.0		µg/Kg	1	6/19/2009 02:15 AM
Aldrin	ND	1.0		µg/Kg	1	6/19/2009 02:15 AM
alpha-BHC	ND	1.0		µg/Kg	1	6/19/2009 02:15 AM
alpha-Chlordane	ND	1.0		µg/Kg	1	6/19/2009 02:15 AM
beta-BHC	ND	1.0		µg/Kg	1	6/19/2009 02:15 AM
Chlordane	ND	8.5		µg/Kg	1	6/19/2009 02:15 AM
delta-BHC	ND	1.0		µg/Kg	1	6/19/2009 02:15 AM
Dieldrin	ND	2.0		µg/Kg	1	6/19/2009 02:15 AM
Endosulfan I	ND	1.0		µg/Kg	1	6/19/2009 02:15 AM
Endosulfan II	ND	2.0		µg/Kg	1	6/19/2009 02:15 AM
Endosulfan sulfate	ND	2.0		µg/Kg	1	6/19/2009 02:15 AM
Endrin	ND	2.0		µg/Kg	1	6/19/2009 02:15 AM
Endrin aldehyde	ND	2.0		µg/Kg	1	6/19/2009 02:15 AM
Endrin ketone	ND	2.0		µg/Kg	1	6/19/2009 02:15 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		

CLIENT:	Geocon Consultants, Inc.	**Client Sample ID:**	Composite TCWA9-A,B,C,D
Lab Order:	105982	**Collection Date:**	6/16/2009
Project:	ANTIOCH BRIDGE RETROFIT, E8435-06-	**Matrix:**	SOIL
Lab ID:	105982-089A		

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
ORGANOCHLORINE PESTICIDES BY GC/ECD						
	EPA 3550B			**EPA 8081A**		
RunID: GC9_090618B	QC Batch: 56045			PrepDate:	6/18/2009	Analyst: **HL**
gamma-BHC	ND	1.0		µg/Kg	1	6/19/2009 02:15 AM
gamma-Chlordane	ND	1.0		µg/Kg	1	6/19/2009 02:15 AM
Heptachlor	ND	1.0		µg/Kg	1	6/19/2009 02:15 AM
Heptachlor epoxide	ND	1.0		µg/Kg	1	6/19/2009 02:15 AM
Methoxychlor	ND	5.0		µg/Kg	1	6/19/2009 02:15 AM
Toxaphene	ND	50		µg/Kg	1	6/19/2009 02:15 AM
Surr: Decachlorobiphenyl	53.8	20-142		%REC	1	6/19/2009 02:15 AM
Surr: Tetrachloro-m-xylene	54.3	25-115		%REC	1	6/19/2009 02:15 AM
MERCURY BY COLD VAPOR TECHNIQUE						
				EPA 7471A		
RunID: AA5_090618C	QC Batch: 55983			PrepDate:	6/17/2009	Analyst: **IL**
Mercury	0.11	0.10		mg/Kg	1	6/18/2009 02:53 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.	**Client Sample ID:**	Composite TCWA10-A,B,C,D
Lab Order:	105982	**Collection Date:**	6/16/2009
Project:	ANTIOCH BRIDGE RETROFIT, E8435-06-	**Matrix:**	SOIL
Lab ID:	105982-090A		

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
ICP METALS						
	EPA 3050B			**EPA 6010B**		
RunID: ICP8_090618F	QC Batch: 55986			PrepDate: 6/17/2009	Analyst: **CL**	
Antimony	ND	2.0		mg/Kg	1	6/18/2009 04:59 PM
Arsenic	11	1.0		mg/Kg	1	6/18/2009 04:59 PM
Barium	190	1.0		mg/Kg	1	6/18/2009 04:59 PM
Beryllium	ND	1.0		mg/Kg	1	6/18/2009 04:59 PM
Cadmium	ND	1.0		mg/Kg	1	6/18/2009 04:59 PM
Chromium	58	1.0		mg/Kg	1	6/18/2009 04:59 PM
Cobalt	9.8	1.0		mg/Kg	1	6/18/2009 04:59 PM
Copper	43	2.0		mg/Kg	1	6/18/2009 04:59 PM
Lead	15	1.0		mg/Kg	1	6/18/2009 04:59 PM
Molybdenum	1.6	1.0		mg/Kg	1	6/18/2009 04:59 PM
Nickel	59	1.0		mg/Kg	1	6/18/2009 04:59 PM
Selenium	ND	1.0		mg/Kg	1	6/18/2009 04:59 PM
Silver	ND	1.0		mg/Kg	1	6/18/2009 04:59 PM
Thallium	ND	1.0		mg/Kg	1	6/18/2009 04:59 PM
Vanadium	85	1.0		mg/Kg	1	6/18/2009 04:59 PM
Zinc	59	1.0		mg/Kg	1	6/18/2009 04:59 PM
ORGANOCHLORINE PESTICIDES BY GC/ECD						
	EPA 3550B			**EPA 8081A**		
RunID: GC9_090618B	QC Batch: 56045			PrepDate: 6/18/2009	Analyst: **HL**	
4,4´-DDD	ND	2.0		µg/Kg	1	6/19/2009 02:29 AM
4,4´-DDE	7.1	2.0		µg/Kg	1	6/19/2009 02:29 AM
4,4´-DDT	15	2.0		µg/Kg	1	6/19/2009 02:29 AM
Aldrin	ND	1.0		µg/Kg	1	6/19/2009 02:29 AM
alpha-BHC	ND	1.0		µg/Kg	1	6/19/2009 02:29 AM
alpha-Chlordane	ND	1.0		µg/Kg	1	6/19/2009 02:29 AM
beta-BHC	ND	1.0		µg/Kg	1	6/19/2009 02:29 AM
Chlordane	ND	8.5		µg/Kg	1	6/19/2009 02:29 AM
delta-BHC	ND	1.0		µg/Kg	1	6/19/2009 02:29 AM
Dieldrin	ND	2.0		µg/Kg	1	6/19/2009 02:29 AM
Endosulfan I	ND	1.0		µg/Kg	1	6/19/2009 02:29 AM
Endosulfan II	ND	2.0		µg/Kg	1	6/19/2009 02:29 AM
Endosulfan sulfate	ND	2.0		µg/Kg	1	6/19/2009 02:29 AM
Endrin	ND	2.0		µg/Kg	1	6/19/2009 02:29 AM
Endrin aldehyde	ND	2.0		µg/Kg	1	6/19/2009 02:29 AM
Endrin ketone	ND	2.0		µg/Kg	1	6/19/2009 02:29 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		

CLIENT:	Geocon Consultants, Inc.	**Client Sample ID:**	Composite TCWA10-A,B,C,D
Lab Order:	105982	**Collection Date:**	6/16/2009
Project:	ANTIOCH BRIDGE RETROFIT, E8435-06-	**Matrix:**	SOIL
Lab ID:	105982-090A		

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed
ORGANOCHLORINE PESTICIDES BY GC/ECD						
	EPA 3550B			**EPA 8081A**		
RunID: GC9_090618B	QC Batch: 56045			PrepDate:	6/18/2009	Analyst: **HL**
gamma-BHC	ND	1.0		µg/Kg	1	6/19/2009 02:29 AM
gamma-Chlordane	ND	1.0		µg/Kg	1	6/19/2009 02:29 AM
Heptachlor	ND	1.0		µg/Kg	1	6/19/2009 02:29 AM
Heptachlor epoxide	ND	1.0		µg/Kg	1	6/19/2009 02:29 AM
Methoxychlor	ND	5.0		µg/Kg	1	6/19/2009 02:29 AM
Toxaphene	ND	50		µg/Kg	1	6/19/2009 02:29 AM
Surr: Decachlorobiphenyl	51.5	20-142		%REC	1	6/19/2009 02:29 AM
Surr: Tetrachloro-m-xylene	52.6	25-115		%REC	1	6/19/2009 02:29 AM
MERCURY BY COLD VAPOR TECHNIQUE						
				EPA 7471A		
RunID: AA5_090618C	QC Batch: 55983			PrepDate:	6/17/2009	Analyst: **IL**
Mercury	0.14	0.10		mg/Kg	1	6/18/2009 02:38 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.
Work Order: 105982
Project: ANTIOCH BRIDGE RETROFIT, E8435-06-18

ANALYTICAL QC SUMMARY REPORT

TestCode: 6010_S

Sample ID: **MB-55985** SampType: **MBLK** TestCode: **6010_S** Units: **mg/Kg** Prep Date: **6/17/2009** RunNo: **110025**
Client ID: **PBS** Batch ID: **55985** TestNo: **EPA 6010B** **EPA 3050B** Analysis Date: **6/18/2009** SeqNo: **1728237**

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	0.021	1.0									
Chromium	ND	1.0									
Cobalt	ND	1.0									
Copper	ND	2.0									
Lead	0.252	1.0									
Molybdenum	ND	1.0									
Nickel	0.064	1.0									
Selenium	ND	1.0									
Silver	0.022	1.0									
Thallium	ND	1.0									
Vanadium	0.028	1.0									
Zinc	0.347	1.0									

Sample ID: **LCS-55985** SampType: **LCS** TestCode: **6010_S** Units: **mg/Kg** Prep Date: **6/17/2009** RunNo: **110025**
Client ID: **LCSS** Batch ID: **55985** TestNo: **EPA 6010B** **EPA 3050B** Analysis Date: **6/18/2009** SeqNo: **1728238**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Antimony	45.742	2.0	50.00	0	91.5	80	120				
Arsenic	46.077	1.0	50.00	0	92.2	80	120				
Barium	47.920	1.0	50.00	0	95.8	80	120				
Beryllium	46.667	1.0	50.00	0	93.3	80	120				
Cadmium	46.543	1.0	50.00	0.02094	93.0	80	120				
Chromium	44.061	1.0	50.00	0	88.1	80	120				
Cobalt	48.302	1.0	50.00	0	96.6	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

CLIENT: Geocon Consultants, Inc.
Work Order: 105982
Project: ANTIOCH BRIDGE RETROFIT, E8435-06-18

ANALYTICAL QC SUMMARY REPORT

TestCode: 6010_S

Sample ID: **LCS-55985** SampType: **LCS** TestCode: **6010_S** Units: **mg/Kg** Prep Date: **6/17/2009** RunNo: **110025**
Client ID: **LCSS** Batch ID: **55985** TestNo: **EPA 6010B** **EPA 3050B** Analysis Date: **6/18/2009** SeqNo: **1728238**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Copper	47.443	2.0	50.00	0	94.9	80	120				
Lead	46.508	1.0	50.00	0.2521	92.5	80	120				
Molybdenum	48.974	1.0	50.00	0	97.9	80	120				
Nickel	46.276	1.0	50.00	0.06351	92.4	80	120				
Selenium	43.203	1.0	50.00	0	86.4	80	120				
Silver	44.051	1.0	50.00	0.02204	88.1	80	120				
Thallium	41.856	1.0	50.00	0	83.7	80	120				
Vanadium	48.045	1.0	50.00	0.02816	96.0	80	120				
Zinc	45.931	1.0	50.00	0.3474	91.2	80	120				

Sample ID: **105982-082ADUP** SampType: **DUP** TestCode: **6010_S** Units: **mg/Kg** Prep Date: **6/17/2009** RunNo: **110025**
Client ID: **Composite TCWA2-** Batch ID: **55985** TestNo: **EPA 6010B** **EPA 3050B** Analysis Date: **6/18/2009** SeqNo: **1728249**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Antimony	0.694	2.0						0.8435	0	20	
Arsenic	7.899	1.0						8.787	10.6	20	
Barium	171.442	1.0						169.9	0.917	20	
Beryllium	0.101	1.0						0.1143	0	20	
Cadmium	0.694	1.0						0.7007	0	20	
Chromium	56.334	1.0						56.95	1.09	20	
Cobalt	8.886	1.0						8.954	0.764	20	
Copper	39.541	2.0						40.67	2.82	20	
Lead	12.884	1.0						13.53	4.89	20	
Molybdenum	1.205	1.0						1.158	3.94	20	
Nickel	56.061	1.0						56.86	1.42	20	
Selenium	ND	1.0						0	0	20	
Silver	ND	1.0						0	0	20	
Thallium	ND	1.0						0	0	20	
Vanadium	75.705	1.0						76.91	1.58	20	
Zinc	65.062	1.0						64.25	1.26	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: 105982
Project: ANTIOCH BRIDGE RETROFIT, E8435-06-18

ANALYTICAL QC SUMMARY REPORT

TestCode: 6010_S

Sample ID: **105982-082AMS** SampType: **MS** TestCode: **6010_S** Units: **mg/Kg** Prep Date: **6/17/2009** RunNo: **110025**
Client ID: **Composite TCWA2-** Batch ID: **55985** TestNo: **EPA 6010B** **EPA 3050B** Analysis Date: **6/18/2009** SeqNo: **1728250**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Antimony	65.135	2.0	125.0	0.8435	51.4	25	106				
Arsenic	105.919	1.0	125.0	8.787	77.7	42	113				
Barium	289.252	1.0	125.0	169.9	95.5	19	140				
Beryllium	98.749	1.0	125.0	0.1143	78.9	50	109				
Cadmium	93.820	1.0	125.0	0.7007	74.5	48	106				
Chromium	154.134	1.0	125.0	56.95	77.7	44	116				
Cobalt	105.044	1.0	125.0	8.954	76.9	47	107				
Copper	151.893	2.0	125.0	40.67	89.0	49	124				
Lead	104.620	1.0	125.0	13.53	72.9	33	120				
Molybdenum	96.758	1.0	125.0	1.158	76.5	46	111				
Nickel	154.640	1.0	125.0	56.86	78.2	43	111				
Selenium	93.411	1.0	125.0	0	74.7	43	104				
Silver	97.392	1.0	125.0	0	77.9	53	114				
Thallium	84.695	1.0	125.0	0	67.8	41	107				
Vanadium	182.939	1.0	125.0	76.91	84.8	48	116				
Zinc	161.018	1.0	125.0	64.25	77.4	24	129				

Sample ID: **105982-082AMSD** SampType: **MSD** TestCode: **6010_S** Units: **mg/Kg** Prep Date: **6/17/2009** RunNo: **110025**
Client ID: **Composite TCWA2-** Batch ID: **55985** TestNo: **EPA 6010B** **EPA 3050B** Analysis Date: **6/18/2009** SeqNo: **1728251**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Antimony	59.911	2.0	125.0	0.8435	47.3	25	106	65.13	8.35	20	
Arsenic	104.282	1.0	125.0	8.787	76.4	42	113	105.9	1.56	20	
Barium	273.893	1.0	125.0	169.9	83.2	19	140	289.3	5.45	20	
Beryllium	97.477	1.0	125.0	0.1143	77.9	50	109	98.75	1.30	20	
Cadmium	91.362	1.0	125.0	0.7007	72.5	48	106	93.82	2.65	20	
Chromium	153.066	1.0	125.0	56.95	76.9	44	116	154.1	0.696	20	
Cobalt	102.755	1.0	125.0	8.954	75.0	47	107	105.0	2.20	20	
Copper	150.359	2.0	125.0	40.67	87.8	49	124	151.9	1.02	20	
Lead	101.796	1.0	125.0	13.53	70.6	33	120	104.6	2.74	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: 105982
Project: ANTIOCH BRIDGE RETROFIT, E8435-06-18

ANALYTICAL QC SUMMARY REPORT

TestCode: 6010_S

Sample ID: **105982-082AMSD** SampType: **MSD** TestCode: **6010_S** Units: **mg/Kg** Prep Date: **6/17/2009** RunNo: **110025**
Client ID: **Composite TCWA2-** Batch ID: **55985** TestNo: **EPA 6010B** **EPA 3050B** Analysis Date: **6/18/2009** SeqNo: **1728251**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Molybdenum	94.722	1.0	125.0	1.158	74.9	46	111	96.76	2.13	20	
Nickel	154.778	1.0	125.0	56.86	78.3	43	111	154.6	0.0891	20	
Selenium	92.135	1.0	125.0	0	73.7	43	104	93.41	1.38	20	
Silver	95.447	1.0	125.0	0	76.4	53	114	97.39	2.02	20	
Thallium	82.534	1.0	125.0	0	66.0	41	107	84.70	2.58	20	
Vanadium	182.596	1.0	125.0	76.91	84.5	48	116	182.9	0.188	20	
Zinc	157.095	1.0	125.0	64.25	74.3	24	129	161.0	2.47	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: 105982
Project: ANTIOCH BRIDGE RETROFIT, E8435-06-18

ANALYTICAL QC SUMMARY REPORT

TestCode: 6010_S

Sample ID: **MB-55986** SampType: **MBLK** TestCode: **6010_S** Units: **mg/Kg** Prep Date: **6/17/2009** RunNo: **110035**
Client ID: **PBS** Batch ID: **55986** TestNo: **EPA 6010B** **EPA 3050B** Analysis Date: **6/18/2009** SeqNo: **1728338**

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	0.011	1.0									
Chromium	ND	1.0									
Cobalt	ND	1.0									
Copper	ND	2.0									
Lead	0.234	1.0									
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	0.434	1.0									

Sample ID: **LCS-55986** SampType: **LCS** TestCode: **6010_S** Units: **mg/Kg** Prep Date: **6/17/2009** RunNo: **110035**
Client ID: **LCSS** Batch ID: **55986** TestNo: **EPA 6010B** **EPA 3050B** Analysis Date: **6/18/2009** SeqNo: **1728339**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Antimony	49.779	2.0	50.00	0	99.6	80	120				
Arsenic	50.548	1.0	50.00	0	101	80	120				
Barium	51.527	1.0	50.00	0	103	80	120				
Beryllium	50.528	1.0	50.00	0	101	80	120				
Cadmium	50.361	1.0	50.00	0.01104	101	80	120				
Chromium	47.299	1.0	50.00	0	94.6	80	120				
Cobalt	51.983	1.0	50.00	0	104	80	120				
Copper	50.822	2.0	50.00	0	102	80	120				
Lead	49.190	1.0	50.00	0.2340	97.9	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

CLIENT: Geocon Consultants, Inc.
Work Order: 105982
Project: ANTIOCH BRIDGE RETROFIT, E8435-06-18

ANALYTICAL QC SUMMARY REPORT

TestCode: 6010_S

Sample ID: **LCS-55986** SampType: **LCS** TestCode: **6010_S** Units: **mg/Kg** Prep Date: **6/17/2009** RunNo: **110035**
Client ID: **LCSS** Batch ID: **55986** TestNo: **EPA 6010B** **EPA 3050B** Analysis Date: **6/18/2009** SeqNo: **1728339**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Molybdenum	52.964	1.0	50.00	0	106	80	120				
Nickel	49.507	1.0	50.00	0	99.0	80	120				
Selenium	47.144	1.0	50.00	0	94.3	80	120				
Silver	47.625	1.0	50.00	0	95.3	80	120				
Thallium	45.370	1.0	50.00	0	90.7	80	120				
Vanadium	51.464	1.0	50.00	0	103	80	120				
Zinc	49.698	1.0	50.00	0.4337	98.5	80	120				

Sample ID: **105982-090ADUP** SampType: **DUP** TestCode: **6010_S** Units: **mg/Kg** Prep Date: **6/17/2009** RunNo: **110035**
Client ID: **Composite TCWA10** Batch ID: **55986** TestNo: **EPA 6010B** **EPA 3050B** Analysis Date: **6/18/2009** SeqNo: **1728348**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Antimony	0.973	2.0						1.182	0	20	
Arsenic	11.033	1.0						11.02	0.126	20	
Barium	191.312	1.0						190.4	0.499	20	
Beryllium	0.193	1.0						0.1887	0	20	
Cadmium	0.707	1.0						0.7284	0	20	
Chromium	58.586	1.0						58.09	0.852	20	
Cobalt	10.003	1.0						9.799	2.06	20	
Copper	43.164	2.0						42.94	0.512	20	
Lead	13.954	1.0						14.60	4.53	20	
Molybdenum	1.400	1.0						1.630	15.1	20	
Nickel	59.499	1.0						58.68	1.38	20	
Selenium	ND	1.0						0	0	20	
Silver	ND	1.0						0	0	20	
Thallium	ND	1.0						0	0	20	
Vanadium	84.843	1.0						84.78	0.0727	20	
Zinc	58.159	1.0						59.23	1.83	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: 105982
Project: ANTIOCH BRIDGE RETROFIT, E8435-06-18

ANALYTICAL QC SUMMARY REPORT

TestCode: 6010_S

Sample ID: **105982-090AMS** SampType: **MS** TestCode: **6010_S** Units: **mg/Kg** Prep Date: **6/17/2009** RunNo: **110035**
Client ID: **Composite TCWA10** Batch ID: **55986** TestNo: **EPA 6010B** **EPA 3050B** Analysis Date: **6/18/2009** SeqNo: **1728349**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Antimony	59.590	2.0	125.0	1.182	46.7	25	106				
Arsenic	105.564	1.0	125.0	11.02	75.6	42	113				
Barium	276.574	1.0	125.0	190.4	69.0	19	140				
Beryllium	96.662	1.0	125.0	0.1887	77.2	50	109				
Cadmium	92.161	1.0	125.0	0.7284	73.1	48	106				
Chromium	147.964	1.0	125.0	58.09	71.9	44	116				
Cobalt	103.456	1.0	125.0	9.799	74.9	47	107				
Copper	147.648	2.0	125.0	42.94	83.8	49	124				
Lead	100.856	1.0	125.0	14.60	69.0	33	120				
Molybdenum	94.466	1.0	125.0	1.630	74.3	46	111				
Nickel	150.646	1.0	125.0	58.68	73.6	43	111				
Selenium	93.030	1.0	125.0	0	74.4	43	104				
Silver	94.512	1.0	125.0	0	75.6	53	114				
Thallium	82.738	1.0	125.0	0	66.2	41	107				
Vanadium	180.866	1.0	125.0	84.78	76.9	48	116				
Zinc	148.360	1.0	125.0	59.23	71.3	24	129				

Sample ID: **105982-090AMSD** SampType: **MSD** TestCode: **6010_S** Units: **mg/Kg** Prep Date: **6/17/2009** RunNo: **110035**
Client ID: **Composite TCWA10** Batch ID: **55986** TestNo: **EPA 6010B** **EPA 3050B** Analysis Date: **6/18/2009** SeqNo: **1728350**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Antimony	59.892	2.0	125.0	1.182	47.0	25	106	59.59	0.505	20	
Arsenic	103.402	1.0	125.0	11.02	73.9	42	113	105.6	2.07	20	
Barium	281.332	1.0	125.0	190.4	72.8	19	140	276.6	1.71	20	
Beryllium	95.873	1.0	125.0	0.1887	76.5	50	109	96.66	0.820	20	
Cadmium	90.117	1.0	125.0	0.7284	71.5	48	106	92.16	2.24	20	
Chromium	145.915	1.0	125.0	58.09	70.3	44	116	148.0	1.39	20	
Cobalt	101.311	1.0	125.0	9.799	73.2	47	107	103.5	2.10	20	
Copper	145.693	2.0	125.0	42.94	82.2	49	124	147.6	1.33	20	
Lead	98.790	1.0	125.0	14.60	67.4	33	120	100.9	2.07	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: 105982
Project: ANTIOCH BRIDGE RETROFIT, E8435-06-18

ANALYTICAL QC SUMMARY REPORT

TestCode: 6010_S

Sample ID: **105982-090AMSD** SampType: **MSD** TestCode: **6010_S** Units: **mg/Kg** Prep Date: **6/17/2009** RunNo: **110035**
Client ID: **Composite TCWA10** Batch ID: **55986** TestNo: **EPA 6010B** **EPA 3050B** Analysis Date: **6/18/2009** SeqNo: **1728350**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Molybdenum	92.892	1.0	125.0	1.630	73.0	46	111	94.47	1.68	20	
Nickel	148.682	1.0	125.0	58.68	72.0	43	111	150.6	1.31	20	
Selenium	89.953	1.0	125.0	0	72.0	43	104	93.03	3.36	20	
Silver	92.156	1.0	125.0	0	73.7	53	114	94.51	2.52	20	
Thallium	81.204	1.0	125.0	0	65.0	41	107	82.74	1.87	20	
Vanadium	178.762	1.0	125.0	84.78	75.2	48	116	180.9	1.17	20	
Zinc	144.990	1.0	125.0	59.23	68.6	24	129	148.4	2.30	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: 105982
Project: ANTIOCH BRIDGE RETROFIT, E8435-06-18

ANALYTICAL QC SUMMARY REPORT

TestCode: 7471_S

Sample ID: **MB-55982**	SampType: **MBLK**	TestCode: **7471_S**	Units: **mg/Kg**	Prep Date: **6/17/2009**	RunNo: **110017**
Client ID: **PBS**	Batch ID: **55982**	TestNo: **EPA 7471A**		Analysis Date: **6/18/2009**	SeqNo: **1728100**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Mercury	ND	0.10									

Sample ID: **LCS-55982**	SampType: **LCS**	TestCode: **7471_S**	Units: **mg/Kg**	Prep Date: **6/17/2009**	RunNo: **110017**
Client ID: **LCSS**	Batch ID: **55982**	TestNo: **EPA 7471A**		Analysis Date: **6/18/2009**	SeqNo: **1728101**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Mercury	0.904	0.10	0.8300	0	109	80	120				

Sample ID: **105982-082A-MS**	SampType: **MS**	TestCode: **7471_S**	Units: **mg/Kg**	Prep Date: **6/17/2009**	RunNo: **110017**
Client ID: **Composite TCWA2-**	Batch ID: **55982**	TestNo: **EPA 7471A**		Analysis Date: **6/18/2009**	SeqNo: **1728102**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Mercury	1.126	0.10	0.8300	0.1490	118	70	130				

Sample ID: **105982-082A-MSD**	SampType: **MSD**	TestCode: **7471_S**	Units: **mg/Kg**	Prep Date: **6/17/2009**	RunNo: **110017**
Client ID: **Composite TCWA2-**	Batch ID: **55982**	TestNo: **EPA 7471A**		Analysis Date: **6/18/2009**	SeqNo: **1728103**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Mercury	1.139	0.10	0.8300	0.1490	119	70	130	1.126	1.18	20	

Sample ID: **105982-082A**	SampType: **DUP**	TestCode: **7471_S**	Units: **mg/Kg**	Prep Date: **6/17/2009**	RunNo: **110017**
Client ID: **Composite TCWA2-**	Batch ID: **55982**	TestNo: **EPA 7471A**		Analysis Date: **6/18/2009**	SeqNo: **1728105**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Mercury	0.143	0.10						0.1490	4.13	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: 105982
Project: ANTIOCH BRIDGE RETROFIT, E8435-06-18

ANALYTICAL QC SUMMARY REPORT

TestCode: 7471_S

Sample ID: **MB-55983**	SampType: **MBLK**	TestCode: **7471_S**	Units: **mg/Kg**	Prep Date: **6/17/2009**	RunNo: **110024**
Client ID: **PBS**	Batch ID: **55983**	TestNo: **EPA 7471A**		Analysis Date: **6/18/2009**	SeqNo: **1728180**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Mercury	ND	0.10									

Sample ID: **LCS-55983**	SampType: **LCS**	TestCode: **7471_S**	Units: **mg/Kg**	Prep Date: **6/17/2009**	RunNo: **110024**
Client ID: **LCSS**	Batch ID: **55983**	TestNo: **EPA 7471A**		Analysis Date: **6/18/2009**	SeqNo: **1728181**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Mercury	0.883	0.10	0.8300	0	106	80	120				

Sample ID: **105982-090A-MS**	SampType: **MS**	TestCode: **7471_S**	Units: **mg/Kg**	Prep Date: **6/17/2009**	RunNo: **110024**
Client ID: **Composite TCWA10**	Batch ID: **55983**	TestNo: **EPA 7471A**		Analysis Date: **6/18/2009**	SeqNo: **1728182**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Mercury	1.100	0.10	0.8300	0.1398	116	70	130				

Sample ID: **105982-090A-MSD**	SampType: **MSD**	TestCode: **7471_S**	Units: **mg/Kg**	Prep Date: **6/17/2009**	RunNo: **110024**
Client ID: **Composite TCWA10**	Batch ID: **55983**	TestNo: **EPA 7471A**		Analysis Date: **6/18/2009**	SeqNo: **1728183**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Mercury	1.061	0.10	0.8300	0.1398	111	70	130	1.100	3.56	20	

Sample ID: **105982-090A**	SampType: **DUP**	TestCode: **7471_S**	Units: **mg/Kg**	Prep Date: **6/17/2009**	RunNo: **110024**
Client ID: **Composite TCWA10**	Batch ID: **55983**	TestNo: **EPA 7471A**		Analysis Date: **6/18/2009**	SeqNo: **1728185**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Mercury	0.131	0.10						0.1398	6.40	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: 105982
Project: ANTIOCH BRIDGE RETROFIT, E8435-06-18

ANALYTICAL QC SUMMARY REPORT

TestCode: 8081_S

Sample ID: **MB-56044** SampType: **MBLK** TestCode: **8081_S** Units: **µg/Kg** Prep Date: **6/18/2009** RunNo: **110053**
Client ID: **PBS** Batch ID: **56044** TestNo: **EPA 8081A** **EPA 3550B** Analysis Date: **6/18/2009** SeqNo: **1728667**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
4,4´-DDD	ND	2.0									
4,4´-DDE	ND	2.0									
4,4´-DDT	ND	2.0									
Aldrin	ND	1.0									
alpha-BHC	ND	1.0									
alpha-Chlordane	ND	1.0									
beta-BHC	ND	1.0									
Chlordane	ND	8.5									
delta-BHC	ND	1.0									
Dieldrin	ND	2.0									
Endosulfan I	ND	1.0									
Endosulfan II	ND	2.0									
Endosulfan sulfate	ND	2.0									
Endrin	ND	2.0									
Endrin aldehyde	ND	2.0									
Endrin ketone	ND	2.0									
gamma-BHC	ND	1.0									
gamma-Chlordane	ND	1.0									
Heptachlor	ND	1.0									
Heptachlor epoxide	ND	1.0									
Methoxychlor	ND	5.0									
Toxaphene	ND	50									
Surr: Tetrachloro-m-xylene	15.639		16.67		93.8	25	115				
Surr: Decachlorobiphenyl	16.934		16.67		102	20	142				

Sample ID: **LCS-56044** SampType: **LCS** TestCode: **8081_S** Units: **µg/Kg** Prep Date: **6/18/2009** RunNo: **110053**
Client ID: **LCSS** Batch ID: **56044** TestNo: **EPA 8081A** **EPA 3550B** Analysis Date: **6/18/2009** SeqNo: **1728668**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Aldrin	14.201	1.0	16.67	0	85.2	59	113				

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: 105982
Project: ANTIOCH BRIDGE RETROFIT, E8435-06-18

ANALYTICAL QC SUMMARY REPORT

TestCode: 8081_S

Sample ID: **LCS-56044** SampType: **LCS** TestCode: **8081_S** Units: **µg/Kg** Prep Date: **6/18/2009** RunNo: **110053**
Client ID: **LCSS** Batch ID: **56044** TestNo: **EPA 8081A** **EPA 3550B** Analysis Date: **6/18/2009** SeqNo: **1728668**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Dieldrin	14.431	2.0	16.67	0	86.6	59	108				
Endrin	14.613	2.0	16.67	0	87.7	41	132				
gamma-BHC	14.541	1.0	16.67	0	87.2	60	111				
Heptachlor	16.362	1.0	16.67	0	98.2	62	108				
Surr: Tetrachloro-m-xylene	13.629		16.67		81.8	25	115				
Surr: Decachlorobiphenyl	14.718		16.67		88.3	20	142				

Sample ID: **MB-56044MS** SampType: **MS** TestCode: **8081_S** Units: **µg/Kg** Prep Date: **6/18/2009** RunNo: **110053**
Client ID: **ZZZZZZ** Batch ID: **56044** TestNo: **EPA 8081A** **EPA 3550B** Analysis Date: **6/18/2009** SeqNo: **1728669**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
4,4´-DDT	15.071	2.0	16.67	0	90.4	29	143				
Aldrin	14.383	1.0	16.67	0	86.3	44	131				
Dieldrin	14.716	2.0	16.67	0	88.3	40	136				
Endrin	14.910	2.0	16.67	0	89.4	41	146				
gamma-BHC	14.764	1.0	16.67	0	88.6	45	129				
Heptachlor	15.796	1.0	16.67	0	94.8	48	126				
Surr: Tetrachloro-m-xylene	13.779		16.67		82.7	25	115				
Surr: Decachlorobiphenyl	14.985		16.67		89.9	20	142				

Sample ID: **MB-56044MSD** SampType: **MSD** TestCode: **8081_S** Units: **µg/Kg** Prep Date: **6/18/2009** RunNo: **110053**
Client ID: **ZZZZZZ** Batch ID: **56044** TestNo: **EPA 8081A** **EPA 3550B** Analysis Date: **6/18/2009** SeqNo: **1728670**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
4,4´-DDT	15.291	2.0	16.67	0	91.7	29	143	15.07	1.45	20	
Aldrin	14.601	1.0	16.67	0	87.6	44	131	14.38	1.50	20	
Dieldrin	14.965	2.0	16.67	0	89.8	40	136	14.72	1.68	20	
Endrin	15.034	2.0	16.67	0	90.2	41	146	14.91	0.826	20	
gamma-BHC	15.019	1.0	16.67	0	90.1	45	129	14.76	1.71	20	
Heptachlor	15.825	1.0	16.67	0	94.9	48	126	15.80	0.184	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

CLIENT: Geocon Consultants, Inc.
Work Order: 105982
Project: ANTIOCH BRIDGE RETROFIT, E8435-06-18

ANALYTICAL QC SUMMARY REPORT

TestCode: 8081_S

Sample ID: **MB-56044MSD**	SampType: **MSD**	TestCode: **8081_S**	Units: **µg/Kg**	Prep Date: **6/18/2009**	RunNo: **110053**
Client ID: **ZZZZZZ**	Batch ID: **56044**	TestNo: **EPA 8081A**	**EPA 3550B**	Analysis Date: **6/18/2009**	SeqNo: **1728670**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Surr: Tetrachloro-m-xylene	13.869		16.67		83.2	25	115		0	0	
Surr: Decachlorobiphenyl	15.070		16.67		90.4	20	142		0	0	

Sample ID: **105982-073ADUP**	SampType: **DUP**	TestCode: **8081_S**	Units: **µg/Kg**	Prep Date: **6/18/2009**	RunNo: **110053**
Client ID: **Composite TAR1-A,**	Batch ID: **56044**	TestNo: **EPA 8081A**	**EPA 3550B**	Analysis Date: **6/18/2009**	SeqNo: **1728672**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
4,4´-DDD	ND	2.0						0	0	20	
4,4´-DDE	0.766	2.0						0.9112	0	20	
4,4´-DDT	ND	2.0						0	0	20	
Aldrin	ND	1.0						0	0	20	
alpha-BHC	ND	1.0						0	0	20	
alpha-Chlordane	ND	1.0						0	0	20	
beta-BHC	ND	1.0						0	0	20	
Chlordane	ND	8.5						0	0	20	
delta-BHC	ND	1.0						0	0	20	
Dieldrin	ND	2.0						0	0	20	
Endosulfan I	ND	1.0						0	0	20	
Endosulfan II	ND	2.0						0	0	20	
Endosulfan sulfate	ND	2.0						0	0	20	
Endrin	ND	2.0						0	0	20	
Endrin aldehyde	ND	2.0						0	0	20	
Endrin ketone	ND	2.0						0	0	20	
gamma-BHC	ND	1.0						0	0	20	
gamma-Chlordane	ND	1.0						0	0	20	
Heptachlor	ND	1.0						0	0	20	
Heptachlor epoxide	ND	1.0						0	0	20	
Methoxychlor	ND	5.0						0	0	20	
Toxaphene	ND	50						0	0	20	
Surr: Tetrachloro-m-xylene	10.332		16.67		62.0	25	115		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		

CLIENT: Geocon Consultants, Inc.
Work Order: 105982
Project: ANTIOCH BRIDGE RETROFIT, E8435-06-18

ANALYTICAL QC SUMMARY REPORT

TestCode: 8081_S

Sample ID: **105982-073ADUP** SampType: **DUP** TestCode: **8081_S** Units: **µg/Kg** Prep Date: **6/18/2009** RunNo: **110053**
Client ID: **Composite TAR1-A,** Batch ID: **56044** TestNo: **EPA 8081A** **EPA 3550B** Analysis Date: **6/18/2009** SeqNo: **1728672**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Surr: Decachlorobiphenyl	9.909		16.67		59.4	20	142		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		

CLIENT: Geocon Consultants, Inc.
Work Order: 105982
Project: ANTIOCH BRIDGE RETROFIT, E8435-06-18

ANALYTICAL QC SUMMARY REPORT

TestCode: 8081_S

Sample ID: **MB-56045** SampType: **MBLK** TestCode: **8081_S** Units: **µg/Kg** Prep Date: **6/18/2009** RunNo: **110054**
Client ID: **PBS** Batch ID: **56045** TestNo: **EPA 8081A** **EPA 3550B** Analysis Date: **6/18/2009** SeqNo: **1728697**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
4,4´-DDD	ND	2.0									
4,4´-DDE	ND	2.0									
4,4´-DDT	ND	2.0									
Aldrin	ND	1.0									
alpha-BHC	ND	1.0									
alpha-Chlordane	ND	1.0									
beta-BHC	ND	1.0									
Chlordane	ND	8.5									
delta-BHC	ND	1.0									
Dieldrin	ND	2.0									
Endosulfan I	ND	1.0									
Endosulfan II	ND	2.0									
Endosulfan sulfate	ND	2.0									
Endrin	ND	2.0									
Endrin aldehyde	ND	2.0									
Endrin ketone	ND	2.0									
gamma-BHC	ND	1.0									
gamma-Chlordane	ND	1.0									
Heptachlor	ND	1.0									
Heptachlor epoxide	ND	1.0									
Methoxychlor	ND	5.0									
Toxaphene	ND	50									
Surr: Tetrachloro-m-xylene	15.827		16.67		94.9	25	115				
Surr: Decachlorobiphenyl	17.063		16.67		102	20	142				

Sample ID: **LCS-56045** SampType: **LCS** TestCode: **8081_S** Units: **µg/Kg** Prep Date: **6/18/2009** RunNo: **110054**
Client ID: **LCSS** Batch ID: **56045** TestNo: **EPA 8081A** **EPA 3550B** Analysis Date: **6/18/2009** SeqNo: **1728698**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Aldrin	14.894	1.0	16.67	0	89.3	59	113				

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: 105982
Project: ANTIOCH BRIDGE RETROFIT, E8435-06-18

ANALYTICAL QC SUMMARY REPORT

TestCode: 8081_S

Sample ID: **LCS-56045** SampType: **LCS** TestCode: **8081_S** Units: **µg/Kg** Prep Date: **6/18/2009** RunNo: **110054**
Client ID: **LCSS** Batch ID: **56045** TestNo: **EPA 8081A** **EPA 3550B** Analysis Date: **6/18/2009** SeqNo: **1728698**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Dieldrin	15.224	2.0	16.67	0	91.3	59	108				
Endrin	15.278	2.0	16.67	0	91.7	41	132				
gamma-BHC	15.236	1.0	16.67	0	91.4	60	111				
Heptachlor	16.310	1.0	16.67	0	97.8	62	108				
Surr: Tetrachloro-m-xylene	14.049		16.67		84.3	25	115				
Surr: Decachlorobiphenyl	15.370		16.67		92.2	20	142				

Sample ID: **MB-56045MS** SampType: **MS** TestCode: **8081_S** Units: **µg/Kg** Prep Date: **6/18/2009** RunNo: **110054**
Client ID: **ZZZZZZ** Batch ID: **56045** TestNo: **EPA 8081A** **EPA 3550B** Analysis Date: **6/18/2009** SeqNo: **1728699**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
4,4´-DDT	14.994	2.0	16.67	0	89.9	29	143				
Aldrin	14.275	1.0	16.67	0	85.6	44	131				
Dieldrin	14.588	2.0	16.67	0	87.5	40	136				
Endrin	14.620	2.0	16.67	0	87.7	41	146				
gamma-BHC	14.653	1.0	16.67	0	87.9	45	129				
Heptachlor	15.652	1.0	16.67	0	93.9	48	126				
Surr: Tetrachloro-m-xylene	13.503		16.67		81.0	25	115				
Surr: Decachlorobiphenyl	14.363		16.67		86.2	20	142				

Sample ID: **MB-56045MSD** SampType: **MSD** TestCode: **8081_S** Units: **µg/Kg** Prep Date: **6/18/2009** RunNo: **110054**
Client ID: **ZZZZZZ** Batch ID: **56045** TestNo: **EPA 8081A** **EPA 3550B** Analysis Date: **6/18/2009** SeqNo: **1728700**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
4,4´-DDT	15.190	2.0	16.67	0	91.1	29	143	14.99	1.30	20	
Aldrin	14.494	1.0	16.67	0	86.9	44	131	14.28	1.52	20	
Dieldrin	14.801	2.0	16.67	0	88.8	40	136	14.59	1.45	20	
Endrin	14.908	2.0	16.67	0	89.4	41	146	14.62	1.95	20	
gamma-BHC	14.829	1.0	16.67	0	89.0	45	129	14.65	1.19	20	
Heptachlor	15.872	1.0	16.67	0	95.2	48	126	15.65	1.40	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: 105982
Project: ANTIOCH BRIDGE RETROFIT, E8435-06-18

ANALYTICAL QC SUMMARY REPORT

TestCode: 8081_S

Sample ID: **MB-56045MSD** SampType: **MSD** TestCode: **8081_S** Units: **µg/Kg** Prep Date: **6/18/2009** RunNo: **110054**
Client ID: **ZZZZZZ** Batch ID: **56045** TestNo: **EPA 8081A** **EPA 3550B** Analysis Date: **6/18/2009** SeqNo: **1728700**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Surr: Tetrachloro-m-xylene	13.646		16.67		81.9	25	115		0	0	
Surr: Decachlorobiphenyl	14.623		16.67		87.7	20	142		0	0	

Sample ID: **105982-083ADUP** SampType: **DUP** TestCode: **8081_S** Units: **µg/Kg** Prep Date: **6/18/2009** RunNo: **110054**
Client ID: **Composite TCWA3-** Batch ID: **56045** TestNo: **EPA 8081A** **EPA 3550B** Analysis Date: **6/19/2009** SeqNo: **1728702**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
4,4´-DDD	2.468	2.0						2.498	1.23	20	
4,4´-DDE	12.751	2.0						14.09	9.95	20	
4,4´-DDT	22.891	2.0						25.73	11.7	20	
Aldrin	ND	1.0						0	0	20	
alpha-BHC	ND	1.0						0	0	20	
alpha-Chlordane	ND	1.0						0	0	20	
beta-BHC	ND	1.0						0	0	20	
Chlordane	ND	8.5						0	0	20	
delta-BHC	ND	1.0						0	0	20	
Dieldrin	0.515	2.0						0.5877	0	20	
Endosulfan I	ND	1.0						0	0	20	
Endosulfan II	ND	2.0						0	0	20	
Endosulfan sulfate	ND	2.0						0	0	20	
Endrin	ND	2.0						0	0	20	
Endrin aldehyde	ND	2.0						0	0	20	
Endrin ketone	ND	2.0						0	0	20	
gamma-BHC	ND	1.0						0	0	20	
gamma-Chlordane	ND	1.0						0	0	20	
Heptachlor	ND	1.0						0	0	20	
Heptachlor epoxide	ND	1.0						0	0	20	
Methoxychlor	ND	5.0						0	0	20	
Toxaphene	ND	50						0	0	20	
Surr: Tetrachloro-m-xylene	10.166		16.67		61.0	25	115		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		

CLIENT: Geocon Consultants, Inc.
Work Order: 105982
Project: ANTIOCH BRIDGE RETROFIT, E8435-06-18

ANALYTICAL QC SUMMARY REPORT

TestCode: 8081_S

Sample ID: **105982-083ADUP** SampType: **DUP** TestCode: **8081_S** Units: **µg/Kg** Prep Date: **6/18/2009** RunNo: **110054**
Client ID: **Composite TCWA3-** Batch ID: **56045** TestNo: **EPA 8081A** **EPA 3550B** Analysis Date: **6/19/2009** SeqNo: **1728702**

Analyte	Result	PQL	SPK value	SPK Ref Val	%REC	LowLimit	HighLimit	RPD Ref Val	%RPD	RPDLimit	Qual
Surr: Decachlorobiphenyl	10.145		16.67		60.9	20	142		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		

CHAIN OF C TODY RECORD

Advanced Technology Laboratories
3275 Walnut Avenue
Signal Hill, CA 90755
(562) 989-4045 • Fax (562) 989-4040

FOR LABORATORY USE ONLY:

P.O.#: _____

Logged By: _____ Date: 6/17/09

Method of Transport: Client ☐ ATL ☐ CA OverN ☐ FEDEX ☐ Other: GW

Sample Condition Upon Receipt (14.5)
1. CHILLED Y☑ N☐ 4. SEALED Y☐ N☑
2. HEADSPACE (VOA) Y☐ N/A☐ 5. # OF SPLS MATCH COC Y☑ N☐
3. CONTAINER INTACT Y☑ N☐ 6. PRESERVED Y☐ N☑

Client: GEOCON
Attn: D. WATTS
Address: 6671 BRISA ST
City LIVERMORE State CA Zip Code 94550
TEL: (925) 371-5900
FAX: (") " 5915

Project Name: ANTIOCH BRIDGE RETROFIT Project #: E8435-06-18A
Sampler: (Printed Name) C. MERRITT / P. WATTS (Signature)

Relinquished by: (Signature and Printed Name)	Date: 6/16/09	Time: 1630	Received by: (Signature and Printed Name)	Date: 6/16/09	Time: 1630
Relinquished by: (Signature and Printed Name)	Date:	Time:	Received by: (Signature and Printed Name)	Date: 6/17/09	Time: 8:00
Relinquished by: (Signature and Printed Name)	Date:	Time:	Received by: (Signature and Printed Name)	Date:	Time:

I hereby authorize ATL to perform the work indicated below:
Project Mgr./Submitter: P. WATTS 6/16/09 (Print Name / Date)
Signature

Send Report To:
Attn: _____
Co: SEE "CLIENT"
Address _____
City _____ State _____ Zip _____

Bill To:
Attn: _____
Co: _____
Address _____
City _____ State _____ Zip _____

Special Instructions/Comments:
12 COMPOSITES (4-PAINT)
LAB TO COMPOSITE
PLEASE RETURN ALL GEOCON COOLERS

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 : $1.00 / ATL workorder / mo (after 1 year)

Circle or Add Analysis(es) Requested: 8081A (Pesticides) (8081B), 8082 (PCB), 8260B (Volatiles), 8270C (BNA), 6010B (Total Metal), 8015B (GRO) / 8020 (BTEX), 8015B (DRO), 8021 (BTEX), TITLE 22 / CAM 17 (6010 / 7000)

SPECIFY APPROPRIATE MATRIX: SOIL, WATER, GROUND WATER, WASTEWATER

QA/QC: RTNE ☐ CT ☑ SWRCB ☐ Logcode ____ OTHER ____

ITEM	LAB USE ONLY: Batch #: / Lab No.	Sample Description: Sample I.D. / Location	Date	Time	TAT	Container(s): #	Type	PRESERVATION	REMARKS
	105187-001, 2, 3, 4	TAR 1 - A, B, C, D	6/16/09	WATER	48 HR	4	J	C	4-PAINT LAB COMP
	5, 6, 7, 8	2 -							
	9, 10, 11, 12	3 -							
	13, 14, 15, 16	4 -							
	17, 18, 19, 20	5 -							
	21, 22, 23, 24	6 -							
	25, 26, 27, 28	SS 1 -							
	29, 30, 31, 32	SS 2 -							
	33, 34, 35, 36	TCWA1 -							
	37, 38, 39, 40	TCWA2 -							

• TAT starts 8 a.m. following day if samples received after 3 p.m.

TAT: A= Overnight ≤ 24 hr 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=$Na_2S_2O_3$

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FOR LABORATORY USE ONLY:

P.O.#: _____

Logged By: _____ Date: _____

Method of Transport: Client ☐ ATL ☐ CA OverN ☐ FEDEX ☐ Other: _____

Sample Condition Upon Receipt
1. CHILLED 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: Attn: SEE Pg 1

Address: City State Zip Code

TEL: ( ) FAX: ( )

Project Name: SEE Pg 1 Project #: Sampler: (Printed Name) (Signature)

Relinquished by: (Signature and Printed Name)	Date: 6/16/09	Time: 1630	Received by: (Signature and Printed Name) UPS	Date: 6/16/09	Time: 1630
Relinquished by: (Signature and Printed Name)	Date:	Time:	Received by: (Signature and Printed Name) C. Bgmk	Date: 6/17/09	Time: 8:40
Relinquished by: (Signature and Printed Name)	Date:	Time:	Received by: (Signature and Printed Name)	Date:	Time:

I hereby authorize ATL to perform the work indicated below:
Project Mgr /Submitter: SEE Pg 1
Print Name Date
Signature

Send Report To: Attn: Co: Address City State Zip

Bill To: Attn: Co: Address 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.

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- Records : $1.00 / ATL workorder / mo (after 1 year)

Circle or Add Analysis(es) Requested: 8081A (Pesticides) (8082 (PCB)) 8260B (Volatiles) 8270C (BNA) 6010B (Total Metal) 8015B (GRO) / 8020 (BTEX) 8015B (DRO) 8021 (BTEX) TITLE 22 / CAM 17 (6010 / 7000)

SPECIFY APPROPRIATE MATRIX: SOIL WATER GROUND WATER WASTEWATER

PRESERVATION

Q A / Q C: RTNE ☐ CT ☒ SWRCB ☐ Logcode ____ OTHER ____

ITEM	LAB USE ONLY: Batch #: / Lab No.	Sample Description: Sample I.D. / Location	Date	Time	TAT	Container(s): #	Type	REMARKS
	105987-41,42,43,44	TCWA3-A,B,C,D	6/14/09	1112	48hr	4	J G	4-Point Lab Comp
	45,46,47,48	4-						
	49,50,51,52	5-						
	53,54,55,56	6-						
	57,58,59,60	7-						
	61,62,63,64	8-						
	65,66,67,68	9-						
	69,70,71,72	10-						

• TAT starts 8 a.m. following day if samples received after 3 p.m.

TAT: A= Overnight ≤ 24 hr 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=$Na_2S_2O_3$

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State of California
Department of Transportation
Division of Engineering Services
Geotechnical Services

Soil and Rock
Logging, Classification, and Presentation Manual

June 2007

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Preface

Detailed soil and rock descriptions and classifications are an essential part of the information developed to support Caltrans' design and construction processes. Subsurface information for any given area is, and can be, generated and accumulated over a prolonged period of time by various geotechnical practitioners for different projects and purposes. It is imperative that geotechnical practitioners working on Caltrans projects use standardized terminology and procedures to maintain consistency in borehole logging and reporting practices. Geotechnical Services in the Division of Engineering Services, has published this Manual to ensure the Department's investment in maintaining consistent logging practices.

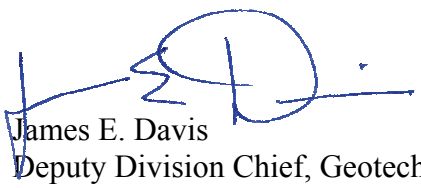
This Manual, "*Soil and Rock Logging, Classification, and Presentation Manual*", improves upon the original version of the manual, "*Soil and Rock Logging Classification Manual (Field Guide)*", published in 1996, by addressing the following:

- Serves as a comprehensive reference for Departmental staff, consultants, and contractors
- Provides standardized soil *description* and *identification* procedures utilizing field data
- Provides standardized soil *classification* procedures utilizing laboratory data
- Provides standardized rock *description* and *identification* procedures utilizing field and laboratory data
- Serves as a basis for Departmental products and tools, such as:
  - Boring Log presentation formats,
  - Log of Test Boring (LOTB) legend sheets,
  - Descriptive terminology presented in geotechnical reports, and
  - Geotechnical Data Management System

The information presented in this Manual is based predominantly on American Standards for Testing Materials (ASTM) and other publications. These references provide standardized methods for identifying, describing, or classifying soil and rock; however, they do not provide adequate descriptive terminology and criteria for identifying soil and rock for engineering purposes. Consequently, this manual extends, and in some cases modifies these standards to include additional descriptive terms and criteria.

In addition to soil and rock identification, description, or classification, this Manual contains instructions that present Departmental standards for borehole and sample identification, minimum material requirements for various laboratory tests, and boring log presentation formats.

Geotechnical Services staff and any other organization providing geotechnical reports or records of geotechnical investigations for the Department shall use the procedures presented in this Manual.



James E. Davis
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(Names have been listed alphabetically.)

Caltrans

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Section 1: Introduction

1.1 Intent of this Manual

The intent of this Manual is to define the Department's practices and procedures for soil and rock description, identification, classification, and preparation of boring logs.

Standardized terminology and consistent presentation procedures for projects statewide benefit the Department's staff, engineering consultants, bidders, and contractors. Geotechnical Services staff as well as any other organization providing geotechnical reports or records of geotechnical investigations to the Department shall follow the procedures presented in this Manual.

The following terms, as defined below, are used throughout this Manual to convey the Department's policy:

Term	Definition
Shall, Required	*Mandatory Standard*. The associated provisions **must** be used. There is no acceptable alternative.
Should	*Advisory Standard*. The associated provisions are preferred practices.
May, Optional	*Permissive Standard.* Use or application of the associated provisions is left to the discretion of the Geoprofessional.

1.2 Limitations

Although this manual may be used to train new employees, this is not its primary intent.

This manual does not replace education or experience and shall be used in conjunction with professional judgment. Not all aspects of this manual may be applicable in all circumstances and should be applied with consideration of a project's many unique aspects.

This manual does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish, or adhere to, appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. The reader shall follow at a minimum, the *Caltrans Code of Safe Drilling Practices*.

1.3 Exceptions to Policy

Exceptions to the policy and procedures set forth in this Manual require prior approval by the Geotechnical Services Deputy Division Chief. Staff shall use the procedure for obtaining approval for an exception, as documented in a memorandum to all staff dated June 15, 2007, included in Appendix C.

1.4 Revisions to the Manual

Staff who wish to propose changes to the Manual shall do so in accordance with the *Soil and Rock Logging, Classification, and Presentation Manual Committee Charter and Standard Procedures,* included in Appendix C.

1.5 Organization of this Manual

The Manual is divided into five sections, as described below:

Section 1

- Explains the intent and organization of this Manual and the process for requesting exceptions and proposing changes to the Manual
- Presents an overview of the logging process and acceptable presentation formats

Section 2

- Presents the Department's field description and indentification procedures for soil and rock, without the benefit of laboratory testing
- Explains procedures for handling and labeling of samples
- Explains how to perform a quality check of borehole logs and soil and rock samples

Section 3

- Describes the Department's classification procedures for soil and rock samples for which the data was refined by appropriate laboratory tests

Section 4

- Presents the process for developing and presenting geotechnical information on a *Log of Test Boring (LOTB)* or a *Boring Record (BR)*.

Section 5

- Specifies presentation content and formats for *Log of Test Boring (LOTB)* and *Boring Record (BR).*

1.6 Overview of the Logging Process and Presentation Formats

The Department uses the following formats to present subsurface information:

- Log of Test Boring (LOTB), and/or
- Boring Record (BR).

An LOTB is typically associated with a structure facility and is attached to Project Plans. A BR is typically associated with an earthwork facility and is attached to a Geotechnical Report.

The process of creating boring logs, i.e., Log of Test Boring (LOTB) and Boring Record (BR) can be summarized in four steps:

- Field sampling and descriptions *(Section 2)*
- Quality check of field descriptions *(Section 2)*
- Refinement of descriptions, and classification of soil, based on laboratory test results, if performed *(Section 3)*
- Preparation of the boring logs *(Sections 4 and 5)*

(See Figure 1-1.)

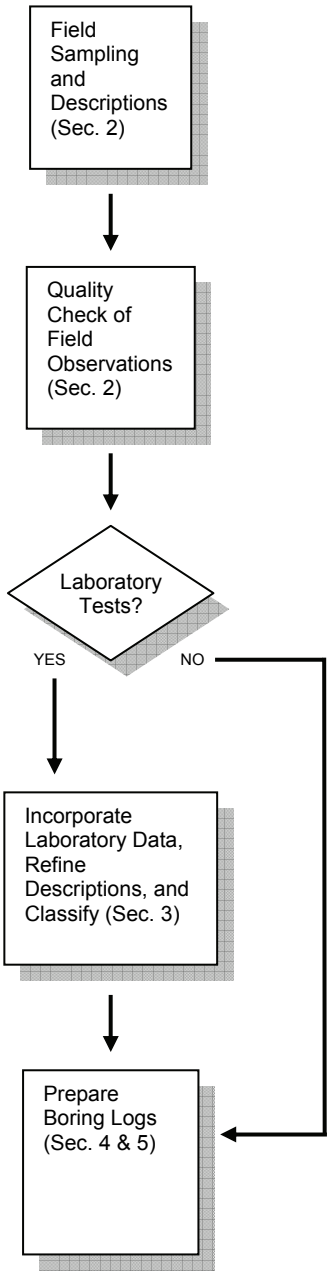
Prior to the field investigation, the geoprofessional should have general understanding of the local soils and geologic information, and know the parameters and the basic descriptors required for the planned analyses. Specific laboratory tests, such as strength, consolidation, or permeability may govern the type of drilling and sampling used.

Recovering and labeling, and accurately describing and classifying samples is a detailed process that typically necessitates a thorough check of field notes and samples in the office before requesting laboratory tests. In some cases, the geoprofessional may use only field observations. *(See Section 2.)*

In other cases, it may be the judgment of the geoprofessional that a combination of field observations and laboratory test results are needed to describe or classify the soil or rock samples, and generate appropriate layer descriptions for LOTB or BR. *(See Sections 2 and 3.)*

If the results of laboratory tests change the description of the sample generated by field observation, the classification and/or description resulting from the laboratory tests shall be used on the LOTB and/or the BR, and in the geotechnical report. Disclosure of the tests on the LOTB and/or the BR makes it clear whether the sample or layer descriptor was based on visual observation or on laboratory test results. *(See Sections 4 and 5.)*

Figure 1-1
Logging and Presentation Process



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Section 2:
Field Procedures for Soil and Rock Logging, Description, and Identification

2.1 Introduction

This section presents the procedures for logging, describing, and identifying soil and rock samples in the field based on visual and manual procedures.

The information presented in this section is predominantly based on:

- American Society for Testing and Materials (ASTM) D 2488-06, *Standard Practice for Description and Identification of Soils (Visual-Manual Procedure)*, and
- The *Engineering Geology Field Manual* published by the Bureau of Reclamation.

Although ASTM D 2488-06 provides a standardized method for indentification of soils, it does not provide adequate descriptive terminology and criteria for identifying soils for engineering purposes. Section 17 of ASTM D 2488-06 states, "*this practice provides qualitative information only,*" and Note 4 adds, "*The ability to describe and identify soils correctly … may also be acquired systematically by comparing numerical laboratory test results for typical soils of each type with their visual and manual characteristics*."

This Manual extends, and in some cases modifies, the ASTM standard to include additional descriptive terms and criteria. It is not our intent to replace the ASTM standards but to build on them, and make them better understood.

The identifications and descriptions in the field logs may be corrected, calibrated, or verified later based on laboratory test results of selected soil samples to develop the final boring logs, as described in Section 3.

The process of correction, calibration, and verification in developing the updated logs based on laboratory test results can effectively serve the purpose of self-training and self-calibration for future field identification and description of soil samples.

In addition to soil and rock identification and description, this section contains instructions that describe proper hole and sample identification practices, and minimum material requirements for various laboratory tests.

2.2 General Project and Hole Information

One of the most important aspects of field work is properly identifying the location of the project site, drilling tools and methods used, and the personnel involved in the field work. Figure 2-1 presents the information that is required to be recorded for every hole.

Figure 2-1
Information Required for Borehole

Item	Description
1	**Date(s) of work**
2	**Hole Identification**
3	**Project and Site Information:** • Project Name • Structure/Bridge Name and Number (if available) • Project Number (Charge District - Expenditure Authorization, 8-digits) • District • County • Route • Postmile, range and prefix

4	**Borehole Location and Elevation:**
	• Location (at least one of the following):
	  ○ Station and offset
	  ○ Latitude and longitude, horizontal datum
	  ○ Northing and Easting, local coordinate reference system
	  Note: In the absence of accurate coordinate data, a suitable and verifiable field description may be temporarily used. (e.g., postmile and centerline offset, distance to fixed object or benchmark, etc.)
	• Elevation, vertical datum, benchmark description
	• Survey method(s) used, approximate accuracy

5	**Personnel:** • Logger/Geoprofessional • Drillers

6	**Drilling and Sampling Equipment (verify with Driller):**
	• Drill rig (manufacturer and model, and Caltrans Equipment Identification number)
	• Drilling method (mud rotary, air rotary, solid auger, hollow stem auger. etc.)
	• Drill rod description (type, diameter)
	• Drill bit description
	• Casing (type, diameter) and installation depth
	• SPT Hammer Type: Safety/Automatic Hammer, etc.
	  ○ Lifting mechanism (for safety hammer)
	  ○ Manufacturer & model
	  ○ Caltrans Equipment Identification number
	  ○ Measured SPT energy efficiency ratio (if available)
	• Type of sampler(s) and size(s)
	  ○ Undisturbed Shelby tube
	  ○ Undisturbed Piston
	  ○ Split spoon (e.g. SPT, Cal Mod, etc.)
	  ○ Core (both rock and soil)
	  ○ Disturbed (include auger cuttings)
	  ○ Other

7	**Groundwater** • Method (observed while drilling, measured in hole, etc.) • Date, time, and depth of each reading
8	**Hole Completion** • Cause of termination (e.g., drilled to depth, refusal, early termination of traffic control, etc.) • Abandonment (e.g., grout, soil cuttings, dry bentonite chips, piezometers installed, slope inclinometer installed, TDR, instrumentation, etc.)

2.3 Assignment of Hole Identification

Holes shall be identified using the following convention:

HHH – YY – NNN

Where:

HHH: The Hole Type or Sounding Codes defined in Figure 2-2, which generally follow ASTM D 6453-99

YY: 2-digit year

NNN: 3-digit number (001-199)

The numbers 001–099 are reserved for holes used to produce a foundation report; numbers 101–199 are reserved for holes used to produce a geotechnical design report.

The *YY-NNN* component of the hole identification is unique and matched to a Caltrans project expenditure authorization number (EA), not to a site, structure, or bridge number. If two drilling methods are used, such as auger boring followed by rotary drilled boring, the prominent tool governs the selection of Hole Type Code (HHH).

Figure 2-2
Hole Type Code and Description

Hole Type Code	Description
A	Auger boring (hollow or solid stem, bucket)
R	Rotary drilled boring (both conventional and wire-line)
P	Rotary percussion boring (Air)
HD	Hand driven (1-inch soil tube)
HA	Hand auger
D	Driven (dynamic cone penetrometer)
CPT	Cone Penetration Test
O	Other

2.4 Soil Description and Identification Procedures

This section presents the method for identification and description of soil based on ASTM D 2488-06 and USBR (2001). The detail of description provided for a particular soil should be dictated by the complexity and objectives of the project. Optional descriptors should be considered by the geoprofessional on a project by project basis.

2.4.1 Soil Description and Identification

When describing and identifying soil in the field, the geoprofessional shall record the field data following the sequence presented in Figure 2-3 below. Items marked "required" shall be used, when applicable, to describe the soil sample to ensure complete descriptive coverage. For example, percent cobbles and/or boulders is only required if cobbles and/or boulders are encountered.

Figure 2-3
Identification and Description Sequence

Sequence	Identification Components	Refer to Section	Required	Optional
1	Group Name	2.4.2	●	
2	Group Symbol	2.4.2	●	
	Description Components			
3	Consistency (for cohesive soils)	2.4.3	●	
4	Apparent Density (for cohesionless soils)	2.4.4	●	
5	Color (in moist condition)	2.4.5	●	
6	Moisture	2.4.6	●	
7	Percent of cobbles or boulders	2.4.7	●	
8	Percent or proportion of soils	2.4.8	●	
9	Particle Size Range	2.4.9	●	
10	Particle Angularity	2.4.10		O
11	Particle Shape	2.4.11		O
12	Plasticity (for fine-grained soils)	2.4.12	●	
13	Dry Strength (for fine-grained soils)	2.4.13		O
14	Dilatency (for fine-grained soils)	2.4.14		O
15	Toughness (for fine-grained soils)	2.4.15		O
16	Structure	2.4.16		O
17	Cementation	2.4.17	●	
18	Description of Cobbles and Boulders	2.4.18	●	
19	Additional Comments	2.4.19		O

Below are some examples that illustrate the application of the descriptive sequence based on field procedures.

Example of a complete descriptive sequence for a sample using required and optional components:

> *Well-graded SAND with GRAVEL (SW), medium dense, brown to light gray, wet, about 20% coarse subrounded to rounded flat and elongated GRAVEL, about 75% coarse to fine rounded SAND, about 5% fines, weak cementation.*

Example of a complete descriptive sequence for a soil sample using only required components:

> *Well-graded SAND with GRAVEL (SW), medium dense, brown to light gray, wet, little coarse GRAVEL, mostly coarse to fine SAND, few fines, weak cementation.*

Example of a complete descriptive sequence that omits the percent or proportion of the primary soil constituent, which may be used when the percentage or proportion of the primary soil constituent can be clearly inferred:

> *Well-graded SAND with GRAVEL (SW), medium dense, brown to light gray, wet, little coarse GRAVEL, few fines, weak cementation.*

2.4.1.1 Soil Description for Intensely Weathered or Decomposed Rock

Intensely weathered or decomposed rock that is friable and that can be reduced to gravel size or smaller by normal hand pressure shall be identified and described as rock followed by the soil identification or classification, and description in parenthesis (per Section 2.5).

2.4.2 Group Name and Group Symbol

Using visual examination and simple manual tests, this section provides standardized criteria and procedures for describing and identifying soil in the field per ASTM D 2488-06. The soil is to be identified by assigning a group name and symbol. The Figures in this section are to be used for the identification of both fine and coarse-grained soil and to determine the appropriate group symbol(s) and name(s) to be used.

The ASTM procedure for identifying and describing fine-grained and coarse-grained soils is only applicable to material passing the 3-inch sieve. If the presence of cobbles or boulders or both is identified during the site exploration, the percentage of cobbles and boulders shall be estimated and reported per Section 2.4.7.

Borderline Symbol – Because ASTM D 2488-06 is based on estimates of particle size distribution and plasticity characteristics, it may be difficult to clearly identify the soil as belonging to one category. To indicate that the soil may fall into one of two possible basic groups, a borderline symbol shall be used with the two symbols separated by a slash. For example: SC/CL or CL/CH.

A borderline symbol shall be used when:

- The percentage of fines is estimated to be between 45 and 55%. One symbol shall be for a coarse-grained soil with fines; the other for a fine-grained soil, e.g., GM/ML or CL/SC.
- The percentage of sand and the percentage of gravel are estimated to be about the same, e.g., GP/SP, SC/GC, GM/SM.
- The soil could be well graded or poorly graded, e.g., GW/GP, SW/SP.
- The soil could either be a silt or a clay, e.g., CL/ML, CH/MH, SC/SM.
- A fine-grained soil has properties that indicate that it is at the boundary between a soil of low plasticity and a soil of high plasticity, e.g., CL/CH, MH/ML.

The order of the borderline symbols shall reflect similarity to surrounding or adjacent soils. For example, soils in a borrow area have been identified as CH, and one sample is considered to have a borderline symbol of CL and CH. To show similarity, the borderline symbol shall be CH/CL.

The group name for a soil with a borderline symbol shall be the group name for the first symbol, except for:

- CL/CH lean to fat clay,
- ML/CL clayey silt, and
- CL/ML silty clay

Borderline symbols should not be used indiscriminately. Use of a single group symbol is preferable.

Dual Symbol – A dual symbol is two symbols separated by a hyphen, e.g., GP-GM, SW-SC, CL-ML. They are used to indicate that the soil has been identified as having the properties of a classification in accordance with ASTM Test Method D 2487-06 requiring dual symbols, i.e., when the soil has between 5 and 12% fines, or when the liquid limit and plasticity index values plot in the CL-ML area of the plasticity chart.

2.4.2.1 Fine Grained Soils

A soil is considered to be fine-grained if it contains 50% or more fines. Particles that pass through a Number 200 sieve are defined as fine-grained. Fine-grained soils shall be assigned the Group Name and Symbol according to Figure 2-4, below.

Figure 2-4

Flow chart for fine-grained soils *(from ASTM D 2488-06)*

Group Symbol	Fines	Coarseness	Sand or Gravel	Group Name
CL	<30% plus No.200	<15% plus No.200		Lean CLAY
		15-25% plus No.200	% sand ≥ % gravel	Lean CLAY with SAND
			% sand < % gravel	Lean CLAY with GRAVEL
	≥30% plus No.200	% sand ≥ % gravel	< 15% gravel	SANDY lean CLAY
			≥ 15% gravel	SANDY lean CLAY with GRAVEL
		% sand < % gravel	< 15% sand	GRAVELLY lean CLAY
			≥ 15% sand	GRAVELLY lean CLAY with SAND
ML	<30% plus No.200	<15% plus No.200		SILT
		15-25% plus No.200	% sand ≥ % gravel	SILT with SAND
			% sand < % gravel	SILT with GRAVEL
	≥30% plus No.200	% sand ≥ % gravel	< 15% gravel	SANDY SILT
			≥ 15% gravel	SANDY SILT with GRAVEL
		% sand < % gravel	< 15% sand	GRAVELLY SILT
			≥ 15% sand	GRAVELLY SILT with SAND
CH	<30% plus No.200	<15% plus No.200		Fat CLAY
		15-25% plus No.200	% sand ≥ % gravel	Fat CLAY with SAND
			% sand < % gravel	Fat CLAY with GRAVEL
	≥30% plus No.200	% sand ≥ % gravel	< 15% gravel	SANDY fat CLAY
			≥ 15% gravel	SANDY fat CLAY with GRAVEL
		% sand < % gravel	< 15% sand	GRAVELLY fat CLAY
			≥ 15% sand	GRAVELLY fat CLAY with SAND
MH	<30% plus No.200	<15% plus No.200		Elastic SILT
		15-25% plus No.200	% sand ≥ % gravel	Elastic SILT with SAND
			% sand < % gravel	Elastic SILT with GRAVEL
	≥30% plus No.200	% sand ≥ % gravel	< 15% gravel	SANDY elastic SILT
			≥ 15% gravel	SANDY elastic SILT with GRAVEL
		% sand < % gravel	< 15% sand	GRAVELLY elastic SILT
			≥ 15% sand	GRAVELLY elastic SILT with SAND
OL/ OH	<30% plus No.200	<15% plus No.200		ORGANIC SOIL
		15-25% plus No.200	% sand ≥ % gravel	ORGANIC SOIL with SAND
			% sand < % gravel	ORGANIC SOIL with GRAVEL
	≥30% plus No.200	% sand ≥ % gravel	< 15% gravel	SANDY ORGANIC SOIL
			≥ 15% gravel	SANDY ORGANIC SOIL with GRAVEL
		% sand < % gravel	< 15% sand	GRAVELLY ORGANIC SOIL
			≥ 15% sand	GRAVELLY ORGANIC SOIL with SAND

Clay and Silt – Identify the soil as a Lean CLAY (CL), a Fat CLAY (CH), a SILT (ML), or an Elastic SILT (MH), using the criteria in Figure 2-5:

Figure 2-5
Identification of clayey and silty soils

Group Symbol	Dry Strength	Dilatancy	Toughness
ML	None to low	Slow to rapid	Low or thread cannot be formed
CL	Medium to high	None to slow	Medium
MH	Low to medium	None to slow	Low to medium
CH	High to very high	None	High

Organic Soil – Identify the soil as organic, OL/OH, if the soil contains enough organic particles to influence the soil properties. Organic soils usually have a dark brown to black color and may have an organic odor. Often, organic soils will change color, for example, black to brown, when exposed to the air. Some organic soils will lighten in color significantly when air-dried. Organic soils normally will not have a high toughness or plasticity. The thread for the toughness test will be spongy.

Identification of Peat – A sample composed primarily of vegetable tissue in various stages of decomposition that has a fibrous to amorphous texture, usually a dark brown to black color, and an organic odor, shall be designated as a highly organic soil and shall be identified with the Group Name and Symbol, PEAT (PT), and not subjected to the identification procedures described hereafter.

2.4.2.2 Coarse-Grained Soil

A soil is considered coarse-grained if it contains fewer than 50% fines. (Coarse-grain particles will not pass through a Number 200 sieve.) Soil is identified as gravel if the percentage of gravel is estimated to be greater than the percentage of sand. Soil is identified as sand if the percentage of gravel is estimated to be equal to or less than the percentage of sand.

Figure 2-7
Flow chart for coarse-grained soils *(from ASTM D-2488-06)*

	Fines	Grade	Type of Fines	Group Symbol	Sand/Gravel	Group Name
Gravel	≤ 5%	Well		GW	< 15% sand	Well-graded GRAVEL
					≥ 15% sand	Well-graded GRAVEL with SAND
		Poorly		GP	< 15% sand	Poorly graded GRAVEL
					≥ 15% sand	Poorly graded GRAVEL with SAND
	10%	Well	ML or MH	GW-GM	< 15% sand	Well-graded GRAVEL with SILT
					≥ 15% sand	Well-graded GRAVEL with SILT and SAND
			CL or CH	GW-GC	< 15% sand	Well-graded GRAVEL with CLAY
					≥ 15% sand	Well-graded GRAVEL with CLAY and SAND
		Poorly	ML or MH	GP-GM	< 15% sand	Poorly graded GRAVEL with SILT
					≥ 15% sand	Poorly graded GRAVEL with SILT and SAND
			CL or CH	GP-GC	< 15% sand	Poorly graded GRAVEL with CLAY
					≥ 15% sand	Poorly graded GRAVEL with CLAY and SAND
	≥ 15%		ML or MH	GM	< 15% sand	SILTY GRAVEL
					≥ 15% sand	SILTY GRAVEL with SAND
			CL or CH	GC	< 15% sand	CLAYEY GRAVEL
					≥ 15% sand	CLAYEY GRAVEL with SAND
Sand	≤ 5%	Well		SW	< 15% gravel	Well-graded SAND
					≥ 15% gravel	Well-graded SAND with GRAVEL
		Poorly		SP	< 15% gravel	Poorly graded SAND
					≥ 15% gravel	Poorly graded SAND with GRAVEL
	10%	Well	ML or MH	SW-SM	< 15% gravel	Well-graded SAND with SILT
					≥ 15% gravel	Well-graded SAND with SILT and GRAVEL
			CL or CH	SW-SC	< 15% gravel	Well-graded SAND with CLAY
					≥ 15% gravel	Well-graded SAND with CLAY and GRAVEL
		Poorly	ML or MH	SP-SM	< 15% gravel	Poorly graded SAND with SILT
					≥ 15% gravel	Poorly graded SAND with SILT and GRAVEL
			CL or CH	SP-SC	< 15% gravel	Poorly graded SAND with CLAY
					≥ 15% gravel	Poorly graded SAND with CLAY and GRAVEL
	≥ 15%		ML or MH	SM	< 15% gravel	SILTY SAND
					≥ 15% gravel	SILTY SAND with GRAVEL
			CL or CH	SC	< 15% gravel	CLAYEY SAND
					≥ 15% gravel	CLAYEY SAND with GRAVEL

2.4.3 Consistency (Cohesive Soils)

The preferred procedure for the determination of consistency of cohesive soils is to obtain relatively undisturbed samples and perform field tests with a pocket penetrometer or torvane. *(See Appendix A for details on the test procedures.)*

Use the terms and criteria indicated in Figure 2-8 below to describe the consistency of cohesive soils. These terms generally follow, with some modifications, AASHTO (1988) and Bureau of Reclamation (2001) standards.

Figure 2-8

Descriptors for Consistency of Cohesive Soils

Description	Pocket Penetrometer Measurement (tsf)	Torvane Measurement (tsf)	Field Approximation
Very Soft	< 0.25	< 0.12	Easily penetrated several inches by fist
Soft	0.25 to 0.50	0.12 to 0.25	Easily penetrated several inches by thumb
Medium Stiff	0.50 to 1.0	0.25 to 0.50	Can be penetrated several inches by thumb with moderate effort
Stiff	1 to 2	0.50 to 1.0	Readily indented by thumb but penetrated only with great effort
Very Stiff	2 to 4	1.0 to 2.0	Readily indented by thumbnail
Hard	> 4.0	> 2.0	Indented by thumbnail with difficulty

2.4.4 Apparent Density (Cohesionless Soils)

Use the AASHTO (1988) standards to describe the apparent density of cohesionless soils, as indicated in Figure 2-9 below.

Figure 2-9
Descriptors for Apparent Density of Cohesionless Soils

Description	SPT N_{60} (blows/ft)
Very loose	0 – 4
Loose	5 – 10
Medium dense	11 – 30
Dense	31 – 50
Very dense	>50

Apparent density of a coarse-grained (cohesionless) soil is based on a corrected Standard Penetration Test (SPT) N_{60} value as described in Appendix A and provided here:

$$N_{60} = N_{measured}\, X\, (ER_i / 60)$$

where,

$$ER_i = Hammer\ energy\ ratio$$

N values are highly dependent on the energy efficiency of the SPT method. Inconsistency in the N values across a site may be attributed to variations in energy efficiency between different drill rigs and crews.

2.4.5 Color

Color is an important property in identifying organic soils, and it may also be useful in identifying materials of similar geologic origin within a given locality. Use the color name from the *Munsell Color System* to describe the color of a moist soil sample at the time of drilling and sampling. If the sample contains layers or patches of varying colors, record this information and describe all observed colors. For example:

Brown to light yellowish brown

For additional information, see ASTM D 1535-06, *Standard Practice for Specifying Color by the Munsell System*.

2.4.6 Moisture

Use the ASTM D 2488-06 standard to describe the moisture condition, as indicated in Figure 2-10 below.

Figure 2-10
Descriptors for Moisture

Description	Criteria
Dry	Absence of moisture, dusty, dry to the touch
Moist	Damp but no visible water
Wet	Visible free water, usually soil is below water table

2.4.7 Percent of Cobbles or Boulders

When particles greater than 3 inches in diameter are encountered, they shall be identified and described as "COBBLES," or "BOULDERS," or "COBBLES and BOULDERS" as defined in Section 2.4.9. Cobbles and boulders reported as present within a matrix shall be estimated, by volume, and reported by percentage of total volume.

Estimation of volume of cobbles and/or boulders is based upon recovered intersected lengths, drilling chatter, and observations and experience of the driller and/or geoprofessional.

A subset of rock descriptors shall be used to describe cobbles and boulders as explained in Section 2.4.18. Isolated boulders may be treated as individual units and described as such.

For example, if it is estimated that 40% by volume of the material is cobbles, describe the sample in this way:

> *Well-graded SAND with GRAVEL and COBBLES (SW), medium dense, brown to light gray, wet, about 40% COBBLES, about 20% coarse subrounded to rounded flat and elongated GRAVEL, about 75% coarse to fine rounded SAND, about 5% fines, weak cementation; COBBLES consist of sandstone, fresh, hard, intersecting lengths from 8 to 10 inches.*

Note, the percentages of constituents in the example do not add up to 100%., as cobbles are estimated by total volume, whereas gravel, sand,

and fines, are estimated by weight of the total sample excluding the cobbles and boulders, per Section 2.4.8

If the sample or layer is estimated to be more than 50% cobbles and/or boulders by volume, the layer shall be described as "COBBLES" or "BOULDERS" or "COBBLES and BOULDERS" with the soil matrix description following. Note, this is a departure from the descriptive sequence in Section 2.4.1. For example, if it is estimated that 60% by volume of the material was cobbles, describe the layer as:

> *COBBLES with some well-graded SAND with GRAVEL, about 60% COBBLES (sandstone, fresh, hard, intersecting lengths from 8 to 10 inches), matrix consists of medium dense, brown to light gray, wet, about 20% coarse subrounded to rounded flat and elongated GRAVEL, about 75% coarse to fine rounded SAND, about 5% fines, weak cementation.*

Note that the Group Symbol is not used in the last example, because the cobbles and boulders were the predominant material.

2.4.8 Percent or Proportion of Soils

Use the ASTM D 2488-06 standard to describe the estimated percentage (to the nearest 5%) or proportion of gravel, sand, and fines, by weight of the total sample excluding the cobbles and boulders, as shown in Figure 2-11, below.

Figure 2-11
Descriptors for percent or proportion of soils

Description	Criteria
Trace	Particles are present but estimated to be less than 5%
Few	5 to 10%
Little	15 to 25%
Some	30 to 45%
Mostly	50 to 100%

The percentages of gravel, sand, and fines must add up to 100 %. The term "about" shall be used if the percentage or proportion of constituents is estimated in the field. (The word "about" shall be removed if the percentage was revised based on laboratory particle size analysis results.)

2.4.9 Particle Size

Use the ASTM D 2488-06 standard to describe the size of particles, as shown in Figure 2-12, below.

Figure 2-12
Descriptors for Particle Size

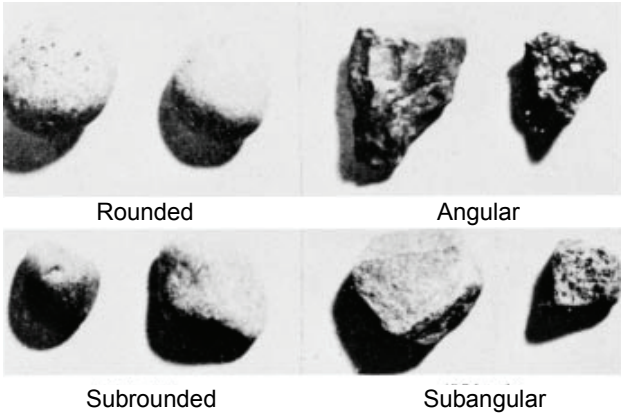
Description	Size	Familiar Example
Boulder	>12 in.	Larger than a basketball
Cobble	3 to 12 in.	Larger than a grapefruit or orange
Coarse Gravel	3/4 to 3 in.	Larger than a walnut or grape
Fine Gravel	No. 4 to 3/4 in.	Larger than a pea
Coarse Sand	No. 10 to No. 4	Larger than rock salt grain
Medium Sand	No. 40 to No. 10	Larger than openings of a window screen
Fine Sand	No. 200 to No. 40	Larger than a sugar grain

2.4.10 Particle Angularity

Use the ASTM D 2488-06 standard to describe the angularity of the sand (coarse sizes only), gravel, cobbles, and boulders, as indicated in Figure 2-13 below.

Figure 2-13
Descriptors for particle angularity

Description	Criteria
Angular	Particles have sharp edges and relatively plane sides with unpolished surfaces
Subangular	Particles are similar to angular description, but have rounded edges
Subrounded	Particles have nearly plane sides, but have well-rounded corners and edges
Rounded	Particles have smoothly curved sides and no edges



2.4.11 Particle Shape

Use the ASTM D 2488-06 standard to describe the shape of the gravel, cobbles, and boulders *if* they meet any of the criteria in Figure 2-14.

The particle shape shall be described as follows where length, width, and thickness refer to the greatest, intermediate, and least dimensions of a particle, respectively.

Figure 2-14
Descriptors for Particle Shape

Description	Criteria
Flat	Particles with width/thickness > 3
Elongated	Particles with length/width > 3
Flat and Elongated	Particles meet criteria for both flat and elongated

2.4.12 Plasticity (for Fine-Grained Soils)

Use the ASTM D 2488-06 standard to describe the plasticity of the material based on observations made during the toughness test, as indicated in Figure 2-15 below.

Figure 2-15
Descriptors for Plasticity

Description	Criteria
Nonplastic	A 1⁄8-in. thread cannot be rolled at any water content.
Low	The thread can barely be rolled and the lump cannot be formed when drier than the plastic limit.
Medium	The thread is easy to roll and not much time is required to reach the plastic limit. The thread cannot be rerolled after reaching the plastic limit. The lump crumbles when drier than the plastic limit.
High	It takes considerable time rolling and kneading to reach the plastic limit. The thread can be rerolled several times after reaching the plastic limit. The lump can be formed without crumbling when drier than the plastic limit.

2.4.13 Dry Strength (for Fine-Grained Soils)

Use the ASTM D 2488-06 standard to determine dry strength, as indicated in Figure 2-16 below. *(See Appendix A for details on field test procedures.)*

Figure 2-16
Descriptors for Dry Strength

Description	Criteria
None	The dry specimen crumbles into powder with mere pressure of handling.
Low	The dry specimen crumbles into powder with some finger pressure.
Medium	The dry specimen breaks into pieces or crumbles with considerable finger pressure
High	The dry specimen cannot be broken with finger pressure. Specimen will break into pieces between thumb and a hard surface.
Very High	The dry specimen cannot be broken between the thumb and a hard surface.

2.4.14 Dilatancy (for Fine-Grained Soils)

Use the ASTM D 2488-06 standard to determine dilatancy, as indicated in Figure 2-17 below. *(See Appendix A for details on field test procedures.)*

Figure 2-17
Descriptors for dilatancy

Description	Criteria
None	No visible change in the specimen
Slow	Water appears slowly on the surface of the specimen during shaking and does not disappear or disappears slowly upon squeezing
Rapid	Water appears quickly on the surface of the specimen during shaking and disappears quickly upon squeezing

2.4.15 Toughness (for Fine-Grained Soils)

Use the ASTM D 2488-06 standard to determine toughness, as indicated in Figure 2-18 below. *(See Appendix A for details on field test procedures.)*

Figure 2-18
Descriptors for toughness

Description	Criteria
Low	Only slight pressure is required to roll the thread near the plastic limit. The thread and the lump are weak and soft.
Medium	Medium pressure is required to roll the thread to near the plastic limit. The thread and the lump have medium stiffness.
High	Considerable pressure is required to roll the thread to near the plastic limit. The thread and the lump have very high stiffness

2.4.16 Structure

Use the ASTM D 2488-06 standard to describe the structure of intact soils, as indicated in Figure 2-19 below.

Figure 2-19
Descriptors for structure

Description	Criteria
Stratified	Alternating layers of varying material or color with layers at least ¼ in. thick; note thickness.
Laminated	Alternating layers of varying material or color with the layers less than ¼ in. thick; note thickness.
Fissured	Breaks along definite planes of fracture with little resistance to fracturing.
Slickensided	Fracture planes appear polished or glossy, sometimes striated.
Blocky	Cohesive soil that can be broken down into small angular lumps which resist further breakdown.
Lensed	Inclusion of small pockets of different soils, such as small lenses of sand scattered through a mass of clay; note thickness.
Homogeneous	Same color and appearance throughout.

2.4.17 Cementation

Use the ASTM D 2488-06 standard to describe the cementation of intact coarse-grained soils, as indicated in Figure 2-20 below.

Figure 2-20
Descriptors for cementation

Description	Criteria
Weak	Crumbles or breaks with handling or little finger pressure.
Moderate	Crumbles or breaks with considerable finger pressure.
Strong	Will not crumble or break with finger pressure.

2.4.18 Description of Cobbles and Boulders

Use the descriptive sequence for rock in Section 2.5. of this Manual to describe cobbles and boulders. The description shall include, at minimum, the following information:

- Rock identification
- Weathering
- Rock hardness
- Range of intersected lengths of core (An "intersected length" is the length of the intact core. This is not necessarily the size of the cobble or boulder.)

2.4.19 Additional Comments

Additional constituents and soil characteristics not included in the previous categories may be noted. Observations may include:

- Presence of roots or root holes
- Presence of mica, gypsum, etc.
- Presence of voids
- Surface coatings on coarse-grained particles
- Oxide staining
- Cementing agents (e.g. calcium carbonate – see Appendix A.7)
- Odor
- Depositional history (i.e. Alluvium, Colluvium, Aeolian, Lacustrine, Fill)
- Geologic formation name or soil survey unit name

All soils shall be examined to see if they contain materials indicative of man-made fills. Man-made fill items shall be listed in each of the soil descriptions. Common fill indicators include glass, brick, clay pipe, dimensioned lumber, concrete debris, in-place pavement sections, asphalt debris, metal, plastics, plaster, etc. Other items that may suggest fill include buried vegetation mats, tree limbs, stumps, etc.

The size and distribution of fill indicators shall be noted. The limits (depth range) of fill material shall be determined and identified at each exploration location.

2.4.20 Other Drilling Observations

Other observations, not included in the descriptive sequence, may include:

- Caving or sloughing of borehole or trench sides
- Difficulty in drilling or excavating, etc.
- Generic name (e.g., hard pan, fault gouge, etc.)
- Ground water inflow, elevation(s), and estimated rate(s)
- Loss of drill fluid circulation

2.5 Rock Identification Procedures for Borehole Cores

Rock identification procedures presented in this section are based on a hybrid of the International Society of Rock Mechanics (ISRM) (1981) standards and the Bureau of Reclamation (2001) standards. The detail of description provided for a particular material shall be dictated by the complexity and objectives of the project. Optional descriptors should be considered by the geoprofessional on a project by project basis.

Intensely weathered or decomposed rock that is friable and that can be reduced to gravel size or smaller by normal hand pressure shall also be classified as a soil. The material shall be identified and described as rock followed by the soil identification or classification, and description in parenthesis.

For example:

> *IGNEOUS ROCK (GRANITE), massive, light gray to light yellowish brown, intensely weathered, soft, unfractured, (Lean CLAY with SAND (CL), medium stiff, moist, mostly clay, little coarse SAND, medium plasticity).*

Note, color is not repeated in the descriptive sequence for soil.

Although not included in the descriptive sequence, Core Recovery (REC) and Rock Quality Designation (RQD) shall be recorded and presented on the boring logs. Core Recovery shall be reported for all rock coring operations as described in Appendix A.9. RQD shall be recorded and presented on the boring logs in accordance with Appendix A.10.

2.5.1 Rock Identification and Descriptive Sequence for Borehole Cores

Use the descriptors and the descriptive sequence, shown in Figure 2-21, when identifying rock specimens collected from exploratory boreholes.

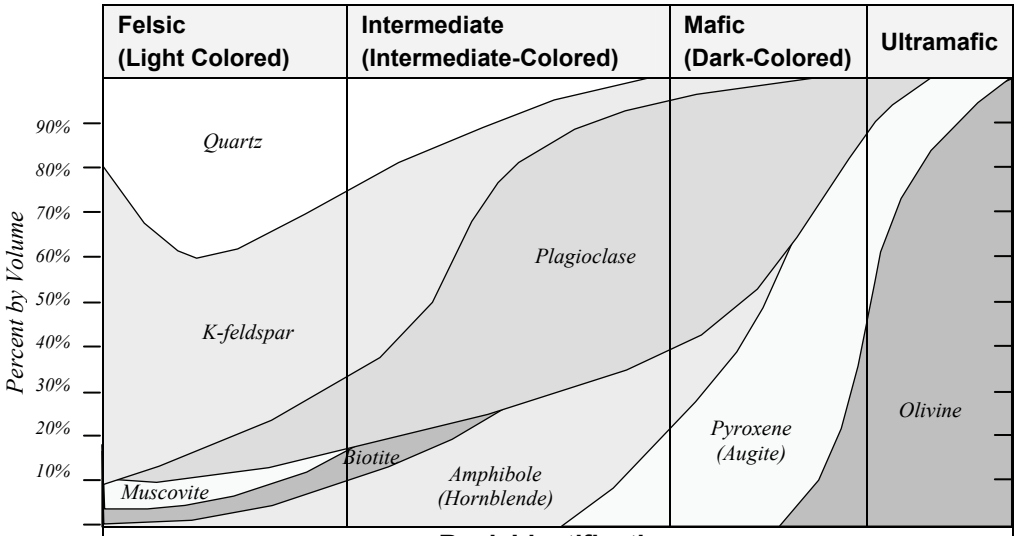
Figure 2-21
Rock Identification and Descriptive Sequence

Sequence	Identification Components	Refer to Section	Required	Optional
1	Rock Name	2.5.2	●	
	Description Components			
2	Rock Grain-size	2.5.3		O
3	Bedding Spacing	2.5.4	●	
4	Color	2.5.5	●	
5	Texture	2.5.6		O
6	Weathering Descriptors for Intact Rock	2.5.7	●	
7	Rock Hardness	2.5.8	●	
8	Fracture Density	2.5.9	●	
9	Discontinuity Type	2.5.10		O
10	Discontinuity Condition (Weathering, Infilling and Healing)	2.5.11		O
11	Discontinuity Dip Magnitude	2.5.12		O
12	Rate of Slaking (Jar Slake Test)	2.5.13		O
13	Odor	2.5.14		O
14	Additional Comments	2.5.15		O

2.5.2 Rock Name

Rock name based on field identification in this section is taken from those presented by Zumberge et al. (2003). As a general practice, a staff geologist should be consulted if there are questions of the correct lithology. Rock name shall be reported using a combination of the *family name* (e.g. sedimentary, igneous, metamorphic), followed by the *rock identification*. The identification can be approximated using Figures 2-22, 2-23, or 2-24, or specifically identified by a qualified geologist.

Figure 2-22
Field identification of Igneous rock



Texture	Rock Identification			
Phaneritic	Granite	Diorite	Gabbro	Peridotite
Phaneritic with Phenocrysts	Granite Porphyry	Diorite Porphyry	Gabbro Porphyry	Peridotite Porphyry
Aphanitic	Rhyolite	Andesite	Basalt	
Aphanitic with Phenocrysts	Rhyolite Porphyry	Andesite Porphyry	Basalt Porphyry	
Vesicular	Pumice, Scoria			
Glassy	Obsidian			
Non-vesicular	Agglomerate, Breccia, Tuff			

Figure 2-23
Field identification of Sedimentary rock

Origin	Textural Features and Particle Size	Composition	Diagnostic Features	Color	Rock Identification
Inorganic Detrital Materials	Clastic (Boulders, Gravels, Pebbles and granules embedded in a matrix of cemented sand grains	Angular rock or mineral fragments			Sedimentary Breccia
		Rounded rock or mineral fragments			Conglomerate
	Clastic (Coarse sand and granules)	angular fragments of feldspar mixed with quartz and other mineral grains	K-feldspar common		Arkose
	Clastic (Sand size particles)	Rounded to subrounded quartz grains		white, buff, pink, brown, tan	Quartz Sandstone
		Calcite and/or dolomite grains	effervesces freely with cold dilute HCl	light-colored	Calcarenite
	Clastic (Sand size particles mixed with clay size particles)	Quartz and other mineral grains mixed with clay		dark gray to gray-green	Wacke (Lithic Arenite)
	Clastic (Silt and clay size particles)	Mineral constituents may be identifiable with a hand lens	usually well stratified	varies	Siltstone
		Mineral constituents not identifiable	fissile, may be scratched with fingernail, usually well stratified	varies	Shale
		Mineral constituents not identifiable	massive (earthy), may be scratched with a fingernail	varies	Claystone
Inorganic Chemical Precipitates	Dense (Crystalline or Oolitic)	Calcium Carbonate	effervesces freely with cold dilute HCl, may contain fossils, generally lacks stratification	white, gray, black	Limestone
	Dense or Crystalline	Calcium Magnesium Carbonate	powder effervesces weakly with cold dilute HCl, may contain fossils, generally lacks stratification	varies, but similar to Limestone	Dolomite
	Dense (Porous)	Silica	conchoidal fracture, scratches glass	black, white, gray, red	Chert
	Dense (Amorphous)	Hydrous Calcium Sulfate	commonly can be scratched with a fingernail	varies, commonly pink, buff, white	Rock Gypsum
	Crystalline	Sodium Chloride	crystalline, salty taste	white to gray	Rock Salt
Organic Detrital Materials	Earthy (Bioclastic)	Calcium Carbonate	effervesces freely with cold dilute HCl, easily scratched with a fingernail	white	Chalk
		Silica	does not react with HCl, soft, commonly stratified	gray to white	Diatomite
	Bioclastic	Calcium Carbonate	effervesces freely with cold dilute HCl, shell fragments in a massive or crystallne matrix		Fossiliferous Limestone
		Calcium Carbonate	effervesces freely with cold dilute HCl, shell fragments cemented with little or no matrix material		Coquina
	Fibrous (Bioclastic)	Plant fibers	soft, porous, low specific gravity	brown	Peat
	Dense (Bioclastic)	Mineral free carbonaceous plant matter	harder than peat, moist	brownish to black	Lignite
		Mineral free carbonaceous plant matter	harder than lignite, dull luster, smudges fingers when handled	black	Bituminous Coal

The names of rocks derived from inorganic detrital materials may be appended to indicate the cementing agent, e.g., arkose with calcite cement.

Figure 2-24
Field identification of Metamorphic rock

Texture	Diagnostic Features	Composition	Color	Rock Identification
Foliated	slaty texture with slaty cleavage, dense, microscopic grains		variable, black and dark gray common	Slate
	phyllitic texture, fine grained to dense, "shiny" appearance	micaceous minerals are dominant		Phyllite
	schistose texture, medium to fine grained, "sparkling" appearance, porphyroblasts common	chlorite, biotite, muscovite, garnet and dark elongate silicate minerals, talc, feldspar commonly absent		Schist
	gneissic texture, coarse grained, foliation present as macroscopic grains arranged in light and dark bands	abundant quartz and feldspar in light bands and hornblende, augite, garnet or biotite in dark bands		Gneiss
	granulitic texture, medium to coarse grained, even grained, foliation present in quartzo-feldspathic rocks			Granulite
Foliated or Nonfoliated	medium to coarse-grained	mostly crystals of amphibole, sometimes feldspar, mica and talc		Amphibolite
Nonfoliated	crystalline, scratches glass, breaks across grains as easily as around them	quartz	color variable, white, pink, buff, brown, red, purple	Quartzite
	dense, dark colored		various shades of gray, gray-green, to nearly black	Hornfels
	texture of conglomerate but breaks across coarse grains as easily as around them	granules, pebbles or cobbles are commonly granitic or jasper, chert, quartz or quartzite		Metaconglomerate
	crystalline, scratches glass, breaks across grains as easily as around them, fossils in some	calcite or dolomite	white, pink, gray	Marble
	microcrystalline texture, usually with smooth wavy surfaces	serpentine, sometimes with crysotile	shades of green	Serpentinite
	granulitic texture, medium to coarse grained, even grained, foliation lacking in pyroxene-plagioclase bearing rocks			Granulite
	shiny luster, conchoidal fracture		black	Anthracite Coal

2.5.3 Rock Grain-size descriptors

The rock grain-size descriptors that follow are based on USBR (2001) standards.

Figure 2-25
Rock grain-size descriptors for Crystalline Igneous rock and Metamorphic rock

Description	Average Crystal Diameter
Very coarse grained or pegmatitic	> 3/8 in
Coarse-grained	3/16 – 3/8 in
Medium-grained	1/32 – 3/16 in
Fine-grained	0.04 – 1/32 in
Aphanitic	<0.04 in

Figure 2-26

Rock grain-size descriptors for Sedimentary and Pyroclastic Igneous rock

USCS (soils only) Particle Size	Size (inches)	Sedimentary (epiclastic) Rounded, subrounded, subangular		Volcanic (pyroclastic)	
		Particle or Fragment	Lithified Product	Fragment	Lithified Product
Boulder	12	Boulder	Boulder Conglomerate	Block (Angular)	Volcanic Breccia
Cobble	10	Cobble	Cobble Conglomerate	Bomb (Rounded)	Agglomerate
Coarse Gravel	3 2.5	Pebble	Pebble Conglomerate		
Fine Gravel	0.8			Lapilli	Lapilli Tuff
Coarse Sand	0.19 0.16	Granule	Granule Conglomerate	Coarse Ash	Coarse Tuff
Medium Sand	0.08 0.04 0.02 0.0165	Very Coarse Sand Coarse Sand Medium Sand	Sandstone (Very Coarse, Coarse, Medium, Fine, or Very Fine)		
Fine Sand	0.0098 0.0049	Fine Sand		Fine Ash	Fine Tuff
Fines Non-plastic Silt	0.0029 0.0025	Very Fine Sand Silt	Siltstone, Shale		
Plastic Clay	0.0002	Clay	Claystone, Shale		

2.5.4 Bedding Spacing Descriptors

Bedding planes are discontinuities along which rock mass failure may occur. They also influence the hydraulic conductivity and shear strength of the rock mass.

The bedding thickness or spacing, modified from USBR (2001), shall be used as indicated in Figure 2-27 below.

Figure 2-27
Bedding Spacing Descriptors

Description	Thickness/Spacing
Massive	Greater than 10 ft.
Very thickly bedded	3 to 10 ft.
Thickly bedded	1 to 3 ft.
Moderately bedded	3-5/8 in. to 1 ft.
Thinly bedded	1-1/4 to 3-5/8 in.
Very thinly bedded	3/8 to 1-1/4 in.
Laminated	Less than 3/8 in.

2.5.5 Rock Colors

Use the color name from the *Munsell Rock Color Chart,* which is based on the National Bureau of Standards/Inter Society Color Council system, to describe the rock at the time of sampling. If the sample contains layers or patches of varying colors, record that information and describe and all colors observed.

For additional information, see ASTM D 1535-06, *Standard Practice for Specifying Color by the Munsell System*.

2.5.6 Textural Descriptors

Textural adjectives are employed to describe the size and shape of voids within the rock mass that are visible to the unaided eye. These voids are relevant to the estimation of the hydraulic conductivity, unconfined compressive strength, and the weathering susceptibility of the intact rock.

Use the USBR (2001) standard to describe the size and shape of voids, as indicated in Figure 2-28 below.

Figure 2-28
Textural Descriptors

Description	Criteria
Pitted	Pinhole to 3/8 in. openings.
Vuggy	Small opening (usually lined with crystals) ranging in diameter from 3/8 in. to 4 in.
Cavity	An opening larger than 4 in., size descriptions are required, and adjectives such as small, or large, may be used, if defined.
Honeycombed	If numerous enough that only thin walls separate individual pits or vugs, this term further describes the preceding nomenclature to indicate cell-like form.
Vesicular	Small openings in volcanic rocks of variable shape formed by entrapped gas bubbles during solidification.

2.5.7 Weathering Descriptors for Intact Rock

Weathering increases the clay content of the intact rock and the amount of separation at grain boundaries. Weathered rock masses have lower unconfined compressive strength, lower intact rock shear strength, lower shear strength along discontinuities, higher hydraulic conductivity, and are more likely to fail through the intact rock. Use USBR (2001) weathering descriptors, as indicated in Figure 2-29 below.

Figure 2-29

Weathering Descriptors for Intact Rock

	Diagnostic Features					
	Chemical weathering-discoloration and/or oxidation		Mechanical weathering-grain boundary conditions (disaggregation) primarily for granitics and some coarse-grained sediments	Texture and solutioning		
Description	Body of rock	Fracture surfaces		Texture	Solutioning	General characteristics
Fresh	No discoloration, not oxidized	No discoloration or oxidation	No separation, intact (tight)	No change	No solutioning	Hammer rings when crystalline rocks are struck.
Slightly Weathered to Fresh						
Slightly Weathered	Discoloration or oxidation is limited to surface of, or short distance from, fractures; some feldspar crystals are dull	Minor to complete discoloration or oxidation of most surfaces	No visible separation, intact (tight)	Preserved	Minor leaching of some soluble minerals may be noted	Hammer rings when crystalline rocks are stuck. Body of rock not weakened.
Moderately to Slightly Weathered						
Moderately Weathered	Discoloration or oxidation extends from fractures usually throughout; Fe-Mg minerals are “rusty,” feldspar crystals are “cloudy”	All fracture surfaces are discolored or oxidized	Partial separation of boundaries visible	Generally preserved	Soluble minerals may be mostly leached	Hammer does not ring when rock is struck. Body of rock is slightly weakened.
Intensely to Moderately Weathered						
Intensely Weathered	Discoloration or oxidation throughout; all feldspars and Fe-Mg minerals are altered to clay to some extent; or chemical alteration produces in situ disaggregation, see grain boundary conditions	All fracture surfaces are discolored or oxidized, surfaces friable	Partial separation, rock is friable; in semiarid conditions granitics are disaggregated	Texture altered by chemical disintegration (hydration, argillation)	Leaching of soluble minerals may be complete	Dull sound when struck with hammer, usually can be broken with moderate to heavy manual pressure or by light hammer blow without reference to planes of weakness such as incipient or hairline fractures, or veinlets. Rock is significantly weakened.
Very Intensely Weathered						
Decomposed	Discolored or oxidized throughout, but resistant minerals such as quartz may be unaltered; all feldspars and Fe-Mg minerals are completely altered to clay		Complete separation of grain boundaries (disaggregated)	Resembles a soil, partial or complete remnant rock structure may be preserved; leaching of soluble minerals usually complete		Can be granulated by hand. Resistant minerals such as quartz may be present as “stringers” or “dikes.”
NOTE: Combination descriptors (such as "slightly weathered to fresh") are permissible where equal distribution of both weathering characteristics is present over significant intervals or where characteristics present are "in between" the diagnostic feature. However, combination descriptors shall not be used where significant identifiable zones can be delineated. Only two adjacent descriptors shall be combined.						

2.5.8 Rock Hardness

Use the modified USBR (2001) descriptors to describe the hardness of intact rock, as indicated in Figure 2-30 below.

Figure 2-30
Descriptors for Rock Hardness

Description	Criteria
Extremely Hard	Specimen cannot be scratched with a pocket knife or sharp pick; can only be chipped with repeated heavy hammer blows
Very Hard	Specimen cannot be scratched with a pocket knife or sharp pick. Breaks with repeated heavy hammer blows.
Hard	Specimen can be scratched with a pocket knife or sharp pick with difficulty (heavy pressure). Heavy Hammer blows required to break specimen
Moderately Hard	Specimen can be scratched with a pocket knife or sharp pick with light or moderate pressure. Core breaks with moderate hammer blows
Moderately Soft	Specimen can be grooved 1/6 in. deep with a pocket knife or sharp pick with moderate or heavy pressure. Breaks with light hammer blow or heavy manual pressure.
Soft	Specimen can be grooved or gouged easily with a pocket knife or sharp pick with light pressure, can be scratched with fingernail. Breaks with light to moderate manual pressure.
Very Soft	Specimen can be readily indented, grooved or gouged with fingernail, or carved with a pocket knife. Breaks with light manual pressure.

2.5.9 Fracture Density

Fractures are defined in Section 2.5.10. The fracture density is based on the spacing of all of the fractures observed in recovered core lengths from boreholes. This measurement excludes mechanical breaks and incipient joints/fractures. It also excludes features not identified as fractures, such as shears, faults, foliations, and bedding plane separations, etc.

Descriptive criteria presented below are based on borehole cores where lengths are measured along the core axis. Use the USBR (2001) fracture density standard, as indicated in Figure 2-31 below.

Figure 2-31
Descriptors for Fracture Density

Description	Observed Fracture Density
Unfractured	No fractures.
Very slightly fractured	Lengths greater than 3 ft.
Slightly to very slightly fractured	
Slightly fractured	Lengths from 1 to 3 ft. with few lengths less than 1 ft. or greater than 3 ft.
Moderately to slightly fractured	
Moderately fractured	Lengths mostly in 4 in. to 1 ft. range with most lengths about 8 in.
Intensely to moderately fractured	
Intensely fractured	Lengths average from 1 to 4 in. with scattered fragmented intervals with lengths less than 4 in.
Very intensely to intensely fractured	
Very intensely fractured	Mostly chips and fragments with a few scattered short core lengths.
NOTE: Combination descriptors (such as “very intensely to intensely fractured”) are used where equal distribution of both fracture density characteristics is present over a significant interval or exposure, or where characteristics are “in between” the descriptor definitions. Only two adjacent descriptors may be combined.	

2.5.10 Discontinuity Type

A single description, or range of descriptors, shall be used to describe the discontinuities observed over the length of the reported fracture density.

Discontinuity: A collective term used for all planes including fractures, joints, faults, shears, bedding planes and foliations. Contacts between rock bodies of different lithologies may also be considered discontinuities.

Fracture: A term used to describe any break in geologic material, excluding shears and shear zones. Additional fracture terminology is provided in Figure 2-32, below.

Shear: A structural break where differential movement has taken place along a surface, or zone of failure by a shear couplet, is termed a shear. Shears are sometimes characterized by striations, slickensides, gouge, breccia, mylonite, or any combination of these. Often direction, amount of displacement, and continuity may not be known because of limited exposures or observations.

Fault: A shear with significant continuity that can be correlated between observations is a fault. Faults demonstrate high spatial continuity, and therefore occur over significant portions of given sites, foundation areas, or regions. The observed fault feature may be a segment of a fault or fault zone, as defined in the literature. The designation of a shear as a fault or fault zone is a site-specific determination.

Shear/Fault Zone: A shear or fault that exhibits significant width when measured perpendicular to the plane of the shear or fault. The zone may consist of gouge, breccia, or many related faults or shears together with fractured and crushed rock between the shears or faults, or any combination of these. In the literature, many fault zones are referred to as faults.

Shear/Fault Disturbed Zone: An associated zone of fractures and/or folds adjacent to a shear or a shear zone where the country rock has been subjected to only minor cataclastic action and may be mineralized. If adjacent to a fault or fault zone, the term *fault-disturbed zone* is used. Occurrence, orientation, and aerial extent of these phenomena depend on the depth of burial (pressure and temperature) during shearing, brittleness of the geo-materials, and the stress conditions.

Figure 2-32
Descriptors for Discontinuity Type

Description		Criteria
Joint (JT)		A relatively planar fracture along which there has been little or no shearing displacement.
Foliation Joint (FJ) or Bedding Joint (BJ)		A relatively planar fracture that is parallel to foliation or bedding along which there has been little or no shearing displacement.
Bedding Plane Separation		A separation along bedding after extraction or exposure due to stress relief or slaking.
Incipient Joint (IJ) or Incipient Fracture (IF)		A joint or fracture that does not continue through the specimen or is not seen with the naked eye. However when the specimen is wetted and then allowed to dry, the joint or fracture trace is evident. When core is broken, it breaks along an existing plane.
Random Fracture (RF)		A natural break (fracture) with a generally rough, very irregular, non-planar surface which does not belong to a joint set.
Mechanical Break (MB)		A break due to drilling, blasting, or handling. Mechanical breaks parallel to bedding or foliation are called *Bedding Breaks* (BB) or *Foliation Breaks* (FB), respectively. Recognizing mechanical breaks may be difficult. The absence of oxidation, staining, or mineral fillings, and often a hackly or irregular surface are clues for recognition.
Fracture Zone (FZ)		Numerous, very closely intersecting fractures. Often fragmented core cannot be fitted together.

2.5.11 Discontinuity Condition (Weathering, Infilling and Healing)

Weathering: Descriptors for discontinuity weathering or alteration of fracture surfaces and fracture fillings (excluding soil materials) are the same as those used for weathering and alteration of intact rock (per Section 2.5.7, Figure 2-29, third column).

Discontinuity Infilling: Descriptors for hardness of fillings, gouges and/or fracture surfaces are the same as those presented for intact rock or consistency of soils.

Discontinuity Healing: Discontinuities may be filled with air, water, soil, or a crystalline mineral material that provides a significant tensile and shear strength to the discontinuity. Discontinuity healing can be observed when there is a color contrast with the bordering intact rock. Features often referred to as veins are healed discontinuities.

In addition to an observation of the amount of the discontinuity that has been healed, the healing material should be observed and recorded. The amount and material of the healing discontinuity is relevant to the estimation of discontinuity shear strength, discontinuity hydraulic conductivity, and to the ease with which the rock can be excavated (e.g., open excavation, tunnel, or borehole).

Use the USBR (2001) standard, as indicated below in Figure 2-33 below, to describe the discontinuity condition.

Figure 2-33
Descriptors for Discontinuity Healing

Descriptor	Criteria
Totally Healed	All fragments bonded, discontinuity is completely healed or recemented to a degree at least as hard as surrounding rock.
Moderately Healed	Greater than 50 percent of fractured or sheared material, discontinuity surface or filling is healed or recemented, and/or strength of healing agent is less hard than surrounding rock.
Partially Healed	Less than 50 percent of fractured or sheared material, discontinuity surface or filling is healed or recemented.
Not Healed	Discontinuity surface, fracture zone, sheared material, or filling is not healed or recemented. Rock fragments or filling (if present) held in place by their own angularity and/or cohesiveness.

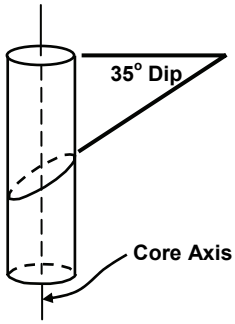
2.5.12 Discontinuity Dip Magnitude

Observation of the magnitude of discontinuity dip made with non-oriented core is useful for anticipating difficulties that may arise from boring piles or shafts in rock masses that contain discontinuities that are oriented close to vertical.

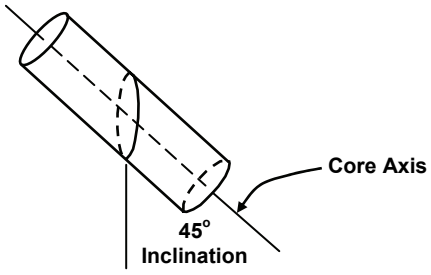
Use the USBR (2001) standard, as indicated below in Figure 2-34 below, to describe the magnitude of discontinuity dip.

Figure 2-34
Discontinuity Dip Magnitude

Vertical Hole: Apparent dip is measured and reported.



Angle Hole: True dip is usually not known, angle is measured from core axis and is called inclination.



2.5.13 Rate of Slaking

Some rock types are subject to degradation when exposed to weathering processes, particularly repeated wetting and drying cycles. Rocks that exhibit slaking may disintegrate into gravel size particles, or they may disaggregate completely to the individual constituent particles: clay, silt, and sand.

Rocks that are prone to slaking include: shale, siltstone, claystone, weakly welded tuff, and highly weathered crystalline igneous and metamorphic rocks. Slaking behavior is relevant to the performance of cut slopes and the stability of bored piles/drilled shafts. See Appendix A for test procedures.

Figure 2-35
Rate of Slaking

Jar Slake Index, I_J	Observed Behavior
1	Degrades to a pile of flakes or mud
2	Breaks rapidly and forms many chips
3	Breaks slowly and forms few chips
4	Breaks rapidly and develops several fractures
5	Breaks slowly and develops few fractures
6	No change to condition of the rock fragment

2.5.14 Odor

Rocks containing significant amounts of organic material usually have a distinctive odor of decaying vegetation. This is especially apparent in fresh samples, but if the samples are dried, the odor often may be revived by heating a moistened sample. Petroleum products or other chemicals may also influence the odor of the sample. Describe the odor, if organic, and identify anything unusual, such as odor of a petroleum product or other chemical.

2.5.15 Additional Comments

Additional rock characteristics not included in the previous categories may be noted.

2.5.16 Other Drilling Observations

Other observations (not included in the descriptive sequence) that may be presented on the LOTB or BR as notes or remarks include:

- Time for core run
- Difficulty in drilling or excavating, etc.
- Generic name (e.g., hard pan, fault gouge, etc.)
- Ground water inflow, elevation(s), and estimated rate(s)
- Loss of drill fluid circulation

2.6 Sample Preparation and Identification for Laboratory Testing and Storage

Geoprofessionals who drill, sample, preserve, and transport soil samples play an important role in ensuring the quality of the laboratory test results. When performing field investigations, the geoprofessional shall be familiar with the procedures contained within the following ASTM standards:

- ASTM D 1586-99, "Test Method for Penetration Test and Split-Barrel Sampling of Soils"
- ASTM D 1587-00, "Practice for Thin-Walled Tube Sampling of Soils"
- ASTM D 3550-01, "Practice for Ring-Lined Barrel Sampling of Soils"
- ASTM D 4220-00, "Standard Practices for Preserving and Transporting Soil Samples"

The information that follows explains the procedures and information required to submit soil samples and request testing services from the Caltrans Geotechnical Laboratory, an AASHTO Materials Reference Laboratory (AMRL) accredited facility located in Sacramento.

2.6.1 Sample Preparation and Identification for Laboratory Testing and Storage

All samples shall be named according to the following convention:

Hole ID – SNN – T

Where,

Hole ID: Refer to Section 2.3

S: The Sample Type Code, as defined in Figure 2-36, which generally follow ASTM D 6453

NN: 2-digit sample number (01–99), sequenced consecutively from the top down.

T: 1-digit tube number, starting with the bottom tube numbered as 1.

For example:

A – 06 – 105 – U02 – 3

Figure 2-36
Sample Type Codes

Code	Description
U	Undisturbed Shelby tube
P	Undisturbed Piston
S	Split spoon (includes SPT and Cal Mod Samplers)
B	Block
C	Core (both rock and soil)
D	Disturbed (include auger cuttings)
R	Reconstituted
O	Other

Label Brass and Shelby Tubes as explained below and shown in Figure 2-37, below:

- Use electrical tape to completely seal the end caps onto the sample tubes.
- Clearly label samples with permanent marker
- Place the top of the label at the top end of the tube to identify the proper orientation of the sample as shown above.
- If the sample tube is only partially filled, use a filler, such as newspaper, cloth rags, or sawdust

to prevent movement of the sample in the tube during shipping and handling.

- Whenever possible use a wax seal on the end of the sample to prevent moisture exchange with or contamination by the filler material.

Label bagged samples as explained below and shown in Figure 2-38:

- Identify the sample by writing directly on the plastic bag or attaching an adhesive label.
- Seal or tie the plastic bag properly to prevent loss of moisture.

Figure 2-37
Brass and Shelby Tube Label

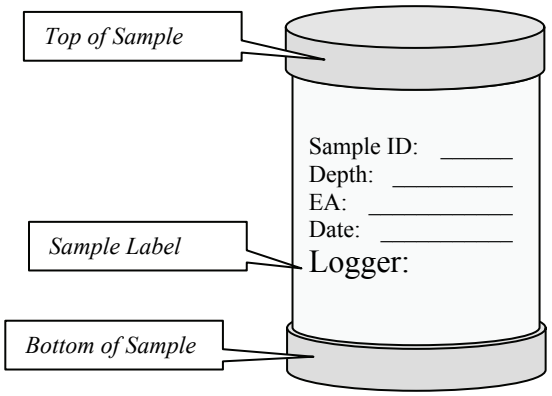
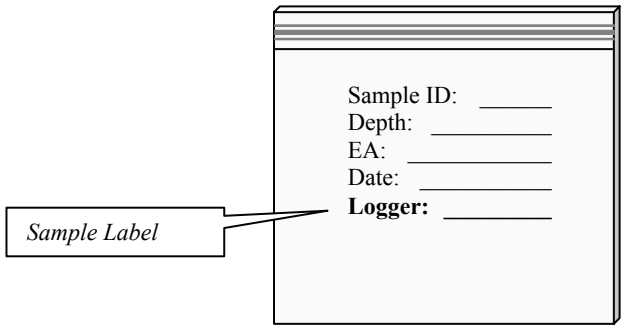


Figure 2-38
Bagged Sample Label



2.6.2 Identification of Large Soil Samples

In addition to the labeling requirements explained above, some soil samples must also be labeled with a Sample Identification Card (Caltrans Form TL-101), including:

- Samples weighing more than 5 lbs.
- Samples to be tested by the Materials Engineering and Testing Services (METS), test names are followed by "**" in Figure 2-39 below.

Place Form TL-101 inside a sealed plastic bag, then place it inside the large plastic or canvas bag that contains the sample.

Figure 2-39
Minimum Material Requirements for Various Test Methods

Test Method(s)	Test Name	Material Required	Typical Sample Size/Type	TL-101 Required
AASHTO T 265-93 (2004) ASTM D 2216-05	Moisture Content	0.5 lb	1/2 Tube	No
ASTM D 4767-04	Unit Weight	1 lb	1 Tube	No
AASHTO T 100-06	Specific Gravity	0.5 lb	1/2 Tube	No
ASTM D 422-63 (2002)	Particle-Size Analysis	1 lb	1 Tube	No
AASHTO T 89-02 AASHTO T 90-00 (2004)	Liquid Limit Plastic Limit, Plasticity Index	1 lb	1 Tube	No
ASTM D 2435-04	Consolidation Undisturbed (2.0" Diameter) (2.5" Diameter) Remolded (2.0" Diameter)	 - - 80 lb	 1 Tube 1 Tube 2 Full Canvas Bags	 No No **Yes**
ASTM D 4546-03	Swell Potential Undisturbed (2.0" Diameter) (2.5" Diameter) Remolded (2.0" Diameter)	 - - 80 lb	 1 Tube 1 Tube 2 Full Canvas Bags	 No No **Yes**
ASTM D 5333-03	Collapse Potential Undisturbed (2.0" Diameter) (2.5" Diameter) Remolded (2.0" Diameter)	 - - 80 lb	 1 Tube 1 Tube 2 Full Canvas Bags	 No No **Yes**
ASTM D 3080-04	Direct Shear Undisturbed Remolded	 - 80 lb	 1 Tube 2 Full Canvas Bags	 No **Yes**
CTM 216 (Oct 2006)	Relative Compaction (Compaction Curve Only)	80 lb	2 Full Canvas Bags	**Yes**

Test Method(s)	Test Name	Material Required	Typical Sample Size/Type	TL-101 Required
CTM 220 (Nov 2005)	Permeability Undisturbed Falling Head Remolded Falling Head Constant Head	- 80 lb 80 lb	1 Tube 2 Full Canvas Bags 2 Full Canvas Bags	No **Yes** **Yes**
ASTM D 2166-06 ASTM D 2938-95 (2002)	Unconfined Compression	-	1 Tube or Core	No
ASTM D 4767-02	Triaxial CU (3 points) Undisturbed (2.0" Diameter) (2.5" Diameter) Remolded (2.8" Diameter)	 - - 80 lb	 3 Tubes - in series 3 Tubes - in series 2 Full Canvas Bags	 No No **Yes**
ASTM D 2850-03	Triaxial UU (1 point) Undisturbed (2.0" Diameter) (2.5" Diameter) Remolded (2.8" Diameter)	 - - 80 lb	 1 Tube 1 Tube 2 Full Canvas Bags	 No No **Yes**
ASTM D 427-04	Shrinkage Limit	1 lb	1 Tube	No
ASTM D 5731-05	Point Load	-	Rock Core	No
ASTM D 4829-03	Expansion Index	40 lb	1 Full Canvas Bag	**Yes**
CTM 217 (Nov 1999) AASHTO T 176-02	Sand Equivalent**	10 lb	1/4 Full Canvas Bag	**Yes**
CTM 301 (Mar 2000) AASHTO T 190-02	R-Value**	80 lb	2 Full Canvas Bags	**Yes**
CTM 643 (Nov 1999) CTM 417 (Nov 2006) CTM 422 (Nov 2006)	Corrosion** Sulfates** Chlorides**	10 lb	1/4 Full Canvas Bag	**Yes**
EPA 9081	Organic Content** PH** Cation Exchange**	10 lb	1/4 Full Canvas Bag	**Yes**

Notes:

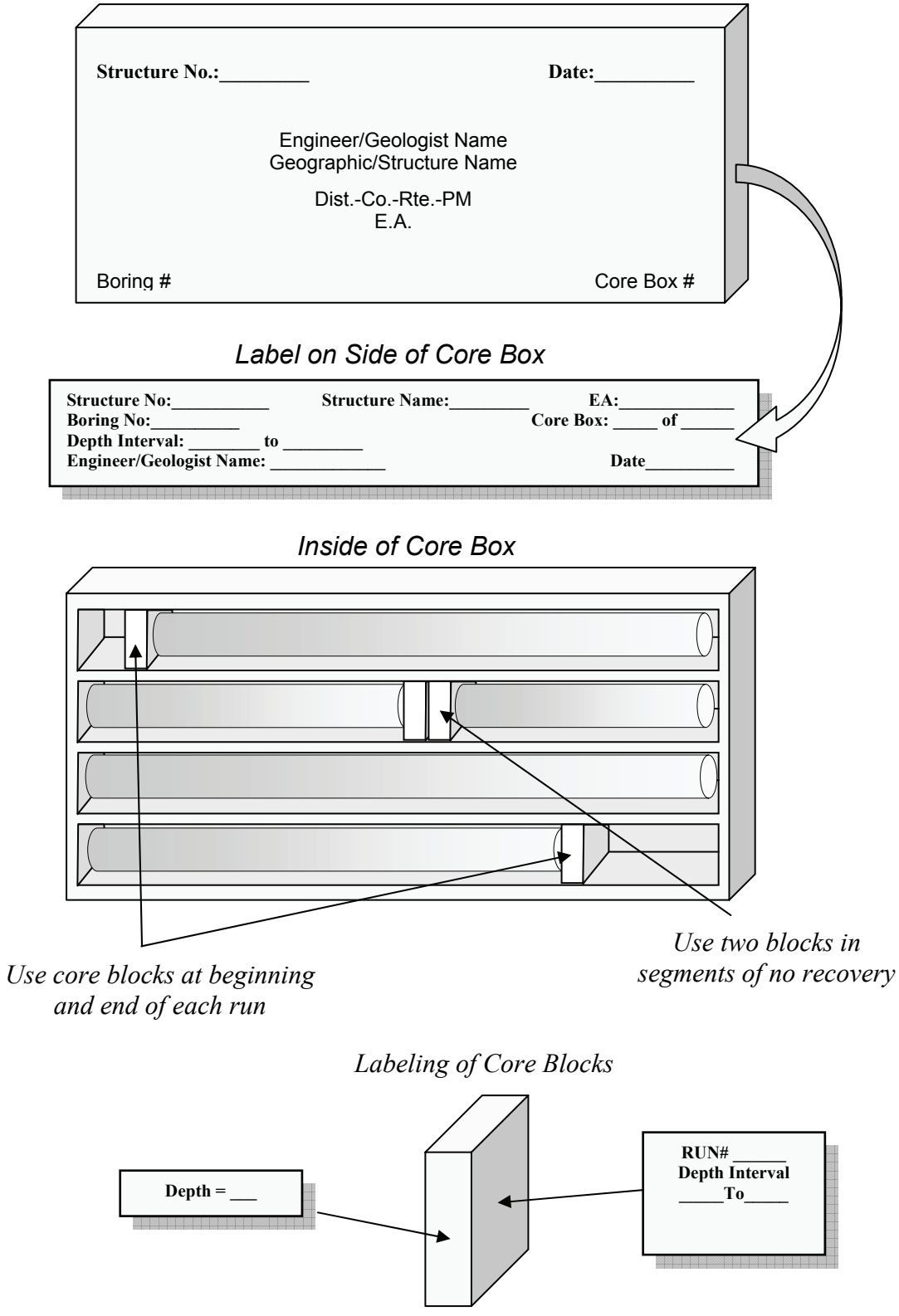
1. ** Tests performed by Materials Engineering and Testing Services (METS)
2. A 12" by 24" canvas bag completely filled contains approximately 40 lb of material.
3. A 2" by 4" tube contains approximately 1 lb. of material.
4. Minimum material weights shown for remolded samples include sufficient material for the development of a moisture density curve.

5. When calculating the number of triaxial samples that can be obtained from a Shelby tube, use a minimum sample length equal to three times the sample diameter.

2.6.3 Core Box Layout

Core boxes shall be labeled as shown in Figure 2-40.

Figure 2-40
Core Box Layout and Label



2.7 Quality Check of Field Observations and Samples

The geoprofessional shall conduct a quality check of his/her field notes and observations once back in the office. Sample descriptions and identifications shall be reviewed and revised as necessary to ensure that they are in compliance with the procedures presented in this section.

Descriptors of sample properties that are subject to change due to time or environment, such as moisture or RQD, shall not be revised. Samples that are to be stored for laboratory testing or other purposes shall be inventoried to ensure correct labeling and accounting.

Section 3:
Procedures for Soil and Rock Description and/or Classification Using Laboratory Test Results

3.1 Introduction

Section 2 describes the procedures for describing and identifying soil and rock samples in the field using visual and manual methods and basic field testing tools. Most of these field procedures are sufficient to generally identify and describe the soil and rock in qualitative terms, and are appropriate for reporting in final boring records, as described later in Sections 4 and 5. In many cases these descriptors can be correlated, to some degree, to engineering parameters for use in geotechnical designs. However, the geoprofessional may want to more quantitatively and definitively characterize a particular sample using laboratory test results.

This Section addresses how to apply the results of specific laboratory tests to revise and supplement the original field observations, identifications, and descriptions. The information presented in this Section is based largely on the American Society for Testing and Materials (ASTM) D 2487-06, *Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)*.

Laboratory test results can be used to systematically refine field observations. The process of correction, calibration, and verification in developing an updated Log of Test Boring (LOTB) or Boring Record (BR) based on laboratory test results can effectively serve the purpose of self-training and self-calibration. This process is described in more detail in Section 4 of this Manual.

3.2 Revising Soil Descriptions and Assigning Soil Classification Using Laboratory Test Results

Six of the 21 attributes in the identification and descriptive sequence for soils, listed previously in section 2.4.1, may be revised with laboratory test results. They are:

- Group Name
- Group Symbol
- Consistency
- Percent or Proportion of Soils
- Particle Size Range
- Plasticity

The *Group Name* and *Group Symbol* are estimated in the field using visual and manual procedures based on ASTM D 2488-06, *Standard Practice for Description and Identification of Soils (Visual-Manual Procedure).* The field method requires the user to make judgments on a number of observations (e.g., percent of constituents by weight, whether a soil is well or poorly graded, and whether the soil is a clay or silt or some combination thereof).

Laboratory particle-size analysis, liquid limit, and plasticity index provide a quantitative basis for *classification* of the soil. Furthermore, the laboratory procedure employs a much more comprehensive listing of possible Group Names, as compared to field methods.

Consistency is estimated in the field using one or more of three methods (thumb test, Torvane, or Pocket Penetrometer), with varying levels of accuracy and repeatability. Laboratory triaxial, direct shear, and unconfined compression tests provide less subjective undrained shear strength values that can be correlated to specific consistency descriptors.

Percent gravel, sand, and fines, and range of particle sizes are estimated in the field using visual methods (e.g. jar test, visual approximation, etc.). The laboratory particle-size analysis test provides a quantitative distribution of particle sizes in proportion to the total sample weight. It is important to recognize that the sample size is significant when dealing with gravel or larger sized soils.

Plasticity is estimated in the field in order to determine Group Name and Group Symbol for fine-grained soils and to provide a plasticity descriptor. The liquid limit and plasticity index used in conjunction with ASTM D 2487-06 provide a Group Name and Group Symbol. The field-based plasticity descriptor is eliminated, as the plasticity is inherent in the Group Name and Group Symbol.

3.2.1 Soil Classification and Description Descriptive Sequence

The descriptive sequence presented in the Figure 3-1 below shall be used when classifying and describing soils. Items indicated by a check mark in the "Required" column shall be repeated to describe all the components of the subject soil to provide complete descriptive coverage. To incorporate laboratory test data in the classification and descriptive sequence, where applicable, refer to the sections in this Manual as noted in Figure 3-1. *(See "Lab" column below.)*

Figure 3-1
Classification and Description Sequence

Sequence	Classification Components	Refer to Section		Required	Optional
		Field	Lab		
1	Group Name	2.4.2	3.2.2	●	
2	Group Symbol	2.4.2	3.2.2	●	
	Description Components				
3	Consistency (for cohesive soils)	2.4.3	3.2.3	●	
4	Apparent Density (for cohesionless soils)	2.4.4		●	
5	Color (in moist condition)	2.4.5		●	
6	Moisture	2.4.6		●	
7	Percent of cobbles or boulders	2.4.7		●	
8	Percent or proportion of soils	2.4.8	3.2.4	●	
9	Particle Size Range	2.4.9	3.2.5	●	
10	Particle Angularity	2.4.10			O
11	Particle Shape	2.4.11			O
12	Hardness (for coarse sand and larger particles)	2.4.12			O
13	Plasticity (for fine-grained soils)*	2.4.13	3.2.6	●	
14	Dry Strength (for fine-grained soils)	2.4.14			O
15	Dilatency (for fine-grained soils)	2.4.15			O
16	Toughness (for fine-grained soils)	2.4.16			O
17	Calcium Carbonate (Reaction with HCl)	2.4.17			O
18	Structure	2.4.18			O
19	Cementation	2.4.19		●	
20	Description of Cobbles and Boulders	2.4.20		●	
21	Additional Comments	2.4.21			O

** This descriptive component is not reported for the primary soil type if the liquid limit and plasticity index are available. (See Section 3.2.7)*

3.2.2 Group Name and Group Symbol

This section presents a procedure for classifying soils for engineering purposes based on laboratory determination of particle-size characteristics, liquid limit, and plasticity index. It shall be used when precise classification is required. This method is based on the ASTM version of the Unified Soil Classification System (USCS).

The ASTM procedure for classifying and describing fine-grained and coarse-grained soils is only applicable to material passing the 3-inch sieve. If the presence of cobbles or boulders or both is identified during the site exploration, the percentage of cobbles and boulders shall be reported per Section 2.4.7.

3.2.2.1 Procedure for Classification of Fine-Grained Soils

If 50% or more by dry weight of the test specimen passes the No. 200 sieve, the soil is fine-grained. Fine-grained soils are classified using the liquid limit and plasticity index in Figures 3-2 and 3-3, below.

Classify the soil as fine-grained:

- In cases where the liquid limit exceeds 110, or the plasticity index exceeds 60, the plasticity chart may be expanded by maintaining the same scale on both axes and extending the "A" line at the indicated slope.
- The soil is organic if organic matter is present in sufficient amounts to influence the liquid limit. Typically, organic soils have a dark color and an organic odor when moist and warm, and may contain visible organic matter. If the geoprofessional suspects there is sufficient organic matter to influence the soil's classification, consult with the Caltrans Geotechnical Laboratory about additional laboratory testing.

Figure 3-2
Classification of Fine-Grained Soils

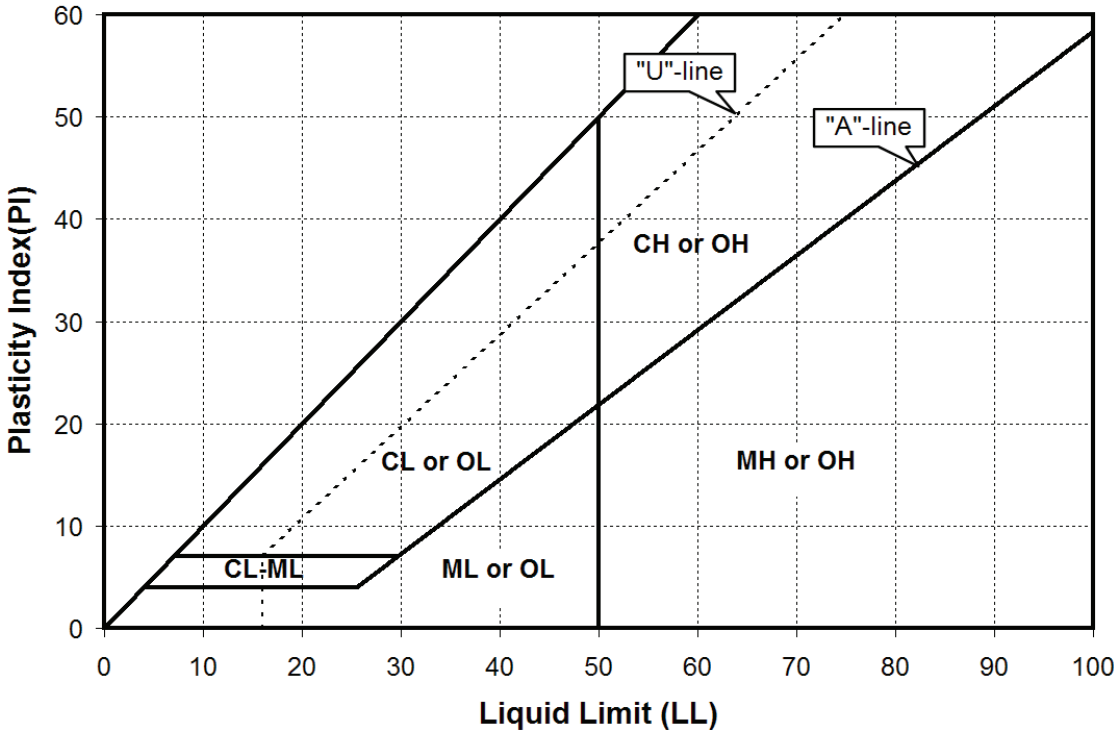


Figure 3-3

Flow chart for fine-grained soils

Liquid Limit	Organic	Plasticity Index	Group Symbol	Fines	Coarseness		Group Name
LL<50	Inorganic	PI>7 and plots on or above "A"-line	CL	<30% plus No. 200	<15% plus No. 200		Lean CLAY
					15-29% plus No. 200	% sand ≥ % gravel	Lean CLAY with SAND
						% sand < % gravel	Lean CLAY with GRAVEL
				≥30% plus No. 200	% sand ≥ % gravel	< 15% gravel	SANDY lean CLAY
						≥ 15% gravel	SANDY lean CLAY with GRAVEL
					% sand < % gravel	< 15% sand	GRAVELLY lean CLAY
						≥ 15% sand	GRAVELLY lean CLAY with SAND
		4≤PI≤7 and plots on or above "A"-line	CL-ML	<30% plus No. 200	<15% plus No. 200		SILTY CLAY
					15-29% plus No. 200	% sand ≥ % gravel	SILTY CLAY with SAND
						% sand < % gravel	SILTY CLAY with GRAVEL
				≥30% plus No. 200	% sand ≥ % gravel	< 15% gravel	SANDY SILTY CLAY
						≥ 15% gravel	SANDY SILTY CLAY with GRAVEL
					% sand < % gravel	< 15% sand	GRAVELLY SILTY CLAY
						≥ 15% sand	GRAVELLY SILTY CLAY with SAND
		PI<4 or plots below "A"-line	ML	<30% plus No. 200	<15% plus No. 200		SILT
					15-29% plus No. 200	% sand ≥ % gravel	SILT with SAND
						% sand < % gravel	SILT with GRAVEL
				≥30% plus No. 200	% sand ≥ % gravel	< 15% gravel	SANDY SILT
						≥ 15% gravel	SANDY SILT with GRAVEL
					% sand < % gravel	< 15% sand	GRAVELLY SILT
						≥ 15% sand	GRAVELLY SILT with SAND
	Organic	PI≥4 and plots on or above "A"-line	OL	<30% plus No. 200	<15% plus No. 200		ORGANIC CLAY
					15-29% plus No. 200	% sand ≥ % gravel	ORGANIC CLAY with SAND
						% sand < % gravel	ORGANIC CLAY with GRAVEL
				≥30% plus No. 200	% sand ≥ % gravel	< 15% gravel	SANDY ORGANIC CLAY
						≥ 15% gravel	SANDY ORGANIC CLAY with GRAVEL
					% sand < % gravel	< 15% sand	GRAVELLY ORGANIC CLAY
						≥ 15% sand	GRAVELLY ORGANIC CLAY with SAND
		PI<4 or plots below "A"-line		<30% plus No. 200	<15% plus No. 200		ORGANIC SILT
					15-29% plus No. 200	% sand ≥ % gravel	ORGANIC SILT with SAND
						% sand < % gravel	ORGANIC SILT with GRAVEL
				≥30% plus No. 200	% sand ≥ % gravel	< 15% gravel	SANDY ORGANIC SILT
						≥ 15% gravel	SANDY ORGANIC SILT with GRAVEL
					% sand < % gravel	< 15% sand	GRAVELLY ORGANIC SILT
						≥ 15% sand	GRAVELLY ORGANIC SILT with SAND

Figure 3-3, continued

Liquid Limit	Organic	Plasticity Index	Group Symbol	Fines	Coarseness		Group Name
LL≥50	Inorganic	Plots on or above "A"-line	CH	<30% plus No. 200	<15% plus No. 200		Fat CLAY
					15-29% plus No. 200	% sand ≥ % gravel	Fat CLAY with SAND
						% sand < % gravel	Fat CLAY with GRAVEL
				≥30% plus No. 200	% sand ≥ % gravel	< 15% gravel	SANDY fat CLAY
						≥ 15% gravel	SANDY fat CLAY with GRAVEL
					% sand < % gravel	< 15% sand	GRAVELLY fat CLAY
						≥ 15% sand	GRAVELLY fat CLAY with SAND
		Plots below "A"-line	MH	<30% plus No. 200	<15% plus No. 200		Elastic SILT
					15-29% plus No. 200	% sand ≥ % gravel	Elastic SILT with SAND
						% sand < % gravel	Elastic SILT with GRAVEL
				≥30% plus No. 200	% sand ≥ % gravel	< 15% gravel	SANDY elastic SILT
						≥ 15% gravel	SANDY elastic SILT with GRAVEL
					% sand < % gravel	< 15% sand	GRAVELLY elastic SILT
						≥ 15% sand	GRAVELLY elastic SILT with SAND
	Organic	Plots on or above "A"-line	OH	<30% plus No. 200	<15% plus No. 200		ORGANIC CLAY
					15-29% plus No. 200	% sand ≥ % gravel	ORGANIC CLAY with SAND
						% sand < % gravel	ORGANIC CLAY with GRAVEL
				≥30% plus No. 200	% sand ≥ % gravel	< 15% gravel	SANDY ORGANIC CLAY
						≥ 15% gravel	SANDY ORGANIC CLAY with GRAVEL
					% sand < % gravel	< 15% sand	GRAVELLY ORGANIC CLAY
						≥ 15% sand	GRAVELLY ORGANIC CLAY with SAND
		Plots below "A"-line		<30% plus No. 200	<15% plus No. 200		ORGANIC SILT
					15-29% plus No. 200	% sand ≥ % gravel	ORGANIC SILT with SAND
						% sand < % gravel	ORGANIC SILT with GRAVEL
				≥30% plus No. 200	% sand ≥ % gravel	< 15% gravel	SANDY ORGANIC SILT
						≥ 15% gravel	SANDY ORGANIC SILT with GRAVEL
					% sand < % gravel	< 15% sand	GRAVELLY ORGANIC SILT
						≥ 15% sand	GRAVELLY ORGANIC SILT with SAND

3.2.2.2 Procedure for Classification of Coarse-Grained Soils

If 50% or more by dry weight of the test specimen is retained on the No. 200 sieve the soil is coarse-grained. Coarse-grained soils are classified using the following procedure:

- Classify the soil as gravel if more than 50% of the coarse fraction (plus No. 200 sieve) is retained on the No. 4 sieve.
- Classify the soil as sand if 50% or more of the coarse fraction (plus No. 200 sieve) passes through the No. 4 sieve.
- If 12% or less of the test specimen passes through the No. 200 sieve, plot the cumulative particle-size distribution and compute the coefficient of uniformity, Cu, and coefficient of curvature, Cc, as given in Equations 1 and 2.

Equation 1

$$Cu = \frac{D_{60}}{D_{10}}$$

Equation 2

$$Cc = \frac{(D_{30})^2}{(D_{10} \times D_{60})}$$

Where D_{10}, D_{30}, and D_{60} are the particle-size diameters corresponding to 10, 30, and 60 percentiles passing on the cumulative particle-size distribution curve. It may be necessary to extrapolate the curve to obtain the D_{10} diameter.

Use the above results to determine the classification according to Figure 3-4 on the following page.

Figure 3-4
Flow chart for coarse-grained soils

	Fines	Grade	Type of Fines	Group Symbol	Sand/ Gravel	Group Name
Gravel	≤ 5%	Cu≥4 1≤Cc≤3		GW	< 15% sand	Well-graded GRAVEL
					≥ 15% sand	Well-graded GRAVEL with SAND
		Cu<4 1>Cc>3		GP	< 15% sand	Poorly graded GRAVEL
					≥ 15% sand	Poorly graded GRAVEL with SAND
	5-12%	Cu≥4 1≤Cc≤3	ML or MH	GW-GM	< 15% sand	Well-graded GRAVEL with SILT
					≥ 15% sand	Well-graded GRAVEL with SILT and SAND
			CL, CH or CL-ML	GW-GC	< 15% sand	Well-graded GRAVEL with CLAY (or SILTY CLAY)
					≥ 15% sand	Well-graded GRAVEL with CLAY and SAND (or SILTY CLAY and SAND)
		Cu<4 1>Cc>3	ML or MH	GP-GM	< 15% sand	Poorly graded GRAVEL with SILT
					≥ 15% sand	Poorly graded GRAVEL with SILT and SAND
			CL, CH or CL-ML	GP-GC	< 15% sand	Poorly graded GRAVEL with CLAY (or SILTY CLAY)
					≥ 15% sand	Poorly graded GRAVEL with CLAY and SAND (or SILTY CLAY and SAND)
	> 12%		ML or MH	GM	< 15% sand	SILTY GRAVEL
					≥ 15% sand	SILTY GRAVEL with SAND
			CL or CH	GC	< 15% sand	CLAYEY GRAVEL
					≥ 15% sand	CLAYEY GRAVEL with SAND
			CL-ML	GC-GM	< 15% sand	SILTY, CLAYEY GRAVEL
					≥ 15% sand	SILTY, CLAYEY GRAVEL with SAND
Sand	≤ 5%	Cu≥6 1≤Cc≤3		SW	< 15% gravel	Well-graded SAND
					≥ 15% gravel	Well-graded SAND with GRAVEL
		Cu<6 1>Cc>3		SP	< 15% gravel	Poorly graded SAND
					≥ 15% gravel	Poorly graded SAND with GRAVEL
	5-12%	Cu≥6 1≤Cc≤3	ML or MH	SW-SM	< 15% gravel	Well-graded SAND with SILT
					≥ 15% gravel	Well-graded SAND with SILT and GRAVEL
			CL, CH or CL-ML	SW-SC	< 15% gravel	Well-graded SAND with CLAY
					≥ 15% gravel	Well-graded SAND with CLAY and GRAVEL
		Cu<6 1>Cc>3	ML or MH	SP-SM	< 15% gravel	Poorly graded SAND with SILT
					≥ 15% gravel	Poorly graded SAND with SILT and GRAVEL
			CL, CH or CL-ML	SP-SC	< 15% gravel	Poorly graded SAND with CLAY
					≥ 15% gravel	Poorly graded SAND with CLAY and GRAVEL
	> 12%		ML or MH	SM	< 15% gravel	SILTY SAND
					≥ 15% gravel	SILTY SAND with GRAVEL
			CL or CH	SC	< 15% gravel	CLAYEY SAND
					≥ 15% gravel	CLAYEY SAND with GRAVEL
			CL-ML	SC-SM	< 15% gravel	SILTY, CLAYEY SAND
					≥ 15% gravel	SILTY, CLAYEY SAND with GRAVEL

3.2.3 Consistency (Cohesive Soils)

Cohesive soil consistency descriptors shall conform to terminology and criteria established in Figure 3-5 below, generally after Das (1983) and Bureau of Reclamation standards (2001). Note that the terms to be used have been modified from those contained in both references.

The preferred procedure for the determination of consistency of cohesive soils is to obtain relatively undisturbed samples and perform laboratory triaxial, direct shear, or unconfined compression tests. The results from these tests can be correlated to specific consistency descriptors as presented in Figure 3-5 below.

A triaxial unconsolidated-undrained (UU) test is recommended for strength determination. This can be converted to an equivalent unconfined compressive strength by multiplying the Undrained Shear Strength value by 2.

Figure 3-5
Consistency

Description	Unconfined Compressive Strength (tsf)
Very Soft	< 0.25
Soft	0.25 to 0.50
Medium Stiff	0.50 to 1.0
Stiff	1 to 2
Very Stiff	2 to 4
Hard	> 4.0

3.2.4 Percent or Proportion of Soils

Percentages of gravel, sand, and fines shall be reported as percentages based on gradation and particle-size analysis (ASTM D 422-63 (2002)). Qualitative proportional descriptors (e.g. trace, some, etc.) shall not be used when gradation data is available.

Figure 3-6
Percent or proportion of soils

Descriptive Term	Size
Gravel	3 inch to No.4 Sieve
Sand	No.4 to No. 200 Sieve
Fines	Passing No. 200 Sieve

3.2.5 Particle Size

When laboratory particle size analyses are performed, the USCS soil descriptions shall be further refined using the results and the Figure 3-8 below.

Figure 3-8
Particle size

Description	Size
Boulder	>12 in
Cobble	3 to 12 in
Coarse Gravel	¾ to 3 in
Fine Gravel	No.4 to ¾ in
Coarse Sand	No.10 to No.4
Medium Sand	No.40 to No.10
Fine Sand	No. 200 to No.40
Clay and Silt	Passing No. 200

3.2.6 Plasticity (for Fine-Grained Soils)

Field estimates of plasticity shall not be included in the descriptive sequence when USCS classifications are based on liquid limit and plasticity index, since the plasticity is inherent in the group name and group symbol.

3.3 Revising Rock Identification and Description for Borehole Cores Using Laboratory Test Results

One additional component, relative strength of intact rock, can be added to the descriptive sequence for rock.

Figure 3-9
Rock Identification and Descriptive Sequence

Sequence	Identification Components	Refer to Section		Required	Optional
		Field	Lab		
1	Rock Name	2.5.2		●	
	Description Components				
2	Rock Grain-size	2.5.3			O
3	Bedding Spacing	2.5.4		●	
4	Color	2.5.5		●	
5	Texture	2.5.6			O
6	Weathering Descriptors for Intact Rock	2.5.7		●	
7	Relative Strength of Intact Rock		3.3.1	●	
8	Rock Hardness	2.5.8		●	
9	Fracture Density	2.5.9		●	
10	Discontinuity Type	2.5.10			O
11	Discontinuity Condition (Weathering, Infilling and Healing)	2.5.11			O
12	Discontinuity Dip Magnitude	2.5.12			O
13	Rate of Slaking (Jar Slake Test)	2.5.13			O
14	Odor	2.5.14			O
15	Additional Comments	2.5.15			O

3.3.1 Strength of Intact Rock

Absent discontinuities, the strength of intact rock is best determined using unconfined compression laboratory testing.

Figure 3-10
Descriptors for Relative Strength of Intact Rock

Description	Uniaxial Compressive Strength (psi)
Extremely Strong	> 30,000
Very Strong	14,500 – 30,000
Strong	7,000 – 14,500
Medium Strong	3,500 – 7,000
Weak	700 – 3,500
Very Weak	150 – 700
Extremely Weak	< 150

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Section 4:
Methods of Presentation of Subsurface Information

4.1 Introduction

The process of creating boring logs, i.e., Log of Test Borings (LOTB) and Boring Records (BR) can be summarized in four steps:

- Field sampling and descriptions *(Section 2)*
- Quality check of field descriptions *(Section 2)*
- Refinement of descriptions, and classification of soil, based on laboratory test results, if performed *(Section 3)*
- Preparation of the boring logs *(Sections 4 and 5)*

This section provides details and guidance for incorporating laboratory test data and preparing boring logs. Figure 4-1 is a schematic representation of the process from obtaining subsurface information to the creation of boring logs.

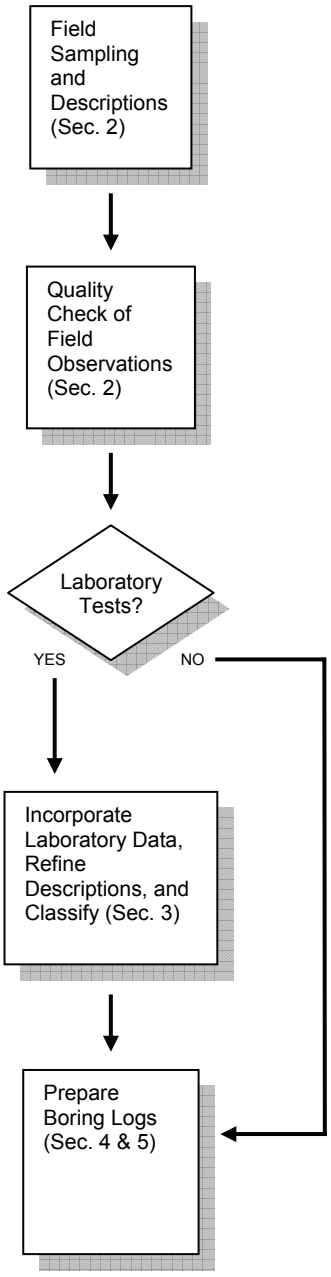
4.2 Factual vs. Interpretive Subsurface Data

FHWA guidelines state: "factual subsurface data which is pertinent to the project subsurface conditions should be presented in an easily understood fashion on the contract documents." However, there is an inherent level of professional interpretation in describing subsurface conditions that cannot be avoided.

Some examples:

- Field description and identification procedures, according to ASTM D 2488-06, require estimation and interpretation.
- Sampling may occur at discrete intervals, yet layer boundaries may fall between sampling locations. The boundaries may be identified based on visual observations of cuttings during boring advancement. There may be uncertainty as to the depth at which a material change occurs.
- Continuity of material types between discrete sampling locations is sometimes difficult to confirm.

Figure 4-1



4.3 Incorporating Laboratory Data, Refining Descriptions, and Classifying Soil

When describing soil or rock, the geoprofessional shall use the most reliable data available. Such data could be field-generated, or a combination of field- and laboratory-generated data. If laboratory tests are performed, and in the opinion of the geoprofessional, those test results represent the actual conditions of the soil or rock, those test results shall control the identification, description, or classification.

Laboratory tests are usually not performed on every sample, especially on contiguous samples within a layer of similar material. Professional judgment should be used to apply test results from one sample to the descriptor of contiguous samples within a boring when the field observations were such that the geoprofessional considers that particular attribute of the material to be consistent across the contiguous samples.

For example, three contiguous samples were determined to be "medium stiff" using the thumb method. However, a triaxial test on one of those samples indicated that the material was in fact "stiff." In this example, the consistency descriptor for the entire layer should be "stiff."

4.3.1 Subsurface Data Presentation Method

A "layer presentation" method shall be used to present soil and rock descriptions on boring logs. *(See Figure 4-3.)* This method presents a single primary description for a layer spanning one or more contiguous sample locations. However, the layer description may vary with depth as observations and/or laboratory testing at sample locations warrant. This method is used to simplify the boring log presentation format and provide clarity, especially to prospective bidders.

4.3.2 General Rules and Considerations

The following general rules apply to the layer presentation method:

- A change in a soil's Group Symbol or a rock type shall result in a new layer within the boring log.
- Reliable laboratory test results shall be used when performed to determine the applicable descriptors within the descriptive sequence (i.e. Group Name and Symbol, consistency, gradation properties, plasticity, and rock strength).
- Individual descriptors for contiguous samples with the same descriptions and classifications should be adjusted based on the test results of one or more representative samples. Use of more than one test sample is encouraged.
- When specifying a descriptive range, the range shall not span more than one step on the range of descriptors. For example, "stiff to very stiff" would be acceptable; but "soft to hard" would not be acceptable because the range is too broad to be useful.
  Exception: Any range of colors is acceptable.
- The descriptive sequence used to describe a layer of soil or rock shall describe that layer in its entirety. Where changes are noted at depths within the layer, those changes shall replace the preceding descriptor and shall apply from that depth to the bottom of the layer.
- The layer presentation of the boring log shall enable the reader to derive individual sample descriptions based on the layer description and sample information provided.

4.3.3 Example

The process for developing boring logs has been presented in detail throughout this Manual In general, field sample descriptions are corrected and calibrated based on laboratory results, layer boundaries are determined by grouping samples within the same group symbol, sample descriptions are consolidated into a single layer description, and, finally, description changes are noted with depth within layers.

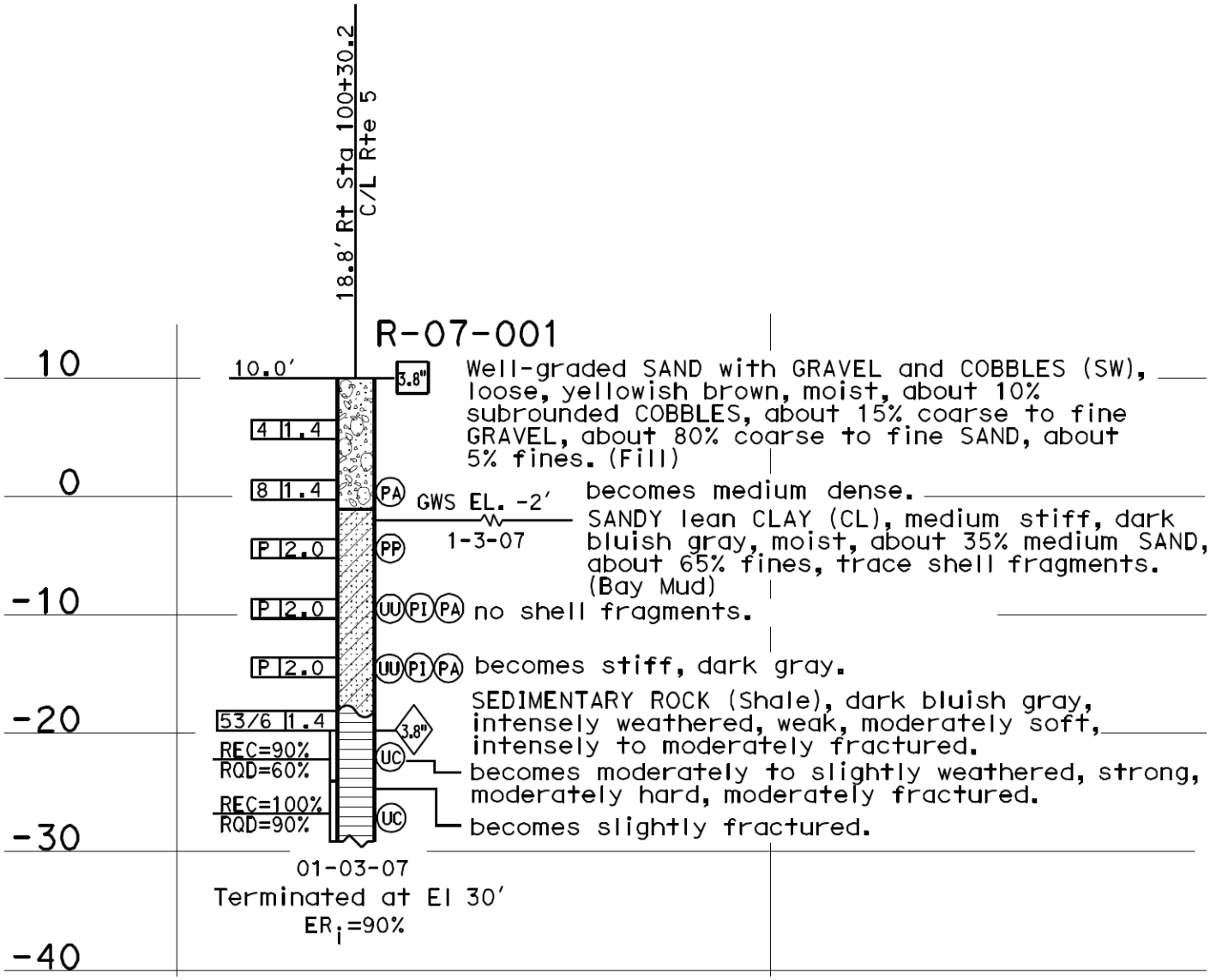
The following example demonstrates how a geoprofessional develops a layer presentation, based on field descriptions and laboratory test results.

Figure 4-2

Depth (ft.)	Sample	Field Testing	Field Description and Identification	Lab Testing	Lab Corrected Description and Identification or Classification	Final Layer Presentation
3.5-5	R-07-001-S01	SPT	Well-graded SAND with GRAVEL and COBBLES (SW), loose, yellowish brown, moist, about 10% subrounded COBBLES, about 15% coarse to fine GRAVEL, about 80% coarse to fine SAND, about 5% fines, (fill)		Well-graded SAND with GRAVEL and COBBLES (SW), loose, yellowish brown, moist, about 10% subrounded COBBLES, about 15% coarse to fine GRAVEL, about 80% coarse to fine SAND, about 5% fines, (fill)	Well-graded SAND with GRAVEL and COBBLES (SW), loose, yellowish brown, moist, about 10% subrounded COBBLES, about 15% coarse to fine GRAVEL, about 80% coarse to fine SAND, about 5% fines, (fill) becomes medium dense
8.5-10	R-07-001-S02	SPT	Well-graded SAND with GRAVEL and COBBLES (SW), medium dense, yellowish brown, moist, about 10% subrounded COBBLES, about 95% coarse to fine SAND, about 5% fines, (fill)	PA	Well-graded SAND with GRAVEL and COBBLES (SW), medium dense, yellowish brown, moist, about 10% subrounded COBBLES, about 95% coarse to fine SAND, about 5% fines, (fill)	
13.5-15	R-07-001-U03	PP	SANDY lean CLAY (CL), medium stiff, dark bluish gray, moist, about 35% medium SAND, about 65% fines, trace shell fragments, (bay mud)		SANDY lean CLAY (CL), medium stiff, dark bluish gray, moist, about 35% medium SAND, about 65% fines, trace shell fragments, (bay mud)	SANDY lean CLAY (CL), medium stiff, dark bluish gray, moist, about 35% medium SAND, about 65% fines, trace shell fragments, (bay mud) as above except no shell fragments becomes stiff, dark gray
18.5-20	R-07-001-U04	PP	SANDY lean CLAY (CL), soft, dark bluish gray, moist, about 35% medium SAND, about 65% fines, (bay mud)	UU, PA, PI	SANDY lean CLAY (CL), medium stiff, dark bluish gray, moist, about 35% medium SAND, about 65% fines, (bay mud)	
23.5-25	R-07-001-U05	PP	SANDY lean CLAY (CL), medium stiff, dark gray, moist, about 35% medium SAND, about 65% fines, trace shell fragments, (bay mud)	UU, PA, PI	SANDY lean CLAY (CL), stiff, dark gray, moist, about 35% medium SAND, about 65% fines, trace shell fragments, (bay mud)	
28-29	R-07-001-S06	SPT	SEDIMENTARY ROCK (SHALE), dark bluish gray, intensely weathered, moderately soft, intensely to moderately fractured		SEDIMENTARY ROCK (SHALE), dark bluish gray, intensely weathered, moderately soft, intensely to moderately fractured	SEDIMENTARY ROCK (SHALE), dark bluish gray, intensely weathered, moderately soft, intensely to moderately fractured becomes moderately to slightly weathered, strong, moderately hard, moderately fractured becomes slightly fractured
29-34	R-07-001-C07		SEDIMENTARY ROCK (SHALE), dark bluish gray, moderately to slightly weathered, moderately hard, moderately fractured	UC	SEDIMENTARY ROCK (SHALE), dark bluish gray, moderately to slightly weathered, strong, moderately hard, moderately fractured	
34-39	R-07-001-C08		SEDIMENTARY ROCK (SHALE), dark bluish gray, moderately to slightly weathered, moderately hard, slightly fractured	UC	SEDIMENTARY ROCK (SHALE), dark bluish gray, moderately to slightly weathered, strong, moderately hard, slightly fractured	

The LOTB for the preceding example would appear as follows:

Figure 4-3



Section 5:
Boring Log and Legend Presentation Formats

5.1 Introduction

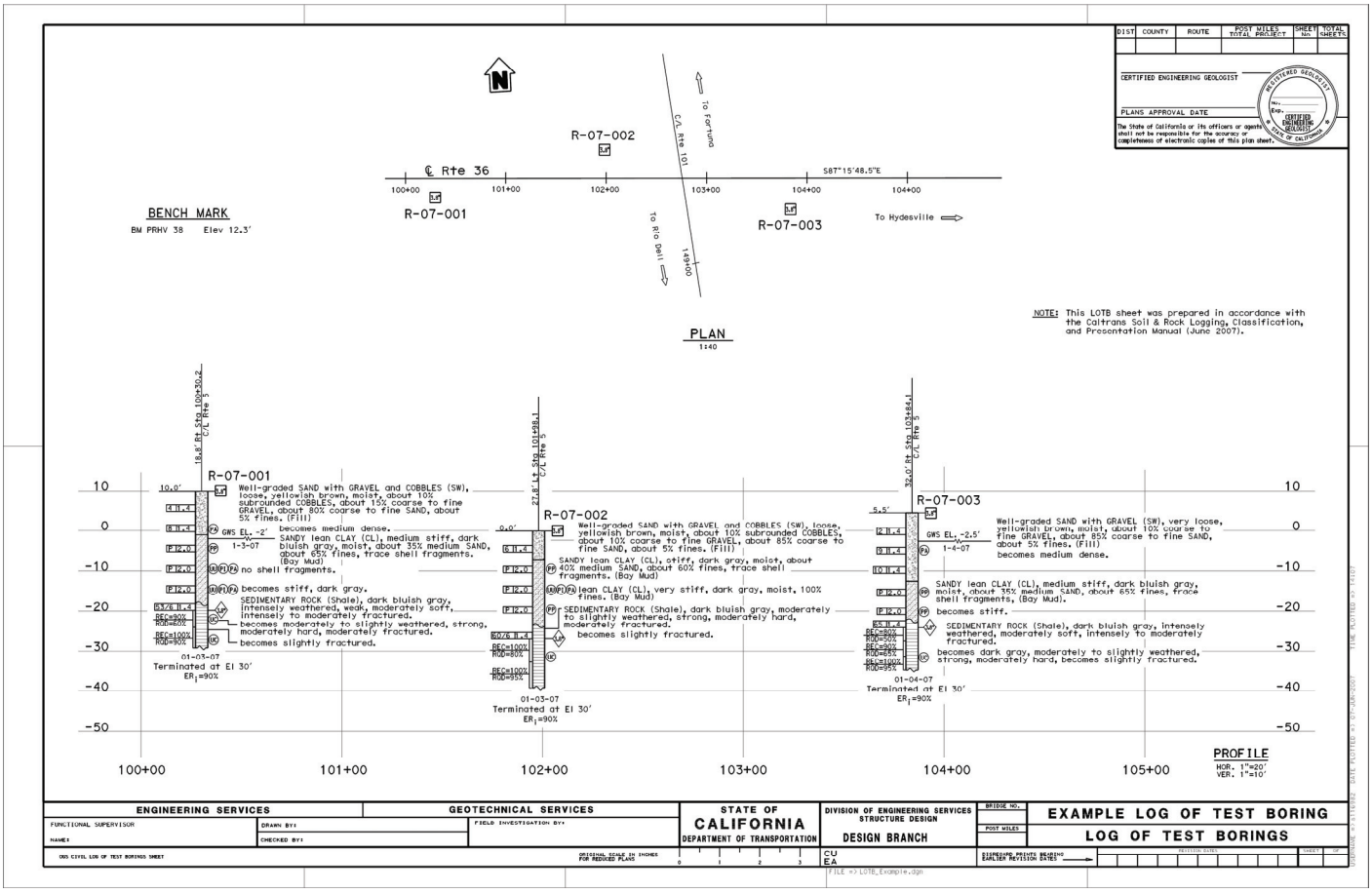
The Department uses the following formats to present subsurface information:

- Log of Test Boring (LOTB), and/or
- Boring Record (BR).

An LOTB is typically associated with a structure facility and is attached to Project Plans. A BR is typically associated with an earthwork facility and is attached to a Geotechnical Report. If a subsurface exploration was performed, there shall be at least one type of log presentation.

5.2 Log of Test Boring

Figure 5-1
Example of LOTB



5.2.1 Contents and Characteristics of the LOTB

The Log of Test Boring (LOTB) document is presented as an attachment to project plans and characterized by the following attributes:

- Presents the boring logs on an elevation scale.
- Presents a plan view showing the location of each boring relative to an alignment and/or existing or planned facility.
- Presents the type of drilling methods used to perform the investigation, the type of sampling performed, and how the sampler was advanced.
- Presents the location and description, both graphical and written, of the types of soil and rock encountered within the borehole.
- Presents the types of field and laboratory testing performed.
- Field and Laboratory test data, if presented, appear at the end of the descriptive sequence.
- Optimized for printing on full-size plan sheets (24" x 36") and typically reproduced on 11" x 17" sized paper.
- Allows presentation of more than one boring log per plan sheet.
- Is accompanied by LOTB legend sheets.

5.2.2 Notes on the LOTB

Each LOTB sheet shall contain a note section for the geoprofessional to present notes deemed to be of interest to the reader. Content of notes is left to the discretion of the geoprofessional except that the one of the following two notes shall be placed on each LOTB sheet:
If the procedures of this manual were followed without exception, then the note shall read:

"This LOTB sheet was prepared in accordance with the Caltrans Soil & Rock Logging, Classification, and Presentation Manual (Date)"

If an exception to the procedures of this manual has been approved and implemented, then the note shall be modified to read:

"This LOTB sheet was prepared in accordance with the Caltrans Soil & Rock Logging, Classification, and Presentation Manual (Date) except as noted in (Section) of (Report Title) dated (Date)"

Optional notes may include:

- Changes in drilling equipment
- Site observations
- Other drilling observations from Sections 2.4.20 or 2.5.16.

5.2.3 LOTB Sheet Formatting

LOTB sheets shall be prepared in accordance with this manual and the Caltrans *Plans Preparation Manual*. The LOTB sheet border shall present the following:

5.2.3.1 Signature Block (Upper Right Corner)

a) The State of California Registered Civil Engineer, Certified Engineering Geologist, or Registered Geologist seal with the signature, date, license number, and registration certificate expiration date of the engineer or geologist in responsible charge of the LOTB sheet;
b) Caltrans District, County, and Route;
c) Name and address of consultant firm in responsible charge of the LOTB sheet (if applicable);
d) Name and address of the lead local agency (if applicable); and
e) A disclaimer stating "The State of California or its officers or agents shall not be responsible for the accuracy or completeness of electronic copies of this plan sheet."

(The Office Engineer will provide the Post Miles Total Project, Sheet Number, Total Sheets, and Plans Approval Date.)

5.2.3.2 Title Block (Bottom, from left to right)

a) Notes stating "DIVISION OF ENGINEERING SERVICES" and "GEOTECHNICAL SERVICES." For consultant-prepared LOTB sheets, instead of those notes, show the name of the Design

Oversight (i.e., OSFP/OSCM Senior Liaison) Engineer and sign-off date.

b) "FUNCTIONAL SUPERVISOR": The name of the person in charge of the functional unit responsible for providing oversight of the registered engineer or geologist who developed the LOTB sheet.
c) "DRAWN BY": The name of the person who prepared (drafted) the LOTB sheet
d) "CHECKED BY": The name of the person who performed the quality control check of the LOTB sheet
e) "FIELD INVESTIGATION BY": The name(s) of the field investigator(s);
f) A note stating "STATE OF CALIFORNIA, DEPARTMENT OF TRANSPORTATION" with a scale below the sub-block and a label on the left side stating "ORIGINAL SCALE IN INCHES FOR REDUCED PLANS." For consultant-prepared LOTB sheets, the note shall state "PREPARED FOR THE STATE OF CALIFORNIA, DEPARTMENT OF TRANSPORTATION."
g) A note stating "DIVISION OF ENGINEERING SERVICES STRUCTURE DESIGN." For consultant-prepared LOTB sheets, instead of this note, show the name of the Project Engineer;
h) The Caltrans Contract Expenditure Authorization (CU and EA) numbers;
i) The State-assigned Bridge (or Structure) Number, Kilometer Post, and the State-assigned Bridge (or Structure) Name;
j) The initial drawn by and subsequent revision dates; and
k) A label stating "LOG OF TEST BORINGS _ OF _" (if applicable).

(The Office Engineer will provide the Sheet Number and Total Sheets Number.)

5.2.3.3 Plan View

a) Plan View shall be shown at the top of the first LOTB sheet. When the site is sufficiently large or complex, the first LOTB sheet should be used entirely for the Plan View.
b) When multiple LOTB sheets are drafted, they shall be numbered with reference to the stationing of the control line (i.e., showing sheet No. 1 with the lowest stationing and the last sheet with the highest stationing).
c) A distinct Plan View of the project site that is independent of the Profile View shall be shown on the LOTB.
d) Show the location, description, and elevation of the benchmark used for determining the top of boring elevations at the top left side of the Plan View under the heading "BENCHMARK". Identify the vertical datum (National Geodetic Vertical Datum, U.S. Geological Survey, U.S. Coast & Geodetic Survey, District, etc.) used to determine the benchmark elevations.
e) Show the scale directly below the Plan View label.
f) Show a North arrow.
g) Lines or control lines shown in the Plan View shall be consistent with those shown on the General Plan sheet.
h) Show stationing and names for control lines. Stationing shall increase from left to right. Show a minimum of two stations on all lines.
i) Show control line intersection stationing and bearings.
j) Show names and directions of nearest cities.
k) Show names and directions of stream flows when applicable.
l) Plot boring locations with symbols as shown in the legend to identify drilling methods (e.g., auger hole, rotary hole, cone penetration). The Hole Identification shall be presented with each symbol.
m) Boring locations are to be identified by reference line, station, and offset. Coordinates, such as Northing and Easting, may also be shown on the LOTB sheets.

5.2.3.4 Profile View

a) Show the control line, increasing from left to right, horizontally across the bottom of the Profile View.
b) Show the elevations and grid lines on both the left and right margins. Numerical values shall be in multiples of 10 (i.e. 20, 10, 0, -10, -20).

c) Show the Hole Identification, top of hole elevation, stationing, and offset at the top of each boring log.
d) Show types and diameters of each boring as shown in the legend.
e) Show the completion date of boring (m/d/y) at the bottom of each boring log.
f) Show "Terminated at EL. XX'" to indicate the bottom of boring elevation.
g) Show the SPT hammer energy ratio, "Hammer Energy Ratio (ER_i) = XX%," at the bottom of each boring.
h) Show date and elevation of groundwater measurement.
i) Show results from field penetration tests at relevant elevations along the boring log.
j) Show types of field and laboratory tests with symbols as indicated in the legend, at relevant elevations along the right side of the boring log.
k) Show the Profile scales (horizontal and vertical) under the heading "PROFILE".

5.2.3.5 Additional information to be included

a) Show standard note identifying the logging practice as follows:

"This LOTB sheet was prepared in accordance with the Caltrans Soil & Rock Logging, Classification, and Presentation Manual"

When a LOTB presents information that deviates from the Caltrans Soil & Rock Logging, Classification, and Presentation Manual standards, the standard note shall be modified to read as follows:

"*This LOTB sheet was prepared in accordance with the Caltrans Soil & Rock Logging, Classification, and Presentation Manual except as noted in (section) of (Report Title) dated (Date)"*

b) Descriptions of types of samplers used for the field exploration.

5.2.4 As-Built LOTB Sheet Formatting

As-Built LOTB sheet(s) shall be prepared according to the following standards.

5.2.4.1 Obtaining and Reproducing the As-Built LOTB Sheet

a) Reproducible copies of As-Built LOTB sheets may be obtained from the Microfilm Services Units in the Caltrans District Offices. If the As-Built LOTB sheets provided to Local Agencies or consultants by the Caltrans District Offices are not legible, a full sized copy should be requested from Geotechnical Services.
b) As-Built LOTB sheets shall be size "D" (24" by 36"). The As-Built LOTB title block shall be sized to fit and placed over any open space (preferably toward the top) on the As-Built LOTB sheet.
c) Information on the As-Built LOTB sheet shall be clear and legible. In order to improve the legibility of the information, it may be necessary to darken the line work and the notations.

5.2.4.2 Typical Modifications to As-Built LOTB Sheets

a) If As-Built LOTB sheets are shown in metric units, the offset and stationing location of each boring must be converted to imperial units. A table shall be added showing the dual dimensions (Metric and English) of each boring. The table shall show the station and offset in relation to the new English line. The General Plan will show the current English control line.

5.2.4.3 The As-Built LOTB Title Block shall include the following information for the current project

a) A note stating "GEOTECHNICAL SERVICES -- DIVISION OF ENGINEERING SERVICES" (if applicable).
b) Caltrans District, County, Route, Post Miles - Total Project, State-assigned Bridge (or Structure) Number and Name, and Expenditure Authorization (CU and EA)

numbers. The Office Engineer will provide the Sheet Number and Total Sheets Number.

c) The State of California Registered Civil Engineer or Registered Geologist seal with the signature, date, license number, and registration certificate expiration date of the engineer or geologist in responsible charge of the LOTB sheet.

d) A note stating, "As-Built Log of Test Borings sheet is considered an informational document only. As such, the State of California registration seal with signature, license number and registration certificate expiration date confirm that this is a true and accurate copy of the original document. It does not attest to the accuracy or validity of the information contained in the original document. This drawing is available and presented only for the convenience of any bidder, contractor or other interested party."

e) A sub-box stating "LOG OF TEST BORINGS _ OF _" (if applicable).

e) A note stating "A COPY OF THIS LOG OF TEST BORINGS IS AVAILABLE AT OFFICE OF STRUCTURE MAINTENANCE AND INVESTIGATIONS, SACRAMENTO, CALIFORNIA" (if applicable).

5.2.5 The LOTB Legend Sheets

The soil and rock legend sheets are standard forms that provide convenient references for the *required* soil and rock description, identification, and/or classification components presented in this Manual. References for *optional* descriptors do not appear on the legend sheets; however, they are explained in this Manual. To correctly interpret the LOTB, the reader shall be familiar with this Manual.

There are two legend sheets, one predominantly for soil and the other for rock, as shown in the Figures 5-2 and 5-3.

The legend sheets define the format for the graphical presentation of a boring log and differentiate among the various borehole and sounding types. The legend sheets also present the symbols used to identify laboratory tests.

GEOTECHNICAL SERVICES – DIVISION OF ENGINEERING SERVICES

As-Built Log of Test Borings sheet is considered an informational document only. As such, the State of California registration seal with signature, license number and registration certificate expiration date confirm that is this a true and accurate copy of the original document. It does not attest to the accuracy or validity of the information contained in the original document. This drawing is available and presented only for the convenience of any bidder, contractor or other interested party.

DIST.	COUNTY	ROUTE	POST MILES – TOTAL PROJECT	SHEET NO.	TOTAL SHEETS
08	SBD	210	10.00-15.00	24	25

REGISTERED ENGINEER – CIVIL DATE

MAIN STREET OVERCROSSING

LOG OF TEST BORINGS 5 OF 6

NOTE: A COPY OF THIS LOG OF TEST BORINGS IS AVAILABLE AT OFFICE OF STRUCTURE MAINTENANCE AND INVESTIGATIONS, SACRAMENTO, CALIFORNIA	CU: 12 EA: 432563	BRIDGE NO. 12-3456

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Figure 5-2

REFERENCE: CALTRANS SOIL & ROCK LOGGING, CLASSIFICATION, AND PRESENTATION MANUAL (JUNE, 2007)

DIST	COUNTY	ROUTE	KILOMETER POST TOTAL PROJECT	SHEET No	TOTAL SHEETS

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 electronic copies of this plan sheet.

GROUP SYMBOLS AND NAMES

Graphic/Symbol	Group Names	Graphic/Symbol	Group Names
GW	Well-graded GRAVEL Well-graded GRAVEL with SAND	CL	Lean CLAY Lean CLAY with SAND Lean CLAY with GRAVEL SANDY lean CLAY SANDY lean CLAY with GRAVEL GRAVELLY lean CLAY GRAVELLY lean CLAY with SAND
GP	Poorly graded GRAVEL Poorly graded GRAVEL with SAND		
GW-GM	Well-graded GRAVEL with SILT Well-graded GRAVEL with SILT and SAND	CL-ML	SILTY CLAY SILTY CLAY with SAND SILTY CLAY with GRAVEL SANDY SILTY CLAY SANDY SILTY CLAY with GRAVEL GRAVELLY SILTY CLAY GRAVELLY SILTY CLAY with SAND
GW-GC	Well-graded GRAVEL with CLAY (or SILTY CLAY) Well-graded GRAVEL with CLAY and SAND (or SILTY CLAY and SAND)		
GP-GM	Poorly graded GRAVEL with SILT Poorly graded GRAVEL with SILT and SAND	ML	SILT SILT with SAND SILT with GRAVEL SANDY SILT SANDY SILT with GRAVEL GRAVELLY SILT GRAVELLY SILT with SAND
GP-GC	Poorly graded GRAVEL with CLAY (or SILTY CLAY) Poorly graded GRAVEL with CLAY and SAND (or SILTY CLAY and SAND)		
GM	SILTY GRAVEL SILTY GRAVEL with SAND	OL	ORGANIC lean CLAY ORGANIC lean CLAY with SAND ORGANIC lean CLAY with GRAVEL SANDY ORGANIC lean CLAY SANDY ORGANIC lean CLAY with GRAVEL GRAVELLY ORGANIC lean CLAY GRAVELLY ORGANIC lean CLAY with SAND
GC	CLAYEY GRAVEL CLAYEY GRAVEL with SAND		
GC-GM	SILTY, CLAYEY GRAVEL SILTY, CLAYEY GRAVEL with SAND	OL	ORGANIC SILT ORGANIC SILT with SAND ORGANIC SILT with GRAVEL SANDY ORGANIC SILT SANDY ORGANIC SILT with GRAVEL GRAVELLY ORGANIC SILT GRAVELLY ORGANIC SILT with SAND
SW	Well-graded SAND Well-graded SAND with GRAVEL		
SP	Poorly graded SAND Poorly graded SAND with GRAVEL	CH	Fat CLAY Fat CLAY with SAND Fat CLAY with GRAVEL SANDY fat CLAY SANDY fat CLAY with GRAVEL GRAVELLY fat CLAY GRAVELLY fat CLAY with SAND
SW-SM	Well-graded SAND with SILT Well-graded SAND with SILT and GRAVEL		
SW-SC	Well-graded SAND with CLAY (or SILTY CLAY) Well-graded SAND with CLAY and GRAVEL (or SILTY CLAY and GRAVEL)	MH	Elastic SILT Elastic SILT with SAND Elastic SILT with GRAVEL SANDY elastic SILT SANDY elastic SILT with GRAVEL GRAVELLY elastic SILT GRAVELLY elastic SILT with SAND
SP-SM	Poorly graded SAND with SILT Poorly graded SAND with SILT and GRAVEL		
SP-SC	Poorly graded SAND with CLAY (or SILTY CLAY) Poorly graded SAND with CLAY and GRAVEL (or SILTY CLAY and GRAVEL)	OH	ORGANIC fat CLAY ORGANIC fat CLAY with SAND ORGANIC fat CLAY with GRAVEL SANDY ORGANIC fat CLAY SANDY ORGANIC fat CLAY with GRAVEL GRAVELLY ORGANIC fat CLAY GRAVELLY ORGANIC fat CLAY with SAND
SM	SILTY SAND SILTY SAND with GRAVEL		
SC	CLAYEY SAND CLAYEY SAND with GRAVEL	OH	ORGANIC elastic SILT ORGANIC elastic SILT with SAND ORGANIC elastic SILT with GRAVEL SANDY ORGANIC elastic SILT SANDY ORGANIC elastic SILT with GRAVEL GRAVELLY ORGANIC elastic SILT GRAVELLY ORGANIC elastic SILT with SAND
SC-SM	SILTY, CLAYEY SAND SILTY, CLAYEY SAND with GRAVEL		
PT	PEAT	OL/OH	ORGANIC SOIL ORGANIC SOIL with SAND ORGANIC SOIL with GRAVEL SANDY ORGANIC SOIL SANDY ORGANIC SOIL with GRAVEL GRAVELLY ORGANIC SOIL GRAVELLY ORGANIC SOIL with SAND
	COBBLES COBBLES and BOULDERS BOULDERS		

FIELD AND LABORATORY TESTING

- (C) Consolidation (ASTM D 2435-04)
- (CL) Collapse Potential (ASTM D 5333-03)
- (CP) Compaction Curve (CTM 216-06)
- (CR) Corrosivity Testing (CTM 643, CTM 422, CTM 417)
- (CU) Consolidated Undrained Triaxial (ASTM D 4767-02)
- (DS) Direct Shear (ASTM D 3080-04)
- (EI) Expansion Index (ASTM D 4829-03)
- (M) Moisture Content (ASTM D 2216-05)
- (OC) Organic Content-% (ASTM D 2974-07)
- (P) Permeability (CTM 220-05)
- (PA) Particle Size Analysis (ASTM D 422-63) (2002)
- (PI) Plasticity Index (AASHTO T 90-00) Liquid Limit (AASHTO T 89-02)
- (PL) Point Load Index (ASTM D 5731-05)
- (PM) Pressure Meter
- (PP) Pocket Penetrometer
- (R) R-Value (CTM 301-00)
- (SE) Sand Equivalent (CTM 217-99)
- (SG) Specific Gravity (AASHTO T 100-06)
- (SL) Shrinkage Limit (ASTM D 427-04)
- (SW) Swell Potential (ASTM D 4546-03)
- (TV) Pocket Torvane
- (UC) Unconfined Compression-Soil (ASTM D 2166-06) Unconfined Compression-Rock (ASTM D 2938-95) (2002)
- (UU) Unconsolidated Undrained Triaxial (ASTM D 2850-03)
- (UW) Unit Weight (ASTM D 4767-04)
- (VS) Vane Shear (AASHTO T 223-96) (2004)

APPARENT DENSITY OF COHESIONLESS SOILS

Description	SPT N_{60}-Value (Blows / 12 in.)
Very loose	0 - 4
Loose	5 - 10
Medium Dense	11 - 30
Dense	31 - 50
Very Dense	> 50

MOISTURE

Description	Criteria
Dry	Absence of moisture, dusty, dry to the touch
Moist	Damp but no visible water
Wet	Visible free water, usually soil is below water table

PERCENT OR PROPORTION OF SOILS

Description	Criteria
Trace	Particles are present but estimated to be less than 5%
Few	5 to 10%
Little	15 to 25%
Some	30 to 45%
Mostly	50 to 100%

PARTICLE SIZE

Description		Size
Boulder		> 12 in.
Cobble		3 to 12 in.
Gravel	Coarse	3/4 to 3 in.
	Fine	No. 4 to 3/4 in.
Sand	Coarse	No. 10 to No. 4
	Medium	No. 40 to No. 10
	Fine	No. 200 to No. 40

CEMENTATION

Description	Criteria
Weak	Crumbles or breaks with handling or little finger pressure.
Moderate	Crumbles or breaks with considerable finger pressure.
Strong	Will not crumble or break with finger pressure.

CONSISTENCY OF COHESIVE SOILS

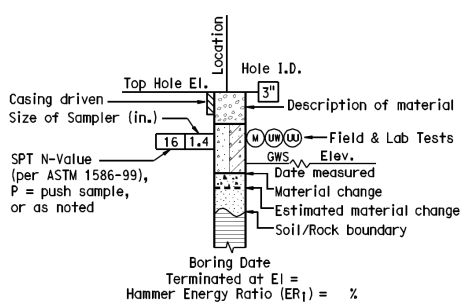
Description	Unconfined Compressive Strength (tsf)	Pocket Penetrometer Measurement (tsf)	Torvane Measurement (tsf)	Field Approximation
Very Soft	< 0.25	< 0.25	< 0.12	Easily penetrated several inches by fist
Soft	0.25 to 0.50	0.25 to 0.50	0.12 to 0.25	Easily penetrated several inches by thumb
Medium Stiff	0.50 to 1.0	0.50 to 1.0	0.25 to 0.50	Penetrated several inches by thumb with moderate effort
Stiff	1 to 2	1 to 2	0.50 to 1.0	Readily indented by thumb but penetrated only with great effort
Very Stiff	2 to 4	2 to 4	1.0 to 2.0	Readily indented by thumbnail
Hard	> 4.0	> 4.0	> 2.0	Indented by thumbnail with difficulty

PLASTICITY OF FINE-GRAINED SOILS

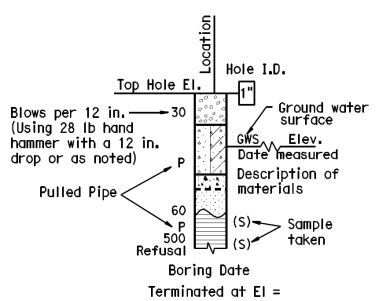
Description	Criteria
Nonplastic	A 1/8-in. thread cannot be rolled at any water content.
Low	The thread can barely be rolled and the lump cannot be formed when drier than the plastic limit.
Medium	The thread is easy to roll and not much time is required to reach the plastic limit. The thread cannot be rerolled after reaching the plastic limit. The lump crumbles when drier than the plastic limit.
High	It takes considerable time rolling and kneading to reach the plastic limit. The thread can be rerolled several times after reaching the plastic limit. The lump can be formed without crumbling when drier than the plastic limit.

BOREHOLE IDENTIFICATION

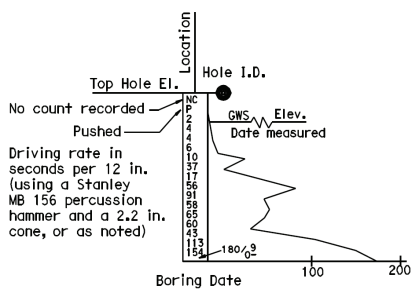
Symbol	Hole Type	Description
Size	A	Auger Boring
Size	R P	Rotary drilled boring Rotary percussion boring (air)
Size	R	Rotary drilled diamond core
Size	HD HA	Hand driven (1-inch soil tube) Hand Auger
●	D	Dynamic Cone Penetration Boring
▲	CPT	Cone Penetration Test (ASTM D 5778-95)
	O	Other



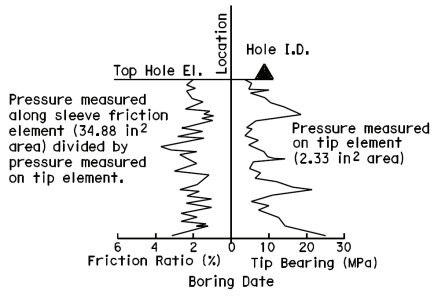
ROTARY BORING



HAND BORING



DYNAMIC CONE PENETRATION BORING



CONE PENETRATION TEST (CPT) SOUNDING

ENGINEERING SERVICES	GEOTECHNICAL SERVICES	STATE OF CALIFORNIA DEPARTMENT OF TRANSPORTATION	DIVISION OF ENGINEERING SERVICES STRUCTURE DESIGN	BRIDGE NO.	SOIL LEGEND
PREPARED BY			DESIGN BRANCH	POST MILE	LOG OF TEST BORINGS
CHECKED BY					
GS LOTB SOIL LEGEND	ORIGINAL SCALE IN INCHES FOR REDUCED PLANS 0 1 2 3	CU EA	DISREGARD PRINTS BEARING EARLIER REVISION DATES →	REVISION DATES	SHEET OF

Figure 5-3

DIST	COUNTY	ROUTE	KILOMETER POST TOTAL PROJECT	SHEET No	TOTAL SHEETS

REGISTERED CIVIL ENGINEER _____ DATE _____

PLANS APPROVAL DATE _____

REGISTERED PROFESSIONAL ENGINEER — No. — Exp. — CIVIL — STATE OF CALIFORNIA

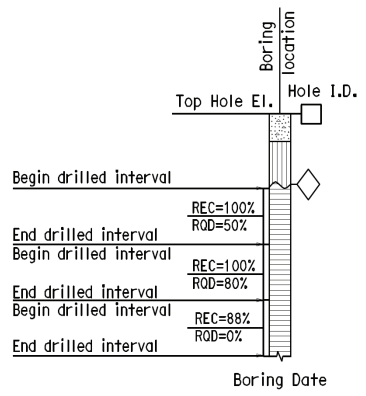
The State of California or its officers or agents shall not be responsible for the accuracy or completeness of electronic copies of this plan sheet.

REFERENCE: CALTRANS SOIL & ROCK LOGGING, CLASSIFICATION, AND PRESENTATION MANUAL (JUNE, 2007)

PERCENT CORE RECOVERY (REC) & ROCK QUALITY DESIGNATION (RQD)

$$REC = \frac{\sum \text{Length of the recovered core pieces (in.)}}{\text{Total length of core run (in.)}} \times 100\%$$

$$RQD = \frac{\sum \text{Length of intact core pieces} \geq 4 \text{ in.}}{\text{Total length of core run (in.)}} \times 100\%$$



RELATIVE STRENGTH OF INTACT ROCK

Term	Uniaxial Compressive Strength (PSI)
Extremely Strong	> 30,000
Very Strong	14,500 - 30,000
Strong	7,000 - 14,500
Medium Strong	3,500 - 7,000
Weak	700 - 3,500
Very Weak	150 - 700
Extremely Weak	< 150

BEDDING SPACING

Description	Thickness / Spacing
Massive	Greater than 10 ft
Very thickly bedded	3 to 10 ft
Thickly bedded	1 to 3 ft
Moderately bedded	4 in. to 1 ft
Thinly bedded	1 in. to 4 in.
Very thinly bedded	3/8 in. to 1 in.
Laminated	Less than 3/8 in.

LEGEND OF ROCK MATERIALS

- IGNEOUS ROCK
- SEDIMENTARY ROCK
- METAMORPHIC ROCK

ROCK HARDNESS

Description	Criteria
Extremely Hard	Specimen cannot be scratched with a pocket knife; no steel marks left on surface.
Very Hard	Specimen cannot be scratched with a pocket knife; steel marks left on surface.
Hard	Specimen can be scratched with a pocket knife with difficulty (heavy pressure).
Moderately Hard	Specimen can be scratched with pocket knife with light or moderate pressure.
Moderately Soft	Specimen can be grooved 1/6 in. deep with a pocket knife with moderate or heavy pressure.
Soft	Specimen can be grooved or gouged easily by a pocket knife with light pressure, can be scratched with fingernail.
Very Soft	Specimen can be readily indented, grooved or gouged with fingernail, or carved with a pocket knife.

FRACTURE DENSITY

Description	Observed Fracture Density
Unfractured	No fractures.
Very slightly fractured	Lengths greater than 3 feet.
Slightly fractured	Lengths from 1 to 3 feet with few lengths less than 1 foot or greater than 3 feet.
Moderately fractured	Lengths mostly in 4 in. to 1 foot range with most lengths about 8 in.
Intensely fractured	Lengths average from 1 to 4 in. with scattered fragmented intervals with lengths less than 4 in.
Very intensely fractured	Mostly chips and fragments with a few scattered short core lengths.

Combination descriptors (such as "Very intensely to intensely fractured") are used where equal distribution of both fracture density characteristics is present over a significant interval or exposure, or where characteristics are "in between" the descriptor definitions. Only two adjacent descriptors may be combined.

WEATHERING DESCRIPTORS FOR INTACT ROCK

Description	Diagnostic features: Chemical Weathering-Discoloration and/or oxidation — Body of Rock	Diagnostic features: Chemical Weathering-Discoloration and/or oxidation — Fracture Surfaces	Diagnostic features: Mechanical Weathering-Grain boundary conditions (disaggregation) primarily for granitics and some coarse-grained sediments	Diagnostic features: Texture and Solutioning — Texture	Diagnostic features: Texture and Solutioning — Solutioning	General Characteristics
Fresh	No discoloration, not oxidized.	No discoloration or oxidation.	No separation, intact (tight).	No change.	No solutioning.	Hammer rings when crystalline rocks are struck.
Slightly Weathered	Discoloration or oxidation is limited to surface of, or short distance from, fractures; some feldspar crystals are dull.	Minor to complete discoloration or oxidation of most surfaces.	No visible separation, intact (tight).	Preserved.	Minor leaching of some soluble minerals may be noted.	Hammer rings when crystalline rocks are struck. Body of rock not weakened.
Moderately Weathered	Discoloration or oxidation extends from fractures usually throughout; Fe-Mg minerals are "rusty," feldspar crystals are "cloudy."	All fracture surfaces are discolored or oxidized.	Partial separation of boundaries visible.	Generally preserved.	Soluble minerals may be mostly leached.	Hammer does not ring when rock is struck. Body of rock is slightly weakened.
Intensely Weathered	Discoloration or oxidation throughout; all feldspars and Fe-Mg minerals are altered to clay to some extent; or chemical alteration produces in-situ disaggregation, see grain boundary conditions.	All fracture surfaces are discolored or oxidized, surfaces friable.	Partial separation, rock is friable; in semiarid conditions granitics are disaggregated.	Texture altered by chemical disintegration (hydration, argillation).	Leaching of soluble minerals may be complete.	Dull sound when struck with hammer, usually can be broken with moderate to heavy manual pressure or by light hammer blow without reference to planes of weakness such as incipient or hairline fractures, or veinlets. Rock is significantly weakened.
Decomposed	Discolored or oxidized throughout, but resistant minerals such as quartz may be unaltered; all feldspars and Fe-Mg minerals are completely altered to clay.		Complete separation of grain boundaries (disaggregated).	Resembles a soil, partial or complete remnant rock structure may be preserved; leaching of soluble minerals usually complete.		Can be granulated by hand. Resistant minerals such as quartz may be present as "stringers" or "dikes."

Combination descriptors (such as "slightly weathered to fresh") are used where equal distribution of both weathering characteristics is present over significant intervals or where characteristics present are "in between" the diagnostic feature. However, combination descriptors should not be used where significant, identifiable zones can be delineated. Only two adjacent descriptors may be combined. "Very intensely weathered" is the combination descriptor for "intensely weathered to decomposed."

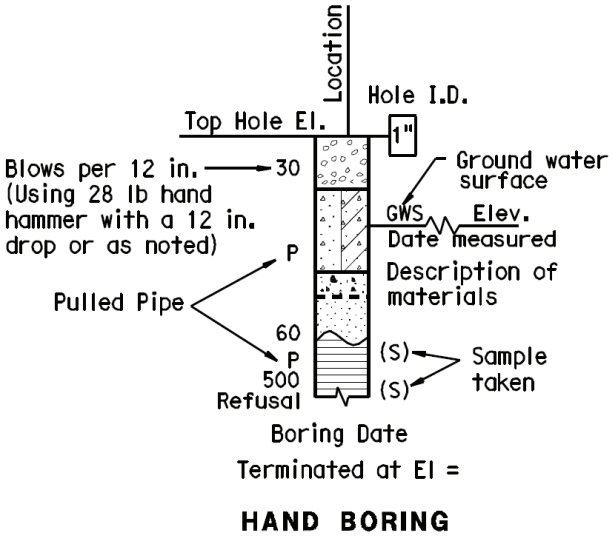
ENGINEERING SERVICES	GEOTECHNICAL SERVICES	STATE OF CALIFORNIA DEPARTMENT OF TRANSPORTATION	DIVISION OF ENGINEERING SERVICES STRUCTURE DESIGN	BRIDGE NO.	ROCK LEGEND
PREPARED BY			DESIGN BRANCH	POST MILE	LOG OF TEST BORINGS
CHECKED BY					
GS LOTB ROCK LEGEND	ORIGINAL SCALE IN INCHES FOR REDUCED PLANS 0 1 2 3	CU EA	DISREGARD PRINTS BEARING EARLIER REVISION DATES →	REVISION DATES	SHEET OF

Four general hole-type formats are graphically presented as follows:

5.2.5.1 Hand Boring

Hand Driven (HD) (1-inch soil tube) and Hand Auger (HA) borings shall be presented using the following format:

Figure 5-4

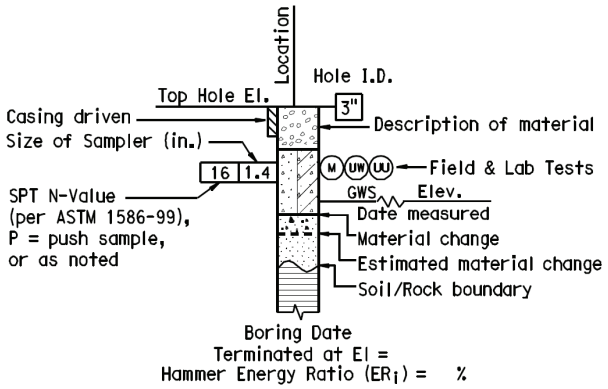


HAND BORING

5.2.5.2 Rotary Boring

Rotary Drilled Boring or Diamond Core (R), Rotary Percussion Boring (Air) (P), Auger Boring (A), shall be presented using the following format:

Figure 5-5



ROTARY BORING

Notes:

If laboratory tests are not shown as being performed, the soil descriptions presented in the LOTB are based solely on the visual practices described in this Manual.

Changes in material with depth shall be noted using the following terms:

Figure 5-6

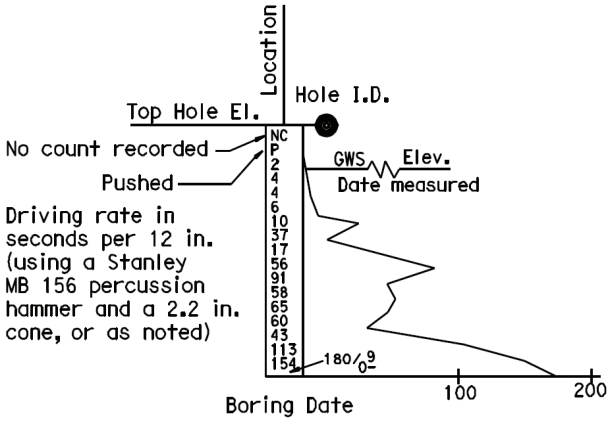
Definitions for changes in material

Term	Definition
Material Change	Change in material is observed in the sample or core, and the location of change can be accurately measured.
Estimated Material Change	Change in material cannot be accurately located because either the change is gradational or because of limitations in the drilling/sampling methods used.
Soil/Rock Boundary	Material changes from soil characteristics to rock characteristics and that change can be measured or estimated.

5.2.5.3 Dynamic Cone Penetration Sounding

The Dynamic Cone Penetration Sounding (D) shall be presented using the following format:

Figure 5-7

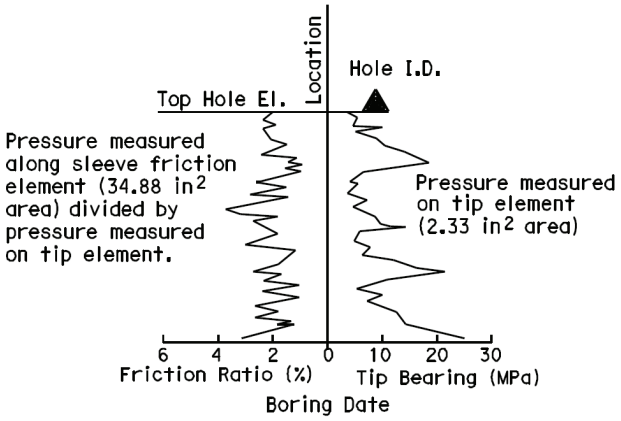


DYNAMIC CONE PENETRATION BORING

5.2.5.4 Cone Penetration Test (CPT) Sounding

A Cone Penetration Test (CPT) sounding shall be presented using the following format:

Figure 5-8

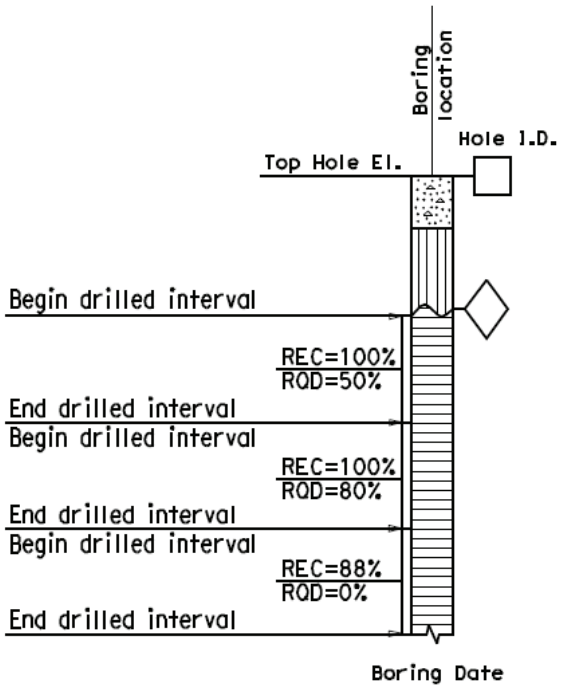


CONE PENETRATION TEST (CPT) SOUNDING

5.2.5.5 Rock Coring

Rock coring logs shall be presented using the following format:

Figure 5-9



5.2.5.6 Hole Type Symbols

Hole type is identified within the hole identification numbering convention (see Section 2.3) and symbolized on the LOTB as follows:

Figure 5-10

BOREHOLE IDENTIFICATION

Symbol	Hole Type	Description
Size	A	Auger Boring
Size	R P	Rotary drilled boring Rotary percussion boring (air)
Size	R	Rotary drilled diamond core
Size	HD HA	Hand driven (1-inch soil tube) Hand Auger
●	D	Dynamic Cone Penetration Boring
▲	CPT	Cone Penetration Test (ASTM D 5778-95)
⬚	O	Other

5.2.5.7 Graphical Representation of Material Types

Soil Group Name and Group Symbol and Rock Type are symbolized on the LOTB as follows:

Figure 5-11

GROUP SYMBOLS AND NAMES

Graphic / Symbol	Group Names	Graphic / Symbol	Group Names
GW	Well-graded GRAVEL Well-graded GRAVEL with SAND	CL	Lean CLAY Lean CLAY with SAND Lean CLAY with GRAVEL SANDY lean CLAY SANDY lean CLAY with GRAVEL GRAVELLY lean CLAY GRAVELLY lean CLAY with SAND
GP	Poorly graded GRAVEL Poorly graded GRAVEL with SAND		
GW-GM	Well-graded GRAVEL with SILT Well-graded GRAVEL with SILT and SAND	CL-ML	SILTY CLAY SILTY CLAY with SAND SILTY CLAY with GRAVEL SANDY SILTY CLAY SANDY SILTY CLAY with GRAVEL GRAVELLY SILTY CLAY GRAVELLY SILTY CLAY with SAND
GW-GC	Well-graded GRAVEL with CLAY (or SILTY CLAY) Well-graded GRAVEL with CLAY and SAND (or SILTY CLAY and SAND)		
GP-GM	Poorly graded GRAVEL with SILT Poorly graded GRAVEL with SILT and SAND	ML	SILT SILT with SAND SILT with GRAVEL SANDY SILT SANDY SILT with GRAVEL GRAVELLY SILT GRAVELLY SILT with SAND
GP-GC	Poorly graded GRAVEL with CLAY (or SILTY CLAY) Poorly graded GRAVEL with CLAY and SAND (or SILTY CLAY and SAND)		
GM	SILTY GRAVEL SILTY GRAVEL with SAND	OL	ORGANIC lean CLAY ORGANIC lean CLAY with SAND ORGANIC lean CLAY with GRAVEL SANDY ORGANIC lean CLAY SANDY ORGANIC lean CLAY with GRAVEL GRAVELLY ORGANIC lean CLAY GRAVELLY ORGANIC lean CLAY with SAND
GC	CLAYEY GRAVEL CLAYEY GRAVEL with SAND		
GC-GM	SILTY, CLAYEY GRAVEL SILTY, CLAYEY GRAVEL with SAND	OL	ORGANIC SILT ORGANIC SILT with SAND ORGANIC SILT with GRAVEL SANDY ORGANIC SILT SANDY ORGANIC SILT with GRAVEL GRAVELLY ORGANIC SILT GRAVELLY ORGANIC SILT with SAND
SW	Well-graded SAND Well-graded SAND with GRAVEL		
SP	Poorly graded SAND Poorly graded SAND with GRAVEL	CH	Fat CLAY Fat CLAY with SAND Fat CLAY with GRAVEL SANDY fat CLAY SANDY fat CLAY with GRAVEL GRAVELLY fat CLAY GRAVELLY fat CLAY with SAND
SW-SM	Well-graded SAND with SILT Well-graded SAND with SILT and GRAVEL		
SW-SC	Well-graded SAND with CLAY (or SILTY CLAY) Well-graded SAND with CLAY and GRAVEL (or SILTY CLAY and GRAVEL)	MH	Elastic SILT Elastic SILT with SAND Elastic SILT with GRAVEL SANDY elastic SILT SANDY elastic SILT with GRAVEL GRAVELLY elastic SILT GRAVELLY elastic SILT with SAND
SP-SM	Poorly graded SAND with SILT Poorly graded SAND with SILT and GRAVEL		
SP-SC	Poorly graded SAND with CLAY (or SILTY CLAY) Poorly graded SAND with CLAY and GRAVEL (or SILTY CLAY and GRAVEL)	OH	ORGANIC fat CLAY ORGANIC fat CLAY with SAND ORGANIC fat CLAY with GRAVEL SANDY ORGANIC fat CLAY SANDY ORGANIC fat CLAY with GRAVEL GRAVELLY ORGANIC fat CLAY GRAVELLY ORGANIC fat CLAY with SAND
SM	SILTY SAND SILTY SAND with GRAVEL		
SC	CLAYEY SAND CLAYEY SAND with GRAVEL	OH	ORGANIC elastic SILT ORGANIC elastic SILT with SAND ORGANIC elastic SILT with GRAVEL SANDY elastic ELASTIC SILT SANDY ORGANIC elastic SILT with GRAVEL GRAVELLY ORGANIC elastic SILT GRAVELLY ORGANIC elastic SILT with SAND
SC-SM	SILTY, CLAYEY SAND SILTY, CLAYEY SAND with GRAVEL		
PT	PEAT	OL/OH	ORGANIC SOIL ORGANIC SOIL with SAND ORGANIC SOIL with GRAVEL SANDY ORGANIC SOIL SANDY ORGANIC SOIL with GRAVEL GRAVELLY ORGANIC SOIL GRAVELLY ORGANIC SOIL with SAND
	COBBLES COBBLES and BOULDERS BOULDERS		

ROCK GRAPHIC SYMBOLS

IGNEOUS ROCK

SEDIMENTARY ROCK

METAMORPHIC ROCK

5.3 Boring Records

Figure 5-12

LOGGED BY	BEGIN DATE	COMPLETION DATE	BOREHOLE LOCATION (Lat/Long or North/East and Datum)	HOLE ID
Sue Pervisor	1-1-07	1-2-07	34° 0' 24.62" / -117° 7' 62.55" WGS 84	R-07-001
DRILLING CONTRACTOR			BOREHOLE LOCATION (Station, Offset, Line)	SURFACE ELEVATION
Gregg Drilling & Testing, Inc.			Offset 24R C/L Rte 36	20.7 ft NAVD 88
DRILLING METHOD			DRILL RIG	BOREHOLE DIAMETER
Rotary Wash			CS 2000 (track)	8.5 in. (soil); 4 in. (rock)
SAMPLER TYPE(S) AND SIZE(S) (ID)			SPT HAMMER TYPE	HAMMER EFFICIENCY, ERi
SPT (1.4"), Shelby (2.87"), HQ core			Safety semi-automatic, 140 lb, 30-inch drop	90%
BOREHOLE BACKFILL AND COMPLETION			GROUNDWATER READINGS DURING DRILLING / AFTER DRILLING (DATE)	TOTAL DEPTH OF BORING
Neat cement grout backfill			12 ft / 21 ft on 1-4-07	39.0 ft

ELEVATION (ft)	DEPTH (ft)	DESCRIPTION	Sample Location	Sample Number	Blows per 6 in.	Blows per Foot	Recovery (%)	RQD (%)	Moisture Content (%)	Dry Unit Weight (pcf)	Shear Strength (tsf)	Drilling Method / Casing Depth	Remarks
	0	Well-graded SAND with GRAVEL and COBBLES (SW); loose; yellowish brown; moist; about 10% subrounded COBBLES; about 15% fine to coarse GRAVEL; about 80% fine to coarse SAND; about 5% fines [FILL].											
18.72	2												
	3			S01	2 2 2	4	94						
16.72	4												
	5												
14.72	6												
	7												
12.72	8												
	9	At 8.5 ft, becomes medium dense.		S02	4 6 6	12	100		5	105			PA
10.72	10												
	11	SANDY lean CLAY (CL); medium stiff; dark bluish gray; moist; about 35% medium SAND; about 65% fines; trace shell fragments [BAY MUD].											
8.72	12												
	13												
6.72	14			U03		0.25	100		22	100	PP = 0.55 TV = 0.25		
	15												
4.72	16												
	17												
2.72	18												
	19	At 18.5 ft, with no shell fragments.		U04			100		20	100	PP = 0.45 UU = 0.50		PA, PI
0.72	20												
	21												
-1.28	22												
	23												
-3.28	24	At 23.5 ft, becomes stiff; dark gray.		U05			100		20	101	PP = 0.45 UU = 0.60		PA, PI
	25												

(continued)

Department of Transportation
Division of Engineering Services
Geotechnical Services
Office of Geotechnical Design - North

REPORT TITLE				HOLE ID
BORING RECORD				R-07-001
DIST.	COUNTY	ROUTE	POSTMILE	EA
12	Orange	I-405	R34.1/R39.2	12-047643
PROJECT OR BRIDGE NAME				
I-880 Realignment, Whitman Dr., O. C.				
BRIDGE NUMBER	PREPARED BY		DATE	SHEET
53-0045	Sue Pervisor		5-25-07	1 of 2

Figure 5-12 (continued)

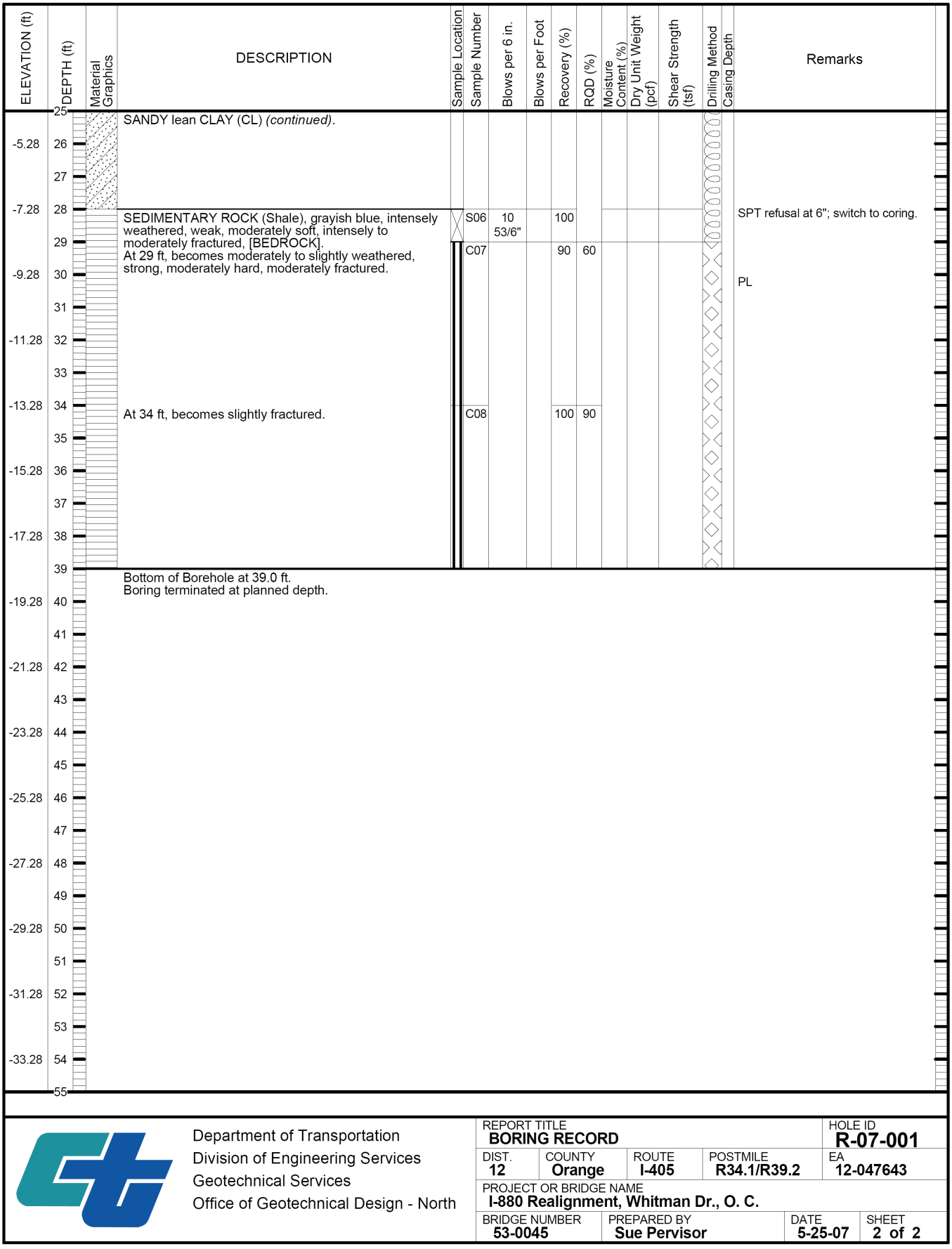
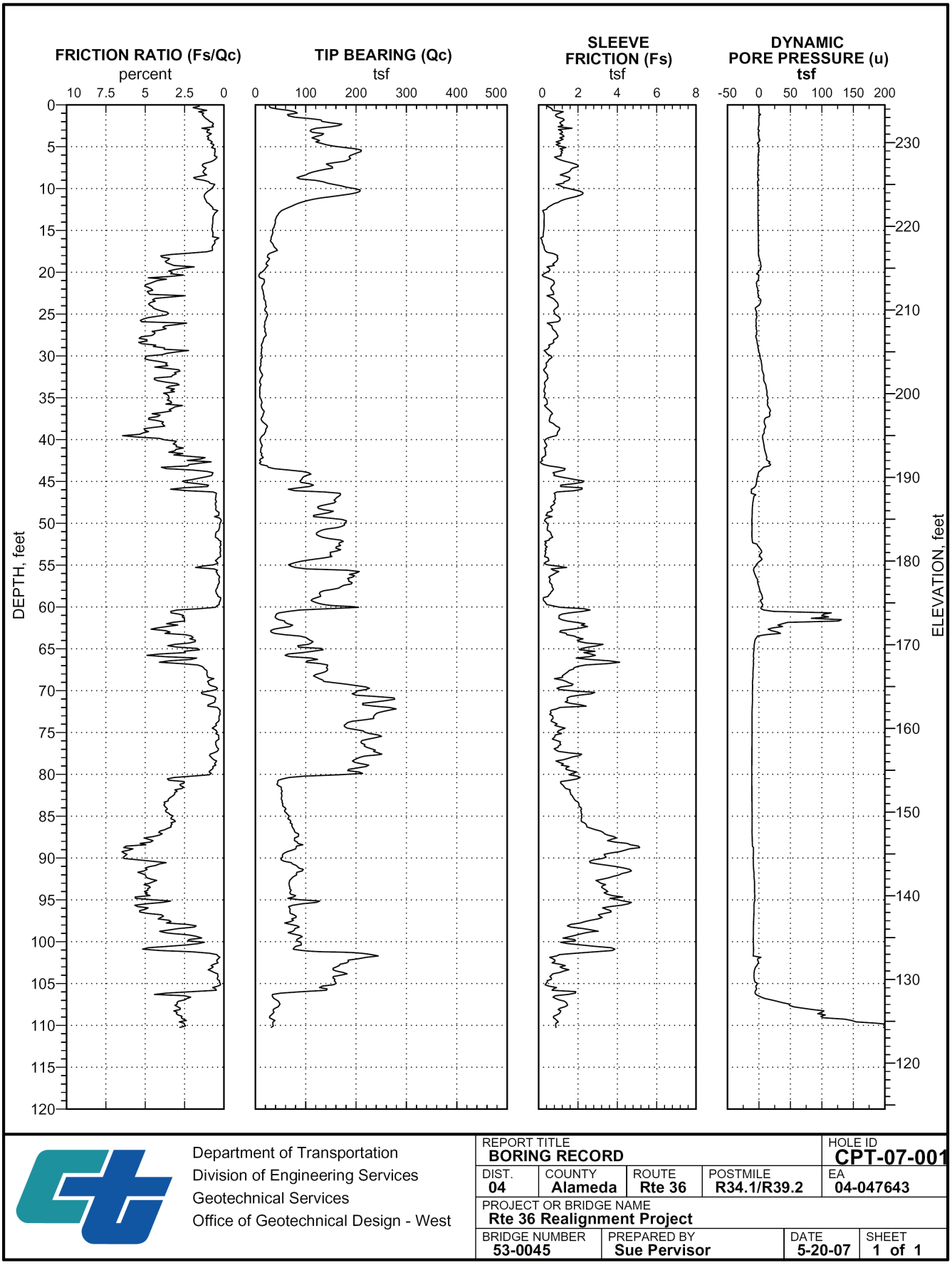


Figure 5-13


FRICTION RATIO (Fs/Qc)
percent
10 7.5 5 2.5 0
TIP BEARING (Qc)
tsf
0 100 200 300 400 500
SLEEVE FRICTION (Fs)
tsf
0 2 4 6 8
DYNAMIC PORE PRESSURE (u)
tsf
-50 0 50 100 150 200
DEPTH, feet
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 105 110 115 120
ELEVATION, feet
230 220 210 200 190 180 170 160 150 140 130 120
Department of Transportation
Division of Engineering Services
Geotechnical Services
Office of Geotechnical Design - West
REPORT TITLE
BORING RECORD
HOLE ID
CPT-07-001
DIST. 04
COUNTY Alameda
ROUTE Rte 36
POSTMILE R34.1/R39.2
EA 04-047643
PROJECT OR BRIDGE NAME
Rte 36 Realignment Project
BRIDGE NUMBER 53-0045
PREPARED BY Sue Pervisor
DATE 5-20-07
SHEET 1 of 1
CALTRANS CPT RECORD 052007 CTSACTO TEST 053107.GPJ CT SACTO 053107.GDT 6/12/07

5.3.1 Content and Characteristics of the BR

A Boring Record (BR) document is presented as an attachment to a geotechnical report and is characterized by the following attributes:

- Presents a single borehole record or CPT sounding.
- Presents the borings to an elevation scale.
- Presents the type of drilling method used to perform the investigation, the type of sampling performed, and how the sampler was advanced.
- Presents the location and description, both graphical and written, of the types of soil and rock encountered within the borehole.
- Accommodates the presentation of select field and laboratory test results.
- Optimized for printing on 8.5" x 11" sheets
- Is accompanied by BR Legend Sheets.

5.3.2 Notes on the BR

If the procedures of this manual were followed without exception, then the following note shall appear on the first page of the BR:

"This Boring Record was prepared in accordance with the Caltrans Soil & Rock Logging, Classification, and Presentation Manual (Date)"

If an exception to the procedures of this manual has been approved and implemented, then the note shall be modified to read:

"This Boring Record was prepared in accordance with the Caltrans Soil & Rock Logging, Classification, and Presentation Manual (Date) except as noted in (Section) of (Report Title) dated (Date)"

Optional notes are left to the discretion of the geoprofessional and, if are specific to an elevation or depth, should be presented at the appropriate location in the "Remarks" column. These notes may include:

- Changes in drilling equipment
- Other drilling observations from Sections 2.4.22 or 2.5.17.

Notes that are more general in content, such as a site observation, should be placed within the body of the geotechnical report.

5.3.3 The Boring Record Legend Sheets

The soil and rock legend sheets are standard forms that provide convenient references for the *required* soil and rock description, identification, and/or classification components presented in this Manual. References for *optional* descriptors do not appear on the legend sheets; however, they are explained in this Manual. To correctly interpret the BR, the reader shall be familiar with this Manual.

There are three legend sheets: one predominantly for soil and the other for rock, as shown in the following figures.

The legend sheets define the format for the graphical presentation of a boring log and differentiate among the various borehole and sounding types. The legend sheets also present the symbols used to identify laboratory tests.

Figure 5-14

GROUP SYMBOLS AND NAMES

Graphic / Symbol	Group Names
GW	Well-graded GRAVEL Well-graded GRAVEL with SAND
GP	Poorly graded GRAVEL Poorly graded GRAVEL with SAND
GW-GM	Well-graded GRAVEL with SILT Well-graded GRAVEL with SILT and SAND
GW-GC	Well-graded GRAVEL with CLAY (or SILTY CLAY) Well-graded GRAVEL with CLAY and SAND (or SILTY CLAY and SAND)
GP-GM	Poorly graded GRAVEL with SILT Poorly graded GRAVEL with SILT and SAND
GP-GC	Poorly graded GRAVEL with CLAY (or SILTY CLAY) Poorly graded GRAVEL with CLAY and SAND (or SILTY CLAY and SAND)
GM	SILTY GRAVEL SILTY GRAVEL with SAND
GC	CLAYEY GRAVEL CLAYEY GRAVEL with SAND
GC-GM	SILTY, CLAYEY GRAVEL SILTY, CLAYEY GRAVEL with SAND
SW	Well-graded SAND Well-graded SAND with GRAVEL
SP	Poorly graded SAND Poorly graded SAND with GRAVEL
SW-SM	Well-graded SAND with SILT Well-graded SAND with SILT and GRAVEL
SW-SC	Well-graded SAND with CLAY (or SILTY CLAY) Well-graded SAND with CLAY and GRAVEL (or SILTY CLAY and GRAVEL)
SP-SM	Poorly graded SAND with SILT Poorly graded SAND with SILT and GRAVEL
SP-SC	Poorly graded SAND with CLAY (or SILTY CLAY) Poorly graded SAND with CLAY and GRAVEL (or SILTY CLAY and GRAVEL)
SM	SILTY SAND SILTY SAND with GRAVEL
SC	CLAYEY SAND CLAYEY SAND with GRAVEL
SC-SM	SILTY, CLAYEY SAND SILTY, CLAYEY SAND with GRAVEL
PT	PEAT
	COBBLES COBBLES and BOULDERS BOULDERS

Graphic / Symbol	Group Names
CL	Lean CLAY Lean CLAY with SAND Lean CLAY with GRAVEL SANDY lean CLAY SANDY lean CLAY with GRAVEL GRAVELLY lean CLAY GRAVELLY lean CLAY with SAND
CL-ML	SILTY CLAY SILTY CLAY with SAND SILTY CLAY with GRAVEL SANDY SILTY CLAY SANDY SILTY CLAY with GRAVEL GRAVELLY SILTY CLAY GRAVELLY SILTY CLAY with SAND
ML	SILT SILT with SAND SILT with GRAVEL SANDY SILT SANDY SILT with GRAVEL GRAVELLY SILT GRAVELLY SILT with SAND
OL	ORGANIC lean CLAY ORGANIC lean CLAY with SAND ORGANIC lean CLAY with GRAVEL SANDY ORGANIC lean CLAY SANDY ORGANIC lean CLAY with GRAVEL GRAVELLY ORGANIC lean CLAY GRAVELLY ORGANIC lean CLAY with SAND
OL	ORGANIC SILT ORGANIC SILT with SAND ORGANIC SILT with GRAVEL SANDY ORGANIC SILT SANDY ORGANIC SILT with GRAVEL GRAVELLY ORGANIC SILT GRAVELLY ORGANIC SILT with SAND
CH	Fat CLAY Fat CLAY with SAND Fat CLAY with GRAVEL SANDY fat CLAY SANDY fat CLAY with GRAVEL GRAVELLY fat CLAY GRAVELLY fat CLAY with SAND
MH	Elastic SILT Elastic SILT with SAND Elastic SILT with GRAVEL SANDY elastic SILT SANDY elastic SILT with GRAVEL GRAVELLY elastic SILT GRAVELLY elastic SILT with SAND
OH	ORGANIC fat CLAY ORGANIC fat CLAY with SAND ORGANIC fat CLAY with GRAVEL SANDY ORGANIC fat CLAY SANDY ORGANIC fat CLAY with GRAVEL GRAVELLY ORGANIC fat CLAY GRAVELLY ORGANIC fat CLAY with SAND
OH	ORGANIC elastic SILT ORGANIC elastic SILT with SAND ORGANIC elastic SILT with GRAVEL SANDY elastic ELASTIC SILT SANDY ORGANIC elastic SILT with GRAVEL GRAVELLY ORGANIC elastic SILT GRAVELLY ORGANIC elastic SILT with SAND
OL/OH	ORGANIC SOIL ORGANIC SOIL with SAND ORGANIC SOIL with GRAVEL SANDY ORGANIC SOIL SANDY ORGANIC SOIL with GRAVEL GRAVELLY ORGANIC SOIL GRAVELLY ORGANIC SOIL with SAND

FIELD AND LABORATORY TESTS

C	Consolidation (ASTM D 2435-04)
CL	Collapse Potential (ASTM D 5333-03)
CP	Compaction Curve (CTM 216 - 06)
CR	Corrosion, Sulfates, Chlorides (CTM 643 - 99; CTM 417 - 06; CTM 422 - 06)
CU	Consolidated Undrained Triaxial (ASTM D 4767-02)
DS	Direct Shear (ASTM D 3080-04)
EI	Expansion Index (ASTM D 4829-03)
M	Moisture Content (ASTM D 2216-05)
OC	Organic Content (ASTM D 2974-07)
P	Permeability (CTM 220 - 05)
PA	Particle Size Analysis (ASTM D 422-63 [2002])
PI	Liquid Limit, Plastic Limit, Plasticity Index (AASHTO T 89-02, AASHTO T 90-00)
PL	Point Load Index (ASTM D 5731-05)
PM	Pressure Meter
PP	Pocket Penetrometer
R	R-Value (CTM 301 - 00)
SE	Sand Equivalent (CTM 217 - 99)
SG	Specific Gravity (AASHTO T 100-06)
SL	Shrinkage Limit (ASTM D 427-04)
SW	Swell Potential (ASTM D 4546-03)
TV	Pocket Torvane
UC	Unconfined Compression - Soil (ASTM D 2166-06) Unconfined Compression - Rock (ASTM D 2938-95)
UU	Unconsolidated Undrained Triaxial (ASTM D 2850-03)
UW	Unit Weight (ASTM D 4767-04)
VS	Vane Shear (AASHTO T 223-96 [2004])

SAMPLER GRAPHIC SYMBOLS

- Standard Penetration Test (SPT)
- Standard California Sampler
- Modified California Sampler
- Shelby Tube
- Piston Sampler
- NX Rock Core
- HQ Rock Core
- Bulk Sample
- Other (see remarks)

DRILLING METHOD SYMBOLS

- Auger Drilling
- Rotary Drilling
- Dynamic Cone or Hand Driven
- Diamond Core

WATER LEVEL SYMBOLS

- First Water Level Reading (during drilling)
- Static Water Level Reading (short-term)
- Static Water Level Reading (long-term)

Department of Transportation
Division of Engineering Services
Geotechnical Services
Office of Geotechnical Design - North

REPORT TITLE
BORING RECORD LEGEND

DIST.	COUNTY	ROUTE	POSTMILE	EA
12	Orange	I-405	R34.1/R39.2	12-047643

PROJECT OR BRIDGE NAME
I-880 Realignment, Whitman Dr., O. C.

BRIDGE NUMBER	PREPARED BY	DATE	SHEET
53-0045			1 of 3

Figure 5-15

CONSISTENCY OF COHESIVE SOILS				
Descriptor	**Unconfined Compressive Strength (tsf)**	**Pocket Penetrometer (tsf)**	**Torvane (tsf)**	**Field Approximation**
Very Soft	< 0.25	< 0.25	< 0.12	Easily penetrated several inches by fist
Soft	0.25 - 0.50	0.25 - 0.50	0.12 - 0.25	Easily penetrated several inches by thumb
Medium Stiff	0.50 - 1.0	0.50 - 1.0	0.25 - 0.50	Can be penetrated several inches by thumb with moderate effort
Stiff	1.0 - 2.0	1.0 - 2.0	0.50 - 1.0	Readily indented by thumb but penetrated only with great effort
Very Stiff	2.0 - 4.0	2.0 - 4.0	1.0 - 2.0	Readily indented by thumbnail
Hard	> 4.0	> 4.0	> 2.0	Indented by thumbnail with difficulty

APPARENT DENSITY OF COHESIONLESS SOILS	
Descriptor	**SPT N_{60} - Value (blows / foot)**
Very Loose	0 - 4
Loose	5 - 10
Medium Dense	11 - 30
Dense	31 - 50
Very Dense	> 50

MOISTURE	
Descriptor	**Criteria**
Dry	Absence of moisture, dusty, dry to the touch
Moist	Damp but no visible water
Wet	Visible free water, usually soil is below water table

PERCENT OR PROPORTION OF SOILS	
Descriptor	**Criteria**
Trace	Particles are present but estimated to be less than 5%
Few	5 to 10%
Little	15 to 25%
Some	30 to 45%
Mostly	50 to 100%

SOIL PARTICLE SIZE		
Descriptor		**Size**
Boulder		> 12 inches
Cobble		3 to 12 inches
Gravel	Coarse	3/4 inch to 3 inches
	Fine	No. 4 Sieve to 3/4 inch
Sand	Coarse	No. 10 Sieve to No. 4 Sieve
	Medium	No. 40 Sieve to No. 10 Sieve
	Fine	No. 200 Sieve to No. 40 Sieve
Silt and Clay		Passing No. 200 Sieve

PLASTICITY OF FINE-GRAINED SOILS	
Descriptor	**Criteria**
Nonplastic	A 1/8-inch thread cannot be rolled at any water content.
Low	The thread can barely be rolled, and the lump cannot be formed when drier than the plastic limit.
Medium	The thread is easy to roll, and not much time is required to reach the plastic limit; it cannot be rerolled after reaching the plastic limit. The lump crumbles when drier than the plastic limit.
High	It takes considerable time rolling and kneading to reach the plastic limit. The thread can be rerolled several times after reaching the plastic limit. The lump can be formed without crumbling when drier than the plastic limit.

CEMENTATION	
Descriptor	**Criteria**
Weak	Crumbles or breaks with handling or little finger pressure.
Moderate	Crumbles or breaks with considerable finger pressure.
Strong	Will not crumble or break with finger pressure.

NOTE: This legend sheet provides descriptors and associated criteria for required soil description components only. Refer to Caltrans Soil and Rock Logging, Classification, and Presentation Manual (July 2007), Section 2, for tables of additional soil description components and discussion of soil description and identification.

Department of Transportation
Division of Engineering Services
Geotechnical Services
Office of Geotechnical Design - North

REPORT TITLE				
BORING RECORD LEGEND				
DIST. **12**	COUNTY **Orange**	ROUTE **I-405**	POSTMILE **R34.1/R39.2**	EA **12-047643**
PROJECT OR BRIDGE NAME **I-880 Realignment, Whitman Dr., O. C.**				
BRIDGE NUMBER **53-0045**	PREPARED BY		DATE	SHEET **2 of 3**

Figure 5-16

ROCK GRAPHIC SYMBOLS

IGNEOUS ROCK

SEDIMENTARY ROCK

METAMORPHIC ROCK

BEDDING SPACING

Descriptor	Thickness or Spacing
Massive	> 10 ft
Very thickly bedded	3 to 10 ft
Thickly bedded	1 to 3 ft
Moderately bedded	3-5/8 inches to 1 ft
Thinly bedded	1-1/4 to 3-5/8 inches
Very thinly bedded	3/8 inch to 1-1/4 inches
Laminated	< 3/8 inch

WEATHERING DESCRIPTORS FOR INTACT ROCK

	Diagnostic Features					
	Chemical Weathering-Discoloration-Oxidation		Mechanical Weathering and Grain Boundary Conditions	Texture and Solutioning		
Descriptor	Body of Rock	Fracture Surfaces		Texture	Solutioning	General Characteristics
Fresh	No discoloration, not oxidized	No discoloration or oxidation	No separation, intact (tight)	No change	No solutioning	Hammer rings when crystalline rocks are struck.
Slightly Weathered	Discoloration or oxidation is limited to surface of, or short distance from, fractures; some feldspar crystals are dull	Minor to complete discoloration or oxidation of most surfaces	No visible separation, intact (tight)	Preserved	Minor leaching of some soluble minerals may be noted	Hammer rings when crystalline rocks are struck. Body of rock not weakened.
Moderately Weathered	Discoloration or oxidation extends from fractures usually throughout; Fe-Mg minerals are "rusty"; feldspar crystals are "cloudy"	All fracture surfaces are discolored or oxidized	Partial separation of boundaries visible	Generally preserved	Soluble minerals may be mostly leached	Hammer does not ring when rock is struck. Body of rock is slightly weakened.
Intensely Weathered	Discoloration or oxidation throughout; all feldspars and Fe-Mg minerals are altered to clay to some extent; or chemical alteration produces in situ disaggregation (refer to grain boundary conditions)	All fracture surfaces are discolored or oxidized; surfaces are friable	Partial separation, rock is friable; in semi-arid conditions, granitics are disaggregated	Altered by chemical disintegration such as via hydration or argillation	Leaching of soluble minerals may be complete	Dull sound when struck with hammer; usually can be broken with moderate to heavy manual pressure or by light hammer blow without reference to planes of weakness such as incipient or hairline fractures or veinlets. Rock is significantly weakened.
Decomposed	Discolored of oxidized throughout, but resistant minerals such as quartz may be unaltered; all feldspars and Fe-Mg minerals are completely altered to clay		Complete separation of grain boundaries (disaggregated)	Resembles a soil; partial or complete remnant rock structure may be preserved; leaching of soluble minerals usually complete		Can be granulated by hand. Resistant minerals such as quartz may be present as "stringers" or "dikes".

Note: Combination descriptors (such as "slightly weathered to fresh") are used where equal distribution of both weathering characteristics is present over significant intervals or where characteristics present are "in between" the diagnostic feature. However, combination descriptors should not be used where significant identifiable zones can be delineated. Only two adjacent descriptors shall be combined. "Very intensely weathered" is the combination descriptor for "decomposed to intensely weathered".

RELATIVE STRENGTH OF INTACT ROCK

Descriptor	Uniaxial Compressive Strength (psi)
Extremely Strong	> 30,000
Very Strong	14,500 - 30,000
Strong	7,000 - 14,500
Medium Strong	3,500 - 7,000
Weak	700 - 3,500
Very Weak	150 - 700
Extremely Weak	< 150

ROCK HARDNESS

Descriptor	Criteria
Extremely Hard	Specimen cannot be scratched with pocket knife or sharp pick; can only be chipped with repeated heavy hammer blows
Very hard	Specimen cannot be scratched with pocket knife or sharp pick; breaks with repeated heavy hammer blows
Hard	Specimen can be scratched with pocket knife or sharp pick with heavy pressure; heavy hammer blows required to break specimen
Moderately Hard	Specimen can be scratched with pocket knife or sharp pick with light or moderate pressure; breaks with moderate hammer blows
Moderately Soft	Specimen can be grooved 1/6 in. with pocket knife or sharp pick with moderate or heavy pressure; breaks with light hammer blow or heavy hand pressure
Soft	Specimen can be grooved or gouged with pocket knife or sharp pick with light pressure, breaks with light to moderate hand pressure
Very Soft	Specimen can be readily indented, grooved, or gouged with fingernail, or carved with pocket knife; breaks with light hand pressure

CORE RECOVERY CALCULATION (%)

$$\frac{\Sigma \text{ Length of the recovered core pieces (in.)}}{\text{Total length of core run (in.)}} \times 100$$

RQD CALCULATION (%)

$$\frac{\Sigma \text{ Length of intact core pieces} > 4 \text{ in.}}{\text{Total length of core run (in.)}} \times 100$$

FRACTURE DENSITY

Descriptor	Criteria
Unfractured	No fractures
Very Slightly Fractured	Lengths greater 3 ft
Slightly Fractured	Lengths from 1 to 3 ft, few lengths outside that range
Moderately Fractured	Lengths mostly in range of 4 in. to 1 ft, with most lengths about 8 in.
Intensely Fractured	Lengths average from 1 in. to 4 in. with scattered fragmented intervals with lengths less than 4 in.
Very Intensely Fractured	Mostly chips and fragments with few scattered short core lengths

Department of Transportation
Division of Engineering Services
Geotechnical Services
Office of Geotechnical Design - North

REPORT TITLE: **BORING RECORD LEGEND**

DIST.	COUNTY	ROUTE	POSTMILE	EA
12	Orange	I-405	R34.1/R39.2	12-047643

PROJECT OR BRIDGE NAME: **I-880 Realignment, Whitman Dr., O. C.**

BRIDGE NUMBER	PREPARED BY	DATE	SHEET
53-0045			3 of 3

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Appendix A:
Field Test Procedures

A.1 Pocket Penetrometer

The Pocket Penetrometer test is conducted using the following general instructions:

- To begin test, remove protective cap, push ring against body so that low side reads 0.
- Slowly insert piston until engraved mark is level with soil.
- Observe the reading in TSF (KG/SQ CM) using low side of ring, (side closest to the piston end): record reading and repeat.
- For weak soils, use 1" adapter foot, multiply reading by 0.0625.

A.2 Torvane

The Torvane test is conducted using the following general instructions:

- To start test, push indicator counter clockwise to zero stop.
- Select reasonably flat surface at least 1 inch in diameter.
- Using midsize vane, one revolution equals 1 TSF (1KG/SQ CM).
- One revolution using small and large vane equals respectively 2.5 and 0.2 TSF (KG/SQ CM).
- Press pocket vane shear tester into soil to depth of blade; maintain constant vertical pressure while turning knob clockwise at rate to develop failure within 5 to 10 seconds.
- After failure develops, release remaining spring tension slowly. Pointer will indicate maximum shear value until manually reset.

A.3 Dry Strength

From the specimen, select enough material to mold into a ball about 1 in. (25 mm) in diameter. Mold the material until it has the consistency of putty, adding water if necessary. From the molded material, make at least three test specimens. A test specimen shall be a ball of material about 1⁄2 in. (12 mm) in diameter. Allow the test specimens to dry in air, or sun, or by artificial means, as long as the temperature does not exceed 60°C. If the test specimen contains natural dry lumps, those that are about 1⁄2 in. (12 mm) in diameter may be used in place of the molded balls. Test the strength of the dry balls or lumps by crushing between the fingers. Note the strength as none, low, medium, high, or very high in accordance with the criteria in the table in Section 2.4.14. If natural dry lumps are used, do not use the results of any of the lumps that are found to contain particles of coarse sand. The presence of high-strength water-soluble cementing materials, such as calcium carbonate, may cause exceptionally high dry strengths. The presence of calcium carbonate can usually be detected from the intensity of the reaction with dilute hydrochloric acid.

A.4 Dilatancy

From the specimen, select enough material to mold into a ball about 1⁄2 in. (12 mm) in diameter. Mold the material, adding water if necessary, until it has a soft, but not sticky, consistency. Smooth the soil ball in the palm of one hand with the blade of a knife or small spatula. Shake horizontally, striking the side of the hand vigorously against the other hand several times. Note the reaction of water appearing on the surface of the soil. Squeeze the sample by closing the hand or pinching the soil between the fingers, and note the reaction as none, slow, or rapid in accordance with the criteria in the table in Section 2.4.15. The reaction is the speed with which water appears while shaking, and disappears while squeezing.

A.5 Toughness

Following the completion of the dilatancy test, the test specimen is shaped into an elongated pat and rolled by hand on a smooth surface or between the palms into a thread about 1⁄8 in. (3 mm) in

diameter. (If the sample is too wet to roll easily, it should be spread into a thin layer and allowed to lose some water by evaporation.) Fold the sample threads and reroll repeatedly until the thread crumbles at a diameter of about 1⁄8 in. The thread will crumble at a diameter of 1⁄8 in. when the soil is near the plastic limit. Note the pressure required to roll the thread near the plastic limit. Also, note the strength of the thread. After the thread crumbles, the pieces should be lumped together and kneaded until the lump crumbles. Note the toughness of the material during kneading. Describe the toughness of the thread and lump as low, medium, or high in accordance with the criteria in the table in Section 2.4.16.

A.6 Jar Slake Index Test

Slaking behavior of intact rock specimens is quantified as an index. A laboratory index test called the Slake Durability Test (ASTM D 4644-04) is the most rigorous method of measuring this behavior. A simple, but less sensitive method can be employed in the field or in the office to screen specimens of the Slake Durability test. The "Jar Slake Test" method is presented here. A water filled jar and a watch are all that are required to perform this simple test. The steps are as follows:

- A fragment of rock is immersed in enough water to cover it by 15 mm. It is best if the rock is oven dried. It has been reported that damp material is relatively insensitive to degradation in this test when compared with dry material.
- After immersion, the fragment is observed continuously for the first 10 minutes and carefully during the first 30 minutes. When a reaction occurs, it is often during the first 30 minutes. A final observation is made after 24 hours.
- The condition of the piece is categorized (complete breakdown, partial breakdown, no change), as shown in the table in Section 2.5.14 (Air Force Manual 1983).

A.7 Calcium Carbonate

Because calcium carbonate is a common cementing agent, it is important to report its presence, which is done on the basis of the reaction with dilute hydrochloric acid (HCl). Use the ASTM D 2488-06 standard to describe the reaction with HCl, as indicated in Figure 2-19 below.

Figure 2-19
Descriptors for calcium carbonate reaction

Description	Criteria
None	No visible reaction.
Weak	Some reaction, with bubbles forming slowly.
Strong	Violent reaction, with bubbles forming immediately.

A.8 Standard Penetration Test

Standard Penetration Tests (SPT) shall be conducted according to the following test methods:

- ASTM D 1586-99, Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils
- ASTM D 6066-96, Standard Practice for Determining the Normalized Penetration Resistance of Sands for Evaluation of Liquefaction Potential

The following guidance is provided:

- Blow counts shall be reported on the LOTB and BR as observed in the field, N, with no corrections.

  Where,

  N The sum of the hammer blows required to drive the sampler over the test interval from 0.5 to 1.5 ft below the cleanout depth.

- Hammer efficiency shall be noted on the LOTB and BR to allow the reader to determine N_{60} or $(N_1)_{60}$.

  Where,

  ER_i Hammer energy ratio

N_{60} Penetration resistance adjusted to a 60 % drill rod energy ratio per ASTM D 6066-96: $N_{60} = N_{measured}$ X (ER_i /60)

$(N_1)_{60}$ Penetration resistance adjusted for energy and normalized to a 1 ton/ft^2 stress level.

- Blow counts for each of the 6 inch increments shall be recorded in the field, but not necessarily reported on the LOTB and BR. The 2nd and 3rd driving intervals shall be summed and reported.

  For example:

  1st 6 in. interval: 10 blows
  2nd 6 in. interval: 15 blows
  3rd 6 in. interval: 18 blows
  N reported as "33"

- For partial increments, the depth of penetration shall be reported to the nearest 1 inch, in addition to the number of blows.

  For example:

  1st 6 in. interval: 20 blows
  2nd 6 in. interval: 40 blows
  3rd 6 in. interval: 60 blows for 2 inches, then refusal
  N reported as "100/8"

- If the seating interval (1st 6 in. interval) is not achieved, note refusal.

  For example:

  1st 6 in. interval: 50 blows for 2 inches, then refusal
  N reported as "REF"

- If a substantial change in material is encountered over the course of driving the sampler, the 2nd and 3rd driving intervals can be reported separately.

  For example:

  1st 6 in. interval: 10 blows
  2nd 6 in. interval: 20 blows
  3rd 6 in. interval: 60 blows for 3 inches, then refusal
  N reported as "20/6, 60/3"

A.9 Core Recovery (REC)

The core recovery value (REC), with few exceptions, provides an indication of the success of the coring operation in recovering the cored rock. Portions of the cored rock mass may not be recovered because the fluid used in the drilling operations transports portions of the rock mass during the coring operation or the rotation of the core barrel traps and grinds away portions of the rock mass. Diminished core recovery can also be attributed to voids within the rock mass. Core recovery is expressed as a percentage.

$$REC = \frac{\Sigma \text{ (Length of the recovered core pieces, inches)(100\%)}}{\text{Total length of the core run, inches}}$$

A.10 Rock Quality Designation (RQD)

Rock Quality Designation is an index that relates to the degree of fracturing in a rock mass as observed in a core specimen. A high value of RQD is indicative of a less fractured rock mass or a rock mass having widely spaced fractures. RQD is valid for core diameters from 1.4 to 3.35 inches. This RQD criteria is generally based on ASTM D 6032-02.

$$RQD = \frac{\Sigma \text{ (Length of intact core pieces} \geq 4 \text{ inches)(100\%)}}{\text{Total length of the core run, inches}}$$

Used alone, RQD is not sufficient to provide an adequate description of rock mass quality. The RQD does not account for joint orientation, tightness, continuity, and gouge material. The RQD shall be used in combination with other geological and geotechnical input.

The RQD denotes the percentage of intact rock retrieved from a borehole of any orientation. All pieces of intact rock core equal to or greater than 4 inches long are summed and divided by the total length of the core run. An intact core is any segment of core between two open, natural discontinuities.

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Appendix B:
Field Logging Aids

B.1 Field Sample Logging Forms

Forms are provided to assist the sample logging process in the field. One form is used specifically for soil samples, while the other used for rock samples.

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Soil Sample Field Description & Identification

Instructions:

- Field Description and Identification based upon *Soil and Rock Logging, Classification, and Presentation Manual*, dated July 1, 2007.
- Shaded fields are *required*, non-shaded fields are *optional*.
- Intensely weathered or decomposed rock that is friable and that can be reduced to gravel size or smaller by normal hand pressure shall be identified and described as rock followed by the soil identification or classification, and description in parenthesis.

Project				**Logged by**		**Date**	**Hole ID**
District	**County**	**Route**	**Postmile**	**EA**		**Sample Depth**	**Sample ID**
Drilling Method				**Sampler Type and Size**			

SPT Blow Counts			**Hammer energy ratio (ER_i)**	**Pocket Penetrometer Measurement**
1st 6 in. interval				
2nd 6 in. interval		$N_{measured}$ =	$N_{60} = N_{measured} \times (ER_i/60)$	**Torvane Measurement**
3rd 6 in. interval				

Group Name	**Group Symbol**	**Color**

Consistency	**Apparent Density**	**Moisture**	**Structure**	**Cementation**	**Additional Description**
☐Very Soft ☐Soft ☐Medium Stiff ☐Stiff ☐Very Stiff ☐Hard	☐Very loose ☐Loose ☐Medium dense ☐Dense ☐Very dense	☐Dry ☐Moist ☐Wet	☐Stratified ☐Laminated ☐Fissured ☐Slickensided ☐Blocky ☐Lensed ☐Homogeneous	☐Weak ☐Moderate ☐Strong	

Percent (est.) 100% Total by Volume of entire sample

Boulders

%	**Rock Identification**	**Weathering**	**Rock Hardness**	**Angularity**	**Shape**
		☐Fresh ☐Slightly Weathered to Fresh ☐Slightly Weathered ☐Moderately to Slightly Weathered ☐Moderately Weathered ☐Intensely to Moderately Weathered ☐Intensely Weathered ☐Very Intensely Weathered ☐Decomposed	☐Extremely Hard ☐Very Hard ☐Hard ☐Moderately Hard ☐Moderately Soft ☐Soft ☐Very Soft	☐Angular ☐Subangular ☐Subrounded ☐Rounded	☐Flat ☐Elongated ☐Flat and Elongated
	Intersected Lengths of Core				

Cobbles

%	**Rock Identification**	**Weathering**	**Rock Hardness**	**Angularity**	**Shape**
		☐Fresh ☐Slightly Weathered to Fresh ☐Slightly Weathered ☐Moderately to Slightly Weathered ☐Moderately Weathered ☐Intensely to Moderately Weathered ☐Intensely Weathered ☐Very Intensely Weathered ☐Decomposed	☐Extremely Hard ☐Very Hard ☐Hard ☐Moderately Hard ☐Moderately Soft ☐Soft ☐Very Soft	☐Angular ☐Subangular ☐Subrounded ☐Rounded	☐Flat ☐Elongated ☐Flat and Elongated
	Intersected Lengths of Core				

Percent (est.) 100% Total by Weight of soils portion

	%	(or) **Proportion**	**Size**	**Angularity**	**Shape**
Gravel		☐Trace ☐Few ☐Little ☐Some ☐Mostly	☐Coarse ☐Fine	☐Angular ☐Subangular ☐Subrounded ☐Rounded	☐Flat ☐Elongated ☐Flat and Elongated
Sand		☐Trace ☐Few ☐Little ☐Some ☐Mostly	☐Coarse ☐Medium ☐Fine	**Angularity** (for coarse only) ☐Angular ☐Subangular ☐Subrounded ☐Rounded	
Fines		☐Trace ☐Few ☐Little ☐Some ☐Mostly	**Plasticity** ☐Nonplastic ☐Low ☐Medium ☐High	**Dry Strength** ☐None ☐Low ☐Medium ☐High ☐Very High	**Dilatency** ☐None ☐Slow ☐Rapid **Toughness** ☐Low ☐Medium ☐High

Rock Sample Field Description & Identification

Instructions:

- Field Description and Identification based upon *Soil and Rock Logging, Classification, and Presentation Manual*, dated July 1, 2007.
- Shaded fields are *required*, non-shaded fields are *optional*.
- Intensely weathered or decomposed rock that is friable and that can be reduced to gravel size or smaller by normal hand pressure shall be identified and described as rock followed by the soil identification or classification, and description in parenthesis.

Project				**Logged by**	**Date**	**Hole ID**
District	**County**	**Route**	**Postmile**	**EA**	**Sample Depth**	**Sample ID**
Drilling or Coring Method				**Sampler Type and Size**		
Length of Core Run				**Length of the recovered core pieces**	**Length of intact core pieces > 4 inches**	
Recovery (REC)				**Rock Quality Designation (RQD)**		

Rock Identification

Color | **Odor**

Additional Description

Family Name
- ☐ Sedimentary
- ☐ Igneous
- ☐ Metamorphic

Bedding Spacing
- ☐ Massive
- ☐ Very thickly bedded
- ☐ Thickly bedded
- ☐ Moderately bedded
- ☐ Thinly bedded
- ☐ Very thinly bedded
- ☐ Laminated

Texture
- ☐ Pitted
- ☐ Vuggy
- ☐ Cavity
- ☐ Honeycombed
- ☐ Vesicular

Rock Grain-Size

(Crystalline Igneous and Metamorphic Rock)
- ☐ Very coarse grained or pegmatitic
- ☐ Coarse-grained
- ☐ Medium-grained
- ☐ Fine-grained
- ☐ Aphanitic

(Sedimentary Rock)
- ☐ Boulder, Boulder Conglomerate
- ☐ Cobble, Cobble Conglomerate
- ☐ Pebble, Pebble Conglomerate
- ☐ Granule, Granule Conglomerate
- ☐ Very Coarse Sand
- ☐ Coarse Sand
- ☐ Medium Sand
- ☐ Fine Sand
- ☐ Very Fine Sand
- ☐ Silt, Siltstone, Shale
- ☐ Clay, Claystone, Shale

(Pyroclastic Igneous Rock)
- ☐ Block (Angular), Volcanic Breccia
- ☐ Bomb (Rounded), Agglomerate
- ☐ Lapilli, Lapilli Tuff
- ☐ Coarse Ash, Coarse Tuff
- ☐ Fine Ash, Fine Tuff

Weathering
- ☐ Fresh
- ☐ Slightly Weathered to Fresh
- ☐ Slightly Weathered
- ☐ Moderately to Slightly Weathered
- ☐ Moderately Weathered
- ☐ Intensely to Moderately Weathered

(Requires completion of *Soil Sample Field Description and Identification* form)
- ☐ Intensely Weathered
- ☐ Very Intensely Weathered
- ☐ Decomposed

Rock Hardness
- ☐ Extremely Hard
- ☐ Very Hard
- ☐ Hard
- ☐ Moderately Hard
- ☐ Moderately Soft
- ☐ Soft
- ☐ Very Soft

Fracture Density
- ☐ Unfractured
- ☐ Very slightly fractured
- ☐ Slightly to very slightly fractured
- ☐ Slightly fractured
- ☐ Moderately to slightly fractured
- ☐ Moderately fractured
- ☐ Intensely to moderately fractured
- ☐ Intensely fractured
- ☐ Very intensely to intensely fractured
- ☐ Very intensely fractured

Discontinuity Type
- ☐ Joint (JT)
- ☐ Foliation Joint (FJ) or Bedding Joint (BJ)
- ☐ Bedding Plane Separation
- ☐ Incipient Joint (IJ) or Incipient Fracture (IF)
- ☐ Random Fracture (RF)
- ☐ Mechanical Break (MB)
- ☐ Fracture Zone (FZ)

Discontinuity Dip Magnitude

Jar Slake Index, I_j
- ☐ 1
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ 5
- ☐ 6

Discontinuity Weathering
- ☐ Fresh
- ☐ Slightly Weathered to Fresh
- ☐ Slightly Weathered
- ☐ Moderately to Slightly Weathered
- ☐ Moderately Weathered
- ☐ Intensely to Moderately Weathered
- ☐ Intensely Weathered
- ☐ Very Intensely Weathered
- ☐ Decomposed

Discontinuity Healing
- ☐ Totally Healed
- ☐ Moderately Healed
- ☐ Partially Healed
- ☐ Not Healed

Healing Material:

Discontinuity Infilling

Rock:
- ☐ Extremely Hard
- ☐ Very Hard
- ☐ Hard
- ☐ Moderately Hard
- ☐ Moderately Soft
- ☐ Soft
- ☐ Very Soft

Soils:
- ☐ Very Soft
- ☐ Soft
- ☐ Medium Stiff
- ☐ Stiff
- ☐ Very Stiff
- ☐ Hard

Appendix C:
Procedural Documents

State of California
DEPARTMENT OF TRANSPORTATION

Business, Transportation and Housing Agency

M e m o r a n d u m

Flex your power!
Be energy efficient!

To: ALL STAFF
GEOTECHNICAL SERVICES
DIVISION OF ENGINEERING SERVICES

Date: June 15, 2007

From: JAMES E. DAVIS
Deputy Division Chief
Geotechnical Services

Subject: Exception Process for the Soil & Rock Logging, Classification, and Presentation Manual

All Geotechnical Services staff, including consultants performing work on behalf of the Department, shall follow the procedures in the Soil & Rock Logging, Classification, and Presentation Manual (ref: memo to all staff dated June 15, 2007). Although the manual attempts to provide for most geotechnical conditions, there may be reason to deviate from its procedures or terminology. This memorandum provides the procedure that staff shall follow in order to gain approval for such deviations.

The policy terminology used in the manual is defined as follows:

Term	Standard Type	Definition
Shall, Required	Mandatory	*Mandatory Standard*. The associated provisions **must** be used. There is no acceptable alternative.
Should	Advisory	*Advisory Standard*. The associated provisions are preferred practices.
May, Optional	Permissive	*Permissive Standard*. Use or application of the associated provisions is left to the discretion of the Geoprofessional.

In cases where exceptions to mandatory or advisory standards are proposed by the geotechnical professional, a *Request for Exception* form shall be completed and signatures retained prior to finalizing or issuing any related document, such as a Log of Test Boring or Geotechnical Report. The completed *Request for Exception* form shall be placed in the project file and any related geotechnical report shall discuss the exception. When a LOTB or Boring Record presents information that deviates from mandatory or advisory standards, the standard note:

"This LOTB sheet (Boring Record) was prepared in accordance with the Caltrans Soil & Rock Logging, Classification, and Presentation Manual (date)"

Shall be modified to read as follows:

"This LOTB sheet (Boring Record) was prepared in accordance with the Caltrans Soil & Rock Logging, Classification, and Presentation Manual (date) except as noted in (section) of (Report Title) dated (Date)"

Attachments

"Caltrans improves mobility across California"

Soil & Rock Logging, Classification, and Presentation Manual
Request for Exception

Name:
Office:
District-EA: -
Project Name:
Manual Section No.:

Description of Exception Being Requested:

Discussion of Why the Exception to Policy is Necessary:

Should the Manual be revised to allow for the exception? Please discuss.

_____	_____
Branch Chief	Office Chief (Advisory & Mandatory Standards)
_____	_____
Deputy Division Chief (Mandatory Standards)	Date Approved

cc: Project File, GS Corporate

Caltrans Soil & Rock Logging, Classification, and Presentation Manual

Committee Charter and Standard Procedures (June 2007)

Committee Members:	Tom Whitman, Chairperson David Jang Bob Price Hector Valencia Mark Hagy Craig Hannenian Loren Turner (DRI)
Committee Sponsor:	Tim Pokrywka

Purpose of Committee

The Soil & Rock Logging, Classification, and Presentation Manual Committee, formed by the Geotechnical Services Management Team (GSMT), shall maintain the manual as follows.

- The manual shall be kept current with respect to the state of practice of all standards and procedures presented in the manual.

- The committee shall consider all requests for modifications to the manual and respond to those requests in a timely manner.

Annual Review

The committee shall perform an annual review of the manual due to the GSMT in June of each year. The review shall consist of the following:

- Review of the manual's references and considerations of changes to reflect updated references, if any.
- Review of approved *"Request for Exception"* forms and consideration for revision to the manual to accommodate approved exceptions.
- Solicitation of comments by our partners such as the Association of Drilled Shaft Contractors (ADSC), Consultants and Construction and consideration of their issues.

Standard Procedure for Modifying the Manual

1. Staff shall post requests for modifications on the *Caltrans Geotechnical Services Discussion Board, Soil & Rock Logging, Classification and Presentation Manual* Category located at:

   http://cap1.dot.ca.gov/forum/GeotechnicalServices/index.php

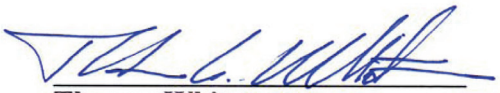
   The request for modification shall include at least the following information:
   - Name of requestor
   - Office
   - Manual Section Number
   - Description of Proposed Change
   - Discussion of Reason or Need for the Proposed Change
   - If applicable, reference to an approved *Request for Exception* relating to the Proposed Change

2. The committee chairperson will monitor the discussion board, review the proposal and assign any additional research to an appropriate person. The person will typically be the Committee Member representing the requesting office, but may be others depending on the proposal topic.
3. If the proposal is minor, the chairperson may implement the revision without input from the committee. Otherwise, depending on the proposal's complexity, the chairperson will either schedule a committee meeting, solicit comments on the discussion board, or ask for each member's recommendation on whether to implement the proposed change or not.
4. Acceptability of proposed changes will be by majority vote of the committee members present at the meeting, or by those who respond to the chairperson by the stated deadline.
5. Unless deemed urgent by the committee chairperson, revisions will be made annually and coincide with the annual report to the GSMT. An exception to this shall be during the first 12 months after initial release where the committee will be expected to address comments on an ongoing basis.

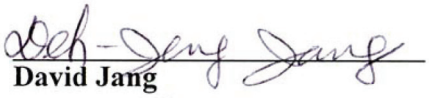
Committee Member Roles and Responsibilities

Committee members pledge to actively participate in maintenance of the manual according to this committee charter. It is expected that each committee member respond to correspondence in a timely manner so not to delay progress of related business.

Member Signatures

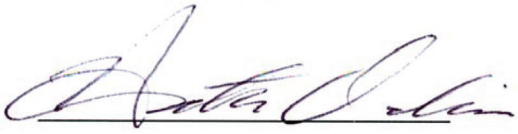


Thomas Whitman

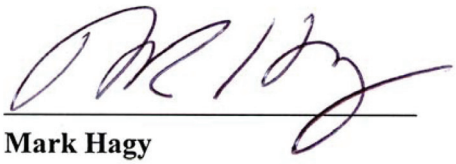


David Jang

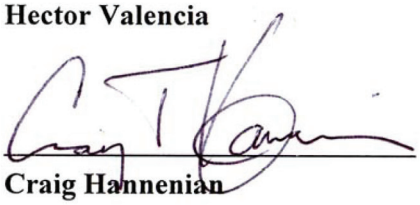
Robert Price



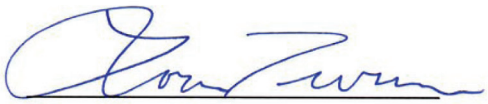
Hector Valencia



Mark Hagy



Craig Hannenian



Loren Turner

Soil and Rock Logging, Classification, and Presentation Manual (June 2007)
Errata Sheet (May 2009)

<table>
<tr><th>Section #
Page #</th><th>Effective Date</th><th>Description</th></tr>
<tr><td>Figure 2-1
Page 6</td><td>5/01/2009</td><td>Item 4, 5th bullet is amended to read:

• Elevation, vertical datum, benchmark description (including station and offset)</td></tr>
<tr><td>Figure 2-1
Page 6</td><td>5/01/2009</td><td>Item 6, 10th bullet is amended to read:

• Measured SPT energy efficiency ratio</td></tr>
<tr><td>Figure 2-3
Page 8</td><td>5/01/2009</td><td>The following item is amended:

Sequence Item 12 – Plasticity (for fine-grained soils) - Optional</td></tr>
<tr><td>Figure 2-3
Page 8</td><td>5/01/2009</td><td>Sequence 19 is amended and Sequence 20 is added to read:

<table>
<tr><td>19</td><td>Consistency Field Test Result (tsf)</td><td>2.4.3</td><td>●</td><td></td></tr>
<tr><td>20</td><td>Additional Comments</td><td>2.4.19</td><td></td><td>○</td></tr>
</table>
</td></tr>
<tr><td>Sec. 2.4.3
Page 13</td><td>5/01/2009</td><td>The first paragraph is amended to read:

The required procedure for the determination of consistency of cohesive soils is to obtain relatively undisturbed samples and perform field tests with a pocket penetrometer or torvane. (See Appendix A for details on the test procedures.) The pocket penetrometer or torvane test result shall be reported near the end of the descriptive sequence (Sequence Item #19) when cohesive soils are described. Use “PP” pocket penetrometer and “TV” for pocket torvane, e.g PP = 1.0</td></tr>
<tr><td>Figure 2-9
Page 15</td><td>5/01/2009</td><td>The figure is amended to read:

<table>
<tr><th>Description</th><th>SPT N_{60} (blows/ft)</th></tr>
<tr><td>Very loose</td><td>$0 < N_{60} < 5$</td></tr>
<tr><td>Loose</td><td>$5 \le N_{60} < 10$</td></tr>
<tr><td>Medium dense</td><td>$10 \le N_{60} < 30$</td></tr>
<tr><td>Dense</td><td>$30 \le N_{60} < 50$</td></tr>
<tr><td>Very dense</td><td>$N_{60} \ge 50$</td></tr>
</table>
</td></tr>
</table>

Soil and Rock Logging, Classification, and Presentation Manual (June 2007)
Errata Sheet (May 2009)

Section # Page #	**Effective Date**	**Description**
Sec. 2.4.4 Page 15	8/01/2007	The following text: *ER_i = Hammer energy ratio* is amended to read: *ER_i = Hammer energy ratio **(%)***
Sec. 2.4.8 Page 16	8/01/2007	The second paragraph is amended to read: *The percentages of gravel, sand, and fines must add up to 100 %. The term "about" shall be used if the percentage of constituents is estimated in the field.*
Sec. 2.4.18 Page 19	5/01/2009	The first two bullets are amended to read: • *Rock Identification **or Rock Family Name*** • *Weathering **(optional)***
Sec. 2.5 Page 20	8/01/2007	The example in Section 2.5 is amended to read: *IGNEOUS ROCK (GRANITE); light gray to light yellowish brown intensely weathered; soft, unfractured; (Lean CLAY with SAND (CL); medium stiff; moist; little coarse SAND; medium plasticity).*
Figure 2-21 Page 20	5/01/2009	Sequence Item #2 is amended to read: *Rock Grain Size **(coarse-grained sedimentary rock – Required; other rock – Optional)***
Figure 2-21 Page 20	5/01/2009	Sequence Item #3 is amended to read: *Bedding Spacing **(sedimentary rock and bedded volcanic rock – Required)***
Figure 2-26 Page 24	5/01/2009	Figure 2-26 is replaced by Figures 2-26a and 2-26b (attached)
Sec. 2.5.5 Page 25	5/01/2009	The first sentence is amended to read: *Use the color name from the Munsell **Soil** Color Chart to describe the rock at the time of sampling.*

Section # **Page #**	**Effective Date**	**Description**
Figure 2-30 Page 27	8/01/2007	The criteria for "Moderately Soft" are amended to read: *Specimen can be grooved **1/16 in**. deep with a pocket knife or sharp pick with moderate or heavy pressure. Breaks with light hammer blow or heavy manual pressure.*
Sec. 2.5.10 Page 28	5/01/2009	The 3rd paragraph is amended to read: *Fracture: A term used to describe any break in geologic material, **including** shears and shear zones. Additional fracture terminology is provided in Figure 2-32*
Sec. 3.2 Page 39	8/01/2007	The first sentence is amended to read: *Six of the **20** attributes in the identification and descriptive sequence for soils, listed previously in section 2.4.1, may be revised with laboratory test results.*
Sec. 4.3.2 Page 50	5/01/2009	The following bullet is added to this section: • *Place the following note on the LOTB when rock strength is reported. **"**Rock strength may be variable within a rock unit or descriptive sequence. Rock strength is valid only at the location where the test was taken.**"***
Sec. 4.3.2 Page 50	8/01/2007	The following text is added to the end of Section 4.3.2: • *If a PA and/or PI is reported for any sample within a layer, then that layer's Group Name and Symbol shall be a classification based on ASTM D 2487 (Section 3). The proportional terms in Section 2.4.8 shall not be used in the layer description.* • *If a layer's Group Name and Symbol is based exclusively on field observations, then the percentages (to the nearest 5%) of gravel, sand and fines shall be preceded by the term "about". Proportional terms per Section 2.4.8 may be used in lieu of percentages.*
Sec. 4.3.3 Page 51	5/01/2009	Page 51 is replaced with the attached Page 51.

Soil and Rock Logging, Classification, and Presentation Manual (June 2007)
Errata Sheet (May 2009)

Section # **Page #**	**Effective Date**	**Description**
Figure 4.3 Page 52	8/01/2007	The note at the bottom of the log is amended to read: *Terminated at EL* ***–29'*** The descriptive sequence at elevation –13.5 is amended to read: *stiff*; *dark gray*; ***trace shell fragments***
Sec. 5.2 Page 53	8/01/2007	The termination elevations presented in Figure 5-1 are amended to read: "*Terminated at EL* ***–29'***" for R-07-001 "*Terminated at EL* ***–39'***" for R-07-002 "*Terminated at EL* ***–35'***" for R-07-003 The descriptive sequence at elevation –13.5 for Boring R-07-001 is amended to read: *stiff; dark gray;* ***trace shell fragments***
Sec. 5.2.1 Page 54	8/01/2007	The 8th bullet is amended to read" • ***Typically*** *allows presentation of more than one boring log per plan sheet.*
Sec. 5.2.2 Page 54	5/01/2009	The 4th paragraph is amended to read: *"This LOTB sheet was prepared in accordance with the Caltrans Soil & Rock Logging, Classification, and Presentation Manual (Date) except as noted* ***below (list description of approved exception(s).***
Sec. 5.2.3.3 Page 55	5/01/2009	The first sentence of Item d is amended to read: • ***List the name, location (including station and offset), physical description****, and elevation of the benchmark used for determining the top of boring elevations at the top left side of the Plan View under the heading "BENCHMARK".*
Figure 5-2 Page 59	5/01/2009	Field test symbols for pocket penetrometer and torvane are eliminated.

Soil and Rock Logging, Classification, and Presentation Manual (June 2007)
Errata Sheet (May 2009)

Section # **Page #**	**Effective Date**	**Description**
Sec. 5.2.5 Page 59 & 60	8/01/2007	The soil and rock LOTB legend sheets are replaced with new sheets to accommodate larger font sizes required by the Department. There are now two soil legend sheets and one rock legend sheet.
Sec. 5.3.1 Page 67	8/01/2007	The following text is added to the end of Section 5.3.1: *The examples presented in Figures 5-12 and 5-13 are intended as examples only and do not represent a presentation standard. Presentation of Boring Records and CPT data is left to the geoprofessional.*

Figure 2-26a
Rock grain-size descriptors for Sedimentary (epiclastic), rounded, subrounded and subangular rock

USCS Particle Size	Lithified Product
Boulder	Boulder Conglomerate
Cobble	Cobble Conglomerate
Coarse Gravel	Coarse Gravel Conglomerate
Fine Gravel	Fine Gravel Conglomerate
Coarse Sand	Coarse Sandstone
Medium Sand	Medium Sandstone
Fine Sand	Fine Sandstone
Silt	Siltstone, Shale
Clay	Claystone, Shale

Figure 2-26b
Rock grain-size descriptors for Pyroclastic Igneous rock

Fragment	Lithified Product	Size, X (inches)
Block (Angular)	Volcanic Breccia	$X > 2.5$
Bomb (Rounded)	Agglomerate	
Lapilli	Lapilli Tuff	$0.05 < X \leq 2.5$
Coarse Ash	Coarse Ash Tuff	$0.0025 < X \leq 0.05$
Fine Ash	Fine Ash Tuff	$X \leq 0.0025$

4.3.3 Example

The process for developing boring logs has been presented in detail throughout this Manual In general, field sample descriptions are corrected and calibrated based on laboratory results, layer boundaries are determined by grouping samples within the same group symbol, sample descriptions are consolidated into a single layer description, and, finally, description changes are noted with depth within layers.

The following example demonstrates how a geoprofessional develops a layer presentation, based on field descriptions and laboratory test results.

Figure 4-2

Depth (ft.)	Sample	Field Testing	Field Description and Identification	Lab Testing	Lab Corrected Description and Identification or Classification	Final Layer Presentation
3.5-5	R-07-001-S01	SPT	Well-graded SAND with GRAVEL and COBBLES (SW), loose, yellowish brown, moist, about 10% subrounded COBBLES, about 15% coarse to fine GRAVEL, about 80% coarse to fine SAND, about 5% fines, (fill)		Well-graded SAND with GRAVEL and COBBLES (SW), loose, yellowish brown, moist, about 10% subrounded COBBLES, about 15% coarse to fine GRAVEL, about 80% coarse to fine SAND, about 5% fines, (fill)	Well-graded SAND with GRAVEL and COBBLES (SW); loose; yellowish brown; moist; about 10% subrounded COBBLES; coarse to fine SAND; little coarse to fine GRAVEL; trace fines; (fill)
8.5-10	R-07-001-S02	SPT	Well-graded SAND with GRAVEL and COBBLES (SW), medium dense, yellowish brown, moist, about 10% subrounded COBBLES, about 15% coarse to fine GRAVEL, about 80% coarse to fine SAND, about 5% fines, (fill)	PA	Well-graded SAND with GRAVEL and COBBLES (SW), medium dense, yellowish brown, moist, about 10% subrounded COBBLES, 17% coarse to fine GRAVEL, 79% coarse to fine SAND, 4% fines, (fill)	medium dense
13.5-15	R-07-001-U03	PP	SANDY lean CLAY (CL), medium stiff, dark bluish gray, moist, about 35% medium SAND, about 65% fines, trace shell fragments, PP=0.8, (bay mud)		SANDY lean CLAY (CL), medium stiff, dark bluish gray, moist, about 35% medium SAND, about 65% fines, trace shell fragments, (bay mud)	SANDY lean CLAY (CL), medium stiff; dark bluish gray; moist; medium SAND; trace shell fragments; PP=0.8 (bay mud)
18.5-20	R-07-001-U04	PP	SANDY lean CLAY (CL), soft, dark bluish gray, moist, about 35% medium SAND, about 65% fines, PP=0.4, (bay mud)	UU, PA, PI	SANDY lean CLAY (CL), medium stiff, dark bluish gray, moist, 38% medium SAND, about 62% fines, (bay mud)	no shell fragments; PP=0.4
23.5-25	R-07-001-U05	PP	SANDY lean CLAY (CL), medium stiff, dark gray, moist, about 35% medium SAND, about 65% fines, trace shell fragments, PP=0.9, (bay mud)	UU, PA, PI	SANDY lean CLAY (CL), stiff, dark gray, moist, 34% medium SAND, 66% fines, trace shell fragments, (bay mud)	stiff; dark gray; PP=0.9; trace shell fragments;
28-29	R-07-001-S06	SPT	SEDIMENTARY ROCK (SHALE), dark bluish gray, intensely weathered, moderately soft, intensely to moderately fractured		SEDIMENTARY ROCK (SHALE), dark bluish gray, intensely weathered, moderately soft, intensely to moderately fractured	SEDIMENTARY ROCK (SHALE); dark bluish gray; intensely weathered; moderately soft; intensely to moderately fractured
29-34	R-07-001-C07		SEDIMENTARY ROCK (SHALE), dark bluish gray, moderately to slightly weathered, moderately hard, moderately fractured	UC	SEDIMENTARY ROCK (SHALE), dark bluish gray, moderately to slightly weathered, strong, moderately hard, moderately fractured	moderately to slightly weathered; strong; moderately hard; moderately fractured
34-39	R-07-001-C08		SEDIMENTARY ROCK (SHALE), dark bluish gray, moderately to slightly weathered, moderately hard, slightly fractured	UC	SEDIMENTARY ROCK (SHALE), dark bluish gray, moderately to slightly weathered, strong, moderately hard, slightly fractured	slightly fractured