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CALTRANS MONITORING PROTOCOLS GUIDANCE MANUAL: PARTICLE MONITORING

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Section 1
Introduction

This manual presents guidance for Caltrans management, staff, and contractors to use in the planning and implementation of monitoring studies that characterize the particles found in storm water runoff. The manual is designed and organized to provide step-by-step descriptions of the processes used to plan and implement successful particle monitoring studies specific to runoff from transportation-related facilities.

The main objective of this manual is to provide consistency in particle study methods among all Caltrans storm water investigations.

Consistency is essential for data comparability, and for ease of data entry in the Caltrans storm water database. In addition to consistency of particle study methods, it is essential that the particle samples are collected and analyzed according to methods and procedures that result in accurate and precise data. This manual therefore features detailed information on quality assurance and quality control procedures as they relate to particle sampling and analysis.

Particle characterization is considered a supplemental monitoring approach that can be used to support other water quality studies by providing further assessment of potential storm water impacts to aquatic systems. Particle monitoring can be performed to determine the range of grain sizes found in storm water runoff and the constituents that become attached to individual particles. The particles can be analyzed using standard laboratory methods.

This guidance manual is specifically prepared to address the particle studies undertaken by Caltrans to evaluate storm water runoff from transportation facilities. Methods for addressing receiving water sediments are beyond the scope of this manual and therefore not discussed in this document. Many of the components involved in planning and implementing particle studies are similar to those presented in the in Caltrans Storm Water Monitoring Protocols (CTSW-RT-00-005, Second Edition). Therefore, this manual is organized in the same manner, with minor variations, as the Storm Water Monitoring Protocols document, with two primary parts presented below.

Part I: Preparing the Study Plan

- Comprised of Sections 2 through 5, covering topics relevant to planning particle studies.
- Topics include developing purpose and objectives, site selection, testing type selection, selection of sample collection methods and equipment, and documentation.

Part II: Implementing the Study Plan

- Comprised of Sections 6 through 10, covering topics relevant to implementing a particle study plan.
- Topics include sample collection, quality assurance / quality control, laboratory sample preparation and analytical methods, quality assurance and quality control (QA / QC) data evaluation, and data reporting.
- Training, preparation, and logistics are additional components of implementing any storm water study. Caltrans Storm Water Monitoring Protocols (CTSW-RT-00-005, Second Edition) provides details concerning training, preparation, and logistics for storm water studies. These sections of the water quality document should be consulted for guidance when conducting Caltrans particle studies.

Section 2
Develop Purpose and Objectives

This section of the manual outlines the systematic decision-making process necessary to plan a Caltrans particle study that will achieve project-specific goals and objectives, including the development of appropriate data quality objectives (DQOs). The process includes the following seven steps that summarize the systematic planning process (U.S. EPA, 2000):

- Determine Project Goals and Objectives
- Identify Resources and Constraints
- Identify Data Characteristics and Tools
- Determine Key Study Parameters
- Specify Methods for Obtaining Data
- Develop Performance / Acceptance Criteria
- Optimize the Design for Obtaining the Data

Throughout this planning process is it essential to bear in mind that runoff from transportation facilities is generally episodic in nature, such as either derived from storm events or snowmelt. The study design must therefore account for the sporadic and transitory nature of the runoff events.

This seven-step process listed above is illustrated in Figure 2-1 and each step of the process is discussed in the following subsections.

2.1 Determine Project Goals and Objectives

The overall goal(s) of the study are used to determine the specific questions that the study will be designed to answer; from these questions, specific study objectives are developed, as discussed below.

The initial step in the development of a particle study plan is to determine the goal of the project based on the task order or problem statement presented by Caltrans. The overall goal of the study will in most cases have been defined previously in the Caltrans Storm Water Management Plan (SWMP) and other planning documents.

Once the goal of the study is defined, the project purpose can be stated so as to direct the project to provide data to fulfill the study goal. The goal and purpose of the study are strongly linked, and should be explicitly stated in the study plan. The purpose of the study is, generally speaking, to provide data in fulfillment of the study goals. Once the program goals and purpose are established, a set of specific study questions and objectives should be developed.

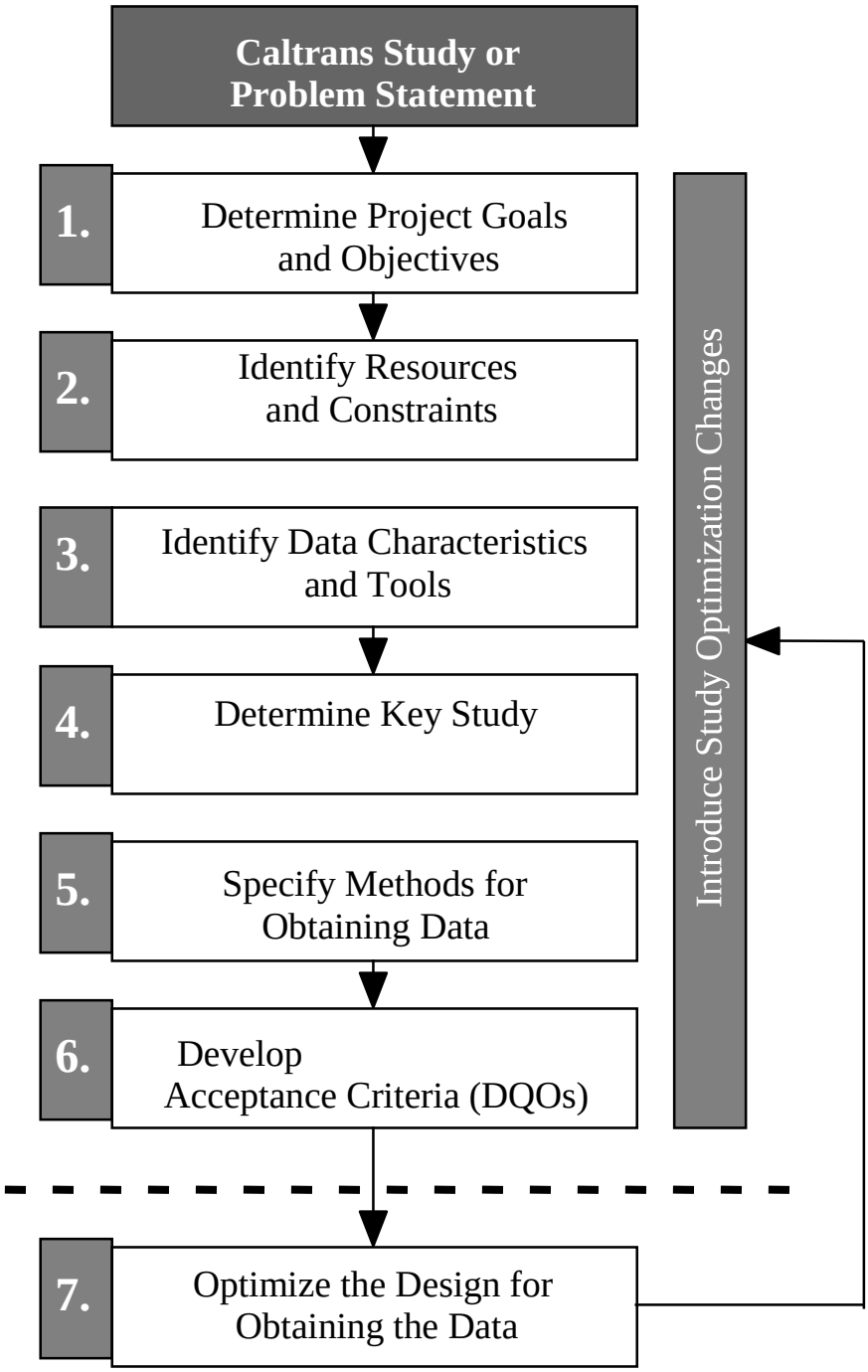


Figure 2-1. Systematic Planning Process Flow Chart

Caltrans particle studies will be designed typically to characterize the particles found in runoff in terms of grain sizes, weight of particles, and chemical content. This can be accomplished using a variety of approaches, depending on the nature of the specific study objectives. When designing specific project goals, applicable regulatory requirements must be considered in formulating the key question(s).

Typical questions that may be applied to Caltrans particle study projects include:

1. *What is the grain size distribution of particles found in runoff?* Figure 2-2 is a diagram of grain size (diameter in microns [µm]) for various classifications of solids expected in runoff.

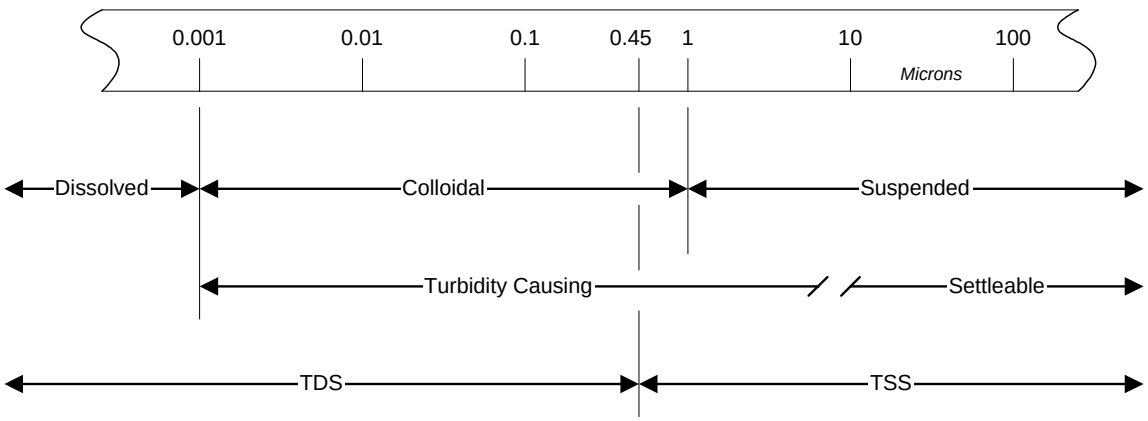


Figure 2-2. Grain Size Classification Scale

As shown, runoff will contain dissolved solids (<0.001 µm), colloidal solids (0.001 – 1 µm) and suspended solids (>1 µm). Colloidal solids and the smaller suspended solids (less than about 10 µm) typically are turbidity-causing while the larger suspended solids (greater than about 10 µm) are typically settleable. Settleable solids will settle out due to gravity over time, with the smaller particles requiring longer periods of time to settle. Colloids are microparticles that remain suspended in waters because their gravitational settling is less than 0.01 cm / sec (Stumm et. al 1981). Differentiation between the various categories of solids generally will vary depending on such parameters as particle density, chemical composition (organic versus inorganic), flow rate, and turbulence. The cut-off between turbidity-causing and settleable solids is especially sensitive to these parameters and will, therefore, vary depending on site conditions. Conversely, the cut-off between total dissolved solids (TDS) and total suspended solids (TSS) is normally defined at 0.45 µm by standard analytical methods. The 0.45 µm filtrate (measuring TDS) will contain turbidity causing colloids in addition to dissolved solids, while the particles retained on the 0.45 µm filter (measuring TSS) will consist primarily of particles in the suspended solids category (both turbidity-causing and settleable), with some larger turbidity-causing colloids.

2. *What is the chemical content, mineral makeup, and physical dimensions associated with particles?* These characteristics of the particles affect their mobility and bioavailability to aquatic organisms. For example, the oxidation / reduction status influences the retention or release of metals; the organic matter content affects the affinity of metals and nonpolar organic contaminants to the sediment; and the size and texture of the particles affects which contaminants are more readily adsorbed to the sediment particles.

   In addition, several particular constituents are found in highway runoff due to exposure to traffic. Typical constituents found in highway runoff and their sources are summarized in Table 2-1.

3. *Are specific chemicals and concentrations associated with certain grain sizes?* If certain grain sizes are found to contain contaminates or have higher levels of contaminates, BMPs should be designed or applied that focus on removing the particles associated with these grain sizes.

4. *What are the particle loads found in runoff?* Loads can be defined in terms of particle numbers and mass. The number of particles can be just as important as mass. Turbidity-causing particles may have a very high number load but represent a relatively low mass load. Removing the majority of the particle mass load may not remove the majority of the turbidity-causing particles.

Other potential objectives of Caltrans particle studies may be related to BMP effectiveness, land use types, and seasonal and / or other temporal trends. Specifically the following additional questions could be incorporated into particle studies:

1. *Are there differences in the particles in runoff from different locations or land uses?* Because runoff may come into contact with different materials, studies may be needed to quantify related differences in grain size and chemical content.

2. *Does BMP implementation change the grain size distribution or chemical load?* Particle evaluation can be an important tool for evaluating BMP performance, as particle data can be used to determine the effectiveness of a BMP at actually removing particles in the runoff, along with the associated pollutants. Knowledge of grain size distribution and the chemical content of each grain size category can also aid in effective selection of storm water BMPs, either through implementation of source controls for specific particles, or by the design and implementation of structural controls targeted at removal of the particles that represent the largest load.

Table 2-1
Sources of Pollutant Constituents

Constituent	Primary Sources
Particulates	Pavement wear, vehicles, atmosphere, maintenance, snow/ice abrasives, sediment disturbance, construction activity, agricultural activities
Nitrogen, Phosphorous	Atmosphere, roadside fertilizer use, sediments
Lead	Tire wear, lubricating oil and grease, bearing wear, atmospheric fallout
Zinc	Tire wear, motor oil, grease
Iron	Auto body rust, steel highway structures, engine parts
Copper	Metal plating, bearing wear, engine parts, brake lining wear, fungicides and insecticides use
Cadmium	Tire wear, insecticide application
Chromium	Metal plating, engine parts, brake lining wear
Nickel	Diesel fuel and gasoline, lubricating oil, metal plating, brake lining wear, asphalt paving
Manganese	Engine parts
Bromide	Exhaust
Cyanide	Anticake compound used to keep deicing salt granular
Sodium, Calcium	Deicing salts, grease
Chloride	Deicing salts
Sulphate	Roadway beds, fuel, deicing salts
Petroleum	Spills, leaks, blow-by motor lubricants, antifreeze, hydraulic fluids, asphalt surface leachate
PCBs, Pesticides	Spraying of highway right of ways, atmospheric deposition, PCB catalyst in synthetic tires
Pathogenic Bacteria	Soil litter, bird and animal droppings, trucks hauling livestock/stockyard waste
Rubber	Tire wear

Source: Kobringer, 1984.

3. *Are there seasonal (within a year) or temporal (between years) trends in particles?* Runoff quality is known to vary significantly from event to event (depending on the hydrological characteristics of the event), within and between seasons (depending upon factors related to the seasonal build-up and wash-off of pollutants, such as the antecedent dry period and cumulative rainfall to date), and from year to year (especially when comparing wet and dry years). It may be necessary to quantify the relative level and nature of particles in the runoff from these various temporal conditions.

Once study questions and objectives are known, specific project information needs are identified. The information needs must address any pertinent requirements (as specified in the NPDES permit or mandated through other state or federal regulations), and focus the study planning effort on providing answers to the key question(s) addressed by the project.

2.2 Identify Resources and Constraints

Specific resources available and constraints pertaining to implementing the particle study should then be identified. Data resources from previous studies, as well as other existing resources such as personnel, equipment, and services often support planned studies. Studies are typically constrained by time, available budget, physical

limitations of the study area, and practical weather constraints (e.g., number of storms in a year). These resources and constraints must be established during the planning process. Budget constraints are typically known from the beginning and generally affect the scope and detail of the study. The project may also be constrained by applicable regulatory or legal requirements.

2.3 Identify Data Characteristics and Tools

The study design should specify the expected characteristics of the data and the planned data analysis tools, so as to:

- Optimize collection of data within the financial and logistical / practical limitations of the proposed study
- Provide results that fulfill study objectives

For example, for a particle grain size study the quantity and quality of the data should be sufficient to develop a clear picture of the characteristics of the grain size distribution (i.e. grain size categories and percent based on either number or mass). This may equate to monitoring fewer sites (i.e., selecting representative sites) to develop detailed data, instead of monitoring a large number of sites to merely confirm that storm water runoff contains particles.

Essential data characteristics include the type of particle data to be collected (e.g., grain size, sediment amount or weight, chemical content), the variables affecting the data (e.g., antecedent conditions, rainfall intensity, site type and location), and the expected variability of the data (derived from previous studies when available).

Prior to the initiation of a particle study, a strategy should be developed for analysis of the data, directed to answering the specific study questions. The selected data analysis technique(s) may influence the type and quantities of data required to satisfy study objectives. The analysis methods applied to data collected for BMP evaluations or characterization studies typically involve straight-forward statistical operations; however, Caltrans data may be applied to multiple applications in the future (e.g., modeling applications, comparisons to other studies, and assessments of particles and sediments in receiving waters), and should be collected and presented in a manner that will allow the most versatile use of the data.

2.4 Determine Key Study Parameters

Key parameters of particle studies are determined using the information gathered in the previous steps of the systematic planning process. Key study parameters include site selection (see Section 3), number of monitored events and their temporal or spatial distribution, characteristics of target events, types of samples (composite, grab, etc.) and particle test methods (see Section 4). The better these characteristics are understood, the more efficiently the monitoring data can be collected.

The monitoring locations can be selected to optimize the physical monitoring of the environmental sample; this is discussed in more detail in Section 3. If possible, sites selected for particle studies should be monitoring stations in place for other programs, which will generate supporting water quality, litter, and toxicity data.

The planned numbers of sites and monitoring events are often constrained by fiscal factors; this involves not only the costs of sample collection, but also the costs of sample analysis. For this reason, the number and types of particle tests should be considered in the early stages of project planning (see Section 4), so the costs of the appropriate sample collection and analysis can be factored into the expected cost per monitoring event.

The types of storms or events to be monitored and optimal temporal distribution of monitoring events also should be considered during project planning. For example, if the project objectives include characterizing seasonal variation in particles, the monitoring events must be adequately distributed throughout the period(s) of interest. Besides seasonal distribution, a number of variables can be considered when selecting types of events to monitor. These variables could include storm size (rainfall amount), duration, and antecedent conditions (such as number of days since the previous rainfall). Event selection criteria should be developed to guide project managers in the appropriate selection of monitoring events during the monitoring season.

In addition to considering the types of storms to monitor, the timing of sample collection (as it relates to the event hydrograph) should also be considered. Possible approaches may include collection of a single grab sample during the initial or “first flush” portion of the event, collection of single grabs during discrete portions of the hydrograph (ascending, peak, and/or descending portions), collection of multiple grab samples at points throughout the event, or collection of an event-length composite sample.

2.5 Specify Methods for Obtaining Data

Once the key study parameters are known, appropriate sample collection and analysis methods are specified (see Sections 6, 7, and 9). This includes the types of samples collected and sample collection techniques (composite, grab, manual, passive, automatic, etc.), the equipment used to collect the samples, the particle evaluation methods, QA/QC procedures, and the specific procedures to be followed in accordance with the physical layout of the study site (e.g., which discharge flows best characterize the highway runoff and the practical considerations for collecting samples at that site). The sample collection methods must consider the laboratory analysis specifications for sample handling, containers, sample type, holding time, and preservation (see Sections 6 and 9).

2.6 Develop Data Quality Objectives

The central goal of any particle study is to provide scientifically defensible data in fulfillment of program objectives. This goal is best achieved through scientific design of the study and sound technical planning. Statistical methods may be used in the design of the study to determine the optimum number of sampling sites and sampling events (monitoring frequency) that will be needed to fulfill specific project objectives. Data quality objectives (DQOs) should be specified for the project to produce the data that will be useful in addressing study objectives, and to establish meaningful confidence levels for the monitoring data.

DQOs, as defined for this guidance document, specify the quality of data required to support the specified objectives of particle studies. DQOs generally are used to determine the level of quality considered to be acceptable in the data produced by the study; in large measure they are used to specify acceptable ranges of field sampling and laboratory performance.

A detailed discussion of the development of DQOs for Caltrans storm water monitoring projects is presented in the Caltrans Storm Water Monitoring Protocols (CTSW-RT-00-005, Second Edition). In general, the same systematic approach for determining DQOs for storm water monitoring projects applies to establishing DQOs for particle studies. Each project should include a thorough QA/QC data review and evaluation to assess project success in meeting accuracy and precision acceptance criteria (refer to Section 8 of this document).

Numerical DQOs should be established for constituent reporting limits, analytical precision, accuracy, completeness, and representativeness. These parameters are summarized below and discussed in detail in Sections 8 and 9 of this document. Project-specific DQOs should be specified in the sampling and analysis plan (SAP).

Reporting limits. Constituent reporting limits should be set low enough to reliably quantify constituents at meaningful levels. All efforts should be made to report constituent concentrations at levels greater than the reporting limit. The program-specific reporting limits identified in Sections 4 and 9 may be modified if site-specific data demonstrate that any change would improve the overall quality of collected data and still meet the DQOs.

Analytical precision and accuracy. Precision and accuracy of analytical results are often determined by historical laboratory performance; in some cases interlaboratory studies conducted by USEPA or others are used to set these limits.

Completeness. Completeness refers to the percentage of samples that are sampled and analyzed as planned, for which results are found to be valid following QA/QC data validation (see Section 8.5 in this document). A typical completeness level that can be expected of environmental analysis is 95%. Constituents that can occur as common laboratory contaminants may require a less restrictive DQO for completeness.

Representativeness. Representativeness for sediment samples in Section 6 and water samples is discussed in Section 7. Representativeness for sediment samples is based on surface variability, spatial coverage, and vertical profile. Representativeness for water samples is based on storm size, percent storm capture, and total number of composite sample aliquots.

2.7 Optimize the Design for Obtaining the Data

The systematic planning process, as applied to the Caltrans Statewide Stormwater Monitoring Program, is a synthesis of currently evolving USEPA guidance and the practical considerations of overall goals (Caltrans, 2000). The seven-step process described in this section is the starting point for structuring specific Caltrans particle studies. The seven-step process is iterative, with the final step providing for feedback to any of the previous six steps. The remaining sections of this manual carry out and build on these steps, from site selection to QA/QC data evaluation.

Ideally, the systematic planning process can be iterative for each project, as needed. It is possible to modify study parameters, with approval from the Caltrans task order manager, to optimize data collection to meet study objectives, based on newly collected data and field observations. This can sometimes be done during natural break points of the study (e.g., at the end of the wet season), when data are analyzed, and achievement of study objectives is assessed. In some cases, the collected information may indicate modifications are required to the study goals, the collection methods, the particle analyses, or the types and frequency of events sampled.

Section 3
Site Selection

Selection of sites for Caltrans particle studies should start with evaluation of monitoring stations that exist for other programs (e.g., existing Caltrans storm water monitoring locations). If possible these existing sites should be selected for particle studies to save time and resources and to provide supporting chemical, litter, or toxicity data. Some modifications and use of different sample collection methods may be required at existing runoff monitoring sites to accommodate the larger sample volumes needed for particle analyses (see Sections 6 and 7). Site selection will also depend on the program objectives and regulatory requirements. However, once these criteria have been used to establish the number and type(s) of monitoring sites, consideration of the following items will help select appropriate monitoring locations for particle studies:

- Representativeness
- Best Management Practices (BMP) Effectiveness
- Site Visit

This section focuses on use of pre-existing Caltrans runoff-monitoring sites for particle study sample collection. Storm water monitoring program site selection is discussed in detail in Caltrans Storm Water Monitoring Protocols (CTSW-RT-00-005, Second Edition), including information on the above items as well as personnel safety, site access, equipment security, flow measurement capability, electrical power, telephone, and run on from areas outside the Caltrans right-of-way (ROW). Site selection for receiving water studies is not included in this manual.

3.1 Representativeness

Types of runoff sampling sites specified for Caltrans monitoring may include highway sites (freeways, expressways and/or conventional highways as shown in Photo 3-1), maintenance yards, park-and-ride lots, or construction sites. It is important to select monitoring sites that are representative of typical Caltrans operations for these site types. The Caltrans Storm Water Monitoring Protocols (CTSW-RT-00-005, Second Edition) provides guidance on site characteristics to consider when selecting representative monitoring sites.

Photo 3-1. Documentation of potential highway monitoring site.

An additional consideration for particle studies may be to select sites that discharge directly into identifiable receiving water bodies. This would support future studies that may be conducted to investigate the potential receiving water impacts of Caltrans discharges.

3.2 BMP Effectiveness

Studies of BMP effectiveness involve different objectives than those for general storm water discharge monitoring. The goals of BMP monitoring programs are somewhat different as well. The Caltrans Storm Water Monitoring Protocols (CTSW-RT-00-005, Second Edition) provides detailed information concerning the selection of sites for BMP performance monitoring.

Site selection for BMP evaluation will depend upon the type of BMP (e.g., structural or non-structural). Structural BMPs typically have well-defined boundaries and may be relatively easy to monitor (Photo 3-2). When evaluating structural BMPs, monitoring locations should be located immediately upstream and downstream of the structure. This will allow for comparison between particles found in the storm water influent of the BMP and the storm water effluent of the BMP. Monitoring within the BMP may also be considered, such as at locations designed to trap sediments.

Photo 3-2. Documentation of potential detention pond BMP monitoring site.

Non-structural BMPs (e.g., street sweeping, catch basin cleaning, illicit discharge elimination) may be more difficult to monitor because they can be influenced by many factors that cannot be "controlled", and may not have clearly defined inlet and outlet flows. In such cases, it may be necessary to determine the particle characteristics in the runoff at the same sites before and after BMP implementation.

3.3 Site Visit

Each potential monitoring site should be visited to confirm the expected site characteristics and verify whether the site is suitable for the needs of the particle

study. When possible, a visit should be conducted during or after a storm, when the discharge flow conditions can be observed. A wet-weather visit can provide valuable information regarding logistical constraints that may not be readily apparent during dry weather. However, a dry-weather visit should also be conducted to observe any non-storm water flows. If any significant dry-weather flows are present this should be noted and considered during final site selection. Because some types of particle analyses require large sample volumes, the sample station equipment should be evaluated to ensure that adequate sample collection is possible. The site visit form used during the site visits conducted during the Statewide monitoring sites is shown in Figure 3-1. The form provides examples of elements to be considered when evaluating various sites during field visits.

FIGURE 3-1. SITE EVALUATION FORM

Date _____ Reviewer _____
District _____ County _____

City _____ Route/Post Mile _____

Address _____

Site Contact _____Telephone_____

TYPE OF SITE

☐ Highway ☐ Maintenance Station ☐ Park-and-Ride
☐ Rest Area ☐ Other

*Describe:*_____

_____

REPRESENTATIVENESS

Surrounding Land Use

☐ Transportation ☐ Agriculture ☐ Residential
☐ Commercial ☐ Industrial ☐ Open

Site Surroundings: ☐ Urban ☐ Rural

Describe: _____

Approximate Tributary Area (acres): _____

Upstream Site Topography (flat, steep, etc.): _____

Downstream Conveyance or Receiving Water Type: (e.g., storm drain, open channel, street, pond): _____

Is the drainage area 100 percent representative of site type? ☐ yes ☐ no
*Describe:*_____

Annual ADT _____ ☐ NA

Tidal influences ☐ yes ☐ no
Illegal dumping ☐ yes ☐ no

llicit connections ☐ yes ☐ no
High groundwater table ☐ yes ☐ no
Erosion ☐ yes ☐ no
Runoff from landscaped areas ☐ yes ☐ no
Is site representative of Caltrans Highways and/or Facilities? ☐ yes ☐ no

Explain for any questions answered "yes" _____

_____

Are there exposed materials that warrant additional analyses beyond the standard suite defined in the Caltrans Guidance Manual: ☐ yes ☐ no
If so, then list:

_____

_____

Other observations:

_____

_____

Overall Representativeness Rating (0 to 10): _____

PERSONNEL SAFETY

Personnel safety issues? ☐ yes ☐ no
(e.g., Proximity to traffic lanes, steep embankments traffic, toxic gases, explosives, slips/trips/falls, fast-moving water, confined spaces, etc.)

*Describe:*_____

Overall Personnel Safety Rating (0 to 10): _____

SITE ACCESS

Vehicular site access? ☐ yes ☐ no

*Describe:*_____

Continuous access during storms? ☐ yes ☐ no

*Describe:*_____

Site remote and/or travel to site subject to traffic delays? ☐ yes ☐ no

*Describe:*_____

Site subject to flooding? ☐ yes ☐ no

*Describe:*_____

Will monitoring activities interfere with Caltrans/motorists ☐ yes ☐ no

*Describe:*_____

Overall Site Access Rating (0 to 10): _____

EQUIPMENT SECURITY

Is the site subject to vandalism? ☐ yes ☐ no

*Describe:*_____

Is the site subject to other damage (e.g., errant drivers)? ☐ yes ☐ no

*Describe:*_____

Overall Equipment Security Rating (0 to 10): _____

FLOW MEASUREMENT CAPABILITY

Type of runoff from site: ☐ Curb and gutter ☐ Overland flow ☐ Other

*Describe:*_____

Potential sampling location (with access to flow):

☐ Storm drain inlet ☐ Ditch, swale ☐ Culvert ☐ Pipe

☐ Other (describe)_____

*Comments*_____

_____

Will the sampling point be unaffected by upstream BMPs? ☐ yes ☐ no

*Describe:*_____

Will the sampling location be unaffected by site activities? ☐ yes ☐ no

*Describe:*_____

Is grab sampling possible? ☐ yes ☐ no

*Describe:*_____

Is the sampling location subject to backwater conditions? ☐ yes ☐ no

*Describe:*_____

Will uniform flow be established? ☐ yes ☐ no

*Describe:*_____

Will the depth of flow be at least ¾ inches? ☐ yes ☐ no

*Describe:*_____

Is flow measurement feasible? ☐ yes ☐ no

*Describe:*_____

Will flow measurement be accurate? ☐ yes ☐ no

*Describe:*_____

Can the site be easily instrumented? ☐ yes ☐ no

*Describe:*_____

Can a primary flow measurement device be easily retrofitted? ☐ yes ☐ no

*Describe:*_____

What type of flow meter is most suitable?

☐ Bubbler ☐ Area/Velocity

☐ Ultrasonic ☐ Combination/Other_____

Overall Flow Measurement Capability Rating (0 to 10): _____

ELECTRICAL POWER AND TELEPHONE ACCESS

Electrical Power Available? ☐ yes ☐ no

_____

Telephone lines available? ☐ yes ☐ no

_____

Clear cellular phone reception at site? ☐ yes ☐ no

_____

Overall Electrical Power and Telephone Access Rating (0 to 10): _____

NON-CALTRANS SOURCES

Contributing off-site runoff	☐ yes	☐ no
Adjacent industrial sites	☐ yes	☐ no
Adjacent commercial farming	☐ yes	☐ no

Overall Non-Caltrans Sources Rating (0 to 10): _____

Note: Obtain site plans or draw a sketch and take photos.

Section 4
Particle Constituent Selection

To select the specific constituents to be included in a given particle monitoring study, the following items should be considered:

- Project Objectives and Resources
- Regulatory Requirements
- Pollutant Sources in the Catchment Area
- Existing Monitoring Data
- Beneficial Uses / Impairments of the Receiving Water
- Typical Constituents to be Measured
- Testing Methods
- Phasing / Screening

Each of these considerations is discussed below, followed by a suite of possible analytical tests Caltrans may use for particle monitoring studies.

A summary schematic of the process for determining the types of tests to be conducted is shown in Figure 4-1. The procedure calls for examining the purpose and goals of the project, existing permit requirements, and any expected sources. Consideration of sampling and analysis costs (i.e., available project resources) is included as a final step in making this determination. This process allows selection of constituents that are the most appropriate for inclusion in the particle monitoring study.

4.1 Project Objectives and Resources

The types and number of particle tests selected for a given study will ultimately depend upon the objectives and available resources (e.g., personnel and funds). As discussed in Section 2, particle monitoring studies should be designed to answer the specific questions that were developed during the study design phase. Some of the objectives of a particle monitoring study include:

- Determine grain size distribution and mineral content of particles found in runoff
- Identify chemicals associated with particles and the concentrations
- Measure concentrations of specific chemicals associated with certain particle sizes
- Assess differences in the particles of runoff from different locations or land uses

- Evaluate BMP implementation effects on the grain size distribution or chemical load
- Identify seasonal (within a year) or temporal (between years) trends in particles

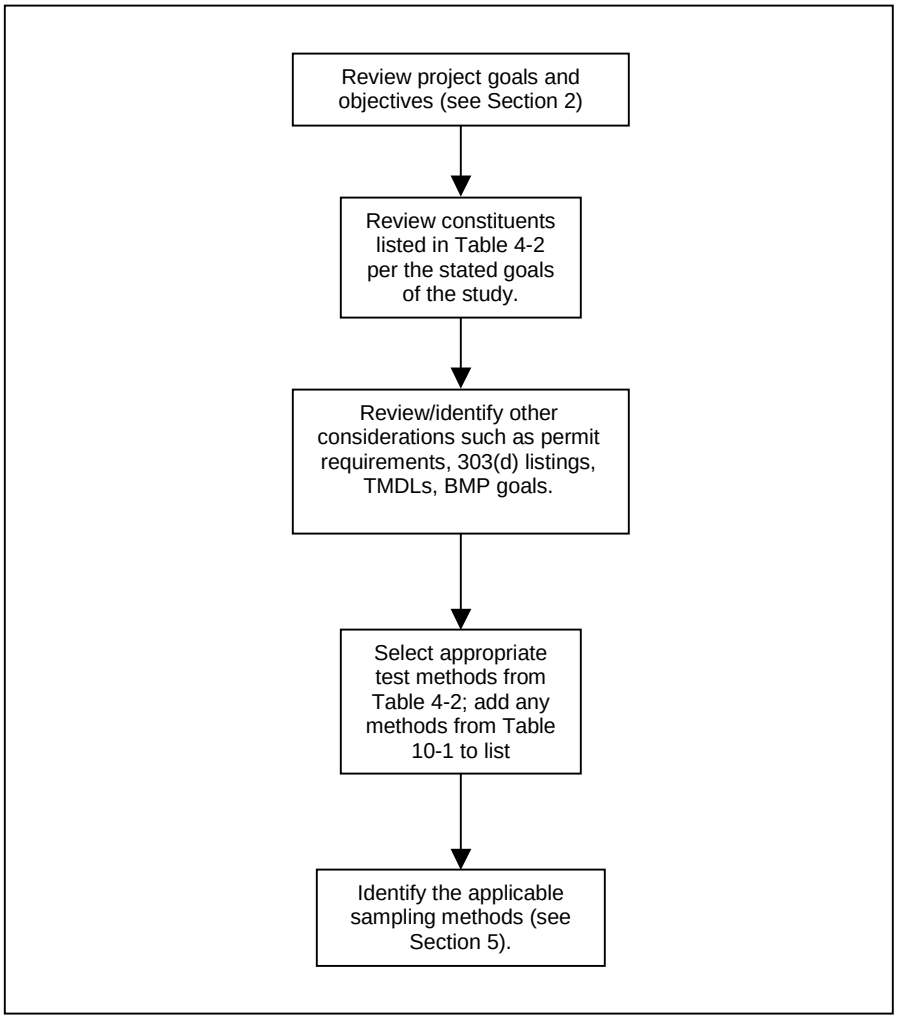


Figure 4-1
Schematic of Particle Test Method Selection Process

4.2 Regulatory Requirements

Currently, specific particle monitoring requirements are not outlined in the Caltrans Statewide Storm water NPDES permit. The permit does state that discharges shall not cause or contribute to violations of water quality objectives nor shall they cause certain conditions to occur which create a condition of nuisance or water quality impairment in receiving waters. As a permitted discharger, Caltrans may be obligated to fulfill related requirements under state or federal regulations, specifically the State Water Code or the Clean Water Act.

4.3 Pollutant Sources in the Catchment Area

Identifying potential constituent sources in the catchment area can aid in identifying the analytical methods to be employed. Caltrans projects may involve monitoring of runoff from highways, maintenance yards, park-and-ride lots, acceleration / deceleration zones, and construction sites. The potential constituent sources associated with each of these facilities may differ. A detailed description of the types of constituents expected from highway runoff, maintenance yards, rest areas, park-n-ride lots, and construction sites is provided in Caltrans Storm Water Monitoring Protocols (CTSW-RT-00-005, Second Edition). Sources of particulates and other highway-related pollutants are also summarized in Table 2-1.

4.4 Existing Monitoring Data

Table 4-1 provides a summary of the results of storm water runoff particle monitoring studies conducted by Caltrans. The existing data from these previous studies were used to form the basis for the list of Caltrans particle test types specified in Table 4-2.

Table 4-1
Related Caltrans Studies with Particle Monitoring

Author (Year)	Study Title	Land Use / Sample Source	Tests
Caltrans (1998)	Solids Transport and Deposition Study (STDS)	Highways	Volume, Quality
Caltrans (2001)	Statewide Stormwater Runoff Characterization Study	All Caltrans facilities	TSS, TDS
Caltrans(2001)	Tahoe Basin Stormwater Runoff Characterization Study	Highways	Weight, TSS, TDS, Grain size, Quality

4.5 Beneficial Uses and Impairments of the Receiving Water

Information on receiving water quality can be used to indicate whether discharges from Caltrans facilities have the potential to adversely affect the receiving water body. For instance, constituents known to be associated with highway and transportation-related facility runoff can be compared with the constituents of concern identified in receiving waters, to determine if highway or transportation-related facility runoff have the potential to impact receiving water quality.

Caltrans guidance should be consulted regarding high priority receiving waters within each Caltrans District, to determine whether any constituents of concern should be added to the analytical constituents list for a particular project.

4.6 Typical Constituents to be Measured

A list of typical constituents to be considered for Caltrans particle monitoring projects is provided in Table 4-2. Data from previous studies conducted by Caltrans form the essential basis for this typical minimum suite of analytical constituents. In some cases it may be necessary to add additional constituents to this list, for example to address specific receiving water concerns.

4.6.1 Conventional Parameters

The conventional parameters that can be included in the analysis of water samples that are collected for particle studies include total dissolved solids (TDS), total suspended solids (TSS), suspended solids concentration (SSC), turbidity, and total organic carbon (TOC). Specific conductance and pH are also measured in water samples in either the field or laboratory. Sediment samples can be analyzed for TOC.

4.6.2 Nutrients

The list of nutrients that sediment samples can be analyzed for includes nitrite (as N), nitrate (as N), total Kjeldahl nitrogen (TKN), and total phosphorous.

4.6.3 Metals

The metal species and analytical methods available to define the contents and characteristics in sediments are listed below. The methods may be used individually or in concert to meet the DQOs of the project.

- Total – Results correspond to total concentrations in the sediment (mg/kg).
- TCLP – Extraction (or leaching) of the sediment sample using the Federal toxicity characteristic leaching procedure (TCLP) method, followed by ICP analysis of the leachate. The TCLP method (1311/6010B) is designed to evaluate the potential of the sediment to generate hazardous leachate (especially after disposal in a Municipal landfill). Results correspond to concentrations in the leachate (mg/L).
- STLC – STLC is the California equivalent of the TCLP (method CAM WET/6010B). In the STLC, a different extraction fluid is used. Results correspond to concentrations in the leachate (mg/L).

Table 4-2
Constituents and Recommended Reporting Limits

Analyte	Matrix	Reporting Limit (RL) [1]	Units
Conventional			
Total Suspended Solids (TSS)	Water	1	mg/L
Total Dissolved Solids (TDS)	Water	1	mg/L
Suspended Sediment Concentration (SSC)	Water	1	mg/L
Turbidity	Water	0.05	NTU
Total Organic Carbon (TOC)	Water / Sediment	50	mg/L or mg/kg
pH	Water	+/- 0.1	SU
Ec	Water	+/- 10	Semens
Nutrients			
Total Kjeldahl Nitrogen (TKN)	Sediment	20	mg/kg
Nitrate (NO3) as N	Sediment	1	mg/kg
Nitrite (NO2) as N	Sediment	1	mg/kg
Total Phosphorous (P)	Sediment	1	mg/kg
Metals (total)			
Arsenic (As)	Sediment	1	mg/kg
Cadmium (Cd)	Sediment	2	mg/kg
Chromium (Cr)	Sediment	5	mg/kg
Copper (Cu)	Sediment	2	mg/kg
Iron (Fe)	Sediment	5	mg/kg
Lead (Pb)	Sediment	5	mg/kg
Nickel (Ni)	Sediment	5	mg/kg
Zinc (Zn)	Sediment	2	mg/kg
Metals (TCLP)			
Arsenic (As)	Sediment	0.5	mg/L
Barium (Ba)	Sediment	5	mg/L
Cadmium (Cd)	Sediment	0.1	mg/L
Chromium (Cr)	Sediment	0.5	mg/L
Lead (Pb)	Sediment	0.5	mg/L
Mercury (Hg)	Sediment	0.01	mg/L
Selenium (Se)	Sediment	0.1	mg/L
Silver (Ag)	Sediment	0.5	mg/L
Metals (STLC)			
Antimony (Sb)	Sediment	1	mg/L
Arsenic (As)	Sediment	0.5	mg/L
Barium (Ba)	Sediment	5	mg/L
Beryllium (Be)	Sediment	0.1	mg/L
Cadmium (Cd)	Sediment	0.1	mg/L
Chromium (Cr)	Sediment	0.5	mg/L
Cobalt (Co)	Sediment	0.5	mg/L
Copper (Cu)	Sediment	0.1	mg/L
Lead (Pb)	Sediment	0.5	mg/L
Mercury (Hg)	Sediment	0.01	mg/L
Molybdenum (Mo)	Sediment	10	mg/L
Nickel (Ni)	Sediment	1	mg/L
Selenium (Se)	Sediment	0.1	mg/L
Thallium (Tl)	Sediment	0.5	mg/L
Vanadium (V)	Sediment	1	mg/L
Zinc (Zn)	Sediment	2	mg/L

Table 4-2
Constituents and Recommended Reporting Limits (continued)

Analyte	Matrix	Reporting Limit (RL) [1]	Units
Hydrocarbons			
TPH-G (gasoline)	Sediment	1	mg/kg
TPH-D (diesel)	Sediment	50	mg/kg
TPH-J (jet fuel)	Sediment	50	mg/kg
TPH-K (kerosene)	Sediment	50	mg/kg
TPH-S (stoddard solvent)	Sediment	50	mg/kg
VOCs			
Benzene	Sediment	5	mg/kg
Toluene	Sediment	5	mg/kg
Ethylbenzene	Sediment	5	mg/kg
Xylene	Sediment	15	mg/kg
Weight			
Dry	Sediment	0.1	g
Wet	Sediment	0.1	g
Grain Size Fraction			
Particle Size Distribution	Sediment	0.1	Fraction
Particle Counting	Water / Sediment	0.1	Fraction
Mineral Content			
Individual Mineral Species	Sediment	0.01	Fraction

[1] Note that the detection limit is usually less than the reporting limit

4.6.4 Organics

Particle samples can be analyzed for total petroleum hydrocarbon (TPH) compounds. TPH analyses for Caltrans monitoring projects will typically focus on gasoline and diesel hydrocarbons.

Additional organic constituents that may be analyzed include solvents. Although the majority of these constituents are volatile organic compounds (which readily evaporate and, therefore, not expected to be found in storm water runoff or the sediments), their inclusion in Caltrans storm water monitoring efforts may be important for characterization of runoff from maintenance yards.

4.6.5 Weight

The sediment samples or filtrate from water samples can be analyzed simply for weight of the collected sample. The weight can be expressed in terms of wet or dry, depending on whether the sample is dried prior to weighting.

4.6.6 Grain Size Fraction

The filtrate from water samples or sediment samples can be analyzed for grain size. Grain size is expressed in percent finer for a given grain size in terms of weight or particle number. Testing a whole range of grain sizes will provide the distribution, a useful method of characterizing particle content.

4.6.7 Mineral Content

There are hundreds of minerals types and infinite combinations found in runoff particles. Analytical methods are available that identify the mineral type and composition in terms of the fraction of the total particle.

4.7 Test Method Selection

Standard test methods have been established for the majority of the listed conventional constituents, nutrients, metals, organics, and grain size. The methods that meet the standard QA/QC requirements for Caltrans monitoring studies are presented in Section 9.

There are no standard methods for particle counting and mineral content. Alternative test methods for both particle counting and mineral content are discussed in Section 9.

4.8 Phasing / Screening

If a significant number of problem constituents are identified from the criteria discussed in this section (e.g., constituent sources, existing monitoring data, permit requirements, receiving water impacts) or if inclusion of certain constituents is questionable, a two-phased approach may be considered. During the first phase, conduct an initial screening by analyzing samples for a broad range of parameters of potential concern. Parameters not detected, or measured at levels well below concern, can be dropped from subsequent monitoring efforts (second phase).

Section 5
Sampling and Analysis Plan (SAP)

Proper documentation is required for all Caltrans particle studies. A SAP and Health and Safety Plan (HSP) should be prepared prior to initiation of any sampling activities.

This section provides general guidance for preparation of practical, useable SAPs for storm water particle monitoring programs. See Appendix D in Caltrans Storm Water Monitoring Protocols (CTSW-RT-00-005, Second Edition) for detailed information regarding individual components to be included in the HSP.

The following are sections that should be included in a SAP:

- Project Overview / Description
- Sampling Site(s)
- Constituents
- Data Quality Objectives (DQOs)
- Monitoring Preparation and Logistics
- Sample Collection, Preservation, and Delivery
- Quality Assurance / Quality Control
- Laboratory Sample Preparation and Analytical Methods
- Data Management and Reporting Procedures

Appendix:

- Health and Safety Plan (HSP)

Inclusion of these sections will allow for the development of a useable and practical SAP. The final product should be a single bound document that can be easily referenced during monitoring activities. The HSP can easily be included as an appendix to the SAP. Printing the SAP / HSP on waterproof paper will reduce the potential for water damage to the document during field use.

All Caltrans storm water monitoring documentation must be assigned a document identification number prior to document completion. The document identification number, assigned by the Storm water Management Program document distribution system manager, is used to track the document and develop document distribution lists. Two weeks prior to expected document deliverable date, the author must contact

the Caltrans storm water management program document distribution system manager to receive a document identification number and mailing labels.

Someone should prepare the SAP with a good understanding of field sampling procedures, laboratory testing methods, and data validation procedures. The analytical and soils laboratory(s) should provide input in order that the SAP (especially the QA / QC portion) is realistic, and consistent with the laboratory's operating procedures. Field personnel should also provide input regarding logistical details in order that the plan is practical and easy to use.

The SAP should include a thorough description of all activities required to implement the particle study. The plan should be organized to provide an overview of the project goals and organization, followed by a description of all monitoring activities in the chronological sequence in which they will typically occur. The plan should specify the quality assurance / quality control protocols that will be followed by field and laboratory personnel, and how the field and laboratory results will be managed and reported.

The contents of a typical storm water SAP are shown in Figure 5-1.

The following sub-sections further describe the contents of a typical storm water SAP that is applicable for particle studies.

5.1 Overview – Project Description, Organization, and Responsibilities

This section of the SAP should briefly describe:

- Description of why the particle study is being conducted
- Description of who is conducting the study
- General approach of particle monitoring activities

Roles and responsibilities of the key field and laboratory personnel who will be involved in the study (typical roles include project manager, sampling coordinator, sampling team leaders, field crew, project QA / QC officer, and laboratory QA / QC manager)

1.0 PROJECT OVERVIEW / DESCRIPTION
- 1.1 Description of why the project is being conducted
- 1.2 Description of who is conducting the project
- 1.3 General scope of monitoring activities
- 1.4 Project organization / roles and responsibilities

2.0 SAMPLING SITES
- 2.1 Site location (map) including Global Positioning System (GPS) coordinates
- 2.2 Written driving directions
- 2.3 Site access instructions (gates, locks, keys, combinations)
- 2.4 Notification procedures

3.0 PARTICLE TESTS
- Specifies the types of particle tests to be conducted to meet program objectives

4.0 DATA QUALITY OBJECTIVES (DQOs)
- 4.1 Analytical reporting limits
- 4.2 Analytical precision, accuracy, and completeness
- 4.3 Data Quality Evaluation Plan

5.0 FIELD EQUPMENT MAINTENANCE
- 5.1 Equipment calibration
- 5.2 Equipment maintenance
- 5.3 Equipment cleaning (bottles / lids / tubing)

6.0 MONITORING PREPARATION AND LOGISTICS
- 6.1 Weather tracking
- 6.2 Monitoring event selection criteria
- 6.3 Action levels
- 6.4 Communications / notification procedures
- 6.5 Sample bottle order
- 6.6 Sample bottle labeling
- 6.7 Field equipment preparation

7.0 SAMPLE COLLECTION, PRESERVATION, AND DELIVERY
- 7.1 Sample collection methods
- 7.2 Field measurement methods
- 7.3 Field equipment list
- 7.4 Sample containers, preservation, and handling
- 7.5 QA / QC sample collection methods
- 7.6 Sample labeling (site names / codes, etc.)
- 7.7 Composite sample splitting
- 7.8 Forms and procedures for documenting sample collection and field measurements
- 7.9 Laboratory communication procedures
- 7.10 Sample shipping / delivery, chain-of-custody

8.0 QUALITY ASSURANCE / QUALITY CONTROL
- Field procedures for QA / QC sample collection

9.0 LABORATORY SAMPLE PREPARATION AND ANALYTICAL METHODS
- 9.1 Laboratory sample preparation procedures
- 9.2 Particle Testing Methods (including testing methods, sample handling, and holding times)

10.0 DATA MANAGEMENT AND REPORTING PROCEDURES
- 10.1 Data validation
- 10.2 Electronic data transfer
- 10.3 Filing of electronic and hard copy data
- 10.4 Reports

APPENDIX
- A Health and Safety Plan

Figure 5-1

A Typical Stormwater Sampling and Analysis Plan Outline

5.2 Sampling Sites

This section should describe the sampling sites selected for the particle study and provide rationale for the inclusion of each site. Site selection for particle studies should focus on existing Caltrans storm water monitoring sites which were selected based upon representativeness of land uses in the area, achievable flow measurement, site access, personnel safety, equipment security, and availability of electrical power and telephone. See Section 3 for monitoring site selection guidance.

The following detailed information should be included for each monitoring site:

- Site location map
- GPS coordinates
- Written driving directions
- Site access instructions (locked gate keys or combinations)
- Reference to encroachment permits issued by the local District
- Notification procedures (if notification is required prior to site access)

5.3 Particle Tests

This section should specify the types of particle tests to be conducted to meet program objectives. See Section 4 for selecting each type of particle test to be conducted. The SAP should include a list of test types, in tabular form, that includes at a minimum the following columns:

- Type of test (amount, grain size, chemical, mineral content)
- Sample collection method (i.e., grab or composite)
- Container type
- Volume or amount required
- Preservation
- Laboratory performing testing

U.S.EPA, ASTM, or other analysis protocols should be included in this section (see Section 9).

5.4 Data Quality Objectives (DQOs)

This section should specify the project goals and objectives, key project parameters, and the DQOs that were deemed appropriate for the project. See Section 2 for

guidance on the development of DQOs. The SAP should also describe the process by which data produced by the study are evaluated to provide a reference point from which a program-consistent QA / QC evaluation can be performed (see Section 8).

5.5 Field Equipment Maintenance

This section should include specific information concerning the maintenance of all sampling equipment. At a minimum, all equipment should be maintained according to manufacturer specifications. The following is a list of items that typically require regular maintenance:

- Passive sediment sampler – filters checked / replace
- Flow measuring device - calibrate, check battery and check / replace desiccant
- Rain gauge - calibrate and check for debris
- Portable field instruments (e.g., pH meter) – calibrate

Container and equipment cleaning should also be covered in this section of the SAP (see Appendix E in Caltrans Storm Water Monitoring Protocols (CTSW-RT-00-005, Second Edition) for guidance on sample bottle and equipment cleaning procedures). In addition, if equipment or sampling locations is located in a confined space, this section should include a discussion on the acceptable confined space entry procedures. See Section 6 and Caltrans Storm Water Monitoring Protocols (CTSW-RT-00-005, Second Edition) for guidance on the selection of sampling methods and equipment and detailed equipment installation and maintenance guidance.

5.6 Monitoring Preparation and Logistics

This section should describe the necessary pre-sampling preparations including:

- Weather tracking (if sampling is storm event driven)
- Storm action levels (if sampling is storm event driven)
- Communication / Notification Procedures
  - Telephone tree
- Sample container order
  - Sample container labeling
- Field equipment preparation
  - Inventory
  - Inspect

- Calibrate
- Charge batteries
- Check / replace desiccant

See Caltrans Storm Water Monitoring Protocols (CTSW-RT-00-005, Second Edition) for monitoring preparation and logistics guidance.

5.7 Sample Collection, Preservation, and Delivery

This section should provide detailed guidance on standard operating procedures for field personnel (i.e., a concise, useable guide for sampling activities). At a minimum, this section should include:

- Description of clean sample handling techniques
- Sample collection methods to be used at each location
- Field measurement equipment (e.g., pH meter) and methods to be used at each location
- Field equipment that will be required for monitoring at each station (includes a checklist so field people can confirm they have everything they will need before proceeding to the sampling location)
- Sample labeling procedures (site name / code, sample date and time, etc.)
- Sample compositing and splitting procedures (including testing prioritization for instances of insufficient sample volume)
- Procedures for collecting and labeling field blanks and duplicate samples
- Forms and procedures for documenting sample collection and field measurements
- Sample preservation and handling procedures
- Laboratory communication procedures, points of contact, and phone numbers
- Procedure for sample shipment or delivery to laboratory
- Details on completing chain-of-custody forms

See Sections 6 and 7 for detailed sample collection, preservation, and delivery guidance.

5.8 Quality Assurance/Quality Control

The QA / QC section should focus on QA / QC procedures necessary for field activities, such as field procedures and collection frequencies for the following:

- Laboratory duplicates
- Field blanks
- Equipment blanks

QA / QC sample collection frequencies are best presented in a QA / QC sample collection schedule table with a column for each event and a row for each site.

Laboratory QA / QC should be discussed in an appendix and should include the frequency and type of laboratory QA samples (e.g., laboratory duplicates, split samples, and bottle blanks), data reporting requirements (electronic and hard copy) and corrective actions. See Sections 8 and 9 for detailed QA / QC guidance.

5.9 Laboratory Sample Preparation and Test Methods

This section should describe the activities to be conducted by the laboratory, including sample preparation procedures. A table containing the following information should be presented:

- Analytical methods
- Reporting limits
- Reporting units
- Holding time
- Constituent name
- Laboratory QA / QC

See Section 9 for laboratory sample preparation and particle test methods guidance.

5.10 Data Management and Reporting Procedures

This section should describe how the data generated from the laboratory and field measurements are to be handled, evaluated, and reported. It should address:

- Data validation (QA / QC review in light of project DQOs, per procedures specified in the DQEP)
- Electronic data transfer

- Filing of electronic and hard copy data
- Data analysis (e.g., statistical evaluation, etc.)
- Reports (e.g., quarterly, annual, end of project)

At the beginning of the project, the field and laboratory personnel should review the entire SAP to obtain an overview of their respective roles and responsibilities. Before each sampling event, the field personnel should review the sampling methods section in detail, and the laboratory personnel should review the laboratory sample preparation and methods section. See Section 8 for QA / QC data evaluation guidance.

Efficient data storage, retrieval, and transfer methods should be established prior to initiation of any monitoring activities, including those to support particle studies. Suggestions are provided in the Caltrans Storm Water Monitoring Protocols (CTSW-RT-00-005, Second Edition) to guide Caltrans contractors and district personnel in the development of a reliable and useful data management system. Data gathered during particle studies will be incorporated into the Caltrans Statewide Stormwater Quality Database. Specific data reporting protocols for particle results are outline in Section 10.

5.11 Health and Safety Plan

Storm water and field monitoring involves activities that have the potential to adversely affect the health and safety of field personnel. Monitoring field crews often work in wet, poor-visibility conditions. Sampling sites may be located along streets or stream channels, or in remote, poorly lit areas, and may require access on a 24-hour basis. Workers may be exposed to traffic hazards, confined spaces, biological hazards, hazardous materials, fast-moving storm waters, and slippery conditions. Besides monitoring activities during storm events, monitoring equipment installation and maintenance activities may also take place under these conditions.

The information contained herein is for guidance only, and does not supersede or otherwise change any applicable state, local, or agency health and safety requirements or programs.

The general steps in HSP development for a given storm water monitoring project are listed below:

- Assign a health and safety officer to oversee all health and safety activities. This officer must be familiar with all applicable health and Safety requirements as well as being familiar with field sampling work.
- Write concise descriptions of all of the field activities that will be included in the program.

- Identify and evaluate the potential physical, chemical, and biological hazards associated with each activity.
- Specify the measures to be employed to reduce the health and safety risks associated with the identified hazards.
- Specify health and safety training and documentation requirements.
- Develop an emergency response/contingency plan.

Each of these steps is described in Appendix D of the Caltrans Storm Water Monitoring Protocols (CTSW-RT-00-005, Second Edition). Figure 5-2 contains an example outline for a project-specific HSP.

1.0 Introduction

2.0 Project And Safety Personnel

3.0 Site Information

4.0 Work Activities Covered By Health And Safety Plan

5.0 Hazard Assessment
- 5.1 Chemical Hazards
- 5.2 Confined Spaces
- 5.3 Physical Hazards
- 5.4 Biological Hazards

6.0 General Health And Safety Requirements
- 6.1 Employee Clearance
- 6.2 Site Safety Meetings
- 6.3 Accident Reporting
- 6.4 Prohibited On-Site Activities
- 6.5 Communications

7.0 Site-Specific Health And Safety Requirements
- 7.1 Special Medical Tests
- 7.2 Special Training
- 7.3 Physical Hazards
- 7.4 Hazardous Materials Identification And Protection
- 7.5 Confined Space Entry
- 7.6 Traffic Control
- 7.7 Personal Protective Equipment
- 7.8 Site Illumination
- 7.9 Biological Hazard

8.0 Emergency Response Procedures
- 8.1 Hospital Information
- 8.2 Emergency Route to Hospital
- 8.3 First Aid & Related Equipment

Figure 5-2
A Typical Outline for a Health and Safety Plan

Section 6
Sediment Sample Collection

Particle monitoring programs may require the collection of sediment samples. These samples will used to characterize the sediments that are deposited in BMPs, drainpipes, and inlets in terms of grain size, mass, chemical and mineral content, and loads (numbers and mass). Both composite and grab samples may be collected.

Particle monitoring studies need to be designed so the collected samples are representative of all sediments within a deposit. Ideally, this means collection of depth-based composite samples for sediments samples. Accumulated sediments may vary both laterally and vertically throughout the cross section of the deposit. Layers of sediment representing different runoff events may form in the deposit. Heavier particles may drop out of suspension first and accumulate in a different location than smaller or less dense particles.

The following are basic sediment sample collection and handling elements required during particle monitoring:

- Personnel Safety
- Sample Collection Methods
- Sampling Equipment and Containers
- Clean Sampling Techniques
- Sediment Sample Collection
- Composite Sediment Sample Collection
- Sample Representativeness Evaluation
- Sample Splitting
- Sample Preservation and Holding Time
- Sample Delivery / Chain of Custody

These elements are described below to provide sediment sample collection and handling guidance for field personnel engaged in storm water monitoring.

6.1 Personnel Safety

Before samples are collected, personnel must demonstrate these tasks can be safely performed at each sampling location. As discussed in Caltrans Storm Water Monitoring Protocols (CTSW-RT-00-005, Second Edition), personnel safety should be considered when selecting monitoring sites. Adherence to the following recommendations will minimize risks to sampling personnel:

- At no time during storm conditions or when significant flows are present should sampling personnel enter a manhole or standpipe.

- Field crews comprised of at least two people should be available for all fieldwork to be conducted under adverse weather conditions, or whenever there are risks to personal safety (Photo 6-1). Additional members may be required for confined-space entry and work performed near active highway lanes.

- Appropriate traffic control measures need to be applied in accordance with encroachment permits and or District directions. Personnel must be trained regarding appropriate traffic control measures. If appropriate, a traffic control plan should be developed for each site and included in the sampling and analysis plan prior to conducting sampling events.

- Only personnel properly trained and equipped for confined space entry may conduct a “confined” space entry; this applies to both the entrant and the observers.

- When appropriate, an encroachment permit must be filed with the local Caltrans district.

Photo 6-1. Two-person field crew working together

6.2 Sample Collection Methods

Sediment samples can be collected to represent a single location in a deposit (i.e., "grab" sample) or the entire deposit (i.e., "composite” sample). A grab sample is essentially a one-time collection of a sample amount adequate to perform the intended analyses. A composite sample is comprised of some number of individual sample aliquots or grab samples mixed together. For sediment monitoring, this usually refers to a series of samples collected over a defined portion of the deposit.

Both composite sampling and grab sampling are appropriate for particle sample collection, depending on the study objectives. The advantages and disadvantages of each sample collection method in terms of particle testing are provided in Table 6-1.

Composite Sampling. Manual and passive sampling are the two methods of composite sediment sample collection. The manual method uses hand-operated equipment to remove a sample or a series of samples from the sediment deposit. The passive method applies equipment designed to filter sediment from the runoff stream. Section 10 of the Caltrans Storm Water Monitoring Protocols (CTSW-RT-00-005, Second Edition) provides a description of manual compositing techniques.

Table 6-1
Advantages and Disadvantages of Grab and Composite Samples

Sample Type	Advantages	Disadvantages
Grab	▪ Require a minimum of equipment. ▪ Provide a measure of point-specific or instantaneous levels. ▪ Variations and changes are not masked by dilution with other samples.	▪ The chances of detecting a change in particles would depend on the spatial coverage and number; the probability of missing a change is high.
Composite	▪ The sample is collected over a greater spatial coverage than grab samples. ▪ Can provide a measure throughout a deposit	▪ Subtle changes may not be detected because they may be masked by dilution from other samples collected to develop the composite.

Grab Sample Collection. A grab sample is an individual sample collected at one specific site at one point at a location. Analysis of a grab sample provides a "snapshot" of sediment characteristics. Grab samples are most often collected using manual methods. Grab sediment samples for particle testing can be collected directly into the container that will be used in the laboratory or an intermediate container may be used to fill the sample container.

6.3 Sampling Equipment and Containers

For particle studies, field personnel may be required to collect composite sediment samples and/or grab sediment samples. It is important to use the appropriate sample containers and equipment for collection of sediment samples. Improper containers and equipment can introduce contaminants and cause other errors, which can invalidate the data. For example, chemicals may leach from the containers into the sample.

Photo 6-2. Example of a sediment sample container

Equipment and containers used in the collection of sediment samples for particle testing must be handled with care to minimize the possibility of contamination. Procedures need to be followed that maximize the ability of sampling personnel to collect samples reliably and with minimal sample contamination.

6.3.1 Selection of Sample Equipment

Selection of the most appropriate sampling equipment will depend upon study objectives, sampling logistics, and what is known about possible constituents at each site.

For all collection efforts, sampling devices must be made of chemical-resistant materials that will not affect the quality of the storm water or sediment sample. In general, suitable sampling devices should be constructed of: Teflon, glass, stainless steel, or polyethylene. These materials are known to be the most inert in terms of adsorption or desorption of compounds. It is important to evaluate each component of the sampling device (e.g., bottle lids, connections, spoons) for possible sources of sample contamination. For example, latex and neoprene rubber tubings should be avoided because latex is organic and neoprene rubber may contain trace metals. Butyl rubber seals may also contribute organics to the sample.

If information is available regarding the targeted constituents at a given site, this should guide the selection of sample containers. For example, if metals are suspected it is more appropriate to collect samples in polyethylene containers. At sites where organics are of concern, glass is preferred over polyethylene. Selection of appropriate sample containers for a given particle study should be evaluated and discussed with the laboratory prior to initiation of the study.

6.3.2 Sediment Sampling Equipment

Key equipment required to collect sediment samples include are presented for both manual and passive collection methods.

Manual Collection:

- Grade rods
- Core samplers
- Spoons, scoops and shovels
- Sample bottle(s)

Passive Collection:

- Particle trapping device
- Filters with structural support such as trays and boxes

The manual sampling equipment can include hand-operated items such as grade rods, core samplers, scoops and shovels that are designed to measure the depth of the sediment deposit or collect a physical portion of the deposit. These types of equipment are relatively inexpensive and easy to maintain. Manual sampling equipment which comes in direct contact with the sample during or after collection must be compatible with the specific constituents to be analyzed, as discussed previously.

Passive sampling equipment is designed to trap sediment and create deposits that can be collected or sampled using manual methods. Devices to trap the coarse-grained or

heavy material include detention ponds, drain inlets with sump bottoms, and sand traps. Any device that lowers the velocity of the flow and causes a portion of the suspended particles to settle out can be applied. An example of one such device is shown in Figure 6-1. This trapping device is a double barrel sand trap. Storm water runoff is directed through a series of two barrels where suspended particles are allowed to settle to the bottom before being discharged. Samples of the sediments that accumulate on the bottom of each barrel are collected using manual methods.

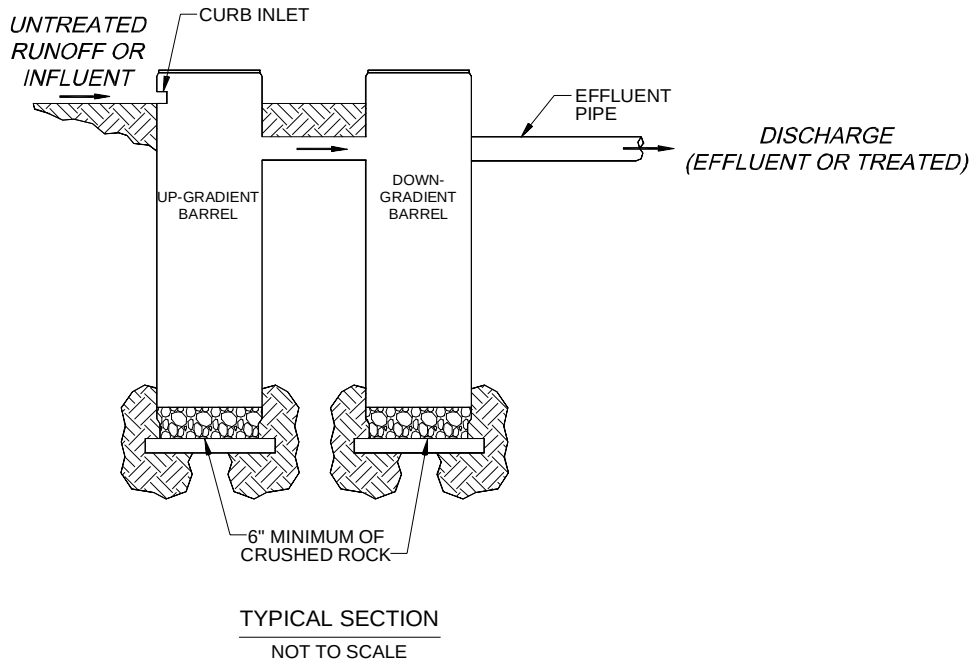
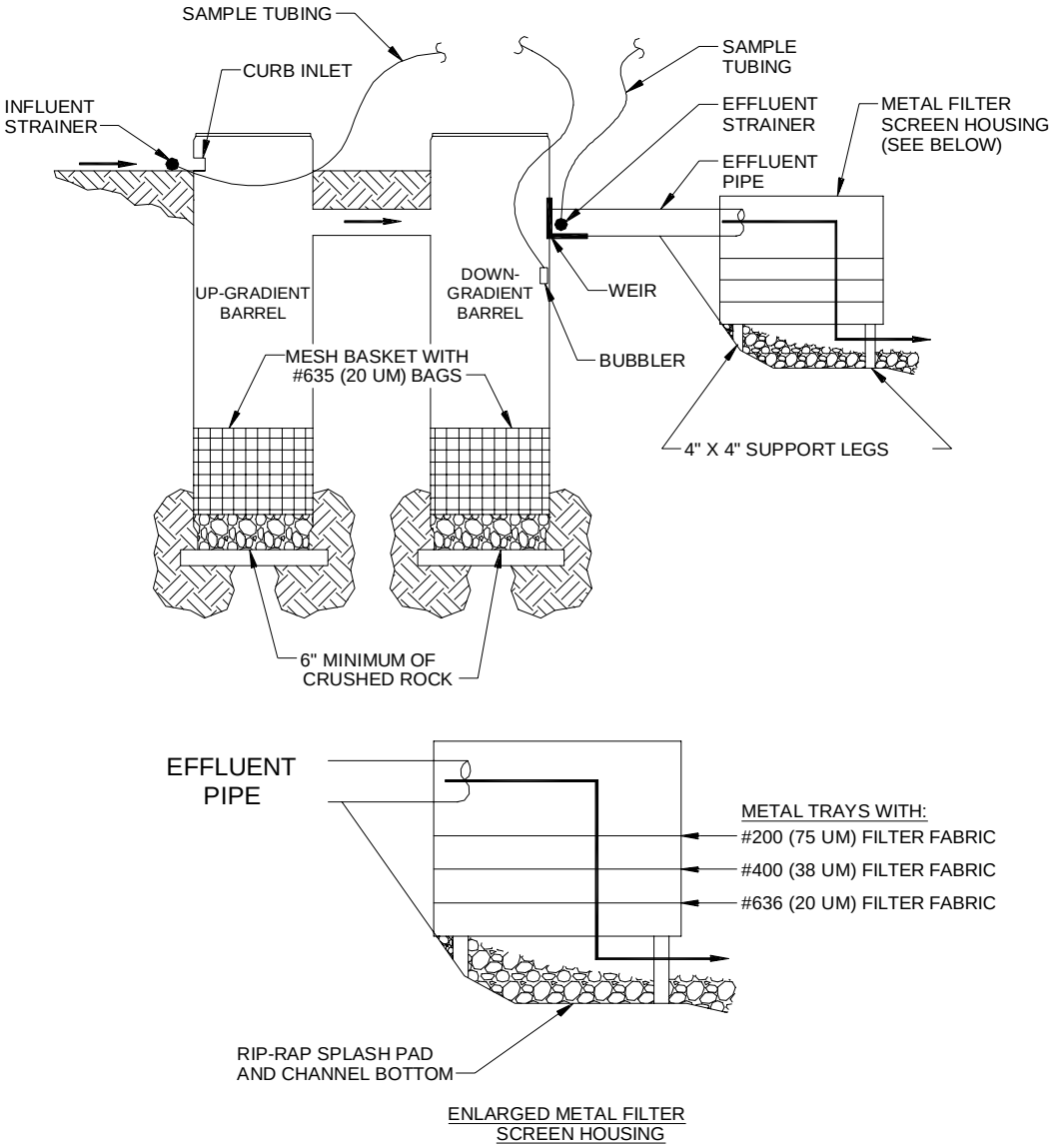


Figure 6-1
Example of a Sediment Trapping Device (Double Barrel Sand Trap)

For particles that do not readily settle out of suspension, filtering can be applied to collect them. Filtering devices are designed to direct the flow through a filter or a series of filters, trapping the desired sediment on the surface of each filter.

An example of a passive filter system is shown in Figure 6-2. Filters were applied to a double barrel sand trap facility shown in Figure 6-1. Filters in the shape of bags were anchored to the bottom of each barrel (Photo 6-3). This design provided a clean boundary at the start of the monitoring program. All the material that settled out of suspension, fell into the bags. The filters allowed the water to pass through and drain out of the bottom of the barrel so the operation of the trap was not compromised. But, the filters trapped all sediment larger than the pore size of the filter fabric. The bags were then retrieved on a regular basis (*i.e.*, per event, weekly, seasonal) and all the accumulated sediment removed or manual sampling was performed with the bags providing the lower boundary.



TYPICAL SECTION

NOT TO SCALE

Figure 6-2
Schematic of Double Barrel Sand Trap with Passive Sediment Collection System

Photo 6-3. Barrel with Filter Bag

The discharge from the sand traps or effluent was directed to a box with a series of stacked trays holding filters. Photo 6-4 shows an example of this design. The discharge flowed onto the top tray and through to the next one before exiting out of the bottom. The top filter had the largest pore size followed by filters with smaller pores sizes with the bottom filter having the smallest. This graduated filter design allowed the top trays to filter out the coarsest material and allow the finer materials to pass through. This design was implemented as a means to minimize clogging of the filters, which would cause the flow to bypass the system. This filter box design can be applied on its own or in conjunction with water quality monitoring.

Photo 6-4. Filter Box with Three Trays

The filters are prone to clogging. Regular cleaning or swapping out with clean filters is required to prevent bypassing. Complete capture of the entire runoff event may not be possible due to this clogging problem. Sediment collected on the filters may only represent a portion

Photo 6-5. Filter Box with Single Bag

of the runoff or sediment load. The filter box design can be modified to hold a single bag filter (Photo 6-5) as another means to reduce the impacts of clogging.

Figure 6-2 also shows how a passive sediment collection system can be combined with automatic water sampling and flow monitoring. The equipment associated with the autosamplers (strainers and sample tubing) and flow monitoring (weir and bubbler) is shown in relation to the passive monitoring equipment.

6.3.3 Sample Containers

Polyethylene, glass, or plastic containers (Photo 6-2) may be appropriate for sediment samples, depending on the objectives of the study, sampling logistics, and what is known about possible constituents present at each site. The selection of the appropriate sample container type should be discussed with the laboratory prior to initiation of the study. Refer to Table 9-1 in Section 9 for additional information.

It is important to keep extra sample bottles available in case bottles are contaminated or damaged. Additional bottles may also be needed when large volumes of sample are required by the grain size tests.

6.3.4 Equipment and Container Cleaning and Handling

Before samples are collected, all sampling equipment and containers are cleaned in a laboratory using appropriate solvent rinses, deionized water and/or other methods (e.g., high temperatures). The laboratory is responsible for generating acceptable sample container blanks to demonstrate that the sampling equipment and containers are free from trace metals and organics contamination before they are delivered to field sampling personnel. An acceptable blank is one that is free from particles and other chemicals. Section 8 provides additional information on collection of equipment blanks.

New plasticware used for sample collection does not require thorough cleaning before use. New glass sample containers should be rinsed before use according to the protocol outlined in the container rinsing and labeling section below.

New glassware must be soaked overnight in 10% acid and rinsed well in deionized water and dilution water. All non-disposable sample containers and other equipment must be washed after each use to remove contaminants as described below:

1. Soak 15 min in tap water and scrub with detergent, or clean in an automatic dishwasher.

2. Rinse twice with tap water.

3. Carefully rinse once with fresh, dilute (10%, V:V) hydrochloric or nitric acid to remove scale, metals and bases. To prepare a 10% solution of acid, add 10 mL of concentrated acid to 90 mL of deionized water.

4. Rinse twice with deionized water.

5. Rinse once with full-strength, pesticide-grade acetone to remove organic compounds (use a fume hood or canopy).

6. Rinse three times with deionized water.

After cleaning, sample containers and laboratory-cleaned sampling equipment are handled only while wearing clean, powder-free nitrile gloves. All laboratory-cleaned sampling equipment is double bagged in clean zip-lock plastic bags for storage or shipment. Clean bottles are stored in a clean area with lids properly secured.

6.4 Clean Sampling Techniques

Caltrans storm water monitoring projects employ "clean" sampling techniques to minimize potential sources of sample contamination, particularly from trace pollutants. Experience has shown that when clean sampling techniques are used, detected concentrations of constituents tend to be lower. Clean sample collection techniques that should be followed during the collection of storm water samples for particle monitoring are described below. More extensive clean sampling techniques may be required under certain conditions, such as monitoring to assess receiving water impacts.

Photo 6-6. Example of using gloves when collecting a sample

Extreme care must be taken during all sampling operations to minimize exposure of the samples to human, atmospheric, and other potential sources of contamination. Care must be taken to avoid contamination whenever handling containers, lids, and sampling equipment. Whenever possible, grab samples should be collected by opening, filling and capping the sample container as quickly as possible, to minimize exposure to airborne particulate matter. Additionally, whenever possible, samples should be collected upstream and upwind of sampling personnel to minimize introduction of contaminants.

To reduce potential contamination, sample collection personnel must adhere to the

following rules while collecting sediment samples:

- No smoking
- Always wear clean, powder-free, nitrile or similar surgical-quality gloves when handling sample containers as shown in Photo 6-6
- Never sample near a running vehicle. Avoid parking vehicles in immediate sample collection area (even non-running vehicles)
- Minimize the amount of time any sample container is left open
- Do not set lids down where they may accumulate contaminants
- Prevent foreign material (blowing dust, leaves, etc.) from entering any open sample container
- Never touch the inside surfaces of sample containers and lids, even with gloved hands
- Do not eat or drink during sample collection
- Do not breathe, sneeze or cough in the direction of an open sample container

6.5 Sediment Sampling Techniques

Sediment sampling may be required for studies that focus on the treatment effectiveness of BMPs and characterizing accumulated solids. Sampling can be performed to define physical properties of volume, amount (weight), and grain size of the accumulated sediments. Sample collection can also be performed for chemical analyses. A number of methods have been developed to collect the require samples. These methods are discussed below.

6.5.1 Volume of Accumulated Sediments

Volume measurements can be determined by first defining the dimensions of the facilities where the sediments are expected to accumulate, such as the floor of drain inlets or chambers in BMPs. These measurements should be made when the facility is clean and free of sediment and other materials. As the sediment and other materials accumulate, only the depth of this material needs to be measured. The total volume is then calculated by multiplying the measured depth by the other established dimensions (length, width, or diameter).

Photo 6-7. Collecting a depth of sediment measurement

A single depth measurement at a given facility may not be representative of the average depth. Depending on the flatness of the surface, multiple measurements may be required to accurately represent the depth. Flat surfaces will require fewer measurements than uneven surfaces. For example, 12 depth measurements were routinely collected at each drain inlet monitored for Caltrans Solids Transport and Deposition Study (Caltrans STDS 1998). However pilot studies conducted at the beginning of STDS found the number of depth measurements at a given site did not have a significant impact on the accuracy of the average depth. A whole range of measurements (3 – 24) generated similar average depth readings due to the flatness of both the surface material and inlet floor.

Depth measurements can be collected directly with a measuring rod. This method requires the rod penetrate the entire depth of material. This method may also require entering a confined space and standing on the accumulated material to take a reading.

The depth can also be determined by an indirect method (Photo 6-7). This method entails measuring from a fixed point to the surface of the accumulated material. This distance is then subtracted from the distance from the fixed point to the floor of the facility to calculate the depth of the material. This method will allow measurements to be collected outside of a confined space and minimize disturbing the accumulated sediment. Again multiple measurements may be required for an accurate representation of the average depth.

6.5.2 Sediment Amount

Collecting sediment samples to determine the amount or weight can be performed using one of two methods. The first method simply removes all material and separates out litter and organic material. The remaining sediment is than weighed to determine the total weight.

Often, the amount of sediment and accumulated material may be too large to handle easily. Under these circumstances, the weight needs to be estimated using the *in situ* volume and a dry density measurement. After the *in situ* volume is calculated using one of the methods discussed above, several representative samples of the entire deposit are collected using a core sampler (discussed below). The core sample will allow the volume of each sample to be determined. All litter and organic material are removed and the remaining sediment is dried and weighed. The dry density is calculated by dividing the total dry weight by the sample volume. The average of the

all the dry densities at a single site is then applied to the *in situ* volume to estimate the total dry weight of the entire deposit.

6.5.3 Manual Sediment Sampling

Sediments samples collected for particle size and chemical analyses under Caltrans studies will most likely come from drainage systems where sediments accumulate (inlets and pipes) or BMPs that are designed to trap sediments. There are several basic methods available for collecting a physical sample at these facilities. They include:

Photo 6-8. Collection of a core sample

Core Method. A metal or plastic tube is used to push through the entire depth of the sediment deposit in the vertical direction to extract a core sample (Photo 6-8).

Depth-Integrate Excavation. A spoon or shovel (metal or plastic) is used to excavate a sample from the entire profile of the sediment deposit.

Scoop Method. A scoop device (metal or plastic) is used to collect random samples of the sediment deposit.

In Situ X-Ray Fluorescence (XRF) Method. A field-portable energy dispersive XRF spectrometer is used to analyze the surface of the sediment deposits for levels of selected metals only. Nutrients and other organic parameters cannot be measured with this method.

Selection of a sampling method will depend on the cohesiveness of the sediment, depth of the deposit, type of sampling, the desired degree of disturbance to the deposit, amount of litter and organic matter present, and access to the deposit. The applications and limitations of each method are presented in Table 6-2.

6.5.4 Passive Sediment Sampling

Sediments samples can also be collected by the passive method for weight, particle size, chemical, and mineral analyses. The passive method uses filters to separate the particles from the runoff. The runoff stream is directed to pass through a filter or a series of filters and the all the particles larger than the pore size of the filter remain on the upstream side of the filter (Photo 6-9). A portion of the particles smaller than the pore size may also be become entrapped as well.

Photo 6-9. Filters with collected sediments

Table 6-2
Applications and Limitations of Sediment Sampling Methods

Sampling Method	Applications	Limitations
Core	▪ Cohesive soils ▪ Depths > 5 cm ▪ Soil profile required ▪ Minimal impact to deposit ▪ Sampling rod extends reach	▪ Shut-off cap required in sand, gravel, or water ▪ Presence of litter and plant material can create problems
Depth-Integrated Excavation	▪ Cohesive soils ▪ Depths < 30 cm ▪ Soil profile required ▪ Locations with limited access to deposit	▪ Disturbs relatively large area ▪ Sample collection may require surface to be disturbed
Scoop	▪ All soils ▪ Depths < 50 cm, unless the entire deposit is removed ▪ Locations with limited access to deposit	▪ Disturbs relatively large area ▪ Does not maintain the profile ▪ Sample collection may require surface to be disturbed
In situ X-Ray Fluorescence	▪ Analysis of metals only ▪ No disturbance to deposit ▪ Clear overhead access to deposit	▪ Presence of litter and plant material can create problems ▪ Access

The filters are than collected and dried (Photo 6-10). The tare weight of the filter is subtracted from the total weight to determine the dry weight of the solids. The dried solids are removed from the filter for use in grain size, chemical, and mineral analyses.

Photo 6-10. Filters being allowed to drain and dry

Filters can be deployed for any length of time. However, they need to be watched to minimize the chances of clogging which may cause the runoff to bypass around the system. All the materials carried along with storm water (e.g., sediment, gravel, litter, and leaves) can clog a filter very quickly if the filter has not been sized to accommodate the anticipated runoff volume and material. Filters have to be exchanged with new clean filters as solids become entrapped on their surface.

The use of a multi-filter system with graduated pore sizes can be applied to

reduce clogging. The filters should be arranged so the filter with the largest pore size is first and the filter with the smallest pore size last. A screen can be included to remove very large materials prior to the filters.

The smaller the pore size, the faster the filter will clog with debris. Pore sizes less than 20 µm are not practical for field installations. The field installations depend on gravity to force the runoff through the filter. Filters with pore sizes less than 20 µm typically required some force other than gravity to push the runoff through at a reasonable rate, such as a vacuum pump.

6.6 Composite Sediment Sample Collection

The sediment sample collected by the passive method can be considered a composite sample. The sample is representative of an entire runoff event, time period, or season similar to flow-weighted composite water samples.

For manual sampling, the composite sediment sample is made up of multiple sub-samples collected over some spatial range, a single sample collected over a vertical profile, or both. Manual composite samples are typically collected from a single location on a given day, not from multiple sites or on multiple days.

Development of a manual composite sample is relatively straightforward. Each subsample is placed in the same mixing bowl and thoroughly mixed together. Either the entire mixture or some portion is then distributed to the sample containers for transport to the laboratory. Profile or core samples are composited the same way. The sample is thoroughly mix so no distinct layers remain and then distributed to the sample containers. Multiple core samples can be mixed together to develop a single composite sample. During the mixing process, litter and other materials can be separated out so only the sediment remains.

Variation in the sediment characteristics (particle size and chemical content) is very common within individual sampling sites. Sufficient number of subsamples must be collected so that the composite sample is representative of the site.

If multiple samples will be collected over a period of time, a pilot test is recommended to estimate the variability and define the minimum number of subsamples required. At each site, a series of subsamples should be collected and analyzed individually. The variation among the values derived from subsets will indicate the minimum number of subsamples to collect for the sample to be representative. The STDS found the minimum number was six subsamples for sediment that accumulated in drain inlets (Caltrans, 1998).

The use of composite samples is an excellent estimate of the mean and helps to hold down costs. However, compositing only provides limited information on variability within a study area and may create statistical problems when testing hypotheses by limiting the size of the database. When planning a particle or water quality study, the use of composite samples have to be considered carefully in order to populate the

database with a sufficient number of points. Collecting composite samples over multiple events or analyzing multiple subsamples from one or more events can accomplish this.

6.7 Sediment Sample Representativeness Evaluation

Each collected sample or measurement must be evaluated for their representativeness to determine whether they meet the minimum acceptable criteria established for the project. Sediment samples not meeting these criteria are generally not tested. However, the Caltrans Project Coordinator should be consulted to make the decision whether or not to analyze the samples.

For volume measurements, a minimum number of depth measurements along a standard grid should be established for each site. These criteria will be based on pilot studies and relative variability among the individual sampling points. Low variability may reduce the number of depth measurements, while high variability may increase the number required in order for the average of all measurements to be representative of the mean depth.

For amount or weight measurements, there are several criteria to establish representativeness. If the deposit is removed and weighed, the entire deposit needs to be collected and none left behind. If subsamples are collected for density measurements, a sufficient number of samples must be collected that represent various locations within the deposit, such as one for every square foot. The subsamples must include the entire vertical profile, not just a portion. The weight must be a dry weight, so each sample must be dried at a standard temperature and time period.

Samples collected for particle size and chemical analyses have similar criteria as the weight measurements. Multiple samples should be collected at each site to account for spatial variability and each sample should include the entire vertical profile.

6.8 Composite Sample Splitting

Composite sediment samples are developed in a single mixing bowl, by the laboratory or the sampling team, and then divided into individual sample containers for analysis (to limit contamination it is recommended that splitting be conducted by the laboratory). When a composite sample duplicate is required, the sampling team will be required to split the composite sediment sample into two containers to generate a subsampling duplicate. As with field duplicate samples (replicate samples collected simultaneously in the field), subsampling duplicates (replicate samples generated from a single composite sample) should be submitted to the analytical laboratory “blind” (labeled using a pseudonym site name). Below is an example of a composite sample splitting procedure:

1. Label sample storage containers for specific analyses.

2. Wear clean powder-free nitrile gloves when handling the mixing bowl, mixing utensils, containers and lids.

3. Clean all items that will contact the sample using protocols presented in Appendix E in Caltrans Storm Water Monitoring Protocols (CTSW-RT-00-005, Second Edition).

4. Use clean bowls to composite and mix samples.

5. Use clean utensils like spoons to stir the sample to create a homogeneous mixture.

6. Transfer samples from the mixing bowl to the sample containers and duplicate containers using a sample splitter device or an alternating distribution process; one spoon full to the sample and the next spoonful to the duplicate. Follow either procedure until both sets of containers are full.

6.9 Sediment Sample Preservation and Holding Time

6.9.1 Preservation

All sediment samples for chemical analyses are kept on ice or refrigerated to 4° C from the time of sample collection until delivery to the analytical laboratory. Samples should be placed in an ice chest with ice immediately following collection.

In addition to keeping samples cool it is also important to minimize the exposure of the samples to direct sunlight, as sunlight may cause chemical and or biological alteration of the sample, resulting in unreliable results. Use of opaque plastic or amber glass bottles should be used to reduce light exposure and all samples should be covered or placed in an ice chest with a closed lid immediately following collection.

6.9.2 Holding Time

When more than one grab sediment samples are collected or a composite sediment sample is collected, sample holding time begins when the last grab sample in a series is taken. The Chain-of-Custody (COC) form should clearly indicate the time of sample collection.

6.10 Sample Delivery and Chain of Custody

For delivery to the laboratory, all sediment sample containers are placed inside coolers, the containers are well packaged (i.e., with bubble wrap, foam, etc.), and cooler lids are secured with packaging tape. All sediment samples for chemical analysis should be kept on ice, or refrigerated, from the time of onset of sample collection to the time of receipt by laboratory personnel. Delivery coolers should be packed with ice (wet ice is preferable to gel ice).

The field crew must coordinate activities with the laboratory(s) performing any of the sediment analyses. The sampling crew must contact the laboratory prior to sample

collection to provide some indication as to when the laboratory should expect to receive the samples. This notice should be provided as soon as possible (i.e., within the next 72 hours), and should be followed by notice to the laboratory once sample collection has commenced.

The sampling team fills out COC forms for all sediment samples submitted to the laboratory. The purpose of COC forms is to keep a record of the transfer of sample custody, and requested analyses. Sample date, sample location, and analysis requested are noted on each COC, including specification of lab quality control requirements (e.g., laboratory duplicate samples; see Section 8). Any special instructions for the laboratory should also be noted. Project-specific COCs that include standard information (e.g., contact information, constituents and methods, and special notes) are recommended. Copies of COC forms are kept with field notes in a field logbook. COC forms should be checked to be sure all analyses specified by the sampling plan are included. Review of the COC forms immediately following a sampling event gives the data reviewer a chance to review the field crews' requests and then to notify the laboratory of additional analyses or necessary clarification.

6.11 Flow and Precipitation Monitoring

Flow and precipitation measurements provide useful information to support storm water runoff sample collection and data interpretation. Flow measurement is necessary for accurate water sample compositing. Flow and concentration data are used to calculate pollutant and particle loads. Flow and precipitation data can be used to understand site hydrology. Other important components of successful collection of storm water runoff samples include system integration, system command/control, and remote communication. Each of these components is discussed in detail in Caltrans Storm Water Monitoring Protocols (CTSW-RT-00-005, Second Edition).

Section 7
Water Sample Collection for Particle Monitoring

Particle monitoring programs may also collect water samples of the runoff. These water samples are typically analyzed for number of particles per grain size and total weight of the particles. The results can be expressed as a concentration on a per liter basis and then applied to flow data to calculate loads. Water samples may also be collected for analysis of grain size based on mass (sieve/hydrometer method) or chemical content but the required sample size may be impractical as discussed in Section 4. Analyses of water samples for total suspended solids (TSS), suspended solids concentration (SSC), and turbidity can also provide information for a particle characterization study. Both composite and grab samples may be collected.

Particle monitoring studies should be designed so the collected samples are representative of runoff quality throughout a given storm event. Ideally, this means collection of flow-proportioned composite samples throughout the runoff hydrograph for water samples.

Particles suspended in runoff may vary both laterally and vertically throughout the cross section of flow. For instance, light particles may be present in significant amounts near the water surface, while heavier or denser particles are often concentrated near the bottom of the conveyance. The particle concentrations may vary with time as well. Concentrations may be higher in the first hour or two of runoff; this is often referred to as a “first flush” effect. During the course of a storm, rainfall intensity also may increase, raising runoff flow rates to the point where additional scouring may occur and more particles are mobilized, resulting in temporarily higher concentrations.

The basic water sample collection and handling elements required during collection of water samples for particle monitoring are listed below. These elements need to be considered when developing the SAP for the study. These elements are very similar to the elements discussed in for sediment sample collection in Section 6.

- Personnel Safety
- Sampling Equipment and Bottles
- Clean Sampling Techniques
- Grab Water Sample Collection
- Composite Water Sample Collection
- Flow Monitoring
- Composite Bottle Changing

- Sample Representativeness Evaluation
- Multi-bottle Compositing and Composite Water Sample Splitting
- Sample Preservation and Holding Time
- Sample Delivery / Chain of Custody

These elements are described in detail in Sections 9 and 10 of the Caltrans Storm Water Monitoring Protocols (CTSW-RT-00-005, Second Edition). This document provides water sample collection and handling guidance for field personnel engaged in runoff water monitoring. The Storm Water Monitoring Protocols document also provides guidance on two related topics required for all water-based monitoring:

- Installation and maintenance of monitoring stations that are equipped with automated monitoring equipment (Section 7 in the Storm Water Protocols)
- Storm water monitoring preparation and logistics (Section 9 in the Storm Water Protocols)

Section 8
Quality Assurance/Quality Control (QA/QC)

The quality of particle data is dependent on the manner in which samples are collected, handled, and analyzed. To demonstrate that the data meet project data quality acceptability limits or objectives, project specific DQOs should be included in the sampling and analysis plan (SAP) prior to implementing any particle monitoring study. The SAP should include QA / QC review procedures for both field and laboratory measures (see Section 5 and the QA / QC data evaluation discussion below).

The three major categories of QA / QC checks are accuracy, precision, and contamination. Accuracy is assessed by measuring percent recovery of a known quantity of analyte (e.g., via a matrix spike or laboratory control spike) and comparing it against prescribed acceptability limits. Calculating the relative difference between results for duplicate samples and comparing the relative percent difference (RPD) against prescribed acceptability limits assesses precision. Contamination is assessed using blank samples to identify sources of contamination.

Improved control of data quality is achieved by incorporating the following typical storm water monitoring QA / QC elements into the sample collection effort:

- Blank Samples
- Duplicate Samples
- Lab-Initiated QA / QC
- QC Sample Schedule
- QA / QC Data Evaluation

Each of these types of samples and the relevant responsibilities of monitoring field personnel as they pertain to particle monitoring are described below. This is then followed by a discussion of recommended minimum frequencies for the various types of QC samples and how the results of the field QC samples are then used to evaluate the quality of the reported data. A similar discussion for water-based samples can be found in the Caltrans Storm Water Monitoring Protocols (CTSW-RT-00-005, Second Edition).

Laboratory QA / QC for physical analyses of sediments (sediment amount and size fraction) generally does not apply. However, where applicable, all field QA / QC (described below) should be conducted for these parameters.

8.1 Blank Samples

Blanks are prepared to identify potential sample contamination occurring during field collection, handling, shipment, storage, and laboratory handling and analysis. Blanks are evaluated during various stages of the sampling and analytical process to determine the level of contamination introduced at each step. The collection and uses of the types of blank samples associated with particle monitoring field procedures are described below. “Blank sediment” refers to contaminant-free sediment provided by the laboratory performing the environmental and blank analyses. Typically, these sediments are either pure quartz sand or glass beads. The analytical laboratory should be consulted when selecting the source of the blank water and sediment.

8.1.1 Equipment Blanks

Before using sampling equipment for sample collection activities, blanks should be collected to verify that the equipment is not a source of sample contamination. Sediment monitoring programs that include chemical analyses normally include equipment blanks to check collection utensils (coring tubes, spoons, scoops, and shovels), mixing bowls, and sample containers. Equipment blanks are usually prepared at the beginning of the monitoring season. Equipment blanks are collected using clean techniques, prior to on-site sample collection, before the equipment has been contaminated by environmental sample sediment or other sources. A decontamination rinsate sample is prepared by pouring analyte-free water over the surface of sampling equipment after decontamination procedures have been performed. After collection, equipment blanks are capped, placed in an ice chest with ice or frozen packets, and delivered to the analytical laboratory in the same manner as environmental samples.

Equipment blanks are analyzed using the same methods as those used for normal sample analysis and submitted to the analytical laboratory “blind” (disguised as a regular environmental sample by labeling with a pseudonym).

To account for any contamination introduced by sampling containers, blanks must be collected for laboratory containers used for sample storage for metals analysis. A sampling container blank is prepared by filling a clean container with blank water which is then measured the concentrations of selected constituents (typically metals only for storage bottles). These blanks may be submitted “blind” to the laboratory by field personnel or prepared internally by the laboratory.

Collection of sample container blanks may not be required if certified pre-cleaned containers are used. The manufacturer can provide certification forms that document the concentration to which the containers are “contaminant-free”; these concentrations should be equivalent to or less than the program reporting limits. If the certification level is above the program reporting limits, 2% of the bottles in a “lot” or “batch” should be blanked at the program detection limits with a minimum frequency of one bottle per batch. A batch is a group of samples that are cleaned at the same time and in the same manner; or, if decontaminated bottles were sent directly from

the manufacturer, the batch would be the lot designated by the manufacturer in their testing of the bottles.

Decontamination rinsate blanks should be collected at a frequency of one per 20 samples, if applicable. Results are used to assess whether decontamination procedures are sufficient, and whether carry over of contamination from sample to sample has occurred.

8.1.2 Field Blanks

Field blanks are necessary to evaluate whether contamination is introduced during field sampling activities. The field crew, under normal sample collection conditions, prepares field blanks at some time during the collection of normal samples. Field blanks are prepared by filling a sample container with blank sediment, transporting the container to the field and processing the water through the same sampling procedures to be used for sample collection. For grab sample collection, grab sample field blanks should be prepared by pouring a sample directly from the bottle of blank sediment, into the grab sample containers. Grab sample blanking should imitate environmental sampling as closely as possible by using scoops, clean intermediate containers, and other clean equipment in the same manner.

Field blanks are collected at a frequency no less than once per field sampling team per sampling season. Additional blanks should be collected when there is a change in sampling personnel, equipment, or procedures. It may also be desirable to prepare field blanks prior to any actual sampling events as an advance check of the overall sampling procedures. Scheduling field blanks is discussed further in Section 8.4.

8.2 Duplicate Samples

Analytical precision is a measure of the reproducibility of data and is assessed by analyzing two samples or measurements that are intended to be identical. Any significant differences between the two data points indicate an unaccounted-for factor or a source of bias. There are typically two types of duplicate samples that require special sampling considerations: field duplicates and laboratory duplicates.

The duplicate test is evaluated by calculating the RPD between the two sets of results for each constituent. This serves as a measure of the reproducibility, or “precision” of the sample collection and analysis. Calculation of RPD is discussed later in this section.

8.2.1 Field Duplicates

Field duplicates are used to assess variability attributable to collection, handling, shipment, storage and/or laboratory handling and analysis. Field duplicates should be collected for sediment volume measurements, mass estimates using density, particle size distributions analyses, and chemical analyses.

The procedures for collecting field duplicate samples will depend upon the field method being applied. There are two types of duplicates applicable to sediment samples. A split that is a subsample collected from a homogenized composite or grab sample, and a co-locate that is an additional subsample collected from near the location of a first grab subsample. All field protocols should be exactly duplicated with the same sets of equipment, to collect the duplicate sample simultaneously with or immediately following collection of the environmental sample.

When collecting duplicate composite samples, the following procedures should be used:

- Collect enough sample for both environmental sample analysis and field duplicate analysis (amount will be specified by the analytical laboratory) in one or more composite bottles.
- Splitting the composite samples as discussed in detail in Sections 6 and 7. Field duplicate samples should be split in the same manner as the environmental samples, and are taken in random order along with the environmental samples to assess the variability introduced during splitting and laboratory analysis.

Field duplicate samples should be submitted to the laboratory "blind" (i.e., not identified as a QC sample, but labeled with a different site identification than the regular sample).

8.3 Lab-Initiated QA/QC

The standard EPA methods require that the laboratory conduct certain QA / QC procedures. Following are the analytical QA / QC results that are normally reported.

8.3.1 Method Blanks

Method blanks (also called control blanks) should be run by the laboratory for each batch of samples to determine the level of contamination associated with laboratory reagents. A method blank is analyzed along with all aqueous and nonaqueous samples submitted for analyses. The method / reagent blank is processed through all procedures, materials, reagents, and labware used for sample preparation and analysis.

The laboratory prepares method blanks with laboratory reagents or blank sediment. An analytical batch is defined as samples that are analyzed together with the same method sequence and the same lots of reagents, and with the manipulations common to each sample within the same time period, or in continuous sequential time periods. Samples in each batch are to be of similar composition or matrix.

Results of the method blank analysis should be reported with the sample results. At a minimum, the laboratory should report method blanks at a frequency of 5% (one method blank with each batch of up to 20 samples).

8.3.2 Laboratory Control Samples

The Laboratory Control Sample (LCS) or Blank Spike (BS) is a quality control check sample (i.e., reference standard) that is carried along with the samples through the entire sample preparation / analysis sequence.

8.3.3 Laboratory Duplicates

Laboratory duplicates (also called laboratory splits) are used to assess the precision of the analytical method and laboratory handling. For the laboratory duplicate analysis, the analytical laboratory will split one sample into two portions and analyze each.

When collecting samples to be analyzed for laboratory duplicates, typically double the normal sample amount is required. This requires filling a larger size sample container, or filling two normal size sample containers, labeling one with the site name and the second with the site name plus "laboratory duplicate." Laboratory duplicate samples are collected, handled, and delivered to the analytical laboratory in the same manner as environmental samples.

8.3.4 Matrix Spikes/Matrix Spike Duplicate Samples

Matrix spike (MS) and matrix spike duplicate (MSD) analyses are used to assess the accuracy (MS) and precision (MSD) of the analytical methods in the sample matrix. A sample matrix spike is prepared by adding a known amount of the pure analyte to the environmental sample before extraction / digestion. The added analyte is the same as that is being analyzed for in the environmental sample. Background and interferences having an effect on the actual sample analyte will have a similar effect on the spike compounds.

The analytical laboratory prepares matrix spike samples by splitting off three aliquots of the environmental sample and adding the target analytes to two of the three environmental sample aliquots. The results of the analysis of the unspiked environmental sample are compared to the MS analysis results, and "percent recovery" of each spike is calculated to determine the accuracy of the analysis. The results of the MS analyses are compared to calculate RPD as an additional measure of analytical precision.

When collecting samples to be specified for MS / MSD analysis, typically triple the normal sample volume or amount is required. This will require filling a larger size sample container, or filling three normal size sample containers, labeling one with the site name and the other two with the site name plus "MS / MSD". MS / MSD samples are collected, handled, and delivered to the analytical laboratory in the same manner as environmental samples. Analytical laboratories often will perform MS / MSD analyses at no additional charge on a specified sample when a certain minimum number of samples are submitted for analysis.

8.3.5 Surrogate Spikes

For the analyses of organic compounds, every sample is spiked before extraction/analysis with a mixture of surrogate compounds which behave similarly, but are not identical to analytes potentially found in naturally-occurring sample matrices. The percent recovery of the surrogate compounds can be used as an indicator of accuracy of the analyses.

8.3.6 ICP Interference Check Sample (ICS)

To verify inter-element correction factors for inductively coupled plasma (ICP) analyses, the laboratory must analyze and report the results for an ICP Interference Check Sample at the beginning and end of each analysis run or a minimum of twice per 8 hours, whichever is more frequent, but not before initial calibration verification. The ICP Interference Check Samples are prepared and analyzed according to EPA Method 6010.

8.4 Quality Control Sample Schedule

Table 8-1 summarizes the recommended frequencies of quality control sample collection/ preparation for Caltrans particle monitoring studies. These frequencies are the minimum and may be increased depending on the nature and objectives of the study being undertaken or if QA/QC problems (e.g., contamination) are discovered. An adequate quality control sample schedule should be included in the analytical budget for the particle study.

A quality control sample schedule should be developed, included in the SAP, and followed closely by field personnel. The project quality control sample schedule should meet the minimum quality control sample frequency criteria over the term of the project. In some cases, quality control samples at one site may be applied to an analogous situation at another site. For example, if the same equipment and protocols are used at Site A and Site B, equipment blank checks at one site can be applied at both sites. The minimum frequency criteria must still be met; however, the quality control sample schedule should consider the location of each quality control sample to maximize coverage at all project sites. A quality control sample schedule should, at a minimum, indicate the types and frequency of quality control sample collection, site of quality control sample collection, and quality control sample pseudonyms for samples that will be submitted “blind” to the laboratory.

Table 8-1
Recommended Quality Control Sample Frequencies

Quality Control Sample Type	Minimum Sampling Frequency	Constituent Class
Field Duplicate	Once every 20 samples collected at a given site or once per sampling station per project, whichever is more frequent.	All
Lab Duplicate	Once every 20 samples collected at a given site or once per sampling station per project, whichever is more frequent.	All
Equipment Blank	Equipment blanks should be collected prior to each sampling season for each piece of equipment to be used for sample collection (bailers, pumps, and carboys).	Metals and other common contaminants. [1]
Container Blanks	Sample containers should be blanked every batch [2]; or manufacturer or laboratory-certified to concentrations below the reporting limits used for the sampling program.	Metals and other common contaminants. [1]
Field Blank	Once every 20 samples collected at a given site or once per sampling station per project, whichever is more frequent.	Metals and other common contaminants. [1]
Method Blank, Lab Control Samples	Once every 20 samples collected at a given site or once per sampling station per project, whichever is more frequent.	Metals and other common contaminants. [1]
Matrix Spike/Matrix Spike Duplicate, Surrogate Spikes	Once every 20 samples collected at a given site or once per sampling station per project, whichever is more frequent.	Metals and other common contaminants. [1]
ICS	Beginning and end of each analysis run or a minimum of twice per 8 hours.	Organics

Notes:
[1] Other common contaminants include organic carbon (TOC and DOC), and nitrate as N. Analyze blanks for these constituents as appropriate for constituents monitored in specific projects.
[2] A batch is defined as the group of bottles that have been cleaned at the same time, in the same manner; or, if decontaminated bottles were sent directly from the manufacturer, the batch would be the lot designated by the manufacturer in their testing of the bottles.

8.5 QA/QC Data Evaluation

All data reported by the analytical laboratory must be carefully reviewed to determine whether the project's data quality acceptability limits or objectives (DQOs) have been met. The data review methods should be outlined in the SAP developed for the project. A detailed discussion of the QA / QC data evaluation process for Caltrans storm water monitoring programs is presented in Caltrans Storm Water Monitoring Protocols (CTSW-RT-00-005, Second Edition). This process includes two steps; initial data quality screening and data quality evaluation.

Data quality screening includes the following steps:

1. Verification check between sampling and analysis plan (SAP), chain of custody forms, and laboratory data reports.

2. Check of laboratory data report completeness.

3. Check for typographical errors and apparent incongruities.

See the Caltrans Storm Water Monitoring Protocols (CTSW-RT-00-005, Second Edition) for details concerning the above.

The data quality evaluation process for particle data is similar to the process developed for water chemistry. Data evaluation as it relates to particle testing includes review of the following QA / QC parameters:

- Reporting limits
- Holding times
- Contamination check results (method, field, and equipment blanks)
- Precision analysis results (laboratory, field, and matrix spike duplicates)
- Accuracy analysis results (matrix spikes, surrogate spikes, laboratory control samples, and external reference standards)

Each of these QA / QC parameters should be compared to data quality acceptability criteria, also known as the project's data quality objectives (DQOs). The key steps that should be adhered to in the analyses of each of these QA / QC parameters are:

1. Compile a complete set of the QA / QC results for the parameter being analyzed.
2. Compare the laboratory QA / QC results to accepted criteria (DQOs).
3. Compile any out-of-range values and report them to the laboratory for verification.
4. Prepare a report that tabulates the success rate for each QA / QC parameter analyzed.

This process should be applied to each of the QA / QC parameters as discussed below.

8.5.1 Reporting Limits

DQOs established for all particle monitoring programs should contain a list of acceptable reporting limits that the lab is contractually obligated to adhere to, except in special cases of insufficient sample volume or matrix interference problems. The reporting limits should be selected to achieve a high probability of detection. Table 4-2 provides recommended reporting limits for selected parameters.

8.5.2 Holding Times

Holding time represents the elapsed time between sample collection time and sample analysis time. Calculate the elapsed time between the sampling time and start of analysis, and compare this to the required holding time.

It is important to review sample holding times to demonstrate the analyses occurred within the time period that is generally accepted to maintain stable parameter concentrations. Table 9-1 contains the holding times for selected parameters. If holding times are exceeded, inaccurate concentrations or false negative results may be reported. Samples that exceed their holding time prior to analysis are qualified as "estimated", or may be rejected depending on the circumstances.

8.5.3 Contamination

Blank samples are used to identify the presence and potential source of sample contamination and are typically one of four types:

- Method blanks are prepared and analyzed by the laboratory to identify laboratory contamination.
- Field blanks are prepared by the field crew during sampling events and submitted to the laboratory to identify contamination occurring during the collection or the transport of environmental samples.
- Equipment blanks are prepared by the field crew or laboratory prior to the monitoring season and used to identify contamination coming from sampling equipment (tubing, pumps, bailers, etc.).

If no contamination is present, all blanks should be reported as "not detected" or "non-detect" (e.g., constituent concentrations should not be detected above the reporting limit). Blanks reporting detected concentrations ("hits") should be noted in the written QA/QC data summary prepared by the data reviewer. In the case that the laboratory reports hits on method blanks, a detailed review of raw laboratory data and procedures should be requested from the laboratory to identify any data reporting errors or contamination sources. When other types of blanks are reported above the reporting limit, a similar review should be requested along with a complete review of field procedures and sample handling. Often times it will also be necessary to refer to historical equipment blank results, corresponding method blank results, and field notes to identify contamination sources. This is a corrective step that should be performed and documented as soon as the hits are reported.

If the blank concentration exceeds the laboratory reporting limit, values reported for each associated environmental sample must be evaluated according to USEPA guidelines for data evaluations of organics and metals (USEPA, 1991; USEPA, 1995) as indicated in Table 8-2.

Table 8-2
USEPA Guidelines for Data Evaluation

Step	Environmental Sample	Phthalates and other common contaminants	Other Organics	Metals
1.	Sample > 10X blank concentration	No action	No action	No action
2.	Sample < 10X blank concentration	Report associated environmental results as “non-detect” at the reported environmental concentration.	No action	Results considered an “upper limit” of the true concentration (note contamination in data quality evaluation narrative).
3.	Sample < 5X blank concentration	Report associated environmental results as “non-detect” at the reported environmental concentration.	Report associated environmental results as “non-detect” at the reported environmental concentration.	Report associated environmental results as “non-detect” at the reported environmental concentration.

8.5.4 Precision

Duplicate samples provide a measure of the data precision (reproducibility) attributable to sampling and analytical procedures. Precision can be calculated as the relative percent difference (RPD) in the following manner:

$$RPD_i = \frac{2 * |O_i - D_i|}{(O_i + D_i)} * 100\,\%$$

where:

RPDi = Relative percent difference for compound i

Oi = Value of compound i in original sample

Di = Value of compound i in duplicate sample

The resultant RPDs should be compared to the laboratory-developed data for RPD obtained from samples of similar matrix and criteria specified in the project’s DQOs. Typical acceptance limits for precision are shown on Table 8-3. The criteria shown in Table 8-3 are based on the analytical method specifications and laboratory-supplied values. Project-specific DQOs should be developed with consideration to the analytical laboratory, the analytical method specifications, and the project objective. Table 8-3 should be used as a reference point as the least stringent set of DQO criteria for Caltrans monitoring projects.

Table 8-3
Typical Control Limits for Precision and Accuracy for Analytes in Sediments

Analyte	EPA Method Number [a]	Maximum Allowable RPD	Lower Recovery Limit	Upper Recovery Limit
Conventionals				
pH	9045C	35%	NA	NA
Eh	D-1498 [b]	35%	NA	NA
Total Organic Carbon (TOC)	9060	35%	65%	135%
Nutrients				
Total Kjeldahl Nitrogen (TKN)	5050/9056	35%	65%	135%
Nitrate (NO3)	5050/9056	35%	65%	135%
Nitrite (NO2)	5050/9056	35%	65%	135%
Total Phosphorus (P)	5050/9056	35%	65%	135%
Metals (total)				
Arsenic (As)	3050A/6010B	35%	65%	135%
Cadmium (Cd)	3050A/6010B	35%	65%	135%
Chromium (Cr)	3050A/6010B	35%	65%	135%
Copper (Cu)	3050A/6010B	35%	65%	135%
Lead (Pb)	3050A/6010B	35%	65%	135%
Nickel (Ni)	3050A/6010B	35%	65%	135%
Zinc (Zn)	3050A/6010B	35%	65%	135%
Iron (Fe)	3050A/6010B	35%	65%	135%
Metals (TCLP)				
Silver (Ag)	1311/6010B	35%	65%	135%
Arsenic (As)	1311/6010B	35%	65%	135%
Barium (Ba)	1311/6010B	35%	65%	135%
Cadmium (Cd)	1311/6010B	35%	65%	135%
Chromium (Cr)	1311/6010B	35%	65%	135%
Lead (Pb)	1311/6010B	35%	65%	135%
Selenium (Se)	1311/6010B	35%	65%	135%
Mercury (Hg)	1311/7061	35%	65%	135%
Metals (STLC)				
Silver (Ag)	CAM WET/6010B	35%	65%	135%
Arsenic (As)	CAM WET/6010B	35%	65%	135%
Barium (Ba)	CAM WET/6010B	35%	65%	135%
Beryllium (Be)	CAM WET/6010B	35%	65%	135%
Cadmium (Cd)	CAM WET/6010B	35%	65%	135%
Cobalt (Co)	CAM WET/6010B	35%	65%	135%
Copper (Cu)	CAM WET/6010B	35%	65%	135%
Chromium (Cr)	CAM WET/6010B	35%	65%	135%
Molybdenum (Mo)	CAM WET/6010B	35%	65%	135%
Nickel (Ni)	CAM WET/6010B	35%	65%	135%
Lead (Pb)	CAM WET/6010B	35%	65%	135%
Antimony (Sb)	CAM WET/6010B	35%	65%	135%
Selenium (Se)	CAM WET/6010B	35%	65%	135%
Thallium (Tl)	CAM WET/6010B	35%	65%	135%
Vanadium (V)	CAM WET/6010B	35%	65%	135%
Zinc (Zn)	CAM WET/6010B	35%	65%	135%
Mercury (Hg)	CAM WET/7061	35%	65%	135%
Amount or Weight				
Dry Weight	-- [c]	NA	NA	NA
Wet Weight	-- [d]	NA	NA	NA

Analyte	EPA Method Number [a]	Maximum Allowable RPD	Lower Recovery Limit	Upper Recovery Limit
Size Fraction				
Particle Size Distribution	D-1498/D-422 [b]	NA	NA	NA
Hydrocarbons				
TPG (gasoline)	8015M	35%	65%	135%
TPD (diesel)	8015M	35%	65%	135%
TPJ (jet fuel)	8015M	35%	65%	135%
TPK (kerosene)	8015M	35%	65%	135%
TPS (stoddard solvent)	8015M	35%	65%	135%
VOCs				
Benzene	8021	35%	65%	135%
Toluene	8021	35%	65%	135%
Ethylbenzene	8021	35%	65%	135%
Xylene	8021	35%	65%	135%

Notes:
[a] EPA SW-846 methods unless otherwise indicated. Equivalent Standard Method or EPA Method can be substituted.
[b] American Society for Testing and Materials (ASTM) Method.
[c] Dry in oven at 50C until constant weight. Record weight using an analytical balance.
[d] Do not dry. Record weight using an analytical balance.

8.5.5 Laboratory and Field Duplicates

The RPDs resulting from analysis of both laboratory and field duplicates should be reviewed during data evaluation. Deviations from the specified limits, and the effect on reported data, should be noted and commented upon by the data reviewer. Laboratories typically have their own set of maximum allowable RPDs for laboratory duplicates based on their analytical history. In most cases these values are more stringent than those listed in Table 8-3. Note that the laboratory will only apply these maximum allowable RPDs to laboratory duplicates. In most cases field duplicates are submitted “blind” (with pseudonyms) to the laboratory.

Environmental samples associated with laboratory duplicate results greater than the maximum allowable RPD (when the numerical difference is greater than the reporting limit) are qualified as “J” (estimated). When the numerical difference is less than the RL, no qualification is necessary. Field duplicate RPDs are compared against the maximum allowable RPDs used for laboratory duplicates to identify any pattern of problems with reproducibility of results. Any significant pattern of RPD exceedances for field duplicates should be noted in the data report narrative.

Corrective action should be taken to address field or laboratory procedures that are introducing the imprecision of results. The data reviewer can apply “J” (estimated) qualifiers to any data points if there is clear evidence of a field or laboratory bias issue that is not related to contamination. Qualification based on contamination is assessed with blank samples.

Laboratories should provide justification for any laboratory duplicate samples with RPDs greater than the maximum allowable value. In some cases, the laboratory will track and document such exceedances. However, in most cases it is the job of the data

reviewer to locate these out-of-range RPDs. Irregularities should be included in the data reviewer's summary, and the laboratory's response should be retained to document laboratory performance, and to track potential chronic problems with laboratory analysis and reporting.

8.5.6 Accuracy

Accuracy is defined as the degree of agreement of a measurement to an accepted reference or true value. Accuracy is measured as the percent recovery (%R) of spike compound(s). Percent recovery of spikes is calculated in the following manner:

$$\%R = 100\% * [(Cs - C) / S]$$

where:

%R = percent recovery

Cs = spiked sample concentration

C = sample concentration for spiked matrices

S = concentration equivalent of spike added

Accuracy (%R) criteria for spike recoveries should be compared with the limits specified in the project DQOs. Acceptance limits for percent recoveries are established by the environmental laboratory per EPA SW-846 protocols. Laboratory-specific quality control acceptance limits are established on a parameter-specific basis for each analysis method after sufficient data have been compiled. A list of typical acceptable recoveries is shown in Table 8-3. A value of 20 percent can be used for volume and density measurements. As in the case of maximum allowable RPDs, laboratories develop acceptable criteria for an allowable range of recovery percentages that may differ from the values listed in Table 8-3.

Percent recoveries should be reviewed during data evaluation, and deviations from the specified limits should be noted in the data reviewer's summary. Justification for out of range recoveries should be provided by the laboratory along with the laboratory reports, or in response to the data reviewer's summary.

8.5.7 Laboratory Matrix Spike, Matrix Spike Duplicate, and Surrogate Spike Samples

Evaluation of analytical accuracy and precision in environmental sample matrices is obtained through the analysis of laboratory matrix spike (MS) and matrix spike duplicate (MSD) samples. A matrix spike is an environmental sample that is spiked with a known amount of the constituent being analyzed. A percent recovery can be calculated from the results of the spike analysis. A MSD is a duplicate of this analysis that is performed as a check on matrix recovery precision. MS and MSD results are used together to calculate RPD as with the duplicate samples. When MS/MSD results

(%R and RPD) are outside the project specifications, as listed in Table 8-3, the associated environmental samples are qualified as "estimates due to matrix interference." Surrogate standards are added to all environmental and quality control samples tested by gas chromatography (GC) or gas chromatography-mass spectroscopy (GC-MS). Surrogates are non-target compounds that are analytically similar to the analytes of interest. The surrogate compounds are spiked into the sample prior to the extraction or analysis. Surrogate recoveries are evaluated with respect to the laboratory acceptance criteria to provide information on the extraction efficiency of every sample.

8.5.8 External Reference Standards

External reference standards (ERS) are artificial certified standards prepared by an external agency and added to a batch of samples. ERSs are not required for every batch of samples, and are often only run quarterly by laboratories. Some laboratories use ERS's in place of laboratory control spikes with every batch of samples. ERS results are assessed the same as laboratory control spikes for qualification purposes (see below). The external reference standards are evaluated in terms of accuracy, expressed as the percent recovery (comparison of the laboratory results with the certified concentrations). The laboratory should report all out-of-range values along with the environmental sample results. ERS values are qualified as "biased high" when the ERS recovery exceeds the acceptable recovery range and "biased low" when the ERS recovery is smaller than the recovery range.

8.5.9 Laboratory Control Samples

LCS analysis is another batch check of recovery of a known standard solution that is used to assess the accuracy of the entire recovery process. LCSs are much like ERSs except that a certified standard is not necessarily used with LCSs, and the laboratory prepares the sample internally so the cost associated with preparing a LCS sample is much lower than the cost of ERS preparation. LCSs are reviewed for percent recovery within control limits provided by the laboratory. LCS out-of-range values are treated in the same manner as ERS out-of-range values. Because LCS and ERS analysis both check the entire recovery process, any irregularity in these results supersedes other accuracy-related qualification. Data are rejected due to low LCS recoveries when the associated environmental result is below the reporting limit.

Section 9
Laboratory Sample Preparation and Analytical Methods

When using analytical laboratories, the following elements provide insight to maximize the data achieving DQOs.

- Laboratory Selection and Contracting
- Pre-Sampling Preparations
- Sample Storage and Handling Prior to Analysis
- Reporting Limit Requirements
- Analytical Methods
- Laboratory Data Package Deliverables

As with the elements listed in Sections 6 and 7, these laboratory elements need to be considered and incorporated into the project-specific SAP.

9.1 Laboratory Selection and Contracting

Important considerations in selecting a laboratory include performance, ability to meet test acceptability criteria, and experience with the types of particle testing included in the study. The laboratory should have a proven record of performance with the sample matrices involved in the study and the particular types of particle tests to be conducted for the project. Additionally, Department of Health Services (DHS) certification is required for Caltrans analytical work involving chemical content. DHS does not have certification for the other types of sediment analyses for grain size, weight, and mineral content.

It is important to establish that the selected laboratory has proven satisfactory performance. The ability of the laboratory to obtain consistent, precise results must be demonstrated. Data from laboratory controls must be checked to establish that the laboratory can consistently meet the test acceptability criteria established for controls.

Finally, it is necessary that laboratories be made contractually accountable to meet all Caltrans' data quality acceptability limits or objectives (DQOs) and project specifications. This is discussed in more detail later in this section.

9.2 Pre-Sampling Preparations

The analytical laboratories will be involved in a number of activities prior to the actual analysis of the particle and sediment samples, including:

- Determining key laboratory performance requirements (e.g., maximum reporting limits, turnaround times, report formats) for the services contract.
- Reviewing and commenting on DQOs, QC sample schedule, and QC sample volumes. This overall package is sometimes referred to as the QA / QC plan.
- Providing clean sample containers and blank water / sediment.
- Coordinating with sampling team prior to each anticipated sampling event.

Determination of Laboratory Performance Criteria. The analytical laboratory must analyze the water and sediment samples using methods that will achieve Caltrans' DQOs for the project (see Section 2). The contract for analytical services should specify laboratory performance criteria designed to meet the project DQOs. The contract should specify the following:

- Analytical reporting limits
- Holding times
- Types and frequency of QA / QC analyses
- Quality control performance limits
- Sample turnaround times
- Electronic and hard copy report formats
- Corrective action procedures

In addition, the contract with the laboratory should specify that at least 90% of the sample results must meet the QA / QC criteria and be deemed usable for the project.

Laboratory Input to Project QA/QC Plan. The contracted analytical laboratories should review and provide input to the QA / QC plan for each Caltrans storm water-related monitoring project including particle monitoring. This input will help prove that the QA / QC plan specifies the correct sample containers, sample volumes or amounts, holding times, analytical methods, reporting limits, and the correct points of contact for communications between field and laboratory personnel. In addition, the laboratories should be involved early in the process so they can provide feedback on methods and performance standards during the planning phase.

Sample Containers and Blank Water/Sediment. Each analytical method has specific requirements with regard to the type of sample container (e.g., plastic, glass, Teflon, amber glass), the size of the container, and the number of containers. Table 9-1 shows the appropriate sample containers for the analytical methods recommended for Caltrans monitoring programs. As noted above, the analytical laboratories should review the QA / QC plan for each Caltrans storm water project with particle

monitoring to confirm the plan specifies the appropriate sample containers, volumes, and preservatives.

As discussed in Sections 6 and 7, sampling personnel will need to request the appropriate containers from the laboratory prior to each sampling event. The containers needed for a given project will vary depending on the constituents to be analyzed, the sample collection procedure, and the DQOs. For example, storm water monitoring programs often include composite samples, wherein subsamples collected during a storm event may be combined in one or more large containers. After the composite sample has been delivered to the laboratory, the water or sediment is transferred from the composite sample containers into the individual containers required for each analysis, and the individual samples are then filtered and/or preserved as required. For monitoring projects that specify collection of grab samples, field personnel must obtain the appropriate clean bottles from the laboratory prior to the sampling event.

Sample volumes or amounts necessary for the requested analyses should be confirmed with the laboratory prior to sample collection, including sufficient sample volumes or amounts for the required laboratory QA/QC analysis. As discussed in Section 8, laboratory quality control samples that make use of sample water or sediments provided by the field crew include splits (laboratory duplicates), matrix spikes, and matrix spike duplicates. Additional sample volume or amount will also be required for field duplicate quality control samples, as discussed in Section 8.

If field blanks are to be collected, the laboratory also will need to provide sufficient quantities of blank water and sediment, and appropriate containers (see Section 8). The blank water supplied by the laboratory should be the same as the water used for equipment cleaning.

Laboratory Coordination Prior to a Sampling Event. It is important for the task manager to notify the laboratories of an anticipated sampling event so that the laboratory can prepare for sample delivery, and to set up for any analyses with short holding times. The laboratory contacts should be notified regarding the number of samples anticipated, approximate date and time of sampling (if known), and when sample containers, blank water or sediment, or ice chests will be required. In addition, the laboratories should be made aware of specific project requirements such as required laboratory performance objectives, required QC samples, and reporting requirements.

Table 9-1
Analytical Constituent Method Specifications and Recommended Reporting Limits

Analyte	Method Type	EPA Method Number [a]	Holding Time [b]	Container Type	Preservation	Reporting Limit (RL)	Units
Conventionals							
Total Suspended Solids (TSS)	Dried filtrate weight	160.1	7 days	Glass or PE [e]	4°C	1	mg/L
Total Dissolved Solids (TDS)	Dried filtrate weight	160.2	7 days	Glass or PE [e]	4°C	1	mg/L
Turbidity	Nephelometric	180.1	48 hours	Glass or PE [e]	4°C	0.05	NTU
Total Organic Carbon (TOC)	Oxidation	9060	28 days	Glass	4°C	50	mg/kg
pH	Slurry; Electrometric	9045C	ASAP	Glass or PE [e]	4°C	+/- 0.1	SU
Electrical Conductivity	Slurry; Electrometric	D-1498 [c]	ASAP	Glass or PE [e]	4°C	+/- 10	Semens
Nutrients							
Total Kjeldahl Nitrogen (TKN)	Digestion/Spectrometric	EPA Method 351.3M	48 hours	Glass or PE [e]	4°C	20	mg/kg
Nitrate (NO3) as N	Combustion/Ion Chromatography	5050/9056 [h]	48 hours	Glass or PE [e]	4°C	1	mg/kg
Nitrite (NO2) as N	Combustion/Ion Chromatography	5050/9056 [i]	48 hours	Glass or PE [e]	4°C	1	mg/kg
Total Phosphorous (P)	Combustion/Ion Chromatography	5050/9056 [j]	28 days	Glass or PE [e]	4°C	1	mg/kg
Metals (total)							
Arsenic (As)	Digestion/Spectrometric	3050A/6010B	180 days	Glass or PE [e]	4°C	1	mg/kg
Cadmium (Cd)	Digestion/Spectrometric	3050A/6010B	180 days	Glass or PE [e]	4°C	2	mg/kg
Chromium (Cr)	Digestion/Spectrometric	3050A/6010B	180 days	Glass or PE [e]	4°C	5	mg/kg
Copper (Cu)	Digestion/Spectrometric	3050A/6010B	180 days	Glass or PE [e]	4°C	2	mg/kg
Iron (Fe)	Digestion/Spectrometric	3050A/6010B	180 days	Glass or PE [e]	4°C	5	mg/kg
Lead (Pb)	Digestion/Spectrometric	3050A/6010B	180 days	Glass or PE [e]	4°C	5	mg/kg
Nickel (Ni)	Digestion/Spectrometric	3050A/6010B	180 days	Glass or PE [e]	4°C	5	mg/kg
Zinc (Zn)	Digestion/Spectrometric	3050A/6010B	180 days	Glass or PE [e]	4°C	2	mg/kg
Metals (TCLP)							
Arsenic (As)	Extraction; Spectrometric	1311/6010B	180 days	Glass or PE [e]	4°C	0.5	mg/L
Barium (Ba)	Extraction; Spectrometric	1311/6010B	180 days	Glass or PE [e]	4°C	5	mg/L
Cadmium (Cd)	Extraction; Spectrometric	1311/6010B	180 days	Glass or PE [e]	4°C	0.1	mg/L
Chromium (Cr)	Extraction; Spectrometric	1311/6010B	180 days	Glass or PE [e]	4°C	0.5	mg/L
Lead (Pb)	Extraction; Spectrometric	1311/6010B	180 days	Glass or PE [e]	4°C	0.5	mg/L
Mercury (Hg)	Extraction; Spectrometric	1311/7061	28 days	Glass or PE [e]	4°C	0.01	mg/L
Selenium (Se)	Extraction; Spectrometric	1311/6010B	180 days	Glass or PE [e]	4°C	0.1	mg/L
Silver (Ag)	Extraction; Spectrometric	1311/6010B	180 days	Glass or PE [e]	4°C	0.5	mg/L

Table 9-1 (continued)
Analytical Constituent Method Specifications and Recommended Reporting Limits

Analyte	Method Type	EPA Method Number [a]	Holding Time [b]	Container Type	Preservation	Reporting Limit (RL)	Units
Metals (STLC)							
Antimony (Sb)	Extraction; Spectrometric	CAM WET/6010B	180 days	Glass or PE [e]	4°C	1	mg/L
Arsenic (As)	Extraction; Spectrometric	CAM WET/6010B	180 days	Glass or PE [e]	4°C	0.5	mg/L
Barium (Ba)	Extraction; Spectrometric	CAM WET/6010B	180 days	Glass or PE [e]	4°C	5	mg/L
Beryllium (Be)	Extraction; Spectrometric	CAM WET/6010B	180 days	Glass or PE [e]	4°C	0.1	mg/L
Cadmium (Cd)	Extraction; Spectrometric	CAM WET/6010B	180 days	Glass or PE [e]	4°C	0.1	mg/L
Chromium (Cr)	Extraction; Spectrometric	CAM WET/6010B	180 days	Glass or PE [e]	4°C	0.5	mg/L
Cobalt (Co)	Extraction; Spectrometric	CAM WET/6010B	180 days	Glass or PE [e]	4°C	0.5	mg/L
Copper (Cu)	Extraction; Spectrometric	CAM WET/6010B	180 days	Glass or PE [e]	4°C	0.1	mg/L
Mercury (Hg)	Extraction; Spectrometric	CAM WET/7061	28 days	Glass or PE [e]	4°C	0.01	mg/L
Molybdenum (Mo)	Extraction; Spectrometric	CAM WET/6010B	180 days	Glass or PE [e]	4°C	10	mg/L
Nickel (Ni)	Extraction; Spectrometric	CAM WET/6010B	180 days	Glass or PE [e]	4°C	1	mg/L
Lead (Pb)	Extraction; Spectrometric	CAM WET/6010B	180 days	Glass or PE [e]	4°C	0.5	mg/L
Selenium (Se)	Extraction; Spectrometric	CAM WET/6010B	180 days	Glass or PE [e]	4°C	0.1	mg/L
Silver (Ag)	Extraction; Spectrometric	CAM WET/6010B	180 days	Glass or PE [e]	4°C	0.5	mg/L
Thallium (Tl)	Extraction; Spectrometric	CAM WET/6010B	180 days	Glass or PE [e]	4°C	0.5	mg/L
Vanadium (V)	Extraction; Spectrometric	CAM WET/6010B	180 days	Glass or PE [e]	4°C	1	mg/L
Zinc (Zn)	Extraction; Spectrometric	CAM WET/6010B	180 days	Glass or PE [e]	4°C	2	mg/L
Hydrocarbons							
TPH-G (gasoline)	GC-FID	8015M	14 days	Glass [d]	4°C	1	mg/kg
TPH-D (diesel)	GC-FID	8015M	14 days	Glass [d]	4°C	50	mg/kg
TPH-J (jet fuel)	GC-FID	8015M	14 days	Glass [d]	4°C	50	mg/kg
TPH-K (kerosene)	GC-FID	8015M	14 days	Glass [d]	4°C	50	mg/kg
TPH-S (stoddard solvent)	GC-FID	8015M	14 days	Glass [d]	4°C	50	mg/kg

Table 9-1 (continued)
Analytical Constituent Method Specifications and Recommended Reporting Limits

Analyte	Method Type	Method Number [a]	Holding Time [b]	Container Type	Preservation	Reporting Limit (RL)	Units
VOCs							
Benzene	GC-PID/ECD	8021	14 days	Glass [d]	4°C	5	mg/kg
Toluene	GC-PID/ECD	8021	14 days	Glass [d]	4°C	5	mg/kg
Ethylbenzene	GC-PID/ECD	8021	14 days	Glass [d]	4°C	5	mg/kg
Xylene	GC-PID/ECD	8021	14 days	Glass [d]	4°C	15	mg/kg
Amount/Weight							
Dry Weight	Gravimetric	-- [f]	NA	Glass or PE [e]	None	0.1	g
Wet Weight	Gravimetric	-- [g]	14 days	Glass or PE [e]	None	0.1	g
Size Fraction							
Particle Size Distribution	Sieve/Hydrometer	D-1498/D-422 [c]	180 days	Glass or PE [e]	None	0.1	Fraction
Particle Counting	Electrical Property	Electrozone Sensing	180 days	Glass or PE [e]	None	0.1	Fraction
Particle Counting	Light Interaction	Laser Diffraction	180 days	Glass or PE [e]	None	0.1	Fraction
Particle Counting	Microscopic	Scanning Electron	180 days	Glass or PE [e]	None	0.1	Fraction
Mineral Content							
Mineral Identification	X-ray Diffraction		180 days	Glass or PE [e]	None	0.1	Fraction
Mineral Identification	Optical Microscopy		180 days	Glass or PE [e]	None	0.1	Fraction
Mineral Identification	Electron Microprobe		180 days	Glass or PE [e]	None	0.1	Fraction

Notes
[a] EPA SW-846 methods unless otherwise indicated. Equivalent Standard Method or EPA Method can be substituted.
[b] Holding time specified in EPA guidance or referenced in Standard Method for equivalent method.
[c] American Society for Testing and Materials (ASTM) Method.
[d] VOA bottle preferred.
[e] Can substitute any other appropriate containers, as necessary, to accommodate required sample size.
[f] Dry in oven at 50C until constant weight. Record weight using an analytical balance.
[g] Do not dry. Record weight using an analytical balance.
[h] Can substitute EPA Method 353.3M.
[i] Can substitute EPA Method 354.1M.
[j] Can substitute EPA Method 365.3M.

9.3 Sample Storage and Handling Prior to Analysis

To minimize the chance of sample contamination and unreliable analytical results, special measures must be taken during the storage and handling of samples prior to analysis. For example, samples must be collected and stored in the appropriate containers and preserved. In addition, some analytical methods require filtration of the sample prior to analysis. Finally, samples must be analyzed within established holding times. Several of these measures are discussed in more detail below.

Sample Filtration. To separate particles from the storm water, water samples must be filtered. Samples should be filtered in the laboratory as required for specific particle-related tests such as TSS, grain size, and sediment quality.

Holding Times. Table 9-1 lists the maximum acceptable analytical holding times for a comprehensive list of constituents potentially monitored in Caltrans projects. Holding times may be a factor affecting allowable sampling times if the laboratory has not agreed to work evenings or weekends.

To minimize the risk of exceeding the holding times, samples must be transferred to the analytical laboratory as soon as possible after sampling is complete. Moreover, the laboratory should be notified before the sampling begins so that it can prepare to analyze the samples immediately upon receipt.

When the holding times are relatively short (e.g., 48 hours and less), the time required to deliver the samples to the laboratory may be critical. Direct delivery by the field teams, overnight shipping, or courier can all provide reliable delivery services that will meet the required holding times. Very few particle-related parameters have short holding times as shown in Table 9-1.

9.4 Reporting Limit Requirements

Table 9-1 lists the reporting limits (RLs) for the comprehensive list of analytical constituents potentially monitored in Caltrans projects. The reporting limit is the minimum concentration at which the analytical laboratory can reliably report detectable values. This operational definition does not distinguish between the type of reporting limit, but relies on the laboratory's historical practice of reporting and a thorough review of laboratory practice and performance. The reporting limits in Table 9-1 are provided as a guide for monitoring projects that do not have historical data sets for reference.

It is important that the RLs derived for the project are low enough to provide useful results. For example, if the analytical results are to be compared with quality objectives every effort should be made that the RLs are lower. Therefore, the selected analytical methods should provide RLs at or below the criteria against which the results are to be compared.

RLs are often specific to a given type of sample matrix. The RL for a given sample may be elevated due to the presence of interfering compounds. For example, RLs for

metals in salt water are generally five to ten times higher than RLs for fresh water (when using the same method), due to salt interference with the atomic absorption instrument.

9.5 Analytical Methods

This section discusses the analytical methods that should be used to meet the reporting limits and other DQOs for the project (Section 2 describes how project DQOs are developed). As discussed in Section 4, analytical constituents are selected based on regulatory requirements, water quality objectives, historical data, and other considerations.

For some constituents, alternative analytical methodologies may be used to meet the data quality objectives for reporting limits and control limits of QC samples. Also, methods are being updated and new methods developed for different analytical parameters.

In selecting the analytical method to be used, the following questions should be addressed:

- Does the method conform to any regulatory requirements for the monitoring program?
- Does the method allow the required reporting limits to be easily obtained on storm water samples?
- Does the method have the same or more stringent control limits for QA/QC samples?
- Will the data provided by the method be comparable to historical data collected at the station?
- Is the method recognized as "standard" so that the data collected at a station can be compared to other stations?
- Is the laboratory proficient with the method? Do they have historical data to show proficiency?

The recommended analytical methods for conventional, nutrient, metal, and organic constituents are discussed below and are shown in Table 9-1. All of these methods are described in the listed EPA method. A complete list of the constituents in each EPA method is available on CD-ROM (Methods and Guidance for Analysis of Water – EPA 821-C-99-004). The 8000 series analyses (modified soils methods) can be downloaded from the Internet at "http://www.epa.gov/SW-846/8xxx.htm". The approved methods should be referenced for more detailed sampling and analytical information.

Conventional Parameters. Totals dissolved solids (also described as filterable residue), described in EPA Method 160.1, are measured by evaporating the filtrate from a previously filtered storm water sample and weighing the remaining solids. TSS is measured by filtering the storm water sample and recording the increase in filter weight, as described by EPA Method 160.2. The recommended RLs for these methods are listed in Table 9-1. Turbidity is a measure of how much light a storm water sample will scatter; highly turbid (cloudy) samples will scatter more light than clear samples. The measurement of turbidity is accomplished using EPA Method 180.1. Total organic carbon is the measure of all forms of carbonaceous material in a sample. Method 9060 converts the carbon into carbon dioxide. The amount of carbon dioxide produced is directly proportional the concentration of TOC.

Nutrients. Nitrite and nitrate are determined in sediment samples using EPA Methods 5050 (combustion) or 9056 (ion chromatography) and are expressed as the concentration of nitrogen. TKN is typically measured using EPA Method 351.3, in which ammonia is determined after distillation by titrimetric, colorimetric, or potentiometric procedures. Phosphorous (total) is also determined in sediment samples using EPA Methods 5050 (combustion) or 9056 (ion chromatography).

Metals. The methods are:

Metals (total) – Digestion of the sediment sample followed by inductively coupled plasma (ICP) spectrometric analysis of the digestate using methods 3050A and 6010B.

Metals (TCLP) – The TCLP method (1311/6010B) is designed to evaluate the potential of the sediment to generate hazardous leachate (especially after disposal in a Municipal landfill). Results correspond to concentrations in the leachate (mg/L).

Metals (STLC) – STLC is the California equivalent of the TCLP (method CAM WET/6010B). In the STLC, a different extraction fluid is used. Results correspond to concentrations in the leachate (mg/L).

Organics. EPA Method 8015 modified/extended is recommended for analysis of Caltrans' storm water samples, because it distinguishes between the types of hydrocarbons present in the sample, and there is no concern of non-petroleum interferences. EPA Method 8015 mod/ext. also provides additional confidence in sample results because of the additional quality control/quality assurance procedures included with the method. Caltrans should specify to the analytical laboratory that the samples should be analyzed by EPA Method 8015 mod/ext. and quantified for the hydrocarbon range(s) of interest. The laboratory should review the chromatograms to confirm that the summary report of analytical results actually represents hydrocarbons, which shows a gas chromatographic trace similar to hydrocarbon range(s) of interest. The gas chromatograms for the samples, quality control samples, and standards can be requested in the data package.

The recommended methods for analysis of solvent-related constituents in sediments are EPA Methods 8021.

Sediment Amount or Weight. The weight of filtrate or sediments samples will be performed using a calibrated scale (analytical balance) with a reporting limit of 0.1 grams. There are no standard methods other than proper analytical procedures for weighing materials, and there are no requirements for container types, preservatives, or holding times.

Grain Size Fraction. The following paragraphs describe individual methods that are applicable to particle size analysis of suspended sediments found in runoff. Selection of applicable methods was based on a number of criteria including sample size, commercial availability of the method, practicality of sample collection and preparation, and capability of analyzing the wide range of particle sizes in storm water runoff.

All particle size measurement methods are based on the assumption of equivalent diameter (i.e., Equivalent Sphere Theory), in that they attempt to measure some physical property (or other behavior or attribute) that can be related to the diameter (size) of an equivalent sphere.

Sieving and Screening. The oldest sorting and classification method is sieving and screening, in which particles are separated into various size fractions based on their ability to pass through a series of wire mesh sieves with square apertures of various standard sizes (i.e., the size determination is sieve diameter). The smallest sieve (#635) has an aperture size of 20 µm, so the method is not capable of separating very small particles. This method is capable of sizing particles ranging between about 20 – 127,000 µm. American Society for Testing and Materials (ASTM) Method D-1498 is recommended sieving and screening method.

Hydrometer. The hydrometer method is a gravitational, sedimentation-based method. This method is among the most commonly used technique for particle size and size distribution determination. The sedimentation method is based on the measure of the velocity with which a particle in a fluid settles due to the gravitational forces acting on the particle, against the buoyancy of the fluid and other drag forces acting against the settling of the particle. An attempt is made to measure the changes in the dispersion of the particles over time.

For the hydrometer method, the changes induced by settling are measured by differences in the density of the dispersion. A hydrometer is simply a vertical float, inscribed with a graduated scale, which sinks into the liquid dispersion until it has displaced a volume of liquid equal in weight to that of the float. As particles settle by gravity, the density of the liquid suspension decreases and the hydrometer readings change accordingly. The method is capable of quantification of grain sizes between 1 and 75 µm. American Society for Testing and Materials (ASTM) Method D-422 is recommended hydrometer method.

Sieving and hydrometer can be combined to measure a range of grain sizes between 1 and 127,000 µm. Both methods express the results in terms of percentage of total

weight. The results can be presented in both tabular and graphic format. Table 9-2 presents an example of tabular results and Figure 9-1 shows the results in a graphical format.

Table 9-2
Example of Tabular Results from Sieve / Hydrometer Tests

Grain size (µm)	Mass Finer (%)		
	Sample #1	Sample #2	Sample #3
12,700	100	100	100
9,530	96.54	100	100
4,750	95.58	99.44	99.94
2,000	91.07	96.03	99.74
850	77.22	87.06	98.76
425	52.03	76.13	96.49
250	31.75	65.95	92.98
150	20.25	56.07	87.65
75	11.60	41.10	71.16
38	7.22	21.90	43.67
20	5.91	15.00	29.62
18	4.30	12.89	26.26
9	1.75	7.00	20.14
5	1.00	5.50	12.57
2	0.63	3.25	7.79

One weakness of the sieve and hydrometer analyses is the amount of sample required to perform the analyses. For both analyses, 120 grams of dry sediment are required. This amount is typically not a problem to collect from sediment deposits. However, it can be a problem when deriving the sediment from relatively clean storm water runoff samples. To collect 120 grams of sediment from storm water, a large volume of storm water may need to be required depending on the total suspended solids (TSS) concentration. Assuming the storm water runoff has an average TSS concentration of 200 milligrams per liter (mg/L), approximately 600 liters (160 gallons) of water sample would be needed to collect 120 grams of dry sediment for this analysis. Table 9-3 summarizes other sample volumes required for different TSS concentrations.

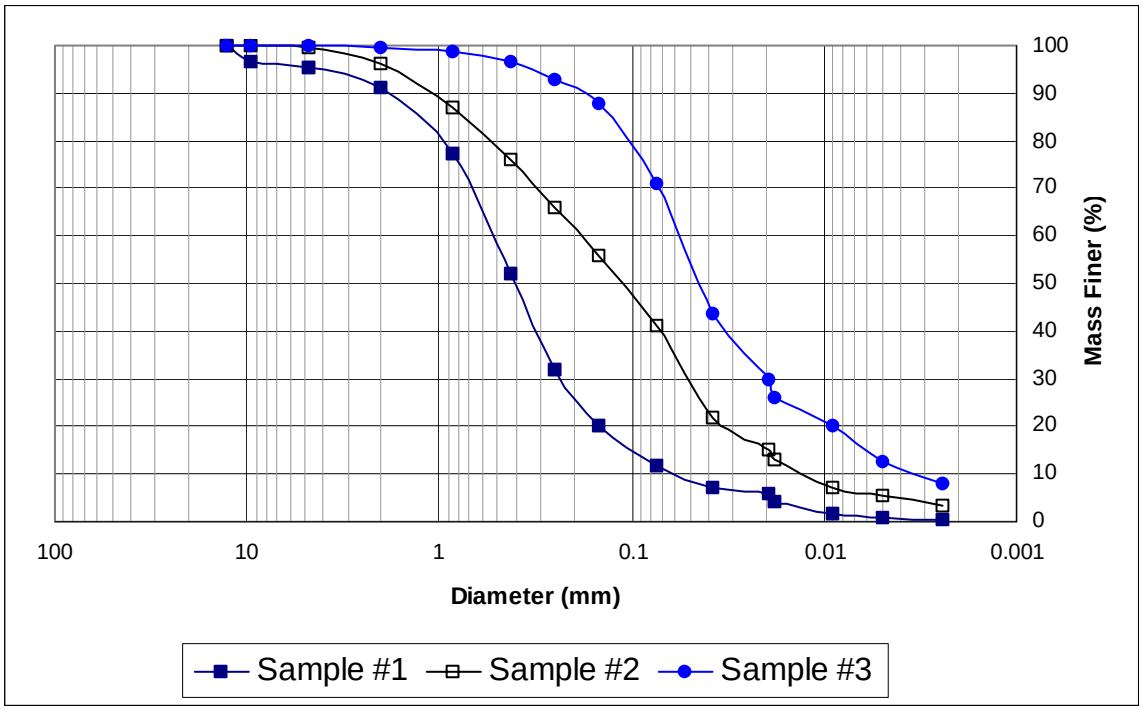


Figure 9-1
Example of Graphical Results from Sieve / Hydrometer Tests

Table 9-3
Example of Sample Volumes Required for Sieve Analysis

TSS Concentration in the Runoff Sample (mg/L)	Runoff Sample Volume Required (liters)
20	6,056
200	606
2,000	60

To overcome this sample amount / volume issue, three methods are available that count the number of particles and partition them in various grain size ranges. Considerably less sample size is required to perform the counting. Results are expressed in terms of percentage of the total number of particles counted. The three methods include electrozone, laser diffraction, and microscopic. They are each described below.

These three methods were selected based on their availability at commercial laboratories. There are no standard methods and there are no requirements for container types, preservatives, or holding times.

Electrozone Method. The electrozone method (based on the Coulter principle) measures the electrical current between two electrodes in the liquid on either side of a small aperture, in which a suspension of particles is forced to flow. As the particles

pass through the aperture, the impedance between the electrodes changes and produces an electrical pulse having a magnitude proportional to the particle volume. The pulses are electronically scaled, counted and accumulated in size related channels. These results produce a size distribution curve. Typical electrozone analyzers can count up to 2,000 particles per second.

Laser Diffraction. Laser diffraction instruments comprise a light source (typically a low power laser source), optical elements to process the incident beam, and a sample cell within which the sample is introduced (as a liquid suspension). Light scattered from the sample is then focused onto a detection system, which is usually a multielement array of numerous detectors placed at discrete locations. The detectors convert the scattered light intensity incident upon them into electrical signals that are then processed to obtain information about the particle size and size distribution.

Microscopic. All microscopic methods involve direct observation of particles and the consequent determination of size based on the diameter of a sphere that has the same projected area as the projected image of the particle. The calculated sizes or size distributions can then be converted to, or expressed in, volume or mass distributions with suitable assumptions (e.g., particle density).

When compared to other techniques of particle size analysis, a significant advantage of microscopic methods lies in the ability to determine the particle shape, in addition to making a direct measurement of size. Numerous commercial instruments and software packages are available for particle size and size distribution analysis. Instruments used for microscopic techniques include optical light microscopes, scanning electron microscopes (SEM), and transmission electron microscopes (TEM). The choice of the instrument to be used is determined by the size range of the particles being studied, magnification, and resolution that are desired. The SEM method (with automatic image analysis) seems the most applicable for sediments found in storm water runoff because of its resolution range of 0.1 – 1,000 mm.

Table 9-4 summarizes each method in terms of range of particle sizes, number of intervals, detection limit, sample volume, and cost.

Table 9-4
Summary of Particle Counting Methods

	SEM	Electrozone	Laser Diffraction
Grain Size Range	0.08 - 5 µm	0.4 - 200 µm	0.5 - 100 µm
No. of Grain Size Intervals	3 – 5	128	8 *
Detection Limit	1 / L	10 /L	1,000 - 10,000 / L
Sample Size	< 1 mL	10 – 200 mL	50 – 100 mL
Average Cost per Sample	$250	$ 110	$135

* Laser diffraction offers eight (8) standard intervals but an infinite number of intervals can be added at a cost of $75 per eight intervals.

To convert the particle numbers to mass, the average volume of each particle grain category or range must be calculated and a density estimated. The volume can be calculated by assuming each particle is spherical in shape with a diameter that represents the midpoint of the grain size range. The mineral content of the sample is used to estimate the average particle density.

Mineral Content. Three general methods commonly available for the mineralogic analysis of sediments include X-ray diffraction (XRD), optical microscopy, and electron microprobe. These methods are briefly described below.

X-ray Diffraction. XRD analysis is conducted with a powder diffractometer using Cu-Kα radiation. The sediment sample is ground to a powder and scanned over a range of angles. This results in a spectrum of diffraction angles where the angle of diffraction corresponds with a particular chrystalline mineral phase and the intensity of diffracted radiation corresponds with the concentration of the mineral phase. Nonchrystalline (amorphous) material is estimated based on the difference between 100 percent and the total mineral concentration. The average detection limit is approximately 1-3 percent for chrystalline mineral phases.

Optical Microscopy. Optical microscopic analysis can include four types: (1) stereo microscopic analysis of the whole sample, (2) reflected light analysis of a polished grain mount, (3) transmitted light analysis of a thin section, and (4) transmitted light analysis of an oil immersion mount. Optical microscopy using all four types allows general characterization of the chrystalline and nonchrystalline composition as well as identification and concentration of major mineral phases. This technique is highly dependent upon the skill and experience of the analyst. The average detection limit is approximately 1-5 percent for mineral phases.

Electron Microprobe. Electron microprobe analysis is conducted with a scanning electron microscope equipped with energy dispersive and/or wavelength dispersive X-ray fluorescence (XRF) spectrometers. A polished mount of the sample is first observed under the scanning electron microscope in backscatter electron mode in which the brightness of sediment grains are directly related to the average atomic number of the elements in each phase. The elemental composition of a selected grain is then determined by energy and/or wavelength dispersive XRF spectral analysis using a narrowly focused beam of electrons. The combination of backscatter scanning and electron microprobe analysis allows the analyst to provide both a general characterization of the sample (similar to optical microscopy) and to obtain detailed elemental compositions for selected mineral grains, which is particularly useful for identifying trace element impurities and geochemical associations. This technique is highly dependent upon the skill and experience of the analyst. The average detection limit is less than 1 percent but depends on the number of grains examined with the microprobe.

These three methods were selected based on their availability at commercial laboratories. There are no standard methods and there are no requirements for container types, preservatives, or holding times.

9.6 Laboratory Data Package Deliverables

As a part of the laboratory contract, the data package that will be delivered to Caltrans and the timing of its delivery (turn around time) should be defined. The data package should be delivered in hard copy and electronic copy (on diskette).

The hard copy data package should include a narrative that outlines any problems, corrections, anomalies, and conclusions, as well as completed chain of custody documentation. A summary of the QA/QC elements must be in the data package:

- Sample extract and analysis dates
- Results of method blanks
- Summary of analytical accuracy (matrix spike compound recoveries, blank spike compound recoveries, surrogate compound recoveries)
- Summary of analytical precision (comparison of laboratory split results and matrix spike duplicate results, expressed as relative percent difference)
- Reporting limits

In addition to the hard copy, an electronic copy of the data needs to be requested from the laboratory. The electronic copy includes all the information found in the hard copy data package. Data reporting and the standardized electronic format for Caltrans data submittals are discussed in Section 10.

Common turn around times for laboratory data packages are three weeks to thirty days for hard copy and electronic copy. The hard copy data package should undergo data review as described in Section 8.

Section 10
Data Reporting Protocols

All data collected as part of a Caltrans storm water monitoring project are entered into the Caltrans Statewide Stormwater Database. To facilitate data management, analysis, and the comparison of results from Caltrans Districts throughout the State, a uniform system for data reporting is required for all Caltrans monitoring projects, including particle studies. On an annual basis, Caltrans updates and distributes a Data Reporting Protocols document that describes the manner in which data should be entered into the Database. An upcoming version of the Data Reporting Protocols will include protocols for water quality data, toxicity data, and litter data in addition to particle data. The data reporting protocols specific to particle results are presented in this section, along with general instructions for all storm water data entered in the Caltrans Stormwater Database and the general organization of the database. These specific topics are covered in the following order:

- General Instructions
- Data Handling and Management
- Organization of the Caltrans Statewide Stormwater Database
- List of Important Fields for the Particle Portion of the Database

The entire document for particle data reporting protocols is presented in Caltrans Data Reporting Protocols Particle Analysis (CTSW-RT-02-041).

10.1 General Instructions

Every monitoring site is assigned an ID number by Caltrans. At the beginning of each monitoring season, data reporters must contact the Caltrans database manager to receive the Site ID for each site to be sampled. Data reporters provide the name of the site, Caltrans District, and constituents to be monitored. The database manager then supplies the appropriate Site IDs, or assigns them, if previously unmonitored sites are added to a project.

Standardized entries are provided for almost every field. These entries must be used exactly as presented in the Protocols (including for example specifications for spacing, hyphenation or capitalization), and attention must be given to the units specified for each constituent. If the standardized list does not contain an appropriate descriptor, the data reporter should contact the database manager prior to submitting any non-standardized entries.

The database manager will provide every data reporter with a data-reporting worksheet (Excel file format) in which all data must be submitted. All data fields should be included, even when they are left blank. For detailed instructions on how to include time series data, see Caltrans Storm Water Monitoring Protocols (CTSW-RT-00-005, Second Edition). For the reporting of dates and times, specific formats and

references are dictated in the Protocols, as is a definition of a precipitation event. The purpose is to provide consistency in data reporting and calculation of summary statistics.

10.2 Data Handling and Management

Efficient data storage, retrieval, and transfer methods should be established prior to initiation of monitoring activities. The following suggestions are provided to guide in the development of a reliable and useful data management system:

- Establish a central file for hard copy information; create a system so that new information is not confused with current information.
- Select a database system that can accommodate digital information such as laboratory analyses and recorded data logger measurements.
- Choose a database program that allows for efficient data input, back up, and retrieval of selected information in response to queries.
- To perform useful queries, include the following categories in the same database: sampling event description, catchment area characteristics, sample identification information, sample collection and runoff data, analytical results, analytical methods, and data qualifiers.
- Coordinate electronic data transfer with the analytical laboratory (i.e., the laboratory should provide analytical results in an electronic format that can be directly input into the program's existing database). This can save time and minimize data entry errors.
- Apply Caltrans hydrologic tool to evaluate flow and rainfall data and to prepare storm-event hydrographs.
- Apply Caltrans data validation and checker tool to all analytical data received from the lab.

All storm water monitoring data will be incorporated into the Caltrans Statewide Storm Water Database. See Section 10.3 and Caltrans Data Reporting Protocols Particle Analysis (CTSW-RT-02-041) for specific data reporting protocols.

10.3 Organization of the Caltrans Statewide Stormwater Database

As discussed in the introduction to this section, all data collected as part of a Caltrans storm water monitoring project are entered into the Caltrans Statewide Storm Water Database as the means to facilitate data management, analysis, and the comparison of results.

The database is separated into four data categories:

- Water quality
- Litter
- Toxicity
- Particle

Each category is further divided into the same four sections:

- Sample Description
- Sampling Event Description
- Site Descriptions
- Constituent List

The first three sections include numerous fields that provide information on the sites, events, and results. These three sections always contain an "Event ID" and "Monitoring Site ID" fields with each entry so the information can be easily cross-referenced. The fourth section, Constituent List, simply provides the possible constituents included in the field measurements and laboratory analyses from a given monitoring program.

The Sample Description portion of the database allows for input of standard information associated with samples. These data can be instrumental in interpreting results. The information included in this section of the database describes the sample itself: when and how it was collected, what it was analyzed for, the method and lab used to perform the analysis, and the result of the analysis. This section also allows the data reporter to characterize the sample source, as well as the portion of an event that is represented by the sample.

The second section of the database contains data that describes the precipitation event itself if relevant to the study. For particle monitoring, sampling may not be conducted during an event but rather during periods of dry weather. For a storm event, this section includes when the rain started and stopped, rainfall intensity, when runoff started and ended, the total amount of rainfall prior to, and during, the event, and antecedent dry days. For non-storm event monitoring, precipitation and runoff information is reported for the entire sampling period if measured and relevant, otherwise this section of the database is left blank.

In the third section of the database, the data reporter enters records that describe the site at which the sample was obtained. The fields include categories like geographic information and governing jurisdictions, such as latitude/longitude coordinates,

hydrologic sub-area, land use, size of the watershed, county, Caltrans District, and Regional Water Quality Control Board (RWQCB).

The final section lists the standard constituent names to be applied in the database for all Caltrans studies. The names may be full names or acronyms. The appropriate units are also listed.

10.4 List of Important Fields within the Particle Portion of the Database

This section lists the data fields in the Database specific to particle monitoring results. It is not meant to reproduce the Protocols, but simply to give the reader an idea of the type of information that is required from data reporters.

The “Sample Description” section for the particle portion of the database is similar to the “Sample Description” portion of the water quality database. One additional field has been added and other fields have been modified to include additional elements. Database fields specific to particle results include information such as particle size fraction, sample source, event representation, sample type, sample matrix, constituent type, units, preparation method, and method reference. The specific data fields included in the “Sample Description” section of the particle portion of the database are presented in the example spreadsheet included as Figure 10-1. Examples of data that may be entered into each of the data fields are also included in Figure 10-1. The various field and sub-fields are described in Caltrans Data Reporting Protocols Particle Analysis (CTSW-RT-02-041).

The “Sampling Event” description section is identical to the water quality portion of the database which includes such fields as the Rain Start Time, Rain End Time, Rain Start Date, Rain End Date, Event Rain, Max Intensity, Total Flow Volume, Peak Flow and the Estimated % Capture, as well as who collected the sample. The various field and sub-fields are described in Caltrans Data Reporting Protocols Particle Analysis (CTSW-RT-02-041).

The “Site Description” portion is also identical to the water quality database fields, which include the Caltrans District, County, RWQCB, Latitude, Longitude, Land Use, Catchment Area, Impervious Fraction, Post Mile, Receiving Water Type, Time Series, and Site Description. BMP Type and Receiving Water Type were modified to include elements unique to particle studies. The various field and sub-fields are described in Caltrans Data Reporting Protocols Particle Analysis (CTSW-RT-02-041).

Site ID	Event ID	Sample Source	Event Representation	Sample Type	Sample Matrix	Constituent Type	Reported Value	Units	Preparation Method	Particle Size Fraction
3-202	2001-3	Sediment	Multiple	CW	Sediment	PS	23.4	%	Drying	
3-202	2001-3	Sediment	Multiple	CW	Sediment	*Cu*	35.6	mg/kg	Drying	60-75
3-202	2001-3	Storm	Discrete	G	Water	*GRAV*	0.8	mg	Drying	

Figure 10-1
Example of Specific Particle Data Fields

Section 11
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Section 12
Acronyms

ASTM	American Society of Testing Methods
BMP	best management practice
BS	blank split
COC	chain-of-custody
DHS	Department of Health Services
DI	deionized water
DQO	data quality objective
DQEP	data quality evaluation plan
EMC	event-mean concentration
EPA	Environmental Protection Agency
ERS	external reference standards
HSP	health and safety plan
ICP	inductively coupled plasma
ICS	interference check sample
LCS	laboratory control samples
MDL	method detection limit
MS	matrix spike
MSD	matrix spike duplicate
ND	not detected
NPDES	National Pollutant Discharge Elimination System
NWS	National Weather Service
PQL	practical quantification limits
QA	quality assurance
QC	quality control
QPF	quantity of precipitation forecast
RPD	relative percent difference
RL	reporting limit
ROW	right-of-way
SAP	sampling and analysis plan
SEM	scanning electron microscope

SOP	standard operating procedure
STDS	Solids Transport and Deposition Study
STLC	State toxicity leaching characteristic
SWMP	Storm Water Management Program
TCLP	toxicity characteristic leaching procedure
TDS	total dissolved solids
TEM	transmission electron microscope
TKN	total Kjeldahl nitrogen
TMDL	total maximum daily load
TOC	total organic carbon
TPH	total petroleum hydrocarbons
TSS	total suspended solids
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
XRF	X-ray fluorescence method