



Integral Consulting Inc.
319 SW Washington Street
Suite 1150
Portland, OR 97204

telephone: 503.284.5545
facsimile: 503.284.5755
www.integral-corp.com

DRAFT MEMORANDUM

To: Sean Sheldrake, EPA
David W. Charters, Ph.D., EPA

From: Mala Pattanayek and Bridgette DeShields

Date: May 8, 2015

Subject: Evaluation of Risk to Benthic Community

Project No.: C167-1509

This memorandum provides the framework for evaluating potential risk to the benthic community and assessing natural recovery in sediment adjacent to the Arkema site in Portland, Oregon (Site). This memorandum provides a brief background and a statement of the problem that has initiated this study, outlines the data quality objectives (DQOs) guiding study design and evaluation, and provides detailed descriptions of the procedures used to implement benthic toxicity testing (bioassays) and toxicity identification evaluation (TIE) procedures to evaluate potential risk to the benthic community in the study area. The project team for this toxicity evaluation is also presented in this memorandum.

A draft sediment sampling work plan (work plan) was submitted to the U.S. Environmental Protection Agency (EPA) on April 30, 2014. The work plan included an approach for evaluating risk to benthic community in sediments adjacent to the Site (Integral 2014). The information in this memorandum will be incorporated into the revised work plan, which will also include general procedures for fieldwork that are referenced in this memorandum (e.g., navigation and positioning, sample collection and processing, handling of investigation-derived waste handling).

BACKGROUND

Bioassay testing has been conducted for the Portland Harbor Superfund site on multiple occasions. Bioassays were last conducted in 2007 for the Portland Harbor Round 3 investigation using freshwater species *Hyalella azteca* and *Chironomus dilutus*. The bioassay results from these investigations were used in the benthic invertebrate risk assessment for

the draft final remedial investigation report for the Portland Harbor site (Integral et al. 2011). Classifications of toxicity were based on the organism responses in the bioassays, as defined in the benthic invertebrate risk assessment in the draft final report (Integral et al. 2011) and are provided in Table 1.

Figure 1 presents the following toxicity levels to benthic community, based on growth (biomass) and survival for both test species, at 19 locations adjacent to or near the Site in Sediment Management Area 14 (SMA 14; between River Miles 6.8 and 7.6 of the Willamette River). Summarized below is the highest toxicity observed at each station:

- “High” toxicity at nearshore stations (G360 and G366) between Dock 1 and the Salt Dock, two stations (G368 and G371) on the upstream portion of the Salt Dock, one upstream station (G689) near the southern edge of SMA 14, one station (G348) adjacent to Outfall 004, and one station between Outfall 004 and the Railroad Bridge (G339).
- “Moderate” toxicity at one station (G351) on the navigation channel side of Dock 2.
- “Low” toxicity at one upstream station (G377) near the southern edge of SMA 14, two stations (G359 and G362-1) between the Salt Dock and Dock 1 near the navigation channel, one nearshore station (G355) between Dock 1 and Dock 2, and one station (G336) between Outfall 004 and the Railroad Bridge.
- “No” toxicity at three stations (G333, G334, and G335) just south of the Railroad Bridge, one station (G345-1) just north of Outfall 004, and two stations (G350 and G353-1) between Dock 2 and the Salt Dock.

DATA QUALITY OBJECTIVES

EPA’s seven step DQO process (USEPA 2006) was followed to systematically generate performance and acceptance criteria for data collected from the study area. Table 1 summarizes the DQOs following EPA’s seven step process. The problem that initiated this evaluation (Step 1 of the DQO process) and goals of this study (Step 2 of the DQO process) are discussed below.

Problem Statement

The observed toxicity from the previous studies in the vicinity of the Salt Dock could have been the result of elevated sodium chloride (salt) concentrations from saline groundwater discharging in the area adjacent to the former Salt Dock. Monitoring well MWA-30, for example, is screened in the shallow groundwater zone and is located between the salt pads and the top of bank just north of the Salt Dock (Attachment 1; ERM 2007, 2010). The

chloride concentration in groundwater collected from this monitoring well decreased by more than 90 percent from 179,000 mg/L in April 2002 to 12,900 mg/L in August 2009 (Attachment 1). This reduction occurred after the cessation of operations at the Site and removal of salt from the pads but prior to the installation of the groundwater barrier wall, so it is likely due to dissolved salt flushing through the shallow groundwater during this period. Beginning in late 2012, an upland groundwater source control remedy was implemented that included the installation of a fully penetrating (to bedrock) groundwater barrier wall (ERM 2013) and a groundwater extraction and treatment system to maintain inward hydraulic gradient behind the wall. The upland groundwater source control measure has likely mitigated the continued effects of dissolved salts in upland groundwater discharging at the bioassay study stations near the Salt Dock, although there may be some dissolved salt working its way through the system. However, it is unknown whether non-salt-related toxicity is also present at the stations near the Salt Dock. Furthermore, the cause of toxicity at these as well as other stations in other areas of the Site, as described above, is also unknown.

The Portland Harbor draft feasibility study's comprehensive benthic risk area (CBRA) evaluation (Anchor QEA et al. 2012) resulted in the prediction of a large footprint of potential benthic risk at SMA 14 based on multiple lines of evidence, including benthic toxicity results. The future SMA14 sediment remedy is intended to address areas of current benthic risk; however, based upon incomplete and uncertain information regarding potential causes of toxicity in the CBRA, currently envisioned sediment remediation will not address benthic risk associated with dissolved salts related to upland groundwater discharges (i.e., the latter toxicity is not associated with contaminants bound to sediment particles but instead to dissolved salts in groundwater passing through the sediment). Moreover, because the previously implemented upland source control addresses upland groundwater plumes, including high concentrations of dissolved salts, the previous benthic toxicity results likely do not represent the current sediment conditions in SMA 14.

Goals of the Study

The goals of this study are to:

- Evaluate whether salt concentrations are still elevated in sediment porewater and, if so, whether they are affecting benthic toxicity in sediment near the Salt Dock
- Assess effects of salt, if salt is still elevated, as a confounding factor affecting toxicity, and mitigate this effect without significantly altering chemical of concern (COC) concentrations
- Assess the current degree of toxicity and potential for unacceptable risks to the benthic community and identify stations exhibiting toxicity

- Attempt to identify the specific chemical or chemical groups that could be causing the observed toxicity to better link COC concentrations to potential risks to the benthic community
- Use the information obtained regarding the COCs most likely to be causing toxicity to develop relevant, appropriate, and effective remedial strategies.

To meet the goals listed above and to fulfill the DQOs, a multi-step study was designed for this evaluation. These steps are referred to below as the pilot study, bioassays, solid phase TIE, and optional confirmation pathways. The study design for each step is discussed below. To provide an understanding of the relationship between benthic toxicity and COC concentrations under current conditions, 11 stations are proposed for benthic toxicity testing (bioassays) (Figure 2). Sampling locations were selected to obtain a wide range of benthic toxicity responses and surface chemistry characteristics to maximize the statistical significance of any correlation between COC concentrations (primarily DDx) and observed toxicity based on previous testing. The wide range of concentrations and effects will best inform remedy selection, design, and footprint. Most of the stations will be located in areas with previously identified moderate to high toxicity and/or COC concentrations. If toxicity is observed based on the bioassays from this evaluation, TIEs will be used selectively to attempt to identify the specific chemical or chemical groups that could be causing the observed toxicity.

Table 2 summarizes the DQOs following EPA's seven step process. Table 3 describes the rationale for benthic toxicity testing at each of the 11 stations selected for these DQOs.

STUDY DESIGN

This study comprises multiple steps, including a pilot study, bioassays, solid-phase TIE, and optional confirmation pathways, with latter options being implemented based on the results from a previous step. Because of the complexity of study design and interpretation of results, along with the study design described below, a flowchart illustrating the decision making framework for this evaluation is presented in Figures 3 through 5.

The analytical methodology will follow the quality assurance project plan (QAPP) to be included as part of the revised work plan. The QAPP will follow the methodology and protocols presented in the EPA-approved QAPPs for the Arkema engineering evaluation and cost analysis (EE/CA) investigation (Integral 2009) and the Portland Harbor remedial investigation (Integral and Windward 2004; Integral 2004). The standard operating procedures (SOPs) specific to the analytical methods described in this memorandum are included in Attachment 2. General field protocols for sample collection are provided in the

EPA-approved standard operating procedures from the Arkema early action work plan addendum (Integral 2009; Attachment 3).

Step 1: Pilot Study—Presence and Potential Impacts of Salt Purging and Selection of Test Species

It is suspected that toxicity observed in sediments near the Salt Dock in previous toxicity tests could have been caused by high sodium chloride concentrations as indicated by high specific conductance in the collocated chemistry data. Because an upland groundwater source control remedy has been implemented since the last benthic toxicity testing was conducted in 2007, it is critical to determine whether dissolved salt continues to be an issue that could confound the interpretation of the toxicity test results with respect to COCs in the study area. Dissolved salts associated with groundwater discharges may cause sediment toxicity as a component (porewater) of the bulk sediment sample. This information would be useful for pre-remedial design.

Concurrent with the deployment of passive samplers, which will take place prior to collection of the sediment samples for bioassays (Figure 1), a trident probe or similar device will be used to identify passive sampler stations with elevated specific conductivity (i.e., exceeding species-specific tolerance levels). If elevated specific conductivity is found, a pilot study will be conducted to evaluate the use of purging techniques to remove dissolved salt using the approach described below.

Specific conductivity measurements will be used as a surrogate for salt concentrations and to determine the need for purging sediment samples to achieve conductivity levels within the test species tolerance levels. Specific conductivity tolerance levels for test species are 23,700 microsiemens per centimeter ($\mu\text{S}/\text{cm}$) for *H. azteca* and 3,700–5,400 $\mu\text{S}/\text{cm}$ for *C. dilutus*.

For the pilot study, approximately 5 L of surface sediment will be collected from at least two stations with elevated specific conductivity. Sediment will be homogenized in the field in a temperature controlled environment on the sampling vessel. Approximately 500 mL of the homogenized sample will be sent to analytical chemistry laboratory and the remaining sample will be sent to the bioassay laboratory. Samples from the stations selected for the pilot study will be sent to the two laboratories and specific conductivity will be measured in the porewater. If the laboratory-measured specific conductivity exceeds the acceptable species-specific salt tolerance level, then a preliminary evaluation of “purging” procedures will be conducted, as outlined below. If laboratory-measured specific conductivity levels do not exceed the lowest species-specific acceptable salt tolerance level, then the study will proceed to the bioassay step (Step 2) with no modifications to standard bioassay protocols for *H. azteca* and *C. dilutus*.

The samples sent to the analytical chemistry laboratory will be analyzed for the suite of bulk sediment chemistry analytes, including the following COCs:

- Specific conductivity using either a Hach Sension 5 or Sension 156 handheld temperature compensated meter. Both digital meters have accuracy after adjustment (via cell constant) of ± 0.5 percent of the measurement value, measure salinity in the range of 0.0 to 42.0 ppt, and measure temperature in the range of -10 °C to 105 °C.
- Conventional analytes (total sulfides, ammonia, and pH)¹
- Dioxins and furans by EPA Method 8290
- DDx by EPA Method 8081B
- PCB congeners by EPA Method 1668C.

Purging will be accomplished by setting up surrogate test chambers following Nautilus' SOPs for *H. azteca* and *C. dilutus* (Attachment 2). Briefly, 1 L glass jars will be filled with approximately 225 mL of sediment and 400 mL of overlying water. Jars have a screened overflow hole and a Zumwalt apparatus top to allow for exchange of overlying water. Chambers will equilibrate for ~24 hours prior to the initiation of the purging process.

A sufficient number of surrogate chambers will be set up to allow for the continuous monitoring of pore water salinity. A strategy for the monitoring frequency (likely daily) and duration will be developed by examining the initial salinity measurements in the pore water from the bulk sediment samples at time of receipt. Additional chambers will also be included for the purpose of subsampling for post-purging bulk chemistry analyses.

Beginning on the day after setup, the full volume of overlying water will be renewed twice daily. A single chamber from each sample will be used for porewater salinity analysis at a frequency to be determined upon receipt of the test sediments. The chamber will be sacrificed at least 2 hours after the first water exchange and before the second water exchange. The porewater collection process is as follows:

- Gently siphon off the overlying water
- Homogenize the sediment
- Transfer 40 mL into a centrifuge tube
- Centrifuge at test temperature for 30 minutes at 3,000 RPM

¹ Total organic carbon by ASTM D4129, total sulfides SM 4500-S2-Modified, ammonia by Hach 8155 Modified, and grain size by ASTM D422.

- Decant pore water into glass vial
- Measure and record salinity with meter.

The overlying water quality will be measured throughout the purging process for salinity, dissolved oxygen, temperature, and pH.

Due to organism-specific differences in salinity tolerance, a separate pore water salinity target will be developed for each test species; *H. azteca* have a higher tolerance for salinity compared to *C. dilutus*. At the time that each species-specific pore water salinity target is achieved, additional chambers will be sacrificed for analytical chemistry analysis. The sediment subsample process for chemistry analysis is as follows:

- Gently siphon off the overlying water
- Homogenize the sediment
- Transfer sufficient volume required for chemistry analyses of same suite of chemicals as the original sample into appropriate vessel(s)
- Ship to designated laboratory.

Concentrations of COCs in pre- and post-purged sediment samples will be compared to determine whether sediment COC concentrations have been significantly altered by the purging procedure (i.e., concentrations reduced by approximately 50 percent after purging). If concentrations of COCs become significantly altered during purging, then an alternate, more salt tolerant species (*Eohaustorius estuarius*) will be used for the bioassay step (step 2). The interpretation of the results based on the pilot study is presented in Figure 3 and in the “Interpretation of Results” section below.

Step 2: Bioassays

At the time passive samplers are retrieved and bulk sediment samples are collected for the sediment chemistry program, approximately 50 L of surface sediment will be collected from each of the 11 stations listed in Table 2. Sediment samples from each station will be homogenized in the field and then split for chemical analysis and bioassays.

The bioassay tests will measure the survival and growth (biomass) of the following organisms (see Attachment 2 for Nautilus’s SOP):

- 10-day growth and survival in the midge *C. dilutus*—ASTM E-1706, EPA-823-B-98-004, and EPA/600/R-99/064 Method 100.2

- 10-day growth and survival in the amphipod *H. azteca*—ASTM E-1706, EPA-823-B-98-004, and EPA/600/R-99/064 Method 100.1.
- 10-day growth and survival in the amphipod *E. estuarius*—ASTM E-1376-99, EPA-823-B-98-004, and EPA/600/R-94/025 Method 100.1.

Standard reference toxicant testing will also be performed (see Attachment 2). If ammonia levels are elevated in the samples, then concurrent ammonia reference toxicant tests will also be conducted. Ammonia levels in overlying water will be monitored daily for the duration of the tests (see Attachment 2).

If toxicity is not observed in the bioassay tests, then no further evaluation will be conducted. If toxicity is observed (see “Interpretation of Results” section below), then the study will progress to the solid-phase TIE step (Step 3) for select stations exhibiting the strongest toxic effects using the most sensitive species. The interpretation of the results based on the bioassays is presented in Figure 4 and discussed in the “Interpretation of Results” section below.

Step 3: Solid Phase Toxicity Identification Evaluation

Results of the bioassay tests (Step 2) will be evaluated to identify the most sensitive species and identify stations where toxicity is present. The solid phase TIE will be conducted with sediment samples from up to two stations, among those with the highest toxic responses (Table 3), providing appropriate spatial coverage of the study area, as applicable.

The solid phase TIE process is an iterative one, and therefore, the procedures will be implemented assuming that particle-bound organic compounds would be the most likely cause of toxicity in the study area. If the solid phase TIE test results do not support that assumption, then additional toxicity evaluations of other chemical classes that can complement these analyses will be conducted. Fidelity of applicable test procedure modifications will be maintained through the pilot study (Step 1), the bioassays (Step 2), and the solid phase TIE procedures (Step 3).

Sediment aliquots from the stations selected for the solid phase TIE will be used to produce sediment dilutions that will then be treated with resin beads that bind and sequester targeted organic compounds, thus rendering them unavailable to the test organisms. Diluted and treated sediment will be used to conduct acute testing with the most sensitive of the species employing the same general methods as the ones used in the bioassay screening (Step 2), with an ample number of replicates per dilution, to determine whether the cause of the toxicity has been partially or completely removed. If toxicity is still observed, other potential causes of toxicity will be explored. This will include employing the same treatment process of producing sediment dilutions and treating them with resin

beads, this time targeting metals. The iterative TIE process will continue for other chemical classes and/or the water accommodated fraction until all chemical classes on the list of COCs are excluded. If all COCs can be excluded using this iterative process, then no further analysis will be conducted. Findings of the solid phase TIE will be reported and a scientific management decision will be made after consultation with EPA on whether further analysis will be warranted, in which case, the optional confirmation pathways (Step 4) will be conducted.

The interpretation of the results based on the solid phase TIE is presented in Figure 5 and discussed in the “Interpretation of Results” section below.

Step 4: Optional Confirmation Pathways

Assuming the toxic class can be identified (i.e., assuming treatment for organic compounds removes the toxic effect observed), we will use extraction “add-back” procedures to confirm the toxicity was captured. Resin beads used to extract the target compounds from the sediment will be placed into columns and eluted with methanol fractionation, which separates compounds by polarity. The different eluents will then be reintroduced into an aqueous phase and isolated on solid phase media, and bioassays will be conducted under the same conditions as the first dilutions as in Step 3 to confirm toxicity has been reintroduced, and polar fractions contributing to the toxic effect can be isolated. If toxicity is confirmed for a chemical class consistent with any of the COCs, then eluents causing toxic effects will then be sent to an analytical laboratory for chemistry analysis to identify specific constituents and measure their concentrations.

INTERPRETATION OF RESULTS

The interpretation of results of the multi-step study design to evaluate potential risk to benthic community and identify the cause of toxicity is discussed in this section.

The goal of the pilot study (Step 1) is three-fold: 1) evaluate whether elevated salts are still present in sediments, 2) evaluate whether effects of salts can be mitigated by purging, and 3) assess whether purging significantly alters the COC concentrations in sediment (see Figure 3):

- If salt concentrations are not elevated, then no further assessment of chloride as a confounding factor will be conducted.
- If purging can mitigate effects of salt without significantly altering the COC concentrations (i.e., reducing COC concentrations by approximately 50 percent), then purging will be conducted for all samples with elevated conductivity collected

from the vicinity of the Salt Dock prior to conducting the bioassays (Step 2) using the freshwater test species (*H. azteca* and *C. dilutus*).

- If purging significantly alters the COC concentrations, then bioassays (Step 2) for all samples will be conducted without purging overlying water, and will substitute with an estuarine species (*E. estuarius*) with higher salt tolerance levels.

The goal of the bioassays (Step 2) is two-fold: 1) identify stations where toxicity to benthic organisms is exhibited under current conditions, and 2) identify stations appropriate for the solid phase TIE (Step 3) for determining the cause of toxicity.

Results of the bioassays will be evaluated for toxicity, with survival considered the primary endpoint for these acute tests. Toxicity will be classified as being not toxic, low, moderate, or high based on definitions from the benthic invertebrate risk assessment in the draft final remedial investigation report (Integral et al. 2011) summarized below and presented in Table 3, and results will be presented in a similar manner as shown in Figure 1:

- Not Toxic—Responses statistically lower than negative control response (one-tailed test; $p \leq 0.05$).
- Low Level Toxicity—Responses above the 90 percent threshold for each species and endpoint.
- Moderate Level Toxicity—Responses below the 90 percent threshold but above the 80 percent threshold.
- High Level Toxicity—Responses below the 80 percent threshold.

Stations will be classified as having no, low, moderate, or high toxicity based on the highest observed toxicity based on survival (i.e., most sensitive species). Results of the bioassay tests (Step 2) will be interpreted as follows:

- If the bioassay results indicate no or low levels of toxicity using the survival endpoint, then no further analysis will be conducted.
- If moderate to high toxicity is observed in one station, then solid phase TIE procedures (Step 3) will be conducted only for that single station using the most sensitive of the species tested.
- If moderate to high toxicity is observed in two or more stations, then only the two stations with the highest toxic responses will be selected for solid phase TIE procedures (Step 3), and testing will be conducted with the most sensitive species.

The goal of the solid phase TIE (Step 3) is to identify the cause of toxicity to benthic organisms. The same criteria and classifications of toxic responses used for the bioassays

(Step 2) will also be applied to determine toxicity as part of solid phase TIE. The cause(s) of toxicity will be identified based on a process of elimination by chemical class and fraction as described above in Step 3. If the COCs are eliminated as a potential cause of toxicity at any point in the process, then further analysis will not be conducted.

The goal of the optional confirmation pathways (Step 4), once the scientific management decision has been made for further analysis, is to confirm the cause of toxicity identified through the solid phase TIE (Step 3). If classes of chemicals consistent with the COC list are identified as toxic, then fractionation and ultimately chemical analysis will be pursued to quantify concentrations of each COC. Through the process of reintroducing eluents to confirm toxicity, combinations of compounds and their relative contributions to the toxic effect will also be identified.

The results of the pilot study, bioassays, solid phase TIE, and optional confirmation pathways will be combined with new surface sediment chemistry and sediment porewater data to evaluate potential risk to benthic community, identify the cause of toxicity (if toxicity is observed), and assess natural recovery in sediment adjacent to the Site.

PROJECT TEAM

The sediment sampling for the pilot study and the bioassay tests will be conducted by Integral Consulting personnel. The benthic toxicity laboratory procedures for the pilot study, bioassays, solid phase TIE, and optional confirmation pathways will be conducted by Nautilus Environmental located in San Diego, California. The sediment chemistry for the pilot study (Step 1; before and after purging) and during the implementation of the bioassays (Step 2) will be conducted by ALS Environmental located in Kelso, Washington. The analysis for the confirmation pathways (Step 4) will be conducted by Physics Environmental Laboratories located in Anaheim, California.

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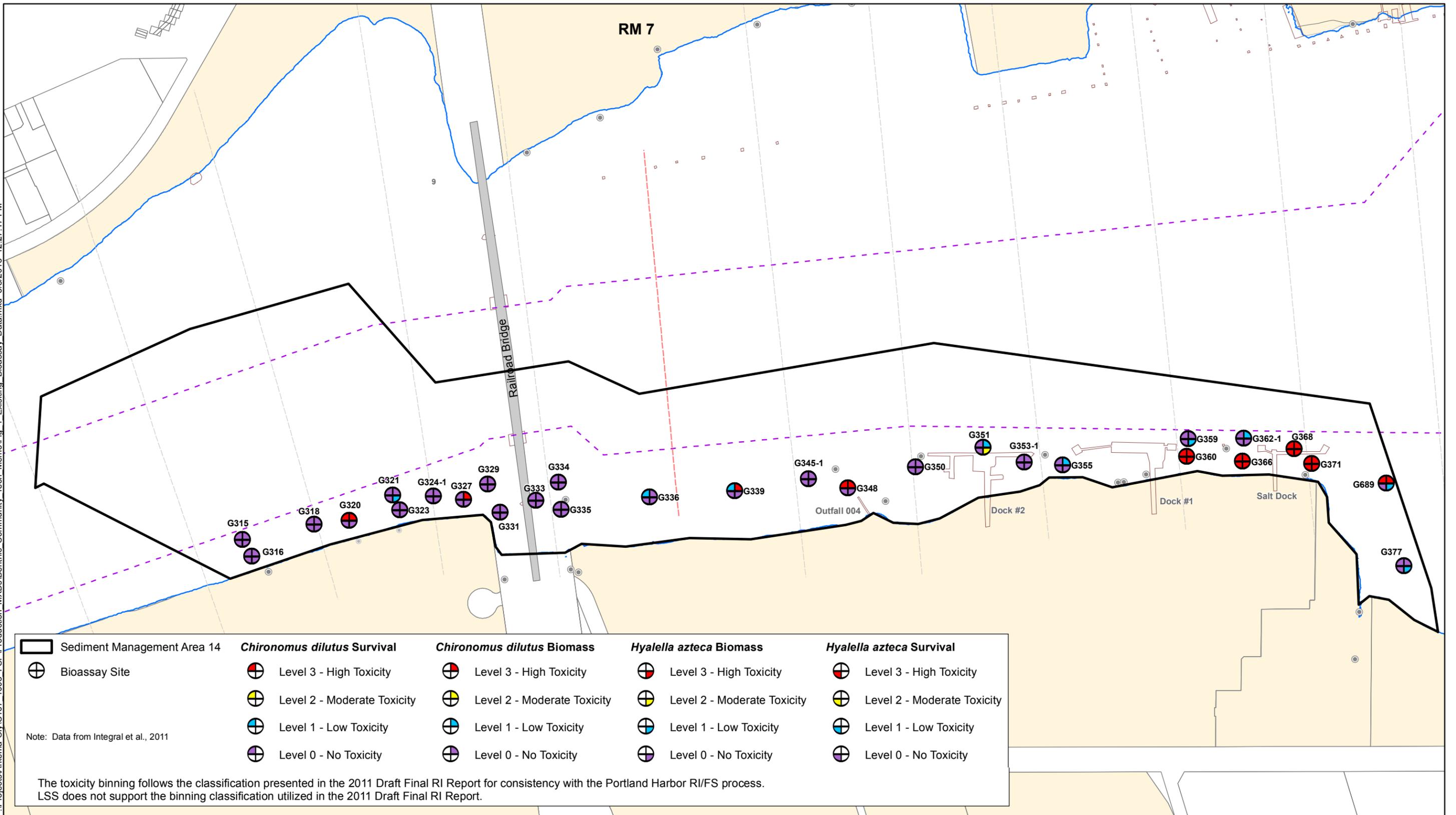
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FIGURES

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Map Features

- River Miles
- Navigation Channel
- Docks and Structures
- ▬ Bridges
- ▬ River Edge 13 ft NAVD
- ▬ Upland ECSI Sites (2008)
- Outfall
- Dock Drain
- Roof Drain

Reference: Integral, Windward, Kennedy/Jenks, and Anchor. 2011. Portland Harbor RI/FS Remedial Investigation Report. Draft final. IC11-0001. Prepared for The Lower Willamette Group, Portland, OR. Integral Consulting Inc., Portland, OR; Windward Environmental LLC, Seattle, WA; Kennedy/Jenks Consultants, Portland, OR; and Anchor QEA, LLC, Seattle, WA. August 29, 2011.

Figure 1.
Existing Bioassay Data
Evaluation of Risk to Benthic Community

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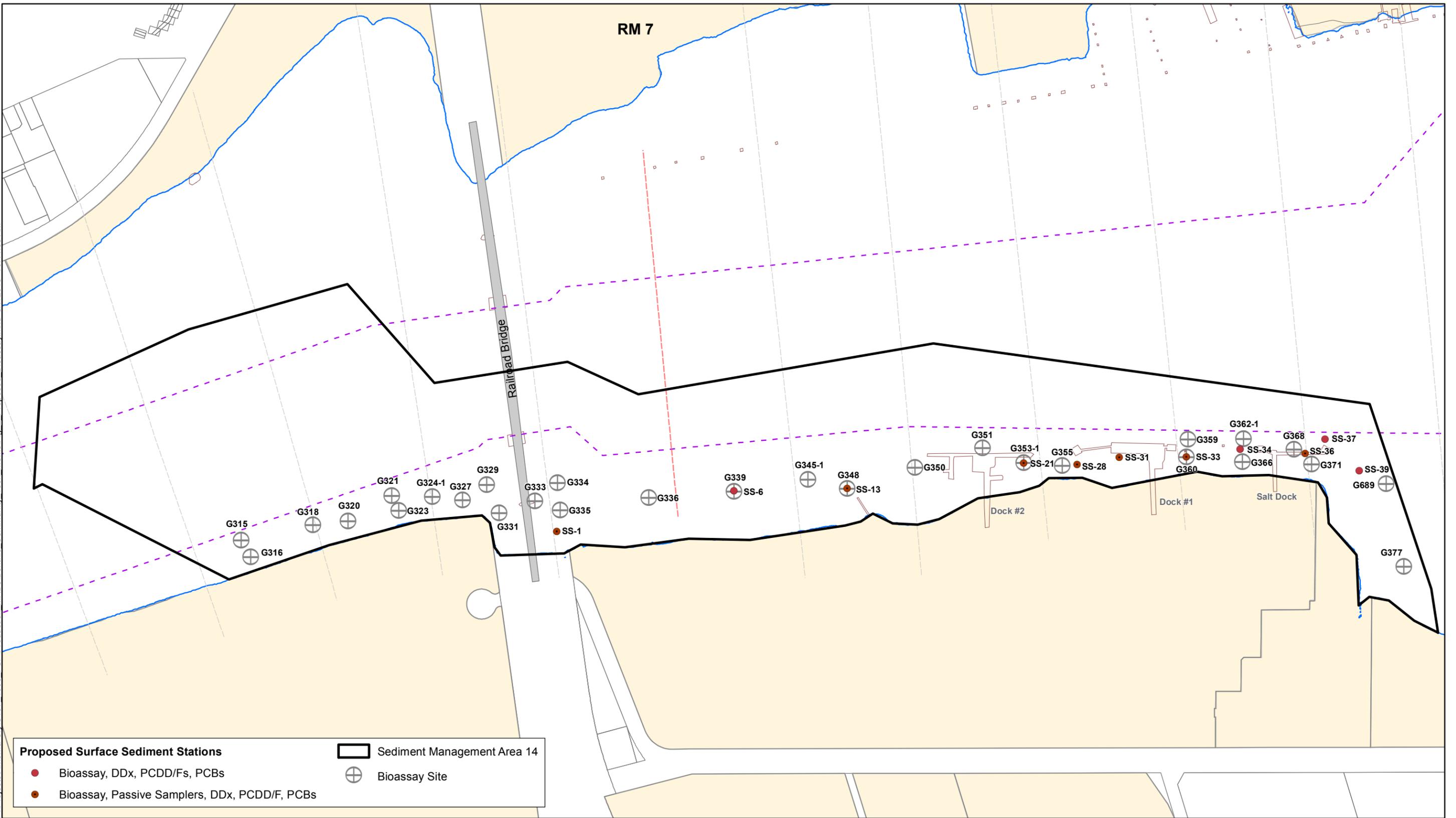


Figure 2.
Proposed Bioassay Sample Collections
Evaluation of Risk to Benthic Community

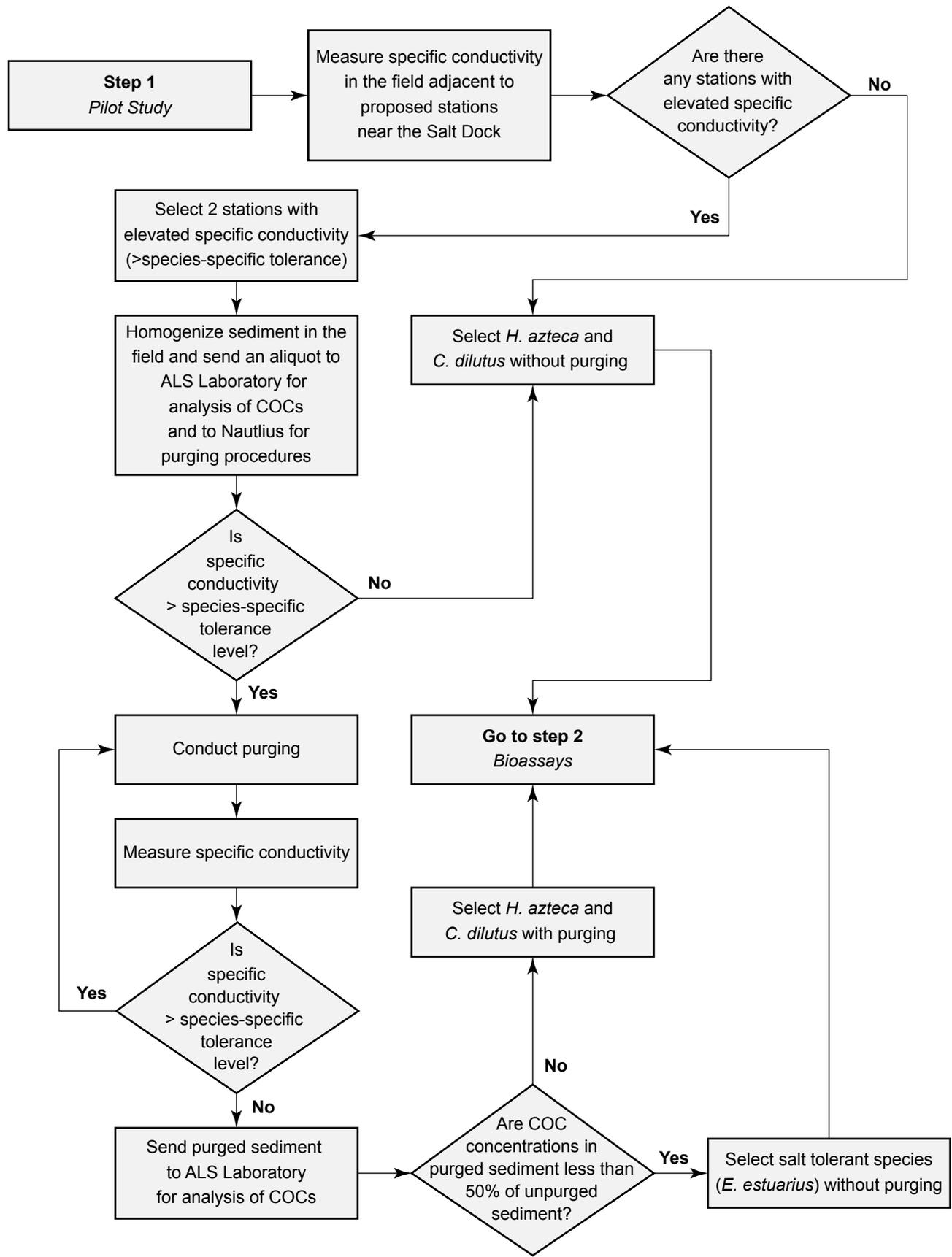
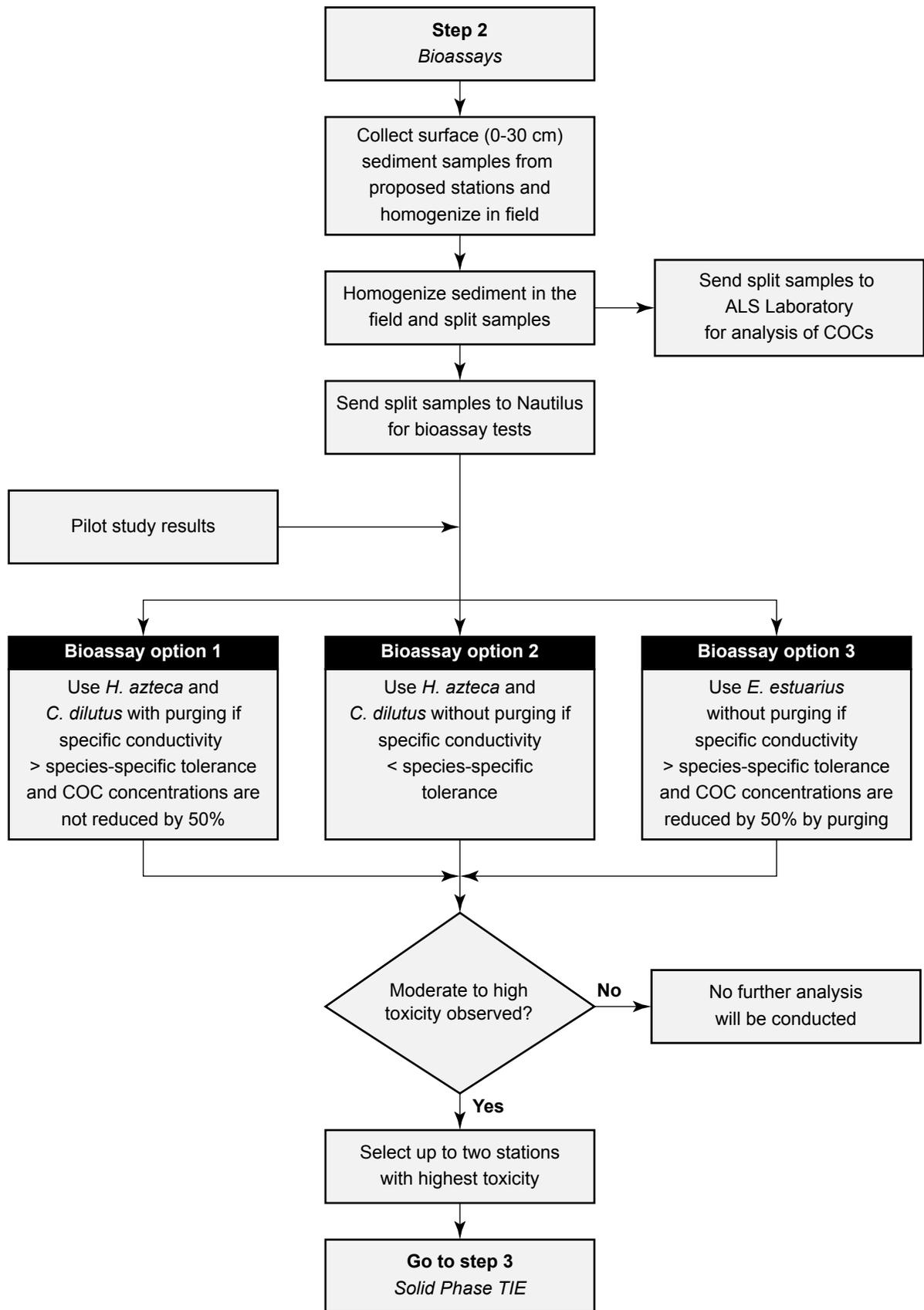
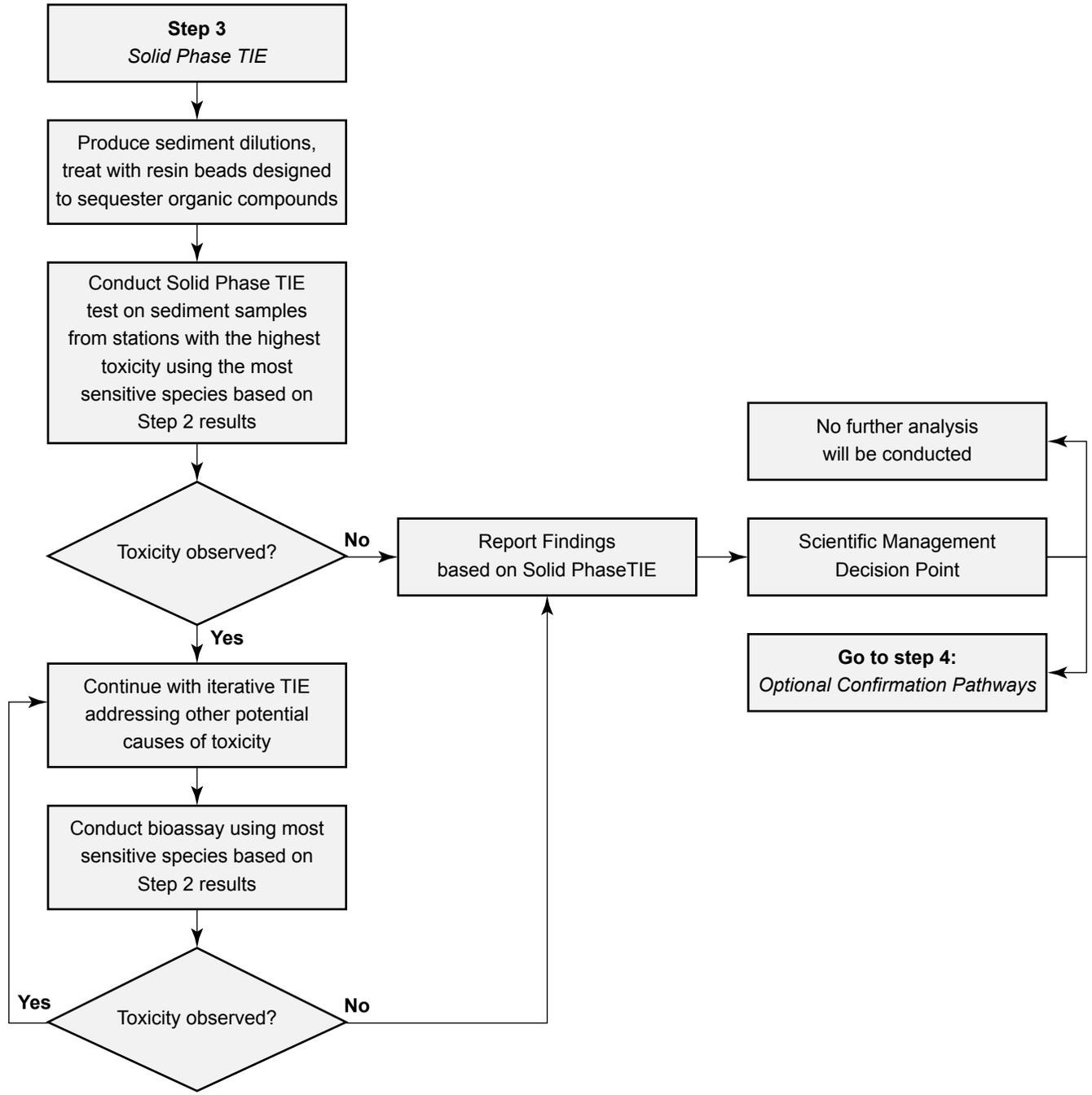


Figure 3.
 Step 1. Pilot Study
 Evaluation of Risk to Benthic Community





TABLES

Table 1. Biological Effects Levels Based on the REV (adapted from Table 6-2 of the final BERA [Integral et al. 2011])

Test and Endpoint ^a	REV (%) ^b	90% Threshold (%)	80% Threshold (%)
<i>Chironomus dilutus</i> survival	93.9	84.5	75.1
<i>Chironomus dilutus</i> biomass	91	81.9	72.8
<i>Hyalella azteca</i> survival	88.1	79.3	70.5
<i>Hyalella azteca</i> biomass	73.6	66.2	58.9

Notes:

BERA = baseline ecological risk assessment

REV = reference envelope value

^a The test response must also be statistically lower than the negative control response (one-tailed test, $p \leq 0.05$) to consider the sediment as having an adverse effect on benthic invertebrates.

^b 5th percentile of negative control-adjusted (test divided by negative control) survival and biomass endpoints for reference sampling locations.

Table 2. Data Quality Objectives to Evaluate Potential Risk To Benthic Community

DQO Step	Description
1. State the problem	<p>Toxicity to benthic organisms (<i>Hyalella azteca</i> and <i>Chironomus dilutus</i>) was observed in previous studies conducted as part of the Portland Harbor 3 investigations (Figure 1). As defined in the Final Remedial Investigation for Portland Harbor (Integral et al. 2011), toxicity was observed as follows:</p> <ul style="list-style-type: none"> • “High” toxicity at nearshore stations (G360 and G366) between Dock 1 and the Salt Dock, two stations (G368 and G371) on the upstream portion of the Salt Dock, one upstream station (G689) near the southern edge of SMA 14, one station (G348) adjacent to Outfall 004, and one station between Outfall 004 and the Railroad Bridge (G339). • “Moderate” toxicity at one station (G351) on the navigation channel side of Dock 2. • “Low” toxicity at two upstream stations (G377) near the southern edge of SMA 14, two stations (G359 and G362-1) between the Salt Dock and Dock 1 near the navigation channel, one nearshore station (G355) between Dock 1 and Dock 2, one station (G351) on the navigation channel side of Dock 2, and two stations (G339 and G336) between Outfall 004 and the Railroad Bridge. • “No” toxicity at three stations (G333, G334, and G335) just south of the Railroad Bridge, one station (G345-1) just north of Outfall 004, six stations (G350, G351, G353-1, G355, G359, and G362-1) between Dock 2 and the Salt Dock, and one station (G377) along the southern edge of SMA 14. <p>The observed toxicity from the previous studies in the vicinity of the Salt Dock could have been a result of elevated sodium chloride (salt) concentrations from saline groundwater discharging in the area adjacent to the former Salt Dock. Beginning in 2012, an upland groundwater source control remedy was implemented including the installation of a fully penetrating (to bedrock) groundwater barrier wall (ERM 2013). The upland groundwater source control measure has likely mitigated the effects of dissolved salts in groundwater discharging at the bioassay study stations near the Salt Dock. However, it is unknown whether non-salt-related toxicity is also present at the stations near the Salt Dock. Furthermore, the cause of toxicity at stations in other areas of the site, as described above, is unknown.</p> <p>The Portland Harbor feasibility study’s CBRA evaluation (Anchor QEA et al. 2012) resulted in the prediction of a large footprint of potential benthic risk at SMA 14 based on multiple lines of evidence, including benthic toxicity results. The future SMA14 sediment remedy is intended to address areas of current benthic risk; however, sediment remediation will not address benthic risk associated with dissolved salts related to upland groundwater discharges (i.e., the latter toxicity is not associated with contaminants bound to sediment particles but instead to dissolved salts in groundwater passing through the sediment). However, because the previously implemented upland source control addresses upland groundwater plumes, including high concentrations of dissolved salts, the previous benthic toxicity results likely do not represent the current sediment conditions in SMA 14.</p>
2. Identify the goals of the study	<p>The goals of this study are to:</p> <ol style="list-style-type: none"> 1. Evaluate whether salt concentrations are still elevated in sediment porewater and if so, whether it could be affecting the toxicity of sediments near the Salt Dock 2. Assess effects of salt, if salt is still elevated, as a confounding factor affecting toxicity, and mitigate this effect without significantly altering COC concentrations 3. Assess the current degree of toxicity and potential for unacceptable risks to the benthic community and identify stations exhibiting toxicity 4. Attempt to identify the specific chemical or chemical groups that could be causing the observed toxicity to better link COC concentrations to potential risks to the benthic community.

Table 2. Data Quality Objectives to Evaluate Potential Risk To Benthic Community

DQO Step	Description
3. Identify information inputs	<ol style="list-style-type: none"> 1. Conductivity measured at stations near the Salt Dock compared with toxicity test organisms' tolerance levels 2. Purging approach and measurements of the effect of purging on COC concentrations (if necessary); data include conductivity measurements as well as COC concentrations before and after purging 3. Benthic toxicity tests for two freshwater test species under current conditions (or a salt-tolerant species, if purging techniques significantly affect COC concentrations) 4. Sediment analytical data (COC concentrations, grain size, TOC, ammonia, sulfide; see Draft Sediment Sampling Work Plan) and results of passive sampling program (for additional data interpretation and lines of evidence; see PE memorandum). 5. Identification of chemical group/COC(s) likely causing benthic toxicity, if observed; potential COCs include DDx, PCBs, PCDD/Fs. Solid phase TIE methods will be used to assess causality. 6. Analytical methods will include: <ul style="list-style-type: none"> Chemical analyses: <ul style="list-style-type: none"> • Specific conductivity using a salinity refractometer • Conventional analytes (total sulfides, ammonia, and pH) • PCDD/F by EPA Method 8290 • DDx by EPA Method 8081B • PCB congeners by EPA Method 1668C. Bioassay methods will include: <ul style="list-style-type: none"> • 10-day growth and survival in the midge <i>C. dilutus</i>—ASTM E-1706, EPA-823-B-98-004, and EPA/600/R-99/064 Method 100.2 • 10-day growth and survival in the amphipod <i>H. azteca</i>—ASTM E-1706, EPA-823-B-98-004, and EPA/600/R-99/064 Method 100.1.
4. Define the boundaries of the study	<p>The study area is located within SMA 14 between River Miles 6.8 and 7.6 of the Willamette River in Portland, Oregon. More specifically, the study area is bounded by the navigation channel to the east, the shoreline to the west, the railroad bridge to the north, and the boundary of SMA 14 to the south. Surface sediment samples (0–30 cm) will be collected at proposed stations.</p> <p>Conductivity will be measured and sediment samples collected to support the purging study prior to collection of sediment samples (0–30 cm) for bioassay testing and analysis of COCs (on a separate mobilization, concurrent with deployment of the passive samplers).</p>
5. Develop the analytic approach	<p>Conduct multi-step study to achieve goals (See Figures 3 through 5):</p> <ol style="list-style-type: none"> 1. Pilot Study: The goal of this step is three-fold (i) evaluate whether salt concentrations of sediments are still elevated, (ii) evaluate if effects of salt can be mitigated by purging, and (iii) evaluate whether purging significantly alters COC concentrations. <ul style="list-style-type: none"> • If salt concentrations are not elevated, then no further assessment of chloride as a confounding factor will be conducted • If purging can mitigate effects of salt without significantly altering the COC concentrations (i.e., reducing COC concentrations by approximately 50 percent), then purging will be conducted for all samples with elevated conductivity collected from vicinity of the Salt Dock prior to conducting the bioassays (Step 2) using the freshwater test species (<i>H. azteca</i> and <i>C. dilutus</i>). • If purging significantly alters the COC concentrations, then bioassays (Step 2) for all samples will be conducted without purging overlying water, and will substitute with an estuarine species (<i>Eohaustorius estuarius</i>), with higher conductivity tolerance levels.

Table 2. Data Quality Objectives to Evaluate Potential Risk To Benthic Community

DQO Step	Description
	<p>2. Bioassays: The goal of this step is two-fold: (i) identify stations exhibiting toxicity to benthic organisms under current conditions, and (ii) identify stations for the Solid Phase TIE (Step 3) to assess potential causes of toxicity (if observed). Sampling locations were selected to obtain a wide range of benthic toxicity responses and surface chemistry characteristics to maximize the statistical significance of any correlation between COC concentrations (primarily DDx) and observed toxicity based on previous testing. The wide range of concentrations and effects will best inform remedy selection, design, and footprint. Most of the stations will be located in areas with moderate to high toxicity and COC concentrations including stations in the vicinity of the Salt Dock, where dissolved salts could be a confounding factor in assessing toxicity to the benthic community from COCs in sediment. Surface sediment samples for bioassays will be collected from 0–30 cm.</p> <ul style="list-style-type: none"> • If the bioassay results indicate no or low levels of toxicity using the survival endpoint, then no further analysis will be conducted. • If moderate to high toxicity is observed in one station, solid phase TIE procedures (Step 3) will be conducted only for that single station using the most sensitive of the species tested. • If moderate to high toxicity is observed in two or more stations, only the two stations with the highest toxic responses will be selected for solid phase TIE procedures (Step 3) with samples selected to provide spatial coverage of the site. Solid phase TIEs will be conducted using the most sensitive species. <p>3. Solid Phase TIE: The goal of this step is to attempt to identify the chemical groups and/or specific COCs most likely to be causing the observed toxicity to benthic organisms. The same criteria and classifications of toxic responses used for the bioassays (Step 2) will also be applied to determine toxicity as part of Solid Phase TIE. The cause(s) of toxicity will be identified based on a process of elimination by chemical class and fraction.</p> <ul style="list-style-type: none"> • If the COCs are eliminated as a potential cause of toxicity at any point in the process, further analysis will not be conducted. • If COCs are identified as potential cause of toxicity, a scientific management decision will be made to either report findings or conduct optional confirmation pathways (Step 4). <p>4. Optional Confirmation Pathways: The goal of this step is to confirm the cause of toxicity identified through the solid phase TIE (Step 3). If classes of chemicals consistent with the COC list are identified as toxic, then fractionation and ultimately chemical analysis will be completed to quantify concentrations of each COC. Through the process of reintroducing eluents to confirm toxicity, combinations of compounds and their relative contributions to the toxic effect will also be identified.</p>
6. Specify performance or acceptable criteria	<p>Sediment samples will be collected and analyzed in accordance with EPA-approved QA/QC requirements as detailed in the appropriate analytical methods (see Table A6-1 of the QAPP). Target analytical methods were selected to ensure that detection limits are sufficiently low to meet ACGs (see Table A6-3 of the QAPP). Conductivity measured in the samples near the Salt Dock will be compared with bioassay test species tolerance levels (23,700 $\mu\text{S}/\text{cm}$ for <i>H. azteca</i> and 5,400 $\mu\text{S}/\text{cm}$ for <i>C. dilutus</i>). The COC concentrations (PCBs, DDx, PCDD/Fs) in sediment near the Salt Dock post-purging will be statistically compared with sediment in the same locations prior to purging to confirm that purging does not significantly alter COC concentrations. Bioassays will be conducted using procedures and acceptance criteria outlined in EPA and ASTM guidance (EPA 600/R-99/064, EPA-823-B-98-004, ASTM E 1706-00 and SOPs in Attachment 2). If ammonia levels are elevated in the samples, then concurrent ammonia reference toxicant tests will also be conducted, and ammonia levels in overlying water will be monitored daily for the duration of the tests (see Attachment 2 for SOP). Control-normalized survivability and biomass using 10-day acute testing will be conducted for all test species. Standard reference toxicant testing will also be performed for the test species selected for the bioassays.</p>

Table 2. Data Quality Objectives to Evaluate Potential Risk To Benthic Community

DQO Step	Description
7. Develop the plan for obtaining data	<p>Surface sediment (0–30 cm) grab samples will be collected from 11 stations adjacent to the Site to:</p> <ul style="list-style-type: none"> • Assess current benthic toxicity conditions in the vicinity of stations where moderate to high toxicity were observed from previous studies • Assess relationship between toxicity and concentrations of COCs • Assess impacts of salts on toxicity or cause of toxicity in sediment near the Salt Dock • Refine the footprint of the benthic toxicity based on current conditions.

Table 2 outlines sampling and analysis methodology for each of the 11 proposed sampling locations and provides rationale for the selection of each location.

For the pilot study, a trident probe will be used to locate stations with elevated conductivity. Surface sediment (0–30 cm) grab samples for chemistry analyses and bioassay tests will be collected using a power grab or equivalent sediment sampler following standard protocols and guidelines in accordance with EPA-approved SOP for surface sediment sampling (see QAPP in the draft sediment sampling work plan [Integral 2014]). EPA-approved bioassay protocol is outlined in SOPs in Attachments 2 and 3. Approximately 5 L of surface sediment will be collected for the pilot study while 500 mL is required for sediment COC concentration from each station for comparisons between pre-and post-purged sediments. Approximately 50 L of sediment will be collected from each station and homogenized in the field and split for chemical analysis and bioassay testing and potential usage in TIE following bioassay tests.

Notes:

- ASTM = ASTM International
- ACG = analytical concentration goal
- CBRA = comprehensive benthic risk approach
- COC = chemical of concern
- DDx = total of 2,4'- and 4,4'-DDD, DDE, and DDT
- DQO = data quality objective
- EPA = U.S. Environmental Protection Agency
- PCB = polychlorinated biphenyl
- PCDD/F = polychlorinated dibenzo-*p*-dioxin and dibenzofuran
- QA/QC = quality assurance and quality control
- QAPP = quality assurance project plan
- SOP = standard operating procedure
- TIE = toxicity identification evaluation
- TOC = total organic carbon

Table 3. Proposed Stations for Sampling and Rationale to Evaluate Risk to Benthic Community

Station No.	Sediment Sample Interval	Proposed X Coordinate	Proposed Y Coordinate	Proposed Sample Analysis	Station Rationale
SS-1	0–30 cm	7626378.8	703850.2	Bioassay, DDX, PCBs, PCDD/F, chloride, conventionals	Assess the area of benthic risk predicted by the CBRA evaluation near City of Portland's Outfall 22B, located immediately upstream of the railroad bridge.
SS-6	0–30 cm	7626957.7	703409.8	Bioassay, DDX, PCBs, PCDD/F, chloride, conventionals	Assess current benthic toxicity conditions in the vicinity of Station G339 and to refine the footprint of benthic toxicity.
SS-13	0–30 cm	7627257.8	703069.0	Bioassay, DDX, PCBs, PCDD/F, chloride, conventionals	Assess current benthic toxicity conditions in the vicinity of Station G348, where DDX concentrations > 1 mg/kg, and to refine footprint of the benthic toxicity.
SS-21	0–30 cm	7627788.9	702592.2	Bioassay, DDX, PCBs, PCDD/F, conventionals	Assess current benthic toxicity conditions in the vicinity of Station G353-1 and Borehole WB-14, where DDX concentrations > 10 mg/kg, and to refine the footprint of benthic toxicity.
SS-28	0–30 cm	7627918.4	702423.1	Bioassay, DDX, PCBs, PCDD/F, conventionals	Assess current benthic toxicity conditions in the vicinity of Borehole WB-11, where DDX concentrations > 10 mg/kg, and to refine the footprint of benthic toxicity.
SS-31	0–30 cm	7628053.1	702314.5	Bioassay, DDX, PCBs, PCDD/F, chloride, conventionals	Assess current benthic toxicity conditions in the vicinity of Borehole WB-10, where DDX concentrations > 1 mg/kg, and to refine the footprint of benthic toxicity.
SS-33	0–30 cm	7628228.1	702110.1	Bioassay, DDX, PCBs, PCDD/F, chloride, conventionals	Assess current benthic toxicity conditions in the vicinity of Station G360 and to refine the footprint of benthic toxicity.
SS-34	0–30 cm	7628388.5	701963.9	Bioassay, DDX, PCBs, PCDD/F, chloride, conventionals	Assess current benthic toxicity conditions in the vicinity of Station G366 and to refine/confirm the footprint of the predicted benthic toxicity in the area immediately downstream of the Salt Dock.

Table 3. Proposed Stations for Sampling and Rationale to Evaluate Risk to Benthic Community

Station No.	Sediment Sample Interval	Proposed X Coordinate	Proposed Y Coordinate	Proposed Sample Analysis	Station Rationale
SS-36	0–30 cm	7628542.4	701754.2	Bioassay, DDx, PCBs, PCDD/F, chloride, conventionals	Assess the current benthic toxicity conditions between Stations G368 and G371 and the potential influence of chloride from the Salt Dock sediment on benthic toxicity.
SS-37	0–30 cm	7628638.6	701730.4	Bioassay, DDx, PCBs, PCDD/F, chloride, conventionals	Assess the current benthic toxicity at the upstream end of the Salt Dock near the navigation channel and refine the footprint of benthic toxicity.
SS-39	0–30 cm	7628628.8	701544.0	Bioassay, DDx, PCBs, PCDD/F, chloride, conventionals	Assess the current benthic toxicity conditions between Stations G371 and G689 to determine if the toxicity observed at Station G689 is contributing to toxicity immediately upstream of the Salt Dock.

Notes:

Based on the results of the bioassays, up to two of stations with the highest observed toxicity and providing adequate spatial coverage will be selected for the solid phase TIE using the most sensitive species.

CBRA = comprehensive benthic risk approach

COC = chemicals of concern

Conventionals = total sulfides, ammonia, and pH

DDx = total of 2,4'- and 4,4'-DDD, DDE, and DDT

PCB = polychlorinated biphenyls

PCDD/F = polychlorinated dibenzo-*p*-dioxin and dibenzofuran

TIE = toxicity identification evaluation

Coordinates:

Datum: NAD 1983 HARN

Projection: State Plane

Zone: Oregon North

Units: International Feet

ATTACHMENT 1

ARKEMA GROUNDWATER DATA

Table 3A
Historical Sitewide Groundwater - Selected Inorganic Results
Arkema, Inc. Facility
Portland, Oregon

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Well ID	Sample ID	Aquifer	Sample Date	Perchlorate (µg/L)	Hexavalent Chromium (µg/L)	Chloride (mg/L)	Arsenic (mg/L)
MWA-1	GW059806	Shallow	5/28/1998			959	
MWA-1	GW019915	Shallow	1/29/1999			710	
MWA-1	GW029916	Shallow	4/29/1999			961	J
MWA-2	GW059801	Shallow	5/28/1998			10.4	
MWA-2	GW059801	Shallow	5/28/1998			10.4	T
MWA-2	GW019907	Shallow	1/27/1999			41	
MWA-2	GW019907	Shallow	1/27/1999			41.1	T
MWA-2	GW029906	Shallow	4/27/1999			16.8	
MWA-2	GW029906	Shallow	4/27/1999			16.65	T
MWA-2	GW039907	Shallow	8/24/1999			33.8	
MWA-2	GW049905	Shallow	11/16/1999			41.7	
MWA-2	GW010111	Shallow	3/29/2001			158	J
MWA-2	GW020106	Shallow	6/12/2001			384	
MWA-2	GW04100205	Shallow	4/10/2002			1400	
MWA-2	GW04100205	Shallow	4/10/2002			1395	T
MWA-2	GW-060903-01	Shallow	6/9/2003	1400		981	
MWA-2	MWA-02	Shallow	7/28/2005				0.0006 J
MWA-2	MWA-2-102705	Shallow	10/27/2005				0.00197
MWA-2	MWA-2-011306	Shallow	1/13/2006				<0.00664 UJ
MWA-3	GW059802	Shallow	5/28/1998			5	
MWA-3	GW019908	Shallow	1/27/1999			39.8	
MWA-3	GW029911	Shallow	4/28/1999			4	
MWA-3	GW039909	Shallow	8/24/1999			10.5	
MWA-3	GW049907	Shallow	11/16/1999			7.1	
MWA-3	GW010113	Shallow	3/29/2001			48.3	J
MWA-3	GW020115	Shallow	6/14/2001			49.2	
MWA-3	GW020115	Shallow	6/14/2001			49.05	T
MWA-3	GW04150203	Shallow	4/15/2002			381	
MWA-3	GW04150203	Shallow	4/15/2002			384	T
MWA-3	GW-060903-04	Shallow	6/9/2003	<92 U		107	
MWA-3	MWA-03	Shallow	7/28/2005				0.00019 J
MWA-3	MWA-3-102605	Shallow	10/26/2005				0.00085 J
MWA-3	MWA-3-112205	Shallow	11/22/2005				0.00181
MWA-3	MWA-3-011306	Shallow	1/13/2006				<0.00664 UJ
MWA-4	GW059803	Shallow	5/28/1998			57.5	
MWA-4	GW019912	Shallow	1/28/1999			68.1	
MWA-4	GW029913	Shallow	4/28/1999			12.8	J
MWA-4	GW029913	Shallow	4/28/1999			12.8	JT
MWA-4	GW039910	Shallow	8/25/1999			16.3	
MWA-4	GW039910	Shallow	8/25/1999			16.2	T
MWA-4	GW049909	Shallow	11/16/1999			71.7	
MWA-4	GW010116	Shallow	3/29/2001			42.1	J
MWA-4	GW010116	Shallow	3/29/2001			39.7	JT
MWA-4	GW020117	Shallow	6/14/2001			53.2	
MWA-4	GW04110201	Shallow	4/11/2002			85.3	
MWA-4	GW-060903-07	Shallow	6/9/2003	<100 U		234	
MWA-4	MWA-4-102605	Shallow	10/26/2005				0.00086 J
MWA-4	MWA-4-112205	Shallow	11/22/2005				<0.000664 U
MWA-4	MWA-4-011306	Shallow	1/13/2006				<0.00664 UJ
MWA-5	GW019905	Shallow	1/27/1999			1130	
MWA-5	GW029904	Shallow	4/27/1999			445	J
MWA-5	GW039903	Shallow	8/23/1999			445	
MWA-5	GW049903	Shallow	11/15/1999			701	
MWA-5	GW010110	Shallow	3/28/2001			588	
MWA-5	GW020105	Shallow	6/12/2001			832	
MWA-5	GW04040201	Shallow	4/4/2002			622	
MWA-5	GW-060603-06	Shallow	6/6/2003			859	
MWA-5	MWA-05	Shallow	7/28/2005				0.00372
MWA-5	MWA-5-102705	Shallow	10/27/2005				0.0101
MWA-5	MWA-5-112105	Shallow	11/21/2005				0.00639
MWA-5	MWA-5-011606	Shallow	1/16/2006				<0.00664 UJ
MWA-6r	GW039912	Shallow	8/25/1999			569	
MWA-6r	GW049911	Shallow	11/17/1999			713	
MWA-6r	GW010107	Shallow	3/28/2001			373	
MWA-6r	GW020108	Shallow	6/12/2001		58.3	986	
MWA-6r	GW04100203	Shallow	4/10/2002			1510	
MWA-6r	GW-060503-02	Shallow	6/5/2003	<27 U		1850	
MWA-6r	MWA-6r-050505	Shallow	5/5/2005		51.2 J		<0.000840 U
MWA-6r	MWA-6r-071205	Shallow	7/12/2005		22		0.0035 J
MWA-6r	MWA-6-R	Shallow	8/1/2005				0.0029
MWA-6r	MWA-6-R	Shallow	8/1/2005				0.0029 J
MWA-6r	MWA-6r-081505	Shallow	8/15/2005		112		0.00194 J
MWA-6r	MWA-6r-090905	Shallow	9/9/2005		50.5	3960	0.0055 J
MWA-6r	MWA-6r-120705	Shallow	12/7/2005		17.1		0.00624
MWA-6r	MWA-6r-011106	Shallow	1/11/2006		<4.55 U		<0.00332 UJ
MWA-6r	MWA-6r-020906	Shallow	2/9/2006		<4.55 U		<0.00332 UJ
MWA-6r	MWA-6r-072506	Shallow	7/25/2006		19.9 BJ		<0.00664 U
MWA-7(i)	GW019903	Intermediate	1/26/1999			303	
MWA-7(i)	GW029902	Intermediate	4/26/1999			233	J
MWA-7(i)	GW039902	Intermediate	8/23/1999			238	
MWA-7(i)	GW049902	Intermediate	11/15/1999			247	
MWA-7(i)	GW010101	Intermediate	3/26/2001			198	
MWA-7(i)	GW010101	Intermediate	3/26/2001			196.5	T
MWA-7(i)	GW020101	Intermediate	6/11/2001			185	
MWA-7(i)	GW020101	Intermediate	6/11/2001			184.5	T
MWA-7(i)	GW04030201	Intermediate	4/3/2002			182	
MWA-7(i)	GW04030201	Intermediate	4/3/2002			182	T

Table 3A
Historical Sitewide Groundwater - Selected Inorganic Results
Arkema, Inc. Facility
Portland, Oregon

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Well ID	Sample ID	Aquifer	Sample Date	Perchlorate (µg/L)	Hexavalent Chromium (µg/L)	Chloride (mg/L)	Arsenic (mg/L)
MWA-7(i)	GW-060403-01	Intermediate	6/4/2003			175	
MWA-8i	GW019906	Intermediate	1/27/1999			2660	
MWA-8i	GW029908	Intermediate	4/27/1999			2290	
MWA-8i	GW039905	Intermediate	8/24/1999			2660	
MWA-8i	GW039905	Intermediate	8/24/1999			2650	T
MWA-8i	GW049906	Intermediate	11/16/1999			2530	
MWA-8i	GW010112	Intermediate	3/29/2001			1660	J
MWA-8i	GW020107	Intermediate	6/12/2001			1420	
MWA-8i	GW04100206	Intermediate	4/10/2002			2110	
MWA-8i	GW-060903-02	Intermediate	6/9/2003	<20	U	2380	
MWA-8i	MWA-08i	Intermediate	7/28/2005				0.0355
MWA-8i	MWA-8i-102705	Intermediate	10/27/2005				0.0947
MWA-8i	MWA-8i-112105	Intermediate	11/21/2005				0.0626
MWA-9i	GW019909	Intermediate	1/28/1999			3250	
MWA-9i	GW029912	Intermediate	4/28/1999			3780	
MWA-9i	GW039908	Intermediate	8/25/1999			2790	
MWA-9i	GW049908	Intermediate	11/16/1999			2510	
MWA-9i	GW010120	Intermediate	3/30/2001			2900	J
MWA-9i	GW020124	Intermediate	6/18/2001			3460	
MWA-9i	GW04150204	Intermediate	4/15/2002			3400	
MWA-9i	GW-060903-06	Intermediate	6/9/2003	730		2860	
MWA-9i	MWA-9i-102605	Intermediate	10/26/2005				0.0746
MWA-9i	MWA-9i-112205	Intermediate	11/22/2005				0.0234
MWA-10i	GW019911	Intermediate	1/28/1999			1160	
MWA-10i	GW019911	Intermediate	1/28/1999			1160	T
MWA-10i	GW029914	Intermediate	4/28/1999			1160	J
MWA-10i	GW039911	Intermediate	8/25/1999			838	
MWA-10i	GW049910	Intermediate	11/16/1999			843	
MWA-10i	GW010115	Intermediate	3/29/2001			964	J
MWA-10i	GW020118	Intermediate	6/14/2001			1070	
MWA-10i	GW04110202	Intermediate	4/11/2002			851	
MWA-10i	GW-061003-01	Intermediate	6/10/2003	260		1240	
MWA-10i	MWA-10i-102605	Intermediate	10/26/2005				0.00171
MWA-10i	MWA-10i-102605	Intermediate	10/26/2005				0.00184
MWA-10i	MWA-10i-112205	Intermediate	11/22/2005				0.0147
MWA-11i(d)	GW019916	Deep	1/29/1999			612	
MWA-11i(d)	GW029905	Deep	4/27/1999			637	
MWA-11i(d)	GW039916	Deep	8/26/1999			802	
MWA-11i(d)	GW049914	Deep	11/17/1999			963	
MWA-11i(d)	GW010118	Deep	3/30/2001			768	J
MWA-11i(d)	GW020119	Deep	6/15/2001			773	
MWA-11i(d)	GW020119	Deep	6/15/2001			773	T
MWA-11i(d)	GW04110204	Deep	4/11/2002			833	
MWA-11i(d)	GW-061003-03	Deep	6/10/2003	<20	U	550	
MWA-11i(d)	MWA-11	Deep	8/1/2005				0.362
MWA-12i(d)	GW019902	Deep	1/26/1999			6	
MWA-12i(d)	GW029901	Deep	4/26/1999			17.9	J
MWA-12i(d)	GW029901	Deep	4/26/1999			17.85	JT
MWA-12i(d)	GW039901	Deep	8/23/1999			9.5	
MWA-12i(d)	GW039901	Deep	8/23/1999			9.35	T
MWA-12i(d)	GW049901	Deep	11/15/1999			8.95	T
MWA-12i(d)	GW049901	Deep	11/15/1999			8.9	
MWA-12i(d)	GW010102	Deep	3/26/2001			10.3	
MWA-12i(d)	GW020102	Deep	6/11/2001			6.3	
MWA-12i(d)	GW04030202	Deep	4/3/2002			5.6	
MWA-12i(d)	GW-060303-01	Deep	6/3/2003			14.5	
MWA-13d	GW019910	Deep	1/28/1999			3100	
MWA-13d	GW029910	Deep	4/28/1999			2910	
MWA-13d	GW039914	Deep	8/25/1999			3070	
MWA-13d	GW049915	Deep	11/18/1999			3360	
MWA-13d	GW010114	Deep	3/29/2001			3070	J
MWA-13d	GW020116	Deep	6/14/2001			2110	
MWA-13d	GW04150201	Deep	4/15/2002			3100	
MWA-13d	GW-060903-03	Deep	6/9/2003	<20	U	3240	
MWA-14i(d)	GW019904	Deep	1/27/1999			2310	
MWA-14i(d)	GW029903	Deep	4/27/1999			1460	J
MWA-14i(d)	GW039904	Deep	8/23/1999			1950	
MWA-14i(d)	GW049904	Deep	11/15/1999			2190	
MWA-14i(d)	GW010108	Deep	3/28/2001			1690	
MWA-14i(d)	GW020103	Deep	6/12/2001			1990	
MWA-14i(d)	GW04040202	Deep	4/4/2002			2220	
MWA-14i(d)	GW-060603-07	Deep	6/6/2003			1720	
MWA-14i(d)	MWA-14i	Deep	7/28/2005				0.0359
MWA-14i(d)	MWA-14i-102705	Deep	10/27/2005				0.0597
MWA-14i(d)	MWA-14i-112105	Deep	11/21/2005				0.035
MWA-15	GW039917	Shallow	8/26/1999			1430	
MWA-15	GW049913	Shallow	11/17/1999			1780	
MWA-15r	GW010117	Shallow	3/30/2001			1960	J
MWA-15r	GW020121	Shallow	6/15/2001			1560	
MWA-15r	GW04160201	Shallow	4/16/2002			407	
MWA-15r	GW04160201	Shallow	4/16/2002			408.5	T
MWA-15r	GW-061003-04	Shallow	6/10/2003	350		388	
MWA-15r	MWA-15r	Shallow	8/1/2005				0.0146
MWA-16i	GW039913	Intermediate	8/25/1999			7770	
MWA-16i	GW049912	Intermediate	11/17/1999			7760	
MWA-16i	GW010106	Intermediate	3/28/2001			5120	
MWA-16i	GW010106	Intermediate	3/28/2001			5175	T

Table 3A
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Well ID	Sample ID	Aquifer	Sample Date	Perchlorate (µg/L)	Hexavalent Chromium (µg/L)	Chloride (mg/L)	Arsenic (mg/L)
MWA-16i	GW020109	Intermediate	6/12/2001		<50 U	4910	
MWA-16i	GW04100204	Intermediate	4/10/2002			3670	
MWA-16i	GW-060503-01	Intermediate	6/5/2003	<33 U		2180	
MWA-16i	MWA-16i-050505	Intermediate	5/5/2005		662		0.00433
MWA-16i	MWA-16i-071305	Intermediate	7/13/2005		395		0.0164
MWA-16i	MWA-16i	Intermediate	8/2/2005				0.0067
MWA-16i	MWA-16i-081505	Intermediate	8/15/2005		378		0.00482
MWA-16i	MWA-16i-090905	Intermediate	9/9/2005		591	2250	0.0055 J
MWA-16i	MWA-16i-120705	Intermediate	12/7/2005		33.7		0.0138
MWA-16i	MWA-16i-011106	Intermediate	1/11/2006		82.8		0.01
MWA-16i	MWA-16i-020906	Intermediate	2/9/2006		17.5		0.00895
MWA-16i	MWA-16i-072506	Intermediate	7/25/2006		18.9 BJ		<0.00664 U
MWA-17si	GW039918	Shallow	8/26/1999			113	
MWA-17si	GW039918	Shallow	8/26/1999			109.5 T	
MWA-17si	GW049916	Shallow	11/18/1999			215	
MWA-17si	GW010121	Shallow	3/30/2001			922 J	
MWA-17si	GW020123	Shallow	6/18/2001			644	
MWA-17si	GW020123	Shallow	6/18/2001			648 T	
MWA-17si	GW04150205	Shallow	4/15/2002			1850	
MWA-17si	GW-060903-05	Shallow	6/9/2003	9900		1970	
MWA-17si	MWA-17si-102605	Shallow	10/26/2005				0.00316
MWA-17si	MWA-17si-112105	Shallow	11/21/2005				0.0127
MWA-17si	MWA-17si-011306	Shallow	1/13/2006				<0.00664 UJ
MWA-18	GW010105	Shallow	3/27/2001			1200	
MWA-18	GW020110	Shallow	6/13/2001		<50 UJ	894 J	
MWA-18	GW04040203	Shallow	4/4/2002			2210	
MWA-18	GW-060603-03	Shallow	6/6/2003	<25 U		1410	
MWA-18	MWA-18-050505	Shallow	5/5/2005		833	612	<0.000840 U
MWA-18	MWA-18-071405	Shallow	7/14/2005		676		0.00266 J
MWA-18	MWA-18	Shallow	8/3/2005				0.0023 J
MWA-18	MWA-18-081605	Shallow	8/16/2005		248		0.0029 J
MWA-18	MWA-18-091205	Shallow	9/12/2005		1180	410	<0.00900 U
MWA-18	MWA-18-120805	Shallow	12/8/2005		5.9 J		0.0166
MWA-18	MWA-18-011006	Shallow	1/10/2006		30		<0.00664 UJ
MWA-18	MWA-18-021306	Shallow	2/13/2006		<4.55 U		0.00406 J
MWA-18	MWA-18-072606	Shallow	7/26/2006		3.4		<0.00664 U
MWA-19	GW010104	Shallow	3/27/2001			5540	
MWA-19	GW020112	Shallow	6/13/2001		<50 UJ	12700 J	
MWA-19	GW04040204	Shallow	4/4/2002			13100	
MWA-19	GW-060603-04	Shallow	6/6/2003	<82 U		5180	
MWA-19	MWA-19-050605	Shallow	5/6/2005		2680	2100	0.0109 J
MWA-19	MWA-19-071305	Shallow	7/13/2005		159		0.00665
MWA-19	MWA-19	Shallow	8/3/2005				0.0074
MWA-19	MWA-19-081705	Shallow	8/17/2005		407		<0.00450 U
MWA-19	MWA-19-091305	Shallow	9/13/2005		824	1240	<0.00900 U
MWA-19	MWA-19-120805	Shallow	12/8/2005		101		0.0154
MWA-19	MWA-19-010906	Shallow	1/9/2006		33.2		<0.00664 UJ
MWA-19	MWA-19-021006	Shallow	2/10/2006		12.1		<0.00332 UJ
MWA-19	MWA-19-021006	Shallow	2/10/2006		12.8		<0.00332 UJ
MWA-19	MWA-19-072606	Shallow	7/26/2006		568		<0.00664 U
MWA-20	GW010103	Shallow	3/27/2001			2780	
MWA-20	GW010103	Shallow	3/27/2001			2810 T	
MWA-20	GW020114	Shallow	6/13/2001		59.5	1780 J	
MWA-20	GW04090204	Shallow	4/9/2002			1130	
MWA-20	GW04090204	Shallow	4/9/2002			1135 T	
MWA-20	GW-060503-03	Shallow	6/5/2003			1500	
MWA-20	MWA-20-050905	Shallow	5/9/2005		436		0.211
MWA-20	MWA-20-071305	Shallow	7/13/2005		74.1		0.183
MWA-20	MWA-20	Shallow	8/4/2005				0.242
MWA-20	MWA-20-081505	Shallow	8/15/2005		676		0.24
MWA-20	MWA-20-090705	Shallow	9/7/2005		573		0.256
MWA-20	MWA-20-121205	Shallow	12/12/2005		9.67 J		0.223
MWA-20	MWA-20-011006	Shallow	1/10/2006		52.5		0.315
MWA-20	MWA-20-020906	Shallow	2/9/2006		43.8		0.109
MWA-20	MWA-20-072506	Shallow	7/25/2006		143 BJ		0.0494
MWA-22	GW020122	Shallow	6/15/2001			4870	
MWA-22	GW04110203	Shallow	4/11/2002			5430	
MWA-22	GW04110203	Shallow	4/11/2002			5430 T	
MWA-22	GW-061003-02	Shallow	6/10/2003			6210	
MWA-22	MWA-22	Shallow	8/1/2005				0.522
MWA-23	GW04050202	Shallow	4/5/2002			69.1	
MWA-23	GW-060403-02	Shallow	6/4/2003			43.4	
MWA-23	GW-072903-01	Shallow	7/29/2003	<20 U			
MWA-23	MWA-23-050405	Shallow	5/4/2005		<4.55 U	26.1	0.0285
MWA-23	MWA-23-071205	Shallow	7/12/2005		<4.55 U		0.0271
MWA-23	MWA-23-081105	Shallow	8/11/2005		<4.55 U		0.024
MWA-23	MWA-23-090605	Shallow	9/6/2005		<4.55 U		0.025
MWA-23	MWA-23-120705	Shallow	12/7/2005		<4.55 U		0.0288
MWA-23	MWA-23-010506	Shallow	1/5/2006		<4.55 U		0.0304
MWA-23	MWA-23-020806	Shallow	2/8/2006		<4.55 U		0.023
MWA-23	MWA-23-072406	Shallow	7/24/2006		7.2 BJ		0.027
MWA-24	GW04080201	Shallow	4/8/2002			408	
MWA-24	GW-060503-04	Shallow	6/5/2003			583	
MWA-24	MWA-24-050505	Shallow	5/5/2005		52.8 J	529	2.73
MWA-24	MWA-24-071205	Shallow	7/12/2005		54.1 J		2.37
MWA-24	MWA-24-081105	Shallow	8/11/2005		35.5		2.26
MWA-24	MWA-24-090705	Shallow	9/7/2005		20.3		2.23

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Well ID	Sample ID	Aquifer	Sample Date	Perchlorate (µg/L)	Hexavalent Chromium (µg/L)	Chloride (mg/L)	Arsenic (mg/L)
MWA-24	MWA-24-120705	Shallow	12/7/2005		63.5		2.88
MWA-24	MWA-24-011106	Shallow	1/11/2006		31.9		1.99
MWA-24	MWA-24-020806	Shallow	2/8/2006		30.6		1.78
MWA-24	MWA-24-020806	Shallow	2/8/2006		29.7		1.79
MWA-24	MWA-24-072506	Shallow	7/25/2006		24 J		2.35
MWA-25	GW04090201	Shallow	4/9/2002			4210	
MWA-25	GW-060603-02	Shallow	6/6/2003			2980	
MWA-25	GW-072903-04	Shallow	7/29/2003	290000			
MWA-25	MWA-25-120303	Shallow	12/3/2003		8010		
MWA-25	MWA-25-011404	Shallow	1/14/2004		9570		
MWA-25	MWA-25-012904	Shallow	1/29/2004		9260		
MWA-25	MWA-25-030204	Shallow	3/1/2004		4470		
MWA-25	MWA-25-040604	Shallow	4/6/2004		14.3		0.0346
MWA-25	MWA-25-051005	Shallow	5/10/2005		4950	5070	0.0675
MWA-25	MWA-25-071905	Shallow	7/19/2005		146		0.0374
MWA-25	MWA-25-081105	Shallow	8/11/2005		111		0.0785
MWA-25	MWA-25-090805	Shallow	9/8/2005			4210	0.055
MWA-25	MWA-25-092305	Shallow	9/23/2005		222		
MWA-25	MWA-25-121405	Shallow	12/14/2005		68.4		0.144
MWA-25	MWA-25-011106	Shallow	1/11/2006		46.2		0.0192
MWA-25	MWA-25-021406	Shallow	2/14/2006		54.1		0.00775
MWA-25	MWA-25-072706	Shallow	7/27/2006		37.3		0.0226
MWA-26	GW04050201	Shallow	4/5/2002			176	
MWA-26	GW04050201	Shallow	4/5/2002			174.5 T	
MWA-26	GW-060403-03	Shallow	6/4/2003			632	
MWA-26	GW-072903-02	Shallow	7/29/2003	1200			
MWA-26	MWA-26-050905	Shallow	5/9/2005		152		0.0143
MWA-26	MWA-26-071505	Shallow	7/15/2005		143		0.00661
MWA-26	MWA-26-081205	Shallow	8/12/2005		98.2		0.0114
MWA-26	MWA-26-090705	Shallow	9/7/2005		289		0.015 J
MWA-26	MWA-26-120805	Shallow	12/8/2005		2.9 J		0.0296
MWA-26	MWA-26-010506	Shallow	1/5/2006		19.9		0.033
MWA-26	MWA-26-020806	Shallow	2/8/2006		11.1		0.0146
MWA-26	MWA-26-072406	Shallow	7/24/2006		11.2 BJ		0.00865
MWA-27	GW04090203	Shallow	4/9/2002			5450	
MWA-27	GW-060403-04	Shallow	6/4/2003	210000		9360	
MWA-27	MWA-27-120303	Shallow	12/3/2003		7640		0.228
MWA-27	MWA-27-011404	Shallow	1/14/2004		3330		0.275
MWA-27	MWA-27-012904	Shallow	1/29/2004		804		0.188
MWA-27	MWA-27-030204	Shallow	3/1/2004		1610		0.126
MWA-27	MWA-27-040604	Shallow	4/6/2004		2020		0.118
MWA-27	MWA-27-050905	Shallow	5/9/2005		1600	2530	0.276
MWA-27	MWA-27-071905	Shallow	7/19/2005		123		0.124
MWA-27	MWA-27-081605	Shallow	8/16/2005		611		0.733
MWA-27	MWA-27-090905	Shallow	9/9/2005		802	856	0.305
MWA-27	MWA-27-090905	Shallow	9/9/2005		811	838	0.303
MWA-27	MWA-27-121205	Shallow	12/12/2005		4.95 J		0.0794
MWA-27	MWA-27-011606	Shallow	1/16/2006		14.5		0.0586
MWA-27	MWA-27-021306	Shallow	2/13/2006		<4.55 U		0.0213
MWA-27	MWA-27-072706	Shallow	7/27/2006		92.9		0.027
MWA-28i(d)	GW04090202	Deep	4/9/2002			5.3	
MWA-28i(d)	GW04090202	Deep	4/9/2002			5.3 T	
MWA-28i(d)	GW-060603-01	Deep	6/6/2003			5.36	
MWA-28i(d)	GW-072903-03	Deep	7/29/2003	<20 U			
MWA-28i(d)	MWA-28i-051005	Deep	5/10/2005		10.3	5.04	0.454
MWA-28i(d)	MWA-28i-071505	Deep	7/15/2005		<4.55 U		0.404
MWA-28i(d)	MWA-28i-081105	Deep	8/11/2005		<4.55 U		0.338
MWA-28i(d)	MWA-28i-090805	Deep	9/8/2005			5.18	0.349
MWA-28i(d)	MWA-28i-092305	Deep	9/23/2005		<4.55 U		
MWA-28i(d)	MWA-28i-121405	Deep	12/14/2005		<4.55 U		0.439
MWA-28i(d)	MWA-28i-011206	Deep	1/12/2006		<4.55 U		0.355
MWA-28i(d)	MWA-28i-021406	Deep	2/14/2006		<4.55 U		0.137
MWA-28i(d)	MWA-28i-072706	Deep	7/27/2006		<6 U		0.0951
MWA-29	GW04080204	Shallow	4/8/2002			21900	
MWA-29	GW-060403-06	Shallow	6/4/2003	<110 U		11700	
MWA-29	MWA-29-050905	Shallow	5/9/2005		14.1	9100	<0.00420 U
MWA-29	MWA-29-071805	Shallow	7/18/2005		<4.55 U		<0.0208 UJ
MWA-29	MWA-29-081205	Shallow	8/12/2005		<4.55 U		<0.000450 U
MWA-29	MWA-29-091205	Shallow	9/12/2005		107	12600	<0.00900 U
MWA-29	MWA-29-120805	Shallow	12/8/2005		186		0.0116
MWA-29	MWA-29-010606	Shallow	1/6/2006		14.1		<0.00664 UJ
MWA-29	MWA-29-020806	Shallow	2/8/2006		19.5		0.0047
MWA-29	MWA-29-072406	Shallow	7/24/2006		<6 U		0.00159
MWA-30	GW04120203	Shallow	4/12/2002			179000	
MWA-30	GW-060403-08	Shallow	6/4/2003	7900		164000	
MWA-30	MWA-30-050605	Shallow	5/6/2005		3040	104000	<0.0807 UJ
MWA-30	MWA-30-071805	Shallow	7/18/2005		13		<0.0420 UJ
MWA-30	MWA-30	Shallow	8/3/2005				0.021 J
MWA-30	MWA-30-081705	Shallow	8/17/2005		6270		0.0192 J
MWA-30	MWA-30-010606	Shallow	1/6/2006		32.8		<0.0332 UJ
MWA-30	MWA-30-021006	Shallow	2/10/2006		<4.55 U		0.00345 J
MWA-30	MWA-30-072606	Shallow	7/26/2006		<2 U		<0.0332 U
MWA-31i(d)	GW04080205	Deep	4/8/2002			39100	
MWA-31i(d)	GW-060403-07	Deep	6/4/2003	4700		61100	
MWA-31i(d)	MWA-31i-050605	Deep	5/6/2005		726	62100	<0.0822 UJ
MWA-31i(d)	MWA-31i-071805	Deep	7/18/2005		250		<0.0420 UJ
MWA-31i(d)	MWA-31i-081705	Deep	8/17/2005		142		<0.00900 U

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Well ID	Sample ID	Aquifer	Sample Date	Perchlorate (µg/L)	Hexavalent Chromium (µg/L)	Chloride (mg/L)	Arsenic (mg/L)
MWA-31i(d)	MWA-31i-091405	Deep	9/14/2005		1020	57900	<0.00900 U
MWA-31i(d)	MWA-31i-120905	Deep	12/9/2005		25.1		0.0454
MWA-31i(d)	MWA-31i-010906	Deep	1/9/2006		45.3		<0.0332 UJ
MWA-31i(d)	MWA-31i-021006	Deep	2/10/2006		104		<0.00332 UJ
MWA-31i(d)	MWA-31i-072606	Deep	7/26/2006		<2 U		<0.0133 U
MWA-32i	GW-060403-10	Intermediate	6/4/2003	200000		31000	
MWA-32i	MWA-32i-050605	Intermediate	5/6/2005		176	17600	<0.00840 U
MWA-32i	MWA-32i-071805	Intermediate	7/18/2005		119		<0.0228 UJ
MWA-32i	MWA-32i	Intermediate	8/3/2005				0.0115 J
MWA-32i	MWA-32i	Intermediate	8/3/2005				0.007 J
MWA-32i	MWA-32i-081705	Intermediate	8/17/2005		555		<0.00450 U
MWA-32i	MWA-32i-091405	Intermediate	9/14/2005		386	13700	0.03 J
MWA-32i	MWA-32i-091405	Intermediate	9/14/2005		335	13500	0.03 J
MWA-32i	MWA-32i-120905	Intermediate	12/9/2005		14.4		0.0912
MWA-32i	MWA-32i-010606	Intermediate	1/6/2006		6.55 J		0.015
MWA-32i	MWA-32i-021006	Intermediate	2/10/2006		6.72 J		0.0238
MWA-32i	MWA-32i-072606	Intermediate	7/26/2006		<0.002 U		<0.0332 U
MWA-33	GW-060503-05	Shallow	6/5/2003	540		198	
MWA-33	GW-061103-02	Shallow	6/11/2003	320		286	
MWA-33	MWA-33-050505	Shallow	5/5/2005		44.6		0.0896
MWA-33	MWA-33-071405	Shallow	7/14/2005		51.8		0.0767
MWA-33	MWA-33-081105	Shallow	8/11/2005		36.2		0.0664
MWA-33	MWA-33-090705	Shallow	9/7/2005		29.7		0.0655
MWA-33	MWA-33-090705	Shallow	9/7/2005		30.2		0.068
MWA-33	MWA-33-120805	Shallow	12/8/2005		17.5		0.0378 J
MWA-33	MWA-33-120805	Shallow	12/8/2005		17.7		0.0746
MWA-33	MWA-33-011106	Shallow	1/11/2006		8.74 J		0.0652
MWA-33	MWA-33-011106	Shallow	1/11/2006		9.14 J		0.0641
MWA-33	MWA-33-020806	Shallow	2/8/2006		14.8		0.0661
MWA-33	MWA-33-072406	Shallow	7/24/2006		11 BJ		0.0495
MWA-34i	GW-060603-05	Intermediate	6/6/2003	4600		3040	
MWA-34i	MWA-34i-050605	Intermediate	5/6/2005		35.8	5260	0.504
MWA-34i	MWA-34i-071805	Intermediate	7/18/2005		14.8		0.491
MWA-34i	MWA-34i-071805	Intermediate	7/18/2005		17.6		0.524
MWA-34i	MWA-34i	Intermediate	8/3/2005				0.425
MWA-34i	MWA-34i-081705	Intermediate	8/17/2005		192		0.534
MWA-34i	MWA-34i-091305	Intermediate	9/13/2005		26.9	4580	0.417
MWA-34i	MWA-34i-120905	Intermediate	12/9/2005		30.2		0.706
MWA-34i	MWA-34i-010906	Intermediate	1/9/2006		13.5		0.503
MWA-34i	MWA-34i-021006	Intermediate	2/10/2006		12.3		0.361
MWA-34i	MWA-34i-072606	Intermediate	7/26/2006		34.5		0.0898
MWA-35	MWA-35-120203	Shallow	12/2/2003		78		
MWA-35	MWA-35-011404	Shallow	1/14/2004		23.5		
MWA-35	MWA-35-012904	Shallow	1/29/2004		42.3		
MWA-35	MWA-35-030204	Shallow	3/1/2004		26.8		
MWA-35	MWA-35-040604	Shallow	4/6/2004		20.2		0.0498
MWA-35	MWA-35-051005	Shallow	5/10/2005		222		0.133
MWA-35	MWA-35-071505	Shallow	7/15/2005		31.8		0.0973
MWA-35	MWA-35-081105	Shallow	8/11/2005		90.5		0.0823
MWA-35	MWA-35-090805	Shallow	9/8/2005			775	0.102
MWA-35	MWA-35-092305	Shallow	9/23/2005		303		
MWA-35	MWA-35-121405	Shallow	12/14/2005		<0.04 UJ		0.108
MWA-35	MWA-35-011206	Shallow	1/12/2006		88.7		0.0136
MWA-35	MWA-35-021406	Shallow	2/14/2006		150		0.0108
MWA-35	MWA-35-072706	Shallow	7/27/2006		72.9		<0.00664 U
MWA-36	MWA-36-120303	Shallow	12/3/2003		14900		0.101
MWA-36	MWA-36-011404	Shallow	1/14/2004		4550		0.0708
MWA-36	MWA-36-012904	Shallow	1/29/2004		1130		0.0905
MWA-36	MWA-36-030204	Shallow	3/1/2004		26.4		0.0221
MWA-36	MWA-36-040604	Shallow	4/6/2004		1280		0.0584
MWA-36	MWA-36-051005	Shallow	5/10/2005		6340		0.058
MWA-36	MWA-36-071505	Shallow	7/15/2005		120		0.0582
MWA-36	MWA-36-081205	Shallow	8/12/2005		36.3		0.0274
MWA-36	MWA-36-090705	Shallow	9/7/2005		27.6		0.015 J
MWA-36	MWA-36-121405	Shallow	12/14/2005		75.9		0.0962
MWA-36	MWA-36-011106	Shallow	1/11/2006		9.83 J		0.0282
MWA-36	MWA-36-021306	Shallow	2/13/2006		65.5		0.008
MWA-36	MWA-36-072706	Shallow	7/27/2006		217		0.0273
MWA-37	MWA-37-120303	Shallow	12/3/2003		8340		0.117
MWA-37	MWA-37-011404	Shallow	1/14/2004		6060		0.131
MWA-37	MWA-37-011404	Shallow	1/14/2004		5820		
MWA-37	MWA-37-012904	Shallow	1/29/2004		58.7		0.0664
MWA-37	MWA-37-012904	Shallow	1/29/2004		59.15 T		
MWA-37	MWA-37-030204	Shallow	3/1/2004		1250		0.144
MWA-37	MWA-37-030204	Shallow	3/1/2004		1295 T		
MWA-37	MWA-37-040604	Shallow	4/6/2004		267		0.127
MWA-37	MWA-37-040604	Shallow	4/6/2004		312		
MWA-37	MWA-37-051005	Shallow	5/10/2005		2810		0.196
MWA-37	MWA-37-071505	Shallow	7/15/2005		239		0.172
MWA-37	MWA-37-081105	Shallow	8/11/2005		2870		0.12
MWA-37	MWA-37-081105	Shallow	8/11/2005		3220		0.118
MWA-37	MWA-37-090805	Shallow	9/8/2005			2050	0.11
MWA-37	MWA-37-092205	Shallow	9/22/2005		1830		
MWA-37	MWA-37-121405	Shallow	12/14/2005		319		0.0765
MWA-37	MWA-37-121405	Shallow	12/14/2005		367		0.0833
MWA-37	MWA-37-011106	Shallow	1/11/2006		61.6		0.0539
MWA-37	MWA-37-021406	Shallow	2/14/2006		14.2		0.0172

Table 3A
Historical Sitewide Groundwater - Selected Inorganic Results
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Well ID	Sample ID	Aquifer	Sample Date	Perchlorate (µg/L)	Hexavalent Chromium (µg/L)	Chloride (mg/L)	Arsenic (mg/L)
MWA-37	MWA-37-021406	Shallow	2/14/2006		13.2		0.0168
MWA-37	MWA-37-072706	Shallow	7/27/2006		545		0.0679
MWA-38	MWA-38-120303	Shallow	12/3/2003		1630		
MWA-38	MWA-38-011404	Shallow	1/14/2004		2090		
MWA-38	MWA-38-012904	Shallow	1/29/2004		3200		
MWA-38	MWA-38-030204	Shallow	3/1/2004		1260		
MWA-38	MWA-38-040604	Shallow	4/6/2004		1720		0.121
MWA-38	MWA-38-050905	Shallow	5/9/2005		9160		0.0997
MWA-38	MWA-38-071405	Shallow	7/14/2005		2220		0.152
MWA-38	MWA-38-081205	Shallow	8/12/2005		1170		0.0806
MWA-38	MWA-38-081205	Shallow	8/12/2005		1110		0.0809
MWA-38	MWA-38-090705	Shallow	9/7/2005		2100		0.0545
MWA-38	MWA-38-121205	Shallow	12/12/2005		398		0.0738
MWA-38	MWA-38-011206	Shallow	1/12/2006		114		0.0242
MWA-38	MWA-38-021306	Shallow	2/13/2006		72.6		0.0968
MWA-38	MWA-38-072706	Shallow	7/27/2006		73		0.0409
MWA-39	MWA-39-050505	Shallow	5/5/2005		<4.55 U		0.0115
MWA-39	MWA-39-071205	Shallow	7/12/2005		<4.55 U		0.00912
MWA-39	MWA-39-081105	Shallow	8/11/2005		<4.55 U		0.0066
MWA-39	MWA-39-090605	Shallow	9/6/2005		<4.55 U		0.00609
MWA-39	MWA-39-120705	Shallow	12/7/2005		<4.55 U		0.00898
MWA-39	MWA-39-010506	Shallow	1/5/2006		<4.55 U		0.011
MWA-39	MWA-39-020806	Shallow	2/8/2006		<4.55 U		0.0122
MWA-39	MWA-39-072406	Shallow	7/24/2006		7.4 BJ		0.00544
MWA-40	MWA-40-050505	Shallow	5/5/2005		<4.55 U		0.0601
MWA-40	MWA-40-071205	Shallow	7/12/2005		<4.55 U		0.0293
MWA-40	MWA-40-081105	Shallow	8/11/2005		<4.55 U		0.0212
MWA-40	MWA-40-090705	Shallow	9/7/2005		4.76 J		0.026 J
MWA-40	MWA-40-120705	Shallow	12/7/2005		<4.55 U		0.0254
MWA-40	MWA-40-011106	Shallow	1/11/2006		<4.55 U		0.037
MWA-40	MWA-40-020806	Shallow	2/8/2006		<4.55 U		0.0808
MWA-40	MWA-40-072406	Shallow	7/24/2006		9.5 BJ		0.117
MWA-41	MWA-41-050905	Shallow	5/9/2005		<4.55 U		<0.00420 U
MWA-41	MWA-41-071505	Shallow	7/15/2005		<4.55 U		<0.00210 U
MWA-41	MWA-41-071505	Shallow	7/15/2005		<4.55 U		<0.00210 U
MWA-41	MWA-41-081205	Shallow	8/12/2005		<4.55 U		0.00026 J
MWA-41	MWA-41-090705	Shallow	9/7/2005		<4.55 U		<0.00450 U
MWA-41	MWA-41-120805	Shallow	12/8/2005		0.6 J		<0.000664 U
MWA-41	MWA-41-010506	Shallow	1/5/2006		<4.55 U		<0.000664 U
MWA-41	MWA-41-020806	Shallow	2/8/2006		<4.55 U		<0.000664 U
MWA-41	MWA-41-072406	Shallow	7/24/2006		15.1 BJ		<0.000664 U
MWA-42	MWA-42-050505	Shallow	5/5/2005		56.2		0.811
MWA-42	MWA-42-071205	Shallow	7/12/2005		<4.55 U		0.113
MWA-42	MWA-42	Shallow	8/2/2005				0.101
MWA-42	MWA-42-081505	Shallow	8/15/2005		11.9		0.123
MWA-42	MWA-42-090805	Shallow	9/8/2005			913	0.016 J
MWA-42	MWA-42-092305	Shallow	9/23/2005		46.7		
MWA-42	MWA-42-120705	Shallow	12/7/2005		27.7		1.15
MWA-42	MWA-42-011106	Shallow	1/11/2006		5.77 J		0.712
MWA-42	MWA-42-020906	Shallow	2/9/2006		6.26 J		0.0153
MWA-42	MWA-42-072506	Shallow	7/25/2006		8.6 BJ		0.0252
MWA-43	MWA-43-050905	Shallow	5/9/2005		<4.55 U		<0.00420 U
MWA-43	MWA-43-071805	Shallow	7/18/2005		<4.55 U		<0.00210 U
MWA-43	MWA-43-081205	Shallow	8/12/2005		<4.55 U		<0.00450 U
MWA-43	MWA-43-090705	Shallow	9/7/2005		<4.55 U		<0.00450 U
MWA-43	MWA-43-120805	Shallow	12/8/2005		1 J		0.00434
MWA-43	MWA-43-010506	Shallow	1/5/2006		<4.55 U		0.00582
MWA-43	MWA-43-020806	Shallow	2/8/2006		<4.55 U		0.00283
MWA-43	MWA-43-072406	Shallow	7/24/2006		7.9 BJ		0.00206
MWA-44	MWA-44-050605	Shallow	5/6/2005		88.5 J		0.21
MWA-44	MWA-44-071305	Shallow	7/13/2005		22.3		0.0524
MWA-44	MWA-44	Shallow	8/3/2005				0.155
MWA-44	MWA-44-081605	Shallow	8/16/2005		33.3		0.155
MWA-44	MWA-44-090905	Shallow	9/9/2005		42.5	2380	0.197
MWA-44	MWA-44-120905	Shallow	12/9/2005		20.9		0.122
MWA-44	MWA-44-010906	Shallow	1/9/2006		14.8		<0.00664 UJ
MWA-44	MWA-44-021006	Shallow	2/10/2006		7.98 J		0.0822
MWA-44	MWA-44-072606	Shallow	7/26/2006		34.1		<0.00664 U
MWA-45	MWA-45-051005	Shallow	5/10/2005		77.1 J		0.123
MWA-45	MWA-45-071305	Shallow	7/13/2005		22.8		0.082
MWA-45	MWA-45	Shallow	8/3/2005				0.0799
MWA-45	MWA-45	Shallow	8/3/2005				0.0828
MWA-45	MWA-45-081605	Shallow	8/16/2005		24.4		0.0814
MWA-45	MWA-45-090905	Shallow	9/9/2005		40.3	1550	0.0785
MWA-45	MWA-45-121205	Shallow	12/12/2005		16.8		0.0574
MWA-45	MWA-45-011006	Shallow	1/10/2006		32.5		0.103
MWA-45	MWA-45-020906	Shallow	2/9/2006		41.8		0.0942
MWA-45	MWA-45-072506	Shallow	7/25/2006		316		0.0303
MWA-46	MWA-46-050605	Shallow	5/6/2005		49.5 J		0.0451 J
MWA-46	MWA-46-071405	Shallow	7/14/2005		41.1		0.0381
MWA-46	MWA-46	Shallow	8/4/2005				0.035
MWA-46	MWA-46-081605	Shallow	8/16/2005		20.3		0.048
MWA-46	MWA-46-091305	Shallow	9/13/2005		43.3	1250	0.06 J
MWA-46	MWA-46-120905	Shallow	12/9/2005		16.5		0.0415
MWA-46	MWA-46-120905	Shallow	12/9/2005		16.7		0.0419
MWA-46	MWA-46-010906	Shallow	1/9/2006		<4.55 U		0.008 J
MWA-46	MWA-46-021306	Shallow	2/13/2006		5.14 J		0.0157

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Well ID	Sample ID	Aquifer	Sample Date	Perchlorate (µg/L)	Hexavalent Chromium (µg/L)	Chloride (mg/L)	Arsenic (mg/L)
MWA-46	MWA-46-072606	Shallow	7/26/2006		35.4		<0.00664 U
MWA-47	MWA-47-050605	Shallow	5/6/2005		<4.55 U		<0.00420 U
MWA-47	MWA-47-071905	Shallow	7/19/2005		<0.04 UJ		<0.0259 UJ
MWA-47	MWA-47-081705	Shallow	8/17/2005		4.63 J		<0.00450 U
MWA-47	MWA-47-090905	Shallow	9/9/2005		<4.55 U	9690	<0.00450 U
MWA-47	MWA-47-121205	Shallow	12/12/2005		<4.55 U		0.0121
MWA-47	MWA-47-010606	Shallow	1/6/2006		14.3		<0.00664 UJ
MWA-47	MWA-47-021006	Shallow	2/10/2006		<4.55 U		<0.00332 UJ
MWA-47	MWA-47-072606	Shallow	7/26/2006		<2 U		<0.00664 U
MWA-48i	MWA-48i-051005	Intermediate	5/10/2005		10.2		<0.0423 U
MWA-48i	MWA-48i-071505	Intermediate	7/15/2005		7.89 J		<0.0224 UJ
MWA-48i	MWA-48i-081105	Intermediate	8/11/2005		5.02 J		<0.00450 U
MWA-48i	MWA-48i-090805	Intermediate	9/8/2005			18400	<0.00450 U
MWA-48i	MWA-48i-092205	Intermediate	9/22/2005		15.1		
MWA-48i	MWA-48i-121405	Intermediate	12/14/2005		4.57 J		<0.00664 UJ
MWA-48i	MWA-48i-011206	Intermediate	1/12/2006		6.81 J		<0.00332 UJ
MWA-48i	MWA-48i-021406	Intermediate	2/14/2006		<4.55 U		<0.00332 UJ
MWA-48i	MWA-48i-072706	Intermediate	7/27/2006		42.1		<0.00664 U
MWA-49i	MWA-49i-050605	Intermediate	5/6/2005		<4.55 U		<0.00840 U
MWA-49i	MWA-49i-071405	Intermediate	7/14/2005		<4.55 U		<0.0271 UJ
MWA-49i	MWA-49i	Intermediate	8/3/2005				<0.00450 U
MWA-49i	MWA-49i-081605	Intermediate	8/16/2005		<4.55 U		<0.00450 U
MWA-49i	MWA-49i-091305	Intermediate	9/13/2005		<4.55 U	10600	<0.00900 U
MWA-49i	MWA-49i-120905	Intermediate	12/9/2005		<4.55 U		0.0122
MWA-49i	MWA-49i-010906	Intermediate	1/9/2006		<4.55 U		<0.00664 UJ
MWA-49i	MWA-49i-021306	Intermediate	2/13/2006		<4.55 U		<0.00332 UJ
MWA-49i	MWA-49i-072606	Intermediate	7/26/2006		<0.02 U		<0.0332 U
MWA-50i	MWA-50i-050605	Intermediate	5/6/2005		<4.55 U		<0.00420 U
MWA-50i	MWA-50i-071905	Intermediate	7/19/2005		<20 UJ		<0.0235 UJ
MWA-50i	MWA-50i-081705	Intermediate	8/17/2005		<4.55 U		<0.00450 U
MWA-50i	MWA-50i-091205	Intermediate	9/12/2005		<4.55 U	11800	<0.00900 U
MWA-50i	MWA-50i-121205	Intermediate	12/12/2005		<4.55 U		0.00948
MWA-50i	MWA-50i-010606	Intermediate	1/6/2006		<4.55 U		<0.00664 UJ
MWA-50i	MWA-50i-020906	Intermediate	2/9/2006		<4.55 U		<0.00332 UJ
MWA-50i	MWA-50i-072506	Intermediate	7/25/2006		7.9 BJ		<0.00664 U
MWA-51i	MWA-51i-050505	Intermediate	5/5/2005		48.5		1.33
MWA-51i	MWA-51i-071405	Intermediate	7/14/2005		63.1		1.21
MWA-51i	MWA-51i	Intermediate	8/3/2005				0.962
MWA-51i	MWA-51i-081605	Intermediate	8/16/2005		24.3		1.05
MWA-51i	MWA-51i-091305	Intermediate	9/13/2005		46.8	8910	1.36
MWA-51i	MWA-51i-120805	Intermediate	12/8/2005		22		1.31
MWA-51i	MWA-51i-011006	Intermediate	1/10/2006		<4.55 U		0.455
MWA-51i	MWA-51i-021306	Intermediate	2/13/2006		10.7		0.4
MWA-52i	MWA-52i-050905	Intermediate	5/9/2005		<4.55 U		<0.00420 U
MWA-52i	MWA-52i-071905	Intermediate	7/19/2005		<20 UJ		<0.0275 UJ
MWA-52i	MWA-52i-081605	Intermediate	8/16/2005		<4.55 U		0.00243 J
MWA-52i	MWA-52i-081605	Intermediate	8/16/2005		<4.55 U		0.00235 J
MWA-52i	MWA-52i-090905	Intermediate	9/9/2005		5.57 J	4030	<0.00450 U
MWA-52i	MWA-52i-121205	Intermediate	12/12/2005		<4.55 U		0.0084
MWA-52i	MWA-52i-010606	Intermediate	1/6/2006		<4.55 U		<0.00664 UJ
MWA-52i	MWA-52i-021306	Intermediate	2/13/2006		<4.55 U		<0.00332 UJ
MWA-52i	MWA-52i-072706	Intermediate	7/27/2006		85		<0.00664 U
MWA-53i	MWA-53i-050905	Intermediate	5/9/2005		<4.55 U		<0.00420 U
MWA-53i	MWA-53i-071805	Intermediate	7/18/2005		<4.55 U		<0.0193 UJ
MWA-53i	MWA-53i-081205	Intermediate	8/12/2005		<4.55 U		<0.000450 U
MWA-53i	MWA-53i-091205	Intermediate	9/12/2005		<4.55 U	14300	0.016 J
MWA-53i	MWA-53i-120805	Intermediate	12/8/2005		1.1 J		0.0141
MWA-53i	MWA-53i-010606	Intermediate	1/6/2006		<4.55 U		<0.00664 UJ
MWA-53i	MWA-53i-020806	Intermediate	2/8/2006		<4.55 U		0.00077 J
MWA-53i	MWA-53i-072406	Intermediate	7/24/2006		6.8 BJ		<0.00664 U
MWA-54i	MWA-54i-050505	Intermediate	5/5/2005		54.8		0.238
MWA-54i	MWA-54i-050505	Intermediate	5/5/2005		52.7		0.24
MWA-54i	MWA-54i-071205	Intermediate	7/12/2005		<130 U		0.326
MWA-54i	MWA-54i-081505	Intermediate	8/15/2005		<4.55 U		0.0783
MWA-54i	MWA-54i-090805	Intermediate	9/8/2005			5540	0.296
MWA-54i	MWA-54i-092305	Intermediate	9/23/2005		6.34 J		
MWA-54i	MWA-54i-120705	Intermediate	12/7/2005		7.2 J		0.0687
MWA-54i	MWA-54i-011106	Intermediate	1/11/2006		11.3		0.145
MWA-54i	MWA-54i-020906	Intermediate	2/9/2006		11.3		0.148
MWA-54i	MWA-54i-072506	Intermediate	7/25/2006		17.5 BJ		0.0454
MWA-55i	MWA-55i-050905	Intermediate	5/9/2005		25.9		0.106
MWA-55i	MWA-55i-071305	Intermediate	7/13/2005		34.5		0.0796
MWA-55i	MWA-55i	Intermediate	8/3/2005				0.0958
MWA-55i	MWA-55i-081505	Intermediate	8/15/2005		23.4		0.0834
MWA-55i	MWA-55i-091205	Intermediate	9/12/2005		32.5	14600	0.082 J
MWA-55i	MWA-55i-121205	Intermediate	12/12/2005		29.3		0.13
MWA-55i	MWA-55i-011206	Intermediate	1/12/2006		10.6		0.005
MWA-55i	MWA-55i-020906	Intermediate	2/9/2006		24.2		0.00405 J
MWA-55i	MWA-55i-072506	Intermediate	7/25/2006		54.6		0.044
MWA-55i	MWA-55i-072706	Intermediate	7/27/2006				0.494
MWA-56d	MWA-56d-050605	Deep	5/6/2005		<4.55 U		<0.00840 U
MWA-56d	MWA-56d-071405	Deep	7/14/2005		22.3		<0.0203 UJ
MWA-56d	MWA-56d-071405	Deep	7/14/2005		14.6 J		<0.0203 UJ
MWA-56d	MWA-56d-081605	Deep	8/16/2005		<4.55 U		<0.00900 U
MWA-56d	MWA-56d-091305	Deep	9/13/2005		<4.55 U	30800	<0.00900 U
MWA-56d	MWA-56d-120905	Deep	12/9/2005		<4.55 UJ		0.0276
MWA-56d	MWA-56d-010906	Deep	1/9/2006		<4.55 U		<0.00664 UJ

Table 3A
Historical Sitewide Groundwater - Selected Inorganic Results
Arkema, Inc. Facility
Portland, Oregon

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Well ID	Sample ID	Aquifer	Sample Date	Perchlorate (µg/L)	Hexavalent Chromium (µg/L)	Chloride (mg/L)	Arsenic (mg/L)
MWA-56d	MWA-56d-021306	Deep	2/13/2006		<4.55 U		<0.00332 UJ
MWA-56d	MWA-56d-072606	Deep	7/26/2006		<2 U		<0.0332 U
MWA-57d	MWA-57d-050905	Deep	5/9/2005		<4.55 U		<0.0436 UJ
MWA-57d	MWA-57d-071305	Deep	7/13/2005		<4.55 U		<0.0282 UJ
MWA-57d	MWA-57d-081505	Deep	8/15/2005		5.46 J		<0.000450 U
MWA-57d	MWA-57d-091205	Deep	9/12/2005		<4.55 U	18900	<0.00900 U
MWA-57d	MWA-57d-121205	Deep	12/12/2005		<4.55 U		<0.0133 UJ
MWA-57d	MWA-57d-011206	Deep	1/12/2006		<4.55 U		0.0068
MWA-57d	MWA-57d-020906	Deep	2/9/2006		<4.55 U		0.00735
MWA-57d	MWA-57d-072506	Deep	7/25/2006		<6 U		<0.00664 U
MWA-58d	MWA-58d-050605	Deep	5/6/2005		<4.55 U		<0.0760 UJ
MWA-58d	MWA-58d-071405	Deep	7/14/2005		<4.55 U		<0.0420 UJ
MWA-58d	MWA-58d-081705	Deep	8/17/2005		<4.55 U		<0.0450 U
MWA-58d	MWA-58d-091305	Deep	9/13/2005		<4.55 U	60700	<0.00900 U
MWA-58d	MWA-58d-120905	Deep	12/9/2005		<4.55 UJ		0.0322
MWA-58d	MWA-58d-010906	Deep	1/9/2006		<4.55 U		<0.0332 UJ
MWA-58d	MWA-58d-010906	Deep	1/9/2006		<4.55 U		<0.0332 UJ
MWA-58d	MWA-58d-021006	Deep	2/10/2006		<4.55 U		<0.00332 UJ
MWA-58d	MWA-58d-072606	Deep	7/26/2006		<2 U		<0.0332 U
MWA-59d	MWA-59d-050605	Deep	5/6/2005		<4.55 U		<0.0819 UJ
MWA-59d	MWA-59d-071905	Deep	7/19/2005		<0.02 UJ		<0.0420 UJ
MWA-59d	MWA-59d-081705	Deep	8/17/2005		<4.55 U		<0.00900 U
MWA-59d	MWA-59d-091205	Deep	9/12/2005		<4.55 U	80500	<0.00900 U
MWA-59d	MWA-59d-121205	Deep	12/12/2005		<4.55 U		0.0524
MWA-59d	MWA-59d-010606	Deep	1/6/2006		<4.55 U		<0.0332 UJ
MWA-59d	MWA-59d-020906	Deep	2/9/2006		<4.55 U		<0.00332 UJ
MWA-59d	MWA-59d-072506	Deep	7/25/2006		7.8 BJ		<0.00664 U
MWA-6	GW019901	Shallow	1/27/1999			403	
MWA-6	GW019901	Shallow	1/27/1999			411.5 T	
MWA-60	MWA-60	Shallow	8/2/2005				0.00512
MWA-60	MWA-60-102705	Shallow	10/27/2005				0.00729
MWA-60	MWA-60-112105	Shallow	11/21/2005				0.00266
MWA-60	MWA-60-011606	Shallow	1/16/2006				<0.00664 UJ
MWA-61	MWA-61	Shallow	8/1/2005				0.0014
MWA-61	MWA-61	Shallow	8/1/2005				0.00134
MWA-61	MWA-61-102605	Shallow	10/26/2005				0.00065 J
MWA-61	MWA-61-112105	Shallow	11/21/2005				0.00191
MWA-61	MWA-61-011306	Shallow	1/13/2006				<0.00664 UJ
MWA-62	MWA-62	Shallow	8/2/2005				0.0008 J
MWA-62	MWA-62-102505	Shallow	10/25/2005				0.000936 J
MWA-62	MWA-62-112205	Shallow	11/22/2005				0.00141
MWA-62	MWA-62-011606	Shallow	1/16/2006				<0.00664 UJ
MWA-63	MWA-63	Shallow	7/27/2005				<0.0000900 U
MWA-63	MWA-63-102705	Shallow	10/27/2005				0.00093 J
MWA-63	MWA-63-112105	Shallow	11/21/2005				<0.000664 U
MWA-64i	MWA-64i	Intermediate	8/1/2005				0.0726
MWA-65i	MWA-65i	Intermediate	8/2/2005				0.00116 J
MWA-66i	MWA-66i	Intermediate	8/2/2005				0.00081 J
MWA-67si	MWA-67si	Shallow	8/1/2005				0.00263
MWA-67si	MWA-67si-102705	Shallow	10/27/2005				0.0059
MWA-67si	MWA-67si-112105	Shallow	11/21/2005				0.00756
MWA-67si	MWA-67si-011306	Shallow	1/13/2006				0.00912 J
MWA-68si	MWA-68si	Shallow	8/2/2005				0.0141
MWA-68si	MWA-68si-102505	Shallow	10/25/2005				0.0242
MWA-68si	MWA-68si-112205	Shallow	11/22/2005				0.0254
MWA-68si	MWA-68si-011306	Shallow	1/13/2006				0.019
MWA-69	MWA-69	Shallow	8/2/2005				0.00632
MWA-69	MWA-69-102505	Shallow	10/25/2005				0.0013
MWA-69	MWA-69-112205	Shallow	11/22/2005				0.0086
MWA-69	MWA-69-011606	Shallow	1/16/2006				<0.00664 UJ
MWA-70i	MWA-70i-1	Intermediate	4/19/2006		<1.62 U	852	1000
NMP-3D	GW-061103-01	Shallow	6/11/2003			2260	
NMP-3D	NMP-3D	Shallow	8/1/2005				0.00056 J
NMP-4D	GW-061003-06	Shallow	6/10/2003			2180	
PMP-4	PMP-4-102705	Shallow	10/27/2005				0.00203
PMP-4	PMP-4-112205	Shallow	11/22/2005				0.00151
PMP-5	PMP-5-102705	Shallow	10/27/2005				0.00124
PMP-5	PMP-5-112205	Shallow	11/22/2005				0.00276
PMP-6	PMP-6-102705	Shallow	10/27/2005				0.00103
PMP-6	PMP-6-112205	Shallow	11/22/2005				0.00328
RP-02-31	RP-02-31-040402	Shallow	4/4/2002				0.132
RP-02-31	RP-02-31-031105	Shallow	3/11/2005			2780	<0.0170 U
RP-02-49	RP-02-49-040402	Intermediate	4/4/2002				0.00377
RP-02-49	RP-02-49-031105	Intermediate	3/11/2005			8330	<0.0170 U
RP-02-66	RP-02-66-031105	Deep	3/11/2005			16500	<0.0170 U
RP-02-66	RP-02-66-041305	Deep	4/13/2005				<0.0084 U

Notes

Blank = Not sampled
µg/L = Micrograms per liter
mg/L = Milligrams per liter
U = Not detected
J = Result is an estimated value
B = Analyte detected in method, value is an estimated value
Bold = Analyte detected

Table 7
 Additional Compound Results
 August 2009 Sitewide Groundwater Monitoring
 Arkema, Inc. Facility
 Portland, Oregon

Wells	Aquifer	Sample ID	Sample Date	Methane ug/l	Chloride mg/l	Perchlorate ug/l	Diesel Range Hydrocarbons mg/l	Petroleum hydrocarbons > C26 mg/l
MWA-2	Shallow	MWA-2-080609	08/06/2009	5.38	340	3.9		
MWA-3	Shallow	MWA-3-081009	08/10/2009	3.48 J	147	1240		
MWA-4	Shallow	MWA-4-081109	08/11/2009		200	582		
MWA-5	Shallow	MWA-5-080509	08/05/2009		152	< 1.7 U		
MWA-6R	Shallow	MWA-6R-081109	08/11/2009	381	2520	< 1.7 U		
MWA-7(I)	Intermediate	MWA-7(I)-081409	08/14/2009	13800 J	245	< 1.7 U		
MWA-8I	Intermediate	MWA-8I-080609	08/06/2009		1020	< 1.7 U		
MWA-9I	Intermediate	MWA-9I-081109	08/11/2009		2870	465		
MWA-10I	Intermediate	MWA-10I-081109	08/11/2009		2160	< 0.68 U		
MWA-11I(D)	Deep	MWA-11I-081909	08/19/2009		1090	< 0.34 U		
MWA-12I(D)	Deep	MWA-12I(D)-081409	08/14/2009		43.3	< 1.7 U		
MWA-13D	Deep	MWA-13D-081009	08/10/2009	5.09 J	2550			
MWA-14I(D)	Deep	MWA-14I(D)-080509	08/05/2009		2590	< 0.68 U		
MWA-15R	Shallow	MWA-15R-081909	08/19/2009	21.7	156			
MWA-16I	Intermediate	MWA-16I-081109	08/11/2009		2470	< 1.7 U		
MWA-17SI	Shallow	MWA-17SI-081009	08/10/2009	31 J	1080	378		
MWA-18	Shallow	MWA-18-081009	08/10/2009		270	< 0.34 U		
MWA-19	Shallow	MWA-19-081009	08/10/2009		406	< 3.4 U		
MWA-20	Shallow	MWA-20-081709	08/17/2009		164	< 3.4 U		
MWA-22	Shallow	MWA-22-081909	08/19/2009		2870	< 3.4 U		
MWA-23	Shallow	MWA-23-080509	08/05/2009	59.4	13.6			
MWA-24	Shallow	MWA-24-080509	08/05/2009		237	17.9		
MWA-25	Shallow	MWA-25-081909	08/19/2009	27.6	469	14900 T		
MWA-26	Shallow	MWA-26-080509	08/05/2009		107	69.5		
MWA-27	Shallow	MWA-27-080509	08/05/2009	3.6	173	146		
MWA-28I(D)	Deep	MWA-28I(D)-081909	08/19/2009		5.72	< 0.34 U		
MWA-29	Shallow	MWA-29-080609	08/06/2009		3750	< 1.7 U		
MWA-30	Shallow	MWA-30-081009	08/10/2009	16 J	12900	< 6.8 U		
MWA-31I(D)	Deep	MWA-31I(D)-081009	08/10/2009		54300	1840		
MWA-32I	Intermediate	MWA-32I-081009	08/10/2009		2520	29900		
MWA-33	Shallow	MWA-33-080509	08/05/2009		929	< 0.68 U		
MWA-34I	Intermediate	MWA-34I-081109	08/11/2009		740	< 3.4 U		
MWA-35	Shallow	MWA-35-081909	08/19/2009		599	5380		
MWA-36	Shallow	MWA-36-081909	08/19/2009		263	4320		
MWA-37	Shallow	MWA-37-081909	08/19/2009		739	10500 T		
MWA-38	Shallow	MWA-38-080509	08/05/2009		77	8160		
MWA-39	Shallow	MWA-39-080509	08/05/2009		178	< 0.68 U		
MWA-40	Shallow	MWA-40-080509	08/05/2009		220	< 1.7 U		
MWA-41	Shallow	MWA-41-080609	08/06/2009		26.3	< 0.34 U		
MWA-42	Shallow	MWA-42-081709	08/17/2009		816	< 3.4 U		
MWA-43	Shallow	MWA-43-080609	08/06/2009		1710 T	< 20 UT		
MWA-44	Shallow	MWA-44-081109	08/11/2009		443	55.9		
MWA-45	Shallow	MWA-45-081709	08/17/2009		332	309		
MWA-46	Shallow	MWA-46-081009	08/10/2009		651	< 3.4 U		
MWA-47	Shallow	MWA-47-080609	08/06/2009		2110	< 1.7 U		
MWA-48I	Intermediate	MWA-48I-081909	08/19/2009		4010	175000		
MWA-49I	Intermediate	MWA-49I-081009	08/10/2009		7560	58900		
MWA-50I	Intermediate	MWA-50I-080609	08/06/2009		4550	< 1.7 U		
MWA-51I	Intermediate	MWA-51I-081009	08/10/2009		2780	< 3.4 U		
MWA-52I	Intermediate	MWA-52I-081709	08/17/2009		1110	2810		
MWA-53I	Intermediate	MWA-53I-080609	08/06/2009		5980	< 1.7 U		
MWA-54I	Intermediate	MWA-54I-081909	08/19/2009		2750	< 3.4 U		
MWA-55I	Intermediate	MWA-55I-081709	08/17/2009		2600	69100		
MWA-56D	Deep	MWA-56D-081009	08/10/2009		22800	2140		
MWA-57D	Deep	MWA-57D-081709	08/17/2009		15400	5070		
MWA-58D	Deep	MWA-58D-081009	08/10/2009		33600	128000		
MWA-59D	Deep	MWA-59D-080609	08/06/2009		37600	1670		
MWA-60	Shallow	MWA-60-080509	08/05/2009		470	< 0.68 U		
MWA-61	Shallow	MWA-61-081009	08/10/2009		473	489		
MWA-62	Shallow	MWA-62-081709	08/17/2009		34.1	864		
MWA-63	Shallow	MWA-63-080509	08/05/2009		690	< 0.68 U		
MWA-64I	Intermediate	MWA-64I-080609	08/06/2009		1590	< 3.4 U		
MWA-65I	Intermediate	MWA-65I-081709	08/17/2009		2220			
MWA-66I	Intermediate	MWA-66I-081109	08/11/2009		1720	1250 T		
MWA-67SI	Shallow	MWA-67SI-080609	08/06/2009		2420	528		
MWA-68SI	Shallow	MWA-68SI-081109	08/11/2009		355	12800		
MWA-69	Shallow	MWA-69-081109	08/11/2009		297	< 1.7 U		
MWA-70I	Intermediate	MWA-70I-080509	08/05/2009		5200	< 1.7 U		
MWA-71	Shallow	MWA-71-080709	08/07/2009		68.1		0.144 J	0.0278 J
MWA-72	Shallow	MWA-72-081709	08/17/2009		18.7		0.101 J	0.0294 J
MWA-73	Shallow	MWA-73-081409	08/14/2009		10.5		0.0808 J	0.0552 J
MWA-74I	Intermediate	MWA-74I-080709	08/07/2009		25.4		0.3 J	0.203 J
MWA-75I	Intermediate	MWA-75I-1-081409	08/14/2009		29.7		0.142 J	0.0355 J
MWA-75I	Intermediate	MWA-75I-2-081409	08/14/2009		29.6		0.126 JT	0.0442 JT
MWA-76G	Gravel	MWA-76G-080709	08/07/2009		42.4		< 0.0174 U	< 0.0270 U
MWA-77G	Gravel	MWA-77G-081709	08/17/2009		28.3		0.0248 J	< 0.0267 U
NMP-3D	Shallow	NMP-3D-081909	08/19/2009	39.4	86.5			
NMP-4D	Shallow	NMP-4D-081909	08/19/2009	34.5 T	1710 T			
PMP-4	Shallow	PMP-4-081109	08/11/2009		41.6 T			
PMP-6	Shallow	PMP-6-081109	08/11/2009		268			
PMP-5	Shallow	PMP-5-081109	08/11/2009		730			

Table 7
Additional Compound Results
August 2009 Sitewide Groundwater Monitoring
Arkema, Inc. Facility
Portland, Oregon

Wells	Aquifer	Sample ID	Sample Date	Methane ug/l	Chloride mg/l	Perchlorate ug/l	Diesel Range Hydrocarbons mg/l	Petroleum hydrocarbons > C26 mg/l
RP-02-49	Intermediate	RP-02-49-081309	08/13/2009		7390		0.102 J	< 0.0267 U
RP-02-66	Basalt	RP-02-66-081309	08/13/2009		8400		0.0725 J	< 0.0262 U
RP-08-23	Shallow	RP-08-23-081309	08/13/2009		55.7 T		0.12 J	0.0342 J
RP-08-80	Intermediate	RP-08-80-081309	08/13/2009		2130 T		0.0703 J	< 0.0265 U
RP-08-107	Basalt	RP-08-107-081309	08/13/2009		796		0.0495 J	< 0.0267 U
RP-09-35	Shallow	RP-09-35-081209	08/12/2009		405	< 6.8 U	< 0.0172 U	< 0.0267 UJ
RP-09-47	Intermediate	RP-09-47-081209	08/12/2009		4120		< 0.0169 U	< 0.0262 U
RP-09-64	Basalt	RP-09-64-081209	08/12/2009		3100		< 0.0170 U	< 0.0265 U
RP-10-30	Shallow	RP-10-30-081209	08/12/2009		9.56		0.192 J	< 0.0265 UJ
RP-10-60	Intermediate	RP-10-60-081209	08/12/2009		98.5		0.414 J	0.496 J
RP-10-97	Gravel	RP-10-97-081209	08/12/2009		12.1		< 0.0172 U	< 0.0267 UJ
RP-10-130	Basalt	RP-10-130-081209	08/12/2009		79.2		< 0.0170 U	< 0.0265 UJ
RP-13-11	Intermediate	RP-13-11-081809	08/18/2009		84		0.0292 J	< 0.0267 U
RP-13-22	Intermediate	RP-13-22-081809	08/18/2009		194		0.0445 J	0.0356 J
RP-13-33	Gravel	RP-13-33-081809	08/18/2009		907 JT		0.106 JT	0.0592 JT
RP-13-43	Basalt	RP-13-43-081809	08/18/2009		2110		0.243	< 0.0267 U
RP-14-26	Intermediate	RP-14-26-081809	08/18/2009		494		0.13 J	0.0664 J
RP-14-39	Gravel	RP-14-39-081809	08/18/2009		1420		0.0588 J	0.0287 J
W-19-D	Basalt	W-19-D-081409	08/14/2009		2180		0.032 J	< 0.0267 U
W-19-I	Deep	W-19-I-081409	08/14/2009		494		0.139 J	0.0451 J

Notes

ug/l = Micrograms per liter

mg/L = Milligrams per liter

Blank Cell = Not sampled

< = Compound not detected above the method detection limit

Data Qualifiers:

U = compound was not detected above the associated numerical value

J = Estimated value. Analyte detected at a level less than the Reporting Limit (RL).

Ja = Estimated value. Analyte detected at a level less than the Reporting Limit (RL) and greater than or equal to the Method Detection Limit (MDL).

The user of this data should be aware that this data is of limited reliability.

A = Total value based on limited number of analytes

T = Result derived or selected from >1 reported value.

ATTACHMENT 2

STANDARD OPERATING PROCEDURES

10-Day Freshwater Sediment Toxicity Tests with the Midge Larvae, *Chironomus dilutus* (formerly *Chironomus tentans*)

To replace old SOP last issued on September 30, 2011

Reason for update: Revisions to porewater collection procedures, overlying water measurements, reference documents, and measurement of ash-free dry weights

Approved By:

	1/21/15		1/21/15
Laboratory Manager	(Date)	QA & Compliance Officer	(Date)

I. PURPOSE

This method is designed to measure the toxicity of freshwater sediments to the midge larvae *Chironomus dilutus* (formerly *Chironomus tentans*) after a 10-day exposure using survival and growth as the endpoints.

II. REFERENCE DOCUMENTS

ASTM, 2000. "Standard Test Methods for Measuring the Toxicity of Sediment-Associated Contaminants with Freshwater Invertebrates." ASTM E1706-00.

US EPA, 2000. "Methods for Measuring the Toxicity and Bioaccumulation of Sediment-Associated Contaminants with Freshwater Invertebrates, Second Edition." EPA 600-R-99/064.

SOP 1900 - "Sample Receipt/Chain-of-Custody Procedures"
SOP 1901 - "Laboratory Bench Quality Control Practices"
SOP 1910 - 1912 - "Calibration and Use of Meters"
SOP 1930 - "Data Review and Report Preparation Guidelines"
Nautilus Environmental - Quick Reference Manual (QRM)
Nautilus Environmental – Sediment Testing Reference Manual

10-Day Freshwater Sediment Toxicity Tests with the Midge Larvae, *Chironomus dilutus* (formerly *Chironomus tentans*)

III. TEST SPECIFICATION SUMMARY

Number of replicates per sample	5 (plus 1 water quality surrogate)
Number of organisms per replicate	10
Test chambers	1L drilled glass jars (or 350mL drilled glass jars), with Zumwalt chamber lids
Sediment volume	2.0 cm (~225mL) per replicate (or 100mL if using 500mL jars)
Overlying water volume	400mL (or 175mL if using 500mL jars)
Overlying water source	Coast water, or other project-specific
Temperature range	23±1°C
Light cycle	16h light:8h dark
Feeding regime	Days 0-9, 1mL of a 6.0mg/mL TetraFin suspension
Test acceptability criteria	≥70% mean control survival and ≥0.6mg mean control dry weight or 0.48mg ash free dry weight

IV. EQUIPMENT

- Proven source of clean freshwater for controls and overlying water (typically Coast water, unless client or project-specific)
- Environmental chamber maintained at 23 ± 1 degrees Celsius (°C), with a light cycle of 16 hours light:8 hours dark
- Cold room maintained at 4°C for sample storage prior to test initiation
- Nitrogen gas for holding samples in anoxic conditions, as necessary
- Thermometer, pH meter, dissolved oxygen (DO) meter, and conductivity meter for routine water quality measurements
- Analytical balance
- 1-liter (L) glass jars OR 500-milliliter (mL) glass jars; hole drilled in side of jar to act as overflow drain at the overlying water mark
- Zumwalt chamber lids with built in aeration capability
- 0.5-millimeter (mm) and 1.0-mm Nitex mesh screens, transfer pipettes, and glass holding bowls
- Aeration source and airline micro-tubing, as necessary
- Test, control, and reference sediments
- 30-mL disposable polystyrene cups for holding animals; freshwater squirt bottle
- *Chironomus dilutus* juveniles (2nd to 3rd instar)

10-Day Freshwater Sediment Toxicity Tests with the Midge Larvae, *Chironomus dilutus* (formerly *Chironomus tentans*)

- . TetraFin® flake food
- . Copper (II) chloride (CuCl₂) or Ammonium chloride (NH₄Cl) for reference toxicant testing
- . HACH reagent kits for measurement of ammonia, alkalinity, and hardness
- . Drying oven
- . Muffle furnace and aluminum weigh boats for ash free dry weight (AFDW)
- . Personal Protective Equipment (PPE) - lab coats, eye protection, gloves, and respirator as required

V. TEST PROCEDURE

A. Pre-test Set-up

1. *Chironomus* are purchased from a reliable, experienced dealer and shipped to the lab via next day delivery service. Upon arrival and at test initiation, *Chironomus* are 2nd to 3rd instar (approximately 10-day old larvae). Organisms are held in plastic bowls on paper towel substrate and allowed to acclimate to laboratory conditions for at least six hours prior to test initiation.
2. During the holding period, the bowls are aerated and animals are acclimated to lab conditions. Animals are acclimated by replacing culture water with laboratory water via a slow drip. During acclimation, temperature changes should not exceed 2°C per 24-hr period. Animals may be fed with a light dusting of TetraFin slurry.
3. Samples are logged in upon receipt. See procedural SOP S-1900 for details on sediment sample check-in procedures.
4. Interstitial porewater is collected from each sample for the measurement of ammonia, pH, and conductivity. Interstitial water is collected by centrifuging a subsample of whole sediment at 3000 rpm for 15 min. Following water quality measurements, subsamples may be preserved with sulfuric acid (H₂SO₄) for later ammonia analysis.
5. Sediment samples are evaluated for resident organisms and debris. Large indigenous organisms and debris may be removed using forceps. Pending discussion with the Project Manager, samples may also be sieved through a 0.5-mm screen to remove organisms and/or debris. The sediment is placed in a clean, labeled, plastic bag, and stored at 4°C until tests are initiated.
6. The sediment is placed in a clean, labeled, food grade plastic bag, and stored at 4°C until tests are initiated.
7. A randomization key is created for all concurrently tested samples using Microsoft Excel. Assign five replicates for each sample.

10-Day Freshwater Sediment Toxicity Tests with the Midge Larvae, *Chironomus dilutus* (formerly *Chironomus tentans*)

8. Sieve peat moss through a 0.5mm screen and soak overnight in control water. One tablespoon of this peat moss will be added to the surface of each control sediment replicate of Scripps sand 24 hours prior to initiation.

24 Hrs Prior to Test Initiation

1. Make sure a 0.5mm Nitex mesh screen is secured over the hole in each test chamber. Label test chambers according to the randomization key, rinse with Coast water, and add the appropriate site or control sediment to the labeled jars to a depth of 2.0-centimeters (cm) (approximately 225 mL sediment).
2. Prepare an additional test chamber for each test site. This surrogate will be used for water quality measurements during the test period. If ammonia is of concern, additional surrogates can be added to evaluate interstitial ammonia levels.
4. Fill jars laboratory test water to overflow port using a baffle to prevent disturbance; place Zumwalt chamber lid on top of each replicate.
5. Place jars in the 23°C environmental chamber to settle and equilibrate overnight. Adjust light cycle in environmental chamber to a 16:8 hour light:dark cycle.

Note: Micro-airline tubing or standard tubing may be attached to the glass Zumwalt chamber pipette at this point in anticipation of aeration later in the test period; however test chambers should not be aerated unless DO levels drop below 4.0 mg/L.

6. Prepare five time zero weigh pans.
7. Place a carboy containing a sufficient amount of aerating test water in the environmental chamber to perform renewals the next day.

B. Test Initiation - Day 0

1. Perform a full volume water renewal on all test chambers. Measure and record water quality parameters (DO, conductivity, temperature, and pH) in each surrogate test chamber. Remove a subsample of overlying water for ammonia analysis from each site and preserve with sulfuric acid. If necessary, break down additional surrogates for interstitial ammonia analysis. Also remove a subsample of overlying water for measurement of alkalinity, hardness, and any other project-specific parameters.
2. Count 5 animals into 30-mL polystyrene plastic cups containing clean laboratory water at the appropriate test temperature. All animals should be of similar size. Five randomly chosen cups are set aside for mean time zero weight.
3. A second count is made by a different employee to verify that there are 5 animals in each cup and in healthy condition.

10-Day Freshwater Sediment Toxicity Tests with the Midge Larvae, *Chironomus dilutus* (formerly *Chironomus tentans*)

4. Randomly distribute 10 test animals (two cups) into each test chamber by gently rinsing the contents of each cup into a test chamber with a squirt bottle containing clean laboratory water.
5. All test chambers are inspected within two hours of initiation to ensure that no *Chironomus* are trapped in the surface tension of the water. Any floating animal observed is replaced with a new animal.

C. Daily Monitoring and Feeding Regime – Days 1 to 9

1. Measure and record pH, DO, conductivity, and temperature daily in surrogate chambers prior to water renewals. Observe all chambers and correct obvious problems (e.g. anoxic layer, aeration rate) as required. Be sure that screens on each jar are kept clean and free of debris to prevent overflow during renewals.
2. Adjust aeration as needed to maintain the DO above 4.0 mg/L.

Note: Nautilus uses 4.0 mg/L as benchmark to potentially begin aeration so the DO does not drop below 2.5 mg/L, as specified in the protocol.

3. Measure and record pH, DO, conductivity, and temperature of renewal water. Perform a full volume renewal twice daily by pouring 400 mL clean laboratory water into the top of each Zumwalt chamber.
4. Feed test chambers days 0 through 9 with 1.0 mL of a 6.0 mg/mL TetraFin suspension. If there is an accumulation of excess food on the sediment surface, document on the observation sheet. Only suspend feeding with the Project Manager's permission; this is done to reduce fungal growth and degraded water quality in the test chambers.

D. Test Termination - Day 10

1. Measure and record water quality (DO, pH, conductivity, and temperature) in surrogate test chambers. Remove a subsample of overlying water for ammonia analysis from each site and preserve with sulfuric acid. Also remove a subsample of overlying water for measurement of alkalinity, hardness, and any other project-specific parameters. It may be necessary to collect a composite subsample from all test replicates in order to obtain the volume necessary for analyses. If present, break down additional surrogates for measurement of interstitial ammonia.
2. Make any final observations on test chambers (i.e. anoxic layer, fungal growth, etc.).
3. Gently suspend sediment in the test chambers and pour onto 0.5-mm cylindrical screen. Rinse away remaining sediment using laboratory water within $\pm 2^{\circ}\text{C}$ of the test temperature.

10-Day Freshwater Sediment Toxicity Tests with the Midge Larvae, *Chironomus dilutus* (formerly *Chironomus tentans*)

- Count and record the number of surviving *Chironomus* making note of any dead animals or parts of animals found.

Note: If any *Chironomus* pupae are recovered, they should be documented and may be included in survival data but not included in growth data.

- Collect and rinse surviving *Chironomus* with deionized water. Using forceps, gently place on an appropriately labeled and tared aluminum boat.

Note: Be sure pans have been ashed in the muffle furnace at 550°C for at least two hours prior to collection of tare weights.

- Dry in an oven at $\geq 60^{\circ}\text{C}$ for 24 hours. Remove animals from oven. Weigh each pan to the nearest 0.0001g and record on the data sheet.
- To measure the ash free dry weight endpoint, place dried and weighed organisms in a muffle furnace at 550°C for minimum 2 hours.
- Very carefully remove from muffle furnace and weigh each replicate again to the nearest 0.0001g and record on the data sheet. Ash free-dry weight is determined as the difference between the weight of the dried larvae plus pan and the weight of the ashed larvae plus pan.

E. Reference Toxicant Testing

- A water-only 96-hour reference toxicant exposure is performed with the same batch of animals as a quality assurance procedure to assess the health of the test organisms and soundness and consistency of procedures. Copper chloride is used as a reference toxicant and Coast filtered water is used for control and dilution water. The test concentrations for the reference toxicant are 0 (Control), 100, 200, 400, 800, and 1600 $\mu\text{g/L}$ copper, with 4 replicates per concentration and 10 organisms per replicate. Alternatively, ammonium chloride may be used as the reference toxicant, at concentrations of 0 (Control), 15.6, 31.2, 62.5, 125, 250, and 500 mg/L ammonia. A monolayer of control sand should be added to each replicate for substrate. Each chamber should be fed 1mL of a 5 g/mL Tetrafin suspension prior to initiation on Day 0 and on Day 2.
- The LC_{50} for survival is calculated and should be within two standard deviations of the historical control chart mean for Nautilus.

VI. TEST ACCEPTABILITY CRITERIA

Mean control survival at test termination must be 70 percent or greater. Mean AFDW in the controls must be 0.48 mg per surviving organism.

10-Day Freshwater Sediment Toxicity Tests with the Midge Larvae, *Chironomus dilutus* (formerly *Chironomus tentans*)

VII. MODIFICATIONS

- a. Aeration trigger – Aeration is begun when dissolved oxygen levels reach 4.0 mg/L and are trending downward, instead of the protocol-specified threshold of 2.5 mg/L

VIII. HEALTH AND SAFETY

Health and safety precautions and applicable regulations should be considered at all times. Gloves must always be worn when handling test sediments.

IX. PERSONNEL

Only qualified technicians who have been properly trained and can demonstrate competency with these techniques are permitted to conduct this test.

X. QUALITY ASSURANCE REQUIREMENTS

Quality assurance practices encompass all aspects of testing including the collection, handling, and preparation of test organisms, samples, and dilution waters. Proper record keeping and documentation is required during all phases of testing, which includes completion of datasheets on a real-time basis and filling out corrective action records for any errors occurring during the test.

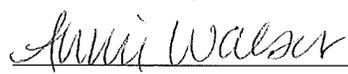
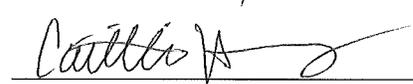
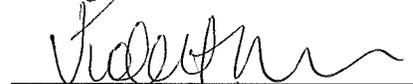
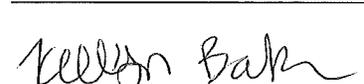
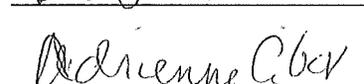
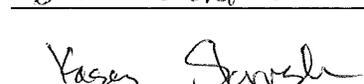
Statistical analyses follow standard EPA flowchart selections and any dose-response relationships are reviewed to ensure the validity of the data. Any deviations from EPA flowchart selection of statistical analyses are explained and justified.

Reference toxicant testing is conducted monthly or concurrently with sediment testing, as required, to ensure continued test organism health and sensitivity, as well as to demonstrate technical staff proficiency and minimization of test variability. This is supported by the generation and examination of quality control charts for each specific test species and procedure.

10-Day Freshwater Sediment Toxicity Tests with the Midge Larvae, *Chironomus dilutus* (formerly *Chironomus tentans*)

XI. Signatures

The following staff have read and understood the protocol:

Signature	Name	Date
	Ashley Donohue	1/21/15
	Beverly Geiszler	1/21/15
	Annie Walser	1/21/15
	Arielle Beaulieu	1/21/15
	Nick Henrikos	1/21/15
	Eric Green	1/21/15
	Alexi Gabriel	1/21/15
	Brian Knevr	1/21/15
	Caitlin Harvey	1/21/15
	Jeff Van Voorhis	1/21/15
	Violet Renick	1/21/15
	Steve Carlson	1/21/15
	Kellyn Baker	1/22/15
	Adrienne Cibor	1/22/15
	Yasey Skrivseth	1/22/15

10-Day Freshwater Sediment Toxicity Tests using *Hyalella azteca*

To replace old SOP last issued on May 22, 2013

Reason for update: Corrected typographical error in sediment volume, added "Modifications" section to highlight differences from protocol

Approved By:

	10/17/14		10/17/14
Laboratory Manager	(Date)	QA & Compliance Officer	(Date)

I. PURPOSE

This method is designed to measure the toxicity of freshwater sediments to the amphipod *Hyalella azteca* using survival and growth as endpoints.

II. REFERENCE DOCUMENTS

ASTM, 2002. "Standard Test Methods for Measuring the Toxicity of Sediment Associated Contaminants with Freshwater Invertebrates." ASTM E 1706-00, 2002.

US EPA/US ACE, 1998. "Evaluation of Dredged Material Proposed for Discharge in Waters of the U.S.-Testing Manual." Environmental Protection Agency Office of Water/Department of the Army, US Army Corps of Engineers. EPA-823-B-98-004, February 1998.

US EPA, 2000. "Methods for Measuring the Toxicity and Bioaccumulation of Sediment-associated Contaminants with Freshwater Invertebrates (Second Edition)." EPA 600/R-99/064, 2000.

SOP 1900 - "Sample Receipt/Chain-of-Custody Procedures"
SOP 1901 - "Laboratory Bench Quality Control Practices"
SOP 1910 - 1912 - "Calibration and use of Meters"
SOP 1930 - "Data Review and Report Preparation Guidelines"
Nautilus Environmental - Quick Reference Manual (QRM)

10-Day Freshwater Sediment Toxicity Tests using *Hyalella azteca*

III. TEST SPECIFICATION SUMMARY

Number of replicates per sample	5
Number of organisms per replicate	10
Test chambers	1L glass jars
Sediment volume	225ml (~2cm) per replicate
Overlying water volume	400ml
Overlying water source	Coast water, or other project-specific
Temperature range	23±1°C
Light cycle	16h light:8h dark
Feeding regime	Daily, 1ml YTC and 1mL wheat grass (0.25g in 100mL water) per chamber
Test acceptability criteria	≥80% mean control survival and measureable mean control growth

IV. EQUIPMENT/SUPPLIES

- Environmental chamber maintained at 23 ± 1°C, with a light cycle of 16 hours light:8 hours dark
- Proven source of clean freshwater for controls and overlying water (typically Coast water)
- Cold room maintained at 4°C for sample storage
- Thermometer, pH meter, dissolved oxygen (DO) meter, and conductivity meter for routine water quality measurements
- 1L glass jars; hole drilled in side of jar to act as overflow drain at the 400ml mark, Zumbolt chamber lids with built in aeration capability
- 0.5-millimeter (mm) and 1.0-mm Nitex mesh screens, 1 ml transfer pipettes, and glass holding bowls
- Aeration source and airline micro-tubing
- Test, control, and reference (if requested) sediments
- Clear Pyrex dish
- 30-ml disposable polystyrene cups for holding animals; freshwater squirt bottle
- *Hyalella azteca* juveniles 7-14 days old
- Yeast/Trout chow/Cerophyll (YTC)
- Wheat grass
- Copper (II) Chloride (CuCl₂) for reference toxicant testing
- Drying oven
- Safety equipment – lab coats, eye protection, gloves, and respirators as required

10-Day Freshwater Sediment Toxicity Tests using *Hyalella azteca*

V. TEST PROCEDURE

A. Pre-test Set up

1. *Hyalella azteca*, 7 to 14 days in age, are purchased from a reliable, experienced dealer and shipped to the lab via next day delivery service. All animals in a single batch shall be within a two-day age range. Organisms are held in plastic bowls for at least six hours prior to test initiation. During the holding period, the bowls are aerated and animals are acclimated to lab conditions by slowly replacing culture water with laboratory water via a slow drip. During acclimation, temperature changes should not exceed 2°C per 24-hr period.
2. Samples are logged in upon receipt. See procedural SOP for details on sediment sample check-in procedures.
3. Interstitial porewater is collected from each sample for the measurement of ammonia, pH, and conductivity. Interstitial water is collected by centrifuging a subsample of whole sediment at 1500-3000 rpm for 15 min. Following water quality measurements, subsamples may be preserved with sulfuric acid (H₂SO₄) for later ammonia analysis.
4. The sediment is placed in a clean, labeled, food-grade plastic bag, and stored at 4°C until tests are initiated.

24 Hrs Prior to Test Initiation

1. Inspect samples for indigenous organisms. If indigenous organisms are present, the sediment sample is sieved through a 0.5-mm screen to filter out any resident organisms and/or debris. A large size sieve may be used if the project specifies or if the grain size of the sample does not allow the material to pass through a smaller size. In some instances, samples may not be sieved and large particles or organisms can be removed with forceps. Thoroughly homogenize sediment samples prior to addition to test chambers.
2. A randomization key is made for all concurrently tested samples using Microsoft Excel. Assign five replicates for each sample. Label test chambers according to the randomization key, rinse with Coast water, and add the appropriate site sediment to the labeled jars at a depth of 2 cm (approximately 225 ml sediment).
3. Prepare an additional test chamber for each test site. This surrogate will be used for water quality measurements during the test period. If ammonia is of concern, additional surrogates can be added to evaluate interstitial ammonia levels.
4. Fill jars with laboratory test water to the overflow port; place Zumwalt chamber lid on top of each replicate.
5. Place jars in the 23°C environmental chamber with a 16:8 hour light:dark cycle to settle and equilibrate overnight.

10-Day Freshwater Sediment Toxicity Tests using *Hyalella azteca*

6. Prepare five time zero weigh pans if growth is an endpoint.
7. Place a sufficient amount of aerating test water in the environmental chamber for renewals.

B. Test Initiation – Day 0

Measure and record water quality parameters (DO, conductivity, temperature, and pH) in each surrogate test chamber. Apply continuous aeration only if DO in overlying water falls below 4.0 mg/L. While the test methods table in the EPA manual says not to aerate unless the DO drops below 2.5 mg/L, section 11.3.6.2.2 says “Dissolved oxygen should be measured daily and should be maintained at a minimum of 2.5 mg/L”. Therefore, Nautilus will use 4.0 mg/L as a benchmark for which to start aeration so the DO does not drop below 2.5 mg/L. If necessary, aerate test chambers by attaching micro-airline tubing to the glass Zumwalt chamber pipette, with special care taken to prevent disturbing the sediment. Aeration should be performed at a rate of 3-4 bubbles per second.

1. Remove a subsample of overlying water for ammonia analysis from each site and preserve with sulfuric acid.
2. Perform a full volume renewal by pouring approximately 400mL of renewal water into the Zumwalt chamber.
3. Count 10 animals into 30-ml polystyrene plastic cups containing clean laboratory water at the appropriate test temperature. All animals should be of similar size. Five randomly chosen cups are set aside for mean time zero weight, if necessary.
4. A second count is made by a different employee to verify that there are 10 healthy animals in each cup.
5. Randomly distribute one cup (10 test animals) into each test chamber by gently rinsing the contents of each cup into a test chamber.
6. Feed each test chamber with 1mL of 1800mg/L YTC solution and 1mL of 0.25g/100mL wheat grass solution.
7. All test chambers are inspected within two hours of initiation to ensure that no amphipods are trapped in the surface tension of the water. Gently push floating animals below the water’s surface. If the animal does not remain submerged, it should be replaced with a new animal.
8. Perform another full volume renewal by pouring approximately 400mL of renewal water into the Zumwalt chamber.

C. Daily Monitoring and Feeding Regime – Days 1-9

1. Measure and record pH, DO, conductivity, and temperature daily in surrogate chambers, prior to water renewals.

10-Day Freshwater Sediment Toxicity Tests using *Hyalella azteca*

2. Observe aeration and conditions in all test chambers. Note and/or correct obvious problems, as required.
3. Measure and record pH, DO, conductivity, and temperature of renewal water. Perform a full volume renewal twice daily by pouring approximately 400 ml of clean laboratory water into the top Zumwalt chamber. This will slowly drip down into the test chamber.
4. Feed test chambers daily with 1ml of a 1800 mg/L YTC solution and 1mL of 0.25g/100mL wheat grass solution, after the morning water renewal is completed. If there is an accumulation of excess food on the sediment surface, suspend feeding to avoid fungal growth and degraded water quality in the test chambers.

D. Test Termination – Day 10

1. Measure and record water quality (DO, pH, conductivity, and temperature) in each surrogate test chamber. Remove a 10mL subsample of overlying water for ammonia analysis from each site surrogate and preserve with sulfuric acid.
2. Prepare, label, and tare weigh pans for growth endpoint measurement, if necessary.
3. Make any final observations on test chambers (i.e., anoxic layer, fungal growth, etc.) Gently suspend sediment in the test chambers and pour onto 0.5-mm cylindrical screen. Rinse away remaining sediment using laboratory water within $\pm 2^{\circ}\text{C}$ of the test temperature.
4. Count and record the number of surviving amphipods making note of any dead amphipods found.
5. Collect and rinse surviving amphipods with deionized water. Using forceps, gently place on an appropriately labeled and tared aluminum pan.
6. Dry in an oven at 60°C for 24 hours.
7. Remove dried animals from oven. Weigh each pan to the nearest 0.0001g and record on the data sheet.

E. Reference Toxicant Testing

1. A water-only 96-hour reference toxicant exposure is performed with the same batch of animals as a quality assurance measure to assess the health of the test organisms and soundness and consistency of procedures. Copper chloride is used as a reference toxicant. The testing concentrations for the reference toxicant are 0 (Control), 100, 200, 400, 800, and 1600 $\mu\text{g/L}$ copper with four replicates per concentration and 10 animals per replicate. Illumination will be on the same light

10-Day Freshwater Sediment Toxicity Tests using *Hyalella azteca*

cycle as the test. A small screen should be added to each test chamber to provide substrate for the organisms.

2. The LC₅₀ for survival is calculated and should be within two standard deviations of the historical control chart mean for Nautilus.

VI. TEST ACCEPTABILITY CRITERIA

The acceptability criteria for the laboratory control at test termination are as follows:

- a. 80% mean survival
- b. Mean growth in the controls must be measurable (compare mean final dry weight to mean time zero dry weight)

VII. MODIFICATIONS

- a. Sediment and overlying water volumes – Volume changes from the method for sediment from 100 mL to 225 mL and for overlying water from 175 mL to 400 mL. The prescribed sediment to water ratio is maintained.
- b. Feeding regime - In addition to the protocol-specified YTC, Nautilus also feeds with wheat grass slurry.
- c. Aeration trigger – Aeration may be started when dissolved oxygen levels reach 4.0 mg/L and are trending downward, instead of the protocol-specified threshold of 2.5 mg/L.

VIII. HEALTH AND SAFETY

Health and safety precautions and applicable regulations should be considered at all times, including good housekeeping, and use of proper personal protective equipment (at minimum, gloves should always be worn when handling sediments). Please see the Health & Safety Program Manual for details.

IX. PERSONNEL

Only qualified technicians who have been properly trained and can demonstrate competence with these techniques are permitted to conduct this test.

X. QUALITY ASSURANCE (QA) REQUIREMENTS

Quality assurance practices encompass all aspects of testing including the collection, handling, and preparation of test organisms, samples, and dilution waters. Proper record keeping and documentation is required during all phases of testing, which includes completion of datasheets on a real-time basis and filling out corrective action records for any errors occurring during the test.

10-Day Freshwater Sediment Toxicity Tests using *Hyalella azteca*

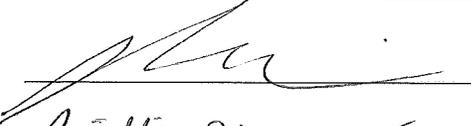
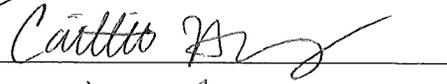
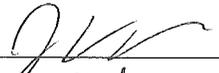
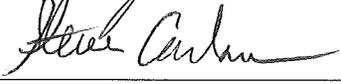
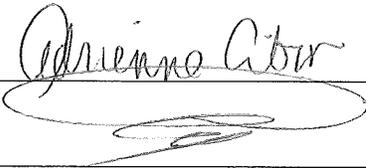
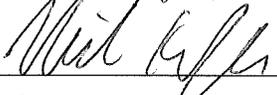
Statistical analyses follow standard EPA flowchart selections and any dose-response relationships are reviewed to ensure the validity of the data. Any deviations from EPA flowchart selection of statistical analyses are explained and justified.

Reference toxicant testing is conducted monthly or concurrently with sediment testing, as required, to ensure continued test organism health and sensitivity, as well as to demonstrate technical staff proficiency and minimization of test variability. This is supported by the generation and examination of quality control charts for each specific test species and procedure.

10-Day Freshwater Sediment Toxicity Tests using *Hyalella azteca*

I. XI. Signatures

The following staff have read and understood the protocol:

Signature	Name	Date
	10/20 Sahar Golshani	10/20/14
	Caitlin Harvey	10/20/14
	ERIC GREEN	10/20/14
	Brian Knerr	10/20/14
	Kellyn Becker	10/20/14
	Jeff Van Vasthis	10/20/14
	Steve Carlson	10/20/14
	Adrienne Cibor saeid Golshani	10/20/14 10/22/14
	Beverly Geiszler	10/22/14
	Nick Hennkens	10/22/14
	Ashley Donohue	10/22/14
	Kasey Skrivseth	10/23/14

10-Day Static Sediment Toxicity Tests with Marine and Estuarine Amphipods

To replace old SOP last issued on July 12, 2011

Reason for update: Changes to ammonia subsample collection and clarification of test set-up procedures

Approved By:



5/22/13

Laboratory Manager

(Date)



5/22/13

QA & Compliance Officer

(Date)

I. PURPOSE

This method is designed to measure the toxicity of marine and estuarine sediments to the amphipods *Eohaustorius estuarius*, *Leptocheirus plumulosus*, *Rhepoxynius abronius*, or *Ampelisca abdita* using survival as an endpoint.

II. REFERENCE DOCUMENTS

ASTM, 1993. "ASTM Standards on Aquatic Toxicology and Hazard Evaluation" ASTM 03-547093-16,1993.

ASTM, 2002. "Conducting Ten-day Static Sediment Toxicity Tests with Marine and Estuarine Amphipods" ASTM E1367-99, 2002.

US EPA 1991. "Evaluation of Dredged Material Proposed for Ocean Disposal" (Green Book Testing Manual), EPA, February 1991.

US EPA, 1994. "Methods for Assessing the Toxicity of Sediment-associated Contaminants to Estuarine and Marine Amphipods" US EPA Office of Research and Development, Washington DC. Method 100.4. EPA 600/R-94/025.

US EPA, 1998. "Evaluation of Dredged Material Proposed for Discharge in Waters of the U.S. – Testing Manual (Inland Testing Manual [ITM]), EPA, February 1998.

SOP 1900 - "Sample Receipt/Chain-of-Custody Procedures"

SOP 1901 - "Laboratory Bench Quality Control Practices"

SOP 1910 - 1912 - "Calibration and use of Meters"

SOP 1930 - "Data Review and Report Preparation Guidelines"

Nautilus Environmental - Quick Reference Manual (QRM)

10-Day Static Sediment Toxicity Tests with Marine and Estuarine Amphipods

III. TEST SPECIFICATION SUMMARY

Number of replicates per sample	5
Number of organisms per replicate	20
Test chambers	1L glass jars
Sediment volume	2 cm (4 cm for <i>A. abdita</i> , per ITM)
Overlying water volume	Fill to 800mL
Overlying water source	30ppt seawater, or other project-specific
Temperature range	15±1°C, <i>E. estuarius</i> and <i>R. abronius</i> 20±1°C, <i>A. abdita</i> 25±1°C, <i>L. plumulosus</i>
Light cycle	24h continuous light
Feeding regime	No feeding during test duration
Test acceptability criteria	Mean control survival ≥90% and no individual control replicate has <80% survival

IV. EQUIPMENT

- . Proven source of clean seawater (e.g., Scripps Institution of Oceanography)
- . Environmental chamber maintained at 15, 20, or 25 ± 1°C (depending on species)
- . Test organisms from a reputable supplier
- . Cold room maintained at 4°C to hold sediment samples prior to test initiation
- . 20-µm filtered seawater (adjusted to test salinity with deionized water)
- . Thermometer, pH meter, dissolved oxygen (D.O.) meter, salinity meter, metric ruler, and analytical balance
- . 1L glass jars with lids to serve as test exposure chambers (6 jars per test site, reference, and control); ¼" holes drilled in lids to permit aeration
- . 0.5-mm and 1.0-mm nitex mesh screens, transfer pipets, and glass bowls
- . Aeration source and micro-airline tubing or airline tubing with cut glass pipette
- . Test, control, and reference (if requested) sediments
- . 30-ml plastic soufflé cups for segregating organisms at test initiation; seawater squirt bottle
- . 60-ml plastic soufflé cups for reburial endpoint (if required)
- . Safety equipment - lab coats, eye protection, gloves, and respirator as required

V. TEST PROCEDURE

10-Day Static Sediment Toxicity Tests with Marine and Estuarine Amphipods

A. Pre-test Set-up

1. Test animals are purchased from a reliable, experienced dealer and shipped to the lab via next day delivery service. Organisms are held in a static 38-L aquarium or other container in clean control or home sediment, sieved to 0.5 mm. The aquarium is dripped with seawater adjusted to a salinity that allows for proper acclimation of the test organisms and is supplied with constant aeration. The holding or acclimation chambers are held under continuous illumination to prevent emergence.
2. Water quality measurements are measured and recorded daily in the Animal Acclimation Log. During acclimation temperature and salinity changes should not exceed $\pm 2^{\circ}\text{C}$ or ± 5 ppt per 24 hr period, respectively.
3. Samples are checked in upon receipt. See procedural SOP for details on sediment sample check-in procedures.
4. Interstitial porewater is collected for the measurement of ammonia, salinity, and pH prior to test initiation to assess any potential confounding factors. Interstitial water is collected by centrifuging a subsample of whole sediment at 1500-3000 rpm for 15 min. If not analyzed for ammonia immediately, subsamples may be preserved with sulfuric acid (H_2SO_4) for later analysis. If total ammonia is $\geq 15\text{mg/L}$ in any sample, the Project Manager must be notified immediately to evaluate the need for ammonia purging.
5. Sediment samples are sieved through a 0.5-mm screen (or other project-specific size screen) to filter out any resident organisms and/or debris. The sieved sediment is placed in a clean, labeled, food grade plastic bag, and stored at 4°C until tests are initiated.

24-Hrs Prior to Test Initiation

1. Set up a randomization table using Microsoft Excel.
2. Label test chambers according to the randomization table, and rinse with seawater.
3. Add 2 cm (4 cm for *A. abdita*, per ITM protocol) of the appropriate sediment to the labeled jars.
4. Prepare one additional test chamber for each test site. This surrogate will be used for water quality measurements during the test period. If ammonia is of concern, additional surrogates can be added to evaluate interstitial ammonia levels.
5. Fill jars to the 800 ml level with seawater of the appropriate salinity.

10-Day Static Sediment Toxicity Tests with Marine and Estuarine Amphipods

6. Place jars in the appropriate environmental chamber (15°C *E. estuaris* and *R. abronius*, 20°C *A. abdita*, 25°C *L. plumulosas*). Adjust light cycle in chamber or on appropriate shelf to 24-hour light cycle (continuous light).
7. Aerate test chambers with either micro-airline tubing or standard airline tubing attached to half of a 1mL glass pipette placed through a hole in the lid. Aeration lines should be placed at mid-depth in the water column, with special care taken to prevent disturbance of the sediment.
8. If purging of ammonia is necessary, then place sufficient seawater (enough to perform 80% water change on all test chambers) adjusted to test salinity in environmental chamber overnight.

B. Test Initiation - Day 0

1. If required, collect and analyze subsamples of interstitial water for ammonia, pH, and salinity from designated surrogates to confirm that total ammonia is below the prescribed threshold in all samples. If ammonia levels are not below thresholds, the Project Manager must be notified, as further water exchanges may be necessary.
2. Measure and record water quality readings (D.O., salinity, temperature, and pH) from the surrogate jars. Remove a 10-ml subsample of overlying water for ammonia analysis from each site surrogate and preserve with acid (H₂SO₄).
3. Count 10 amphipods into a 30-ml cup containing seawater of appropriate salinity.
4. A second count by a different technician is made to verify that there are 10 amphipods in each cup.
5. Turn off air supply, and randomly distribute 20 test animals (2 cups) to each test chamber by gently rinsing the contents of each cup with a seawater squirt bottle.
6. Allow enough time for organisms to burrow, and re-adjust aeration as needed to maintain the dissolved oxygen above 4.0 mg/L (3-4 bubbles per second). Make sure that no organisms are trapped in the surface tension.

C. Daily Monitoring - Days 1 to 9

1. Measure and record pH, D.O., salinity, and temperature daily in surrogate chambers.
2. Observe aeration and record conditions in all test chambers and note and/or correct obvious problems as required.

D. Test Termination - Day 10

10-Day Static Sediment Toxicity Tests with Marine and Estuarine Amphipods

1. If the reburial endpoint is required, label the appropriate number of 30-ml plastic cups with randomization numbers. Add control sediment to each cup and fill with filtered seawater at the appropriate temperature and salinity. If not, proceed to Step 2.
2. Measure and record water quality (D.O., pH, salinity, and temperature) in surrogate test chambers. Remove a 10mL subsample of overlying water for ammonia analysis from each site surrogate and preserve with acid (H₂SO₄). If required, collect subsamples of interstitial water for ammonia, salinity, and pH analysis from each designated site surrogate.
3. Gently suspend sediment in the test chambers and pour onto 0.5-mm cylindrical screen. Rinse away remaining sediment using seawater within 2°C of the test temperature.
4. Count and record the number of surviving amphipods making note of any dead amphipods found. A second technician should verify counts on 10% of replicates.
5. If necessary, place the surviving organisms in the appropriately labeled 30-ml plastic cups for reburial experiment.
6. Allow cups to sit in environmental chamber for exactly 1 hour. Record the number of reburied organisms.

E. Reference Toxicant Testing

A water-only 96-hour reference toxicant exposure is performed concurrently to ensure test organism health and sensitivity, as well as demonstrate technical staff proficiency. Cadmium chloride is the standard reference toxicant, and test concentrations include 0 (Control), 0.25, 0.5, 1.0, 2.0, and 4.0 mg/L cadmium for *L. plumulosus*, *A. abdita*, and *R. abronius*. For *E. estuarius*, concentrations include and 0 (Control), 1.25, 2.5, 5.0, 10, and 20 mg/L cadmium. An additional reference toxicant using ammonium chloride may also be conducted. All reference toxicant tests are conducted at 30 ppt salinity in the dark. If the client test is conducted at salinity more than 5ppt different from the reference toxicant test, organisms shall be acclimated accordingly.

VI. TEST ACCEPTABILITY CRITERIA

Mean control sediment survival at test termination must be 90 percent or greater, and no individual control replicate can have less than 80 percent survival.

VII. HEALTH AND SAFETY

Health and safety precautions and applicable regulations should be considered at all times. Gloves must always be worn when handling test sediments.

VIII. PERSONNEL

10-Day Static Sediment Toxicity Tests with Marine and Estuarine Amphipods

Only qualified technicians who have been properly trained and can demonstrate competency with these techniques is permitted to conduct this test.

IX. QUALITY ASSURANCE REQUIREMENTS

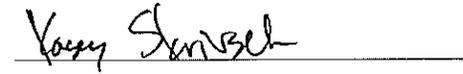
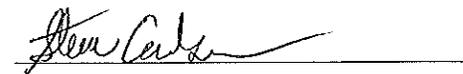
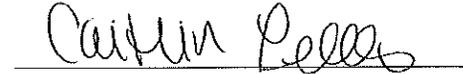
Quality assurance practices encompass all aspects of testing including the collection, handling, and preparation of test organisms, samples, and dilution waters. Proper record keeping and documentation is required during all phases of testing, which includes completion of datasheets on a real-time basis and filling out corrective action records for any errors during the test.

Statistical analyses follow standard EPA flowchart selections, and any dose-response relationships are reviewed to ensure the validity of the data. Any deviations from EPA flowchart selection of statistical analyses are explained and justified.

10-Day Static Sediment Toxicity Tests with Marine and Estuarine Amphipods

X. SIGNATURES

The following staff have read and understood the protocol:

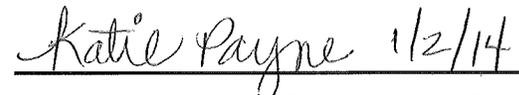
Signature	Name	Date
	Sarah Douglas	5/23/13
	Kasey Skrivseth	5/23/13
	Steve Carlson	5/23/13
	Jessica Anderson	5/23/13
	Caitlin Belles	5/23/13
	Beverly Griffith	5/23/13
	Ming Lai	5/23/13
	Ashley Donohue	5/23/13
	Brian Knerr	5/24/13
	Nick Kenrick	7/1/14

Total Ammonia Analysis

To replace S-1920 last issued on September 27, 2011

Reason for update: New model spectrophotometer

Approved By:

 
Laboratory Manager (Date) QA & Compliance Officer (Date)

I. PURPOSE

This document provides a summary of steps to analyze aqueous test material for total ammonia using the Hach colorimetric "Test 'N Tube" Salicylate Method 10031 and DR 2800 spectrophotometer. The Hach method cited is an EPA-accepted procedure equivalent to EPA Method 350.2.

II. EQUIPMENT/SUPPLIES

- 100- μ l pipette and disposable tips
- AmVer High Range Ammonia Test N' Tube Reagent Set
- Deionized water (DI)
- 10 mg/L ammonia as ammonia standard (equivalent to 8.2 mg/L ammonia as nitrogen)
- Seawater (if sample is marine)
- Hach DR 2800 Spectrophotometer
- Fume Hood
- Personal Protective Equipment (PPE) – lab coats, eye protection, gloves, and respirators as required

III. PROCEDURE

Note: Perform steps A through D inside the fume hood and with proper PPE.

- A. Obtain enough test tubes from a Hach AmVer High Range Ammonia test kit for all blanks and samples to be run. Label one test tube for the DI Blank and one test tube for the Blank Spike. If running marine samples, also label a test tube for the Seawater Blank. Label each of the remaining test tubes with the appropriate sample ID.
1. Also include one Sample Duplicate and Sample Duplicate + Spike for each batch of 20 samples. Typically, the last sample listed on

Total Ammonia Analysis

the datasheet is used for the Sample Duplicate and Sample Duplicate + Spike.

- B. Uncap all of the tubes, and set them aside (in the same order as the tubes on the tray) on a clean paper towel.
- C. Remove 100 μ l of distillate from the Sample Duplicate + Spike tube(s). (This is to keep all volumes equal. All other vials will only receive 100 μ l of sample, but the Sample Duplicate + Spike receive two aliquots of 100 μ l).
- D. Add 100 μ l of DI to the DI Blank. Add 100 μ l of seawater to the Seawater Blank, if applicable.
- E. Before pipetting each sample, swirl sample vial to thoroughly homogenize. Add 100 μ l of each sample to the appropriate test tube using a clean pipette tip for each sample; aim directly into the solution in the tube so no sample sticks to the glass.
- F. Mix ammonia standard with a stir bar on a magnetic stir plate for 5 minutes prior to use. Add 100 μ l of ammonia standard to the Blank Spike tube and each Sample Duplicate + Spike tube,
- G. To each tube, first add the contents of one Ammonia Salicylate reagent packet. Next, add the contents of one Ammonia Cyanurate reagent packet. Replace caps and shake thoroughly to dissolve reagents.
- H. Set a timer for 20 minutes for the reaction to complete. During that time, turn on the DR 2800 Spectrophotometer. Select "Favorite Programs" from the Main Menu. Select "343 N Ammonia HR TNT 50.0 mg/L" then "Start".
- I. After 20 minutes have passed, wipe the outside of the DI Blank or Seawater Blank tube with a Kimwipe to remove any fingerprints or other residue. Insert the tube into the spectrophotometer cell holder. Cover the tube with the protective cover, and select "Zero" to zero the instrument. Record the measured value on the datasheet.
- J. For each subsequent sample tube, wipe the outside with a Kimwipe and insert into the cell holder. Cover with protective cover and select "Read". Record the measured value on the test datasheet in the "NH₃-N" column.
 - 1. **Note:** Record ammonia measurements that are below the method detection limit of 0.5 mg/L as "<0.5 mg/L".

Total Ammonia Analysis

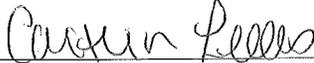
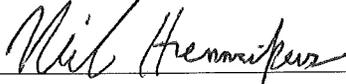
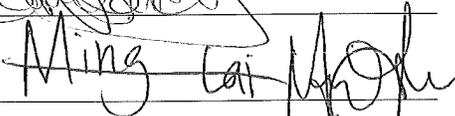
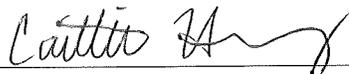
- K. Perform the calculations (multiply each result by 1.22) to convert ammonia as nitrogen ($\text{NH}_3\text{-N}$) to total ammonia.

- L. Perform the necessary percent recovery and relative percent difference calculations on the datasheet. Place completed data in the proper raw data box in the main lab.

Total Ammonia Analysis

IV. SIGNATURES

The following staff have read and understood the protocol:

Signature	Name	Date
	Beverly Geiszler	1/8/14
	Curtin Lelles	1/8/14
	Nick Hennikus	1/8/14
	Ashley Dorchie	1/8/14
	Tami Sanchez	1/8/14
	Ming Lai	1/8/14
	Alexi Gabriel	1/10/14
	Sean Ables	7/29/14
	Caitlin Harvey	7/16/14
		

ATTACHMENT 3

2009 ARKEMA EE/CA FIELD SAMPLING PLAN

**ARKEMA EARLY ACTION
EE/CA WORK PLAN**

Work Plan Addendum

**Appendix A
Field Sampling Plan**

Prepared for
Legacy Site Services LLC
468 Thomas Jones Way
Exton, PA 19341



319 SW Washington Street
Suite 1150
Portland, OR 97204

May 15, 2009

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ACRONYMS AND ABBREVIATIONS

ASTM	American Society for Testing and Materials
CDF	confined disposal facility
COI	constituent of interest
CPT	cone penetration testing
CU	consolidated, undrained triaxial shear stress
DDx	total of 2,4'- and 4,4'-DDD, DDE, DDT
DEQ	Oregon Department of Environmental Quality
DGPS	differential global positioning system
DOT	U.S. Department of Transportation
EE/CA	engineering evaluation and cost analysis
EPA	U.S. Environmental Protection Agency
EVS	Environmental Visual Software
FSP	field sampling plan
GUS	Gregory Undisturbed Sampler
Integral	Integral Consulting Inc.
IRM	interim remedial measure
LSS	Legacy Site Services LLC
NAD	North American Datum
NTCRA	non-time-critical removal action
OVM	organic vapor meter
PCB	polychlorinated biphenyl
PCDD/F	polychlorinated dibenzo- <i>p</i> -dioxin and polychlorinated dibenzofuran
PPE	personal protective equipment
QA	quality assurance
QAPP	quality assurance project plan
RAA	removal action area
SOP	standard operating procedure

SPT	standard penetration testing
SVOC	semivolatile organic compound
TCLP	toxicity characteristic leaching procedure
TZW	transition-zone water
UU	unconsolidated, undrained triaxial shear stress
VOC	volatile organic compound

1 INTRODUCTION

This field sampling plan (FSP) was prepared for the engineering evaluation/cost analysis (EE/CA) non-time-critical removal action (NTCRA) at the Arkema site (Site). This FSP is Appendix A to the EE/CA Work Plan Addendum (Work Plan Addendum). The Work Plan Addendum modifies and updates the May 11, 2007 EPA/Parametrix Arkema Early Action EE/CA Work Plan (EPA/Parametrix Work Plan) pursuant to agreements between the U.S. Environmental Protection Agency (EPA) and Legacy Site Services LLC (LSS), agent for Arkema Inc., between May 2007 and May 4, 2009, and findings by EPA (USEPA 2008). Together, the EPA/Parametrix Work Plan, the Work Plan Addendum, and this and other revised appendices encompass the Final EE/CA Work Plan for the Site.

The Site is located in Portland, Oregon on the northwest bank of the lower Willamette River between approximately river mile 6.9 and 7.6 (Parametrix 2007, Figure 1-1). The upland portion of the Site encompasses approximately 54 acres of land. The in-water portion of the Site is defined as the land below mean high water (18.1 ft City of Portland Datum)^[1]; however, the NTCRA evaluation will include portions of the riverbank to the top of bank, as the riverbank cannot easily be subdivided for construction purposes. The EE/CA NTCRA is primarily focused on the in-water portion of the Site; however, elements of the removal action will be integrated with the upland portion of the Site. The portions of the riverbank (to the top of bank) that are deemed to be recontamination sources or to impact the removal and/or remedial action alternatives may be addressed by the NTCRA, while the remainder of the riverbank may be addressed directly with the Oregon Department of Environmental Quality (DEQ) in accordance with the Agreed Order on Consent dated October 31, 2008. Ultimately, the timing and coordination between the Upland and NTCRA projects will dictate under which program the NTCRA-affected riverbank portions will ultimately be addressed in the field.

This FSP describes the sampling design and rationale to meet the data needs of the removal action characterization activities associated with the EE/CA and, along with the Quality Assurance Project Plan (QAPP; Appendix B), provides specific field methodology and quality assurance procedures that will be followed by Integral Consulting Inc. (Integral) and its subcontractors. Integral is conducting this work under contract to LSS with approval and oversight by EPA and DEQ.

The primary objective of the EE/CA characterization activities is to fill data gaps to further refine the 5 mg/kg preliminary removal action area (RAA) boundary, especially at depth, as cited in the May 23, 2008 Final Decision on Disputes from Dan Opalski, Director, Office of

¹ The in-water portion of the Site below mean low tide is leased from the Oregon Division of State Lands.

Environmental Cleanup (Opalski Decision). The additional characterization falls into two general categories:

- Defining sediment quality characteristics
- Defining sediment physical and engineering characteristics.

The remainder of this FSP is organized as follows:

- Section 2: Data Gaps and Field Investigation Rationale—This section describes the rationale used to fill data gaps at the Site and provides a description of the EE/CA characterization activities.
- Section 3: Field Sampling Methods—This section provides a general description of the field methods that will be employed to fill data gaps at the Site.
- Section 4: References—References cited in this document.
- Attachment A: Standard Operating Procedures—These numbered documents provide specific, detailed information on conducting routine, repetitive field techniques (e.g., split-spoon sampling from a drill rig).
- Attachment B: Field Forms—These field forms will be utilized to record data in the field.

2 DATA GAPS AND FIELD INVESTIGATION RATIONALE

This section identifies data needs and presents approaches to fill data gaps for the removal action technologies and alternatives presented in the EE/CA EPA/Parametrix Work Plan and Work Plan Addendum (Parametrix 2007; Integral 2008), and as clarified by the Opalski Decision. The data needs for removal action technology groups are summarized in Table 2-1. The proposed investigation activities described in this FSP are intended to support the analysis and selection of removal action alternatives during the EE/CA, to identify a preferred removal action alternative, and in part to support engineering analyses during the design phase of the Arkema NTCRA.

2.1 DATA GAPS

The following sections address data gaps identified to complete the EE/CA.

2.1.1 Removal Action Technologies and Alternatives

Table 2-1 presents the sampling and analysis methods that will be considered for each potential removal and/or remedial action technology for the Site. Table 2-2 presents the sampling and analysis methods that may be considered for each potential disposal alternative. A checkmark (✓) indicates that sufficient data are available and that no additional data are needed for the sampling or analysis method. An "X" indicates that available data are insufficient and that additional data are needed for the sampling or analysis method.

These methods are discussed in more detail in the following sections.

2.1.2 Nature and Extent of Contamination

Although extensive sediment data have been gathered over portions of the Site, especially in the area of Arkema Docks 1 and 2 (Figure 2-1), additional data are needed for completion of the EE/CA. Sediment data are limited in certain portions of the study area, and additional sediment chemistry data are needed (predominantly vertically) to refine the RAA boundary limits at depth. Additional borings will also be used to further confirm the 5 mg/kg RAA boundary laterally. Currently sufficient data exist, including recent Round 3b Lower Willamette Group sampling data, upstream of Dock 1 to support the evaluation of recontamination caused by resuspension and redeposition of nearby upstream sediments into the RAA. Sediment quality data are generally less abundant with depth, as determined in part by the Environmental Visual Software (EVS) Drill Guide, resulting in greater statistical uncertainty about levels of contamination at different depth intervals between the sediment surface and bedrock within the 5 mg/kg total of 2,4'- and 4,4'-DDD, DDE, DDT (DDx) preliminary RAA. Therefore, in

accordance with the Opalski Decision, much of the EE/CA characterization is focused on and designed to provide higher confidence in the definition of the base of the RAA within the RAA boundary. In addition, some ancillary sediment chemistry data are also needed for other non-site-specific analytes (e.g., dioxin/furan congeners and polychlorinated biphenyls [PCBs]) to obtain a better understanding of these river-wide constituents of interest (COIs) within the Arkema RAA for sediment management and handling.

2.1.3 Sediment Physical and Engineering Characteristics

A suite of physical tests is proposed to evaluate sediment properties pertinent to dredging and capping technologies, dredged material behavior in a disposal site, potential short-term impacts at the dredge and disposal sites, capacity of existing sediments to provide foundation support for capping material, and the viability of sheet pile wall construction or other technology for nearshore containment. The tests discussed below will be required to evaluate these technologies.

2.1.3.1 Index Properties

Grain Size

Grain size provides information on site geologic character and engineering properties and behavior of sediment proposed for capping, dredging, or nearshore containment. Sediment grain-size information is available for most surface sediments previously collected from the Site. Fewer grain-size data are available for the subsurface sediments within the 5 mg/kg DDx preliminary RAA boundary.

Atterberg Limits

Atterberg limits, which include the liquid limit, plastic limit, and plasticity index, are used to define plasticity characteristics of cohesive sediments and are useful index parameters for sediment characterization, engineering behavior, and shear strength correlations. Limited Atterberg limit data are available from historical studies within the preliminary RAA boundary. Selected fine-grained surface and subsurface sediments collected for grain size will also be analyzed for Atterberg limits.

Specific Gravity

The specific gravity of sediment samples is used to determine weight-volume relationships of sediment, which are used for unit weights and void ratio calculations. Limited data for specific gravity in sediment are available between the docks and nearshore (Portland Harbor Remedial Investigation sampling locations only). Selected samples will be analyzed in support of the remedial alternative selection.

Moisture/Bulk Density

Moisture content is used to determine the initial *in situ* void ratio of the sediment, to estimate short-term bulking (or increase in volume) during dredging activities, and to correlate with other geotechnical parameters. There have been no direct measurements in site sediments for moisture content or bulk density. Selected samples will be analyzed in support of the remedial alternative selection.

2.1.3.2 Subsurface Information and Advanced Geotechnical Parameters

In addition to index property testing, more advanced testing will be performed to estimate subsurface information and geotechnical parameters such as shear strength, stress history, compressibility, and hydraulic conductivity of the *in situ* material. These parameters are needed to support the analysis and design of the various removal action technologies under consideration for the Site. Analysis and design of sediment caps involves the evaluation of long-term stability and integrity, based upon physical and chemical parameters expected at the Site. Parameters to be evaluated during the design of a cap include chemical isolation, cap thickness, cap materials, cap armoring, shear strength and consolidation characteristics of underlying sediments, bioturbation, cap erosion and scour, vessel prop wash, slope stability, and settlement/consolidation (USACE 1998; USEPA 1998). Physical characteristics and shear strength parameters are also needed to assess the stability of proposed dredge cuts and potential impacts to adjacent shorelines and structures. Geotechnical parameters will also be needed to assess the suitability of the Site subsurface materials to support a nearshore confined disposal facility (CDF) and other structures that may be necessary during remedial construction. The geotechnical tests required to support evaluation of these removal action technologies are described below. None of these tests has been conducted previously on site sediments.

Shear Strength Testing

Shear strength test results are used to assess bearing capacity, slope stability, and earth pressures for analysis and design of removal action technologies such as *in situ* capping, CDFs, and dredging. Drained and undrained shear strength parameters will be used during design. These parameters will be assessed using a variety of approaches and include the use of unconsolidated, undrained (UU) and consolidated, undrained (CU) triaxial shear tests. In addition, shear strength will also be assessed based on the results of standard penetration testing (SPT), cone penetration testing (CPT), and index property testing, in conjunction with published correlations and engineering judgment.

In addition to the shear strength testing on sediment samples, the unconfined compressive strength of rock samples will be tested by performing point load index tests and unconfined compressive strength tests. These tests will be performed to assess the “rippability” and bearing characteristics of the underlying bedrock. These characteristics may become important

in the assessment of constructability and feasibility of sheet pile structures such as CDF containment structures.

Consolidation Testing

Consolidation tests are performed to determine the compressibility and stress history parameters. These parameters are used for assessment of consolidation behavior of sediment deposits under loading conditions associated with capping materials and assessment of the shear strength of cohesive materials. An understanding of the consolidation of underlying sediment is important in evaluating the effective (or minimum) thickness of a cap (USACE 1998). The effective thickness of a cap is reduced by the consolidation in the underlying sediment. Vertical loads for cap consolidation testing and analyses are determined on the basis of the anticipated cap configuration and thickness (modified EM-1110-2-5027). Additionally, stress history parameters are useful in assessing the in-situ strength of the cohesive material. The use of strength data is explained in more detail under Shear Strength Testing.

Hydraulic Conductivity

Hydraulic conductivity testing will be conducted to assess the permeability of lower cohesive strata within the RAA boundary, which may serve as a key-in feature for nearshore CDF options considered during the EE/CA.

2.1.4 Upland Disposal of Dredged Material

In order to identify the appropriate type of upland disposal options for the dredged sediments, a waste determination analysis must be conducted. The waste determination analysis involves evaluating the source of the waste and the waste characteristics, including toxicity characteristic leaching procedure (TCLP) testing. For example, for assessing disposal options at offsite landfills, the waste would have to be evaluated per the Oregon Administrative Rules prior to disposal at a Subtitle D landfill.

Additionally, landfill-specific criteria such as the presence of free liquids and other permit required testing (e.g., total petroleum hydrocarbons, asbestos) will apply. These criteria are specific to the landfill selected to receive the dredged sediments. Therefore, other offsite landfill-specific testing may be performed to evaluate disposal options for any dredged material.

2.1.5 Hydrogeologic Characteristics

Groundwater characteristics have been evaluated for upland soils and in-water sediments, including the transition zone between sediments and overlying water (Integral 2007). Upland groundwater zones and their characteristics (including hydraulic gradient) are summarized in Section 3.2.2.3 of the Final EE/CA Work Plan (Parametrix 2007; Integral 2008). As stated in the

Final EE/CA Work Plan, the quality of some of the transition-zone water (TZW) data is considered to be unusable for the purpose of evaluating recontamination potential for chlorinated pesticides because of the collection method (i.e., unfiltered, turbid water samples from Trident probes). Other TZW data, including peepers samples (a sample device that uses a semi-permeable membrane) and filtered Trident probe samples, are more likely to be representative of water moving through the sediment prior to discharge at the sediment surface. These latter data will be used to evaluate the potential for long-term release and sediment or cap recontamination at the sediment interface for the EE/CA. No additional TZW data collection is proposed in this FSP.

Transition-zone groundwater seepage rates were measured as part of the recent Portland Harbor remedial investigation groundwater study, as described in Section 3.2.2.1 of the Final EE/CA Work Plan (Parametrix 2007; Integral 2008). The information from these studies, and other relevant site data, will be used in calculations and modeling to estimate long-term contaminant release or loss associated with placement of an isolation cap and to assist in the evaluation of hydraulic containment technologies. An understanding of groundwater advection in the sediments is important in evaluating the effective (or minimum) thickness of a cap. This information will also be beneficial in evaluating hydraulic containment alternatives for the Site.

Additional information is also needed to understand the depth to basalt bedrock and low-permeability horizons within the in-water portion of the Site. No other hydrogeologic data are required in support of the EE/CA.

2.1.6 Debris Survey, Dock Encumbrances, and Utilities

The nature and extent of debris within the project site RAA will need to be considered in the development and evaluation of sediment capping, dredging, and hydraulic containment technologies. Accordingly, a reconnaissance survey of the project area will be conducted to estimate the quantity and nature of surface debris. In addition, boring logs will be reviewed to identify subsurface debris encountered during both historical and proposed site investigations. This information will be compiled for consideration during the EE/CA and also will be useful for inclusion in the final design documents and remedial construction contract.

2.2 REMOVAL ACTION CHARACTERIZATION ACTIVITIES

This section summarizes the rationale for removal action sampling and analytical methods that will be employed in support of the EE/CA. Future sampling methods that may be necessary for the removal action, but are beyond the scope of this FSP, are also noted below.

2.2.1 Nature and Extent of Contamination

This section presents the sampling design and rationale for the EE/CA characterization to evaluate sediment characteristics at the Site. Additional information on sediment characteristics is required per the Opalski Decision to further refine the horizontal and vertical extent of the 5 mg/kg DDx preliminary RAA boundary. For the vertical boundary definition, the Opalski decision specifically states: *“the EE/CA shall proceed with analyses that considers the implications of dredging to a range of concentrations vertically, with that range to include at least the SLVs and the approximate 5 ppm concentration suggested by LSS’ mass-based analysis.”* The proposed investigations are designed to fill data gaps identified by conventional data gap analysis and by the Drill Guide to adequately define the base of the removal action within the RAA boundary, and to provide a baseline for monitoring remedial activities.

2.2.1.1 Rationale

Surface and subsurface samples will be collected and analyzed to support delineation of the 5 mg/kg RAA boundary in accordance with the Opalski Decision and development of removal action alternatives. Sampling locations have been selected to characterize sediment in areas identified by conventional data gap analysis and identified by the Drill Guide¹ to provide a higher statistical certainty in the 5 mg/kg RAA boundary contour.

2.2.1.2 Sampling Strategy

A total of 37 sediment chemistry boreholes are proposed (WB-30 through WB-66; Figure 2-1) and will be completed to basalt (or refusal) to evaluate the horizontal and vertical extent of COIs within and adjacent to the 5 mg/kg DDx RAA boundary. Samples will be collected for chemical analyses and/or archived at all proposed sampling locations. The proposed sampling, analysis, and archiving plan and rationale for each borehole location is summarized in Table 2-3. Proposed sediment samples are distributed at representative locations within the vicinity of the preliminary RAA boundary to measure the vertical and horizontal extent of DDx and other chemicals. In addition to characterizing the broader Site conditions, this sampling will focus on the perimeter of the 5 mg/kg preliminary RAA Boundary contour where the majority of DDx mass is located. Selected samples will be archived for possible subsequent analysis, depending on the analytical results from samples collected at nearby boreholes (Table 2-3; Figure 2-1).

In some locations, sediment chemistry cores will be near geotechnical borehole locations. In general, the installation sequence for the sediment chemistry and geotechnical boreholes does not matter. However in the area immediately downstream of Dock 2, sediment chemistry cores WB-49, WB-50, and WB-51 will be installed prior to the CPT boreholes (CPT-1 and CPT-3). If

¹ A description of EVS Drill Guide methodology is presented in Section 8.2 of the Work Plan Addendum (Integral 2008).

the geotechnical engineer determines that the sediment lithology in the Dock 2 area is substantially different² than the sediment lithology near Dock 1 then one of the collocated geotechnical boreholes (SPT) may be moved to this downstream location.

Sediment quality samples will be collected using a barge-mounted hollow-stem auger drill rig (or equivalent) advanced to basalt or refusal. Samples will be collected continuously at 2- to 3-ft intervals in accordance with Table 2-3 for the entire length of the borehole, using a variety of samplers, depending on the sample location and bottom conditions. Sampling equipment may include split-spoon samplers, Gregory Undisturbed Sampler (GUS) or Osterberg sampler, and/or Shelby tubes.

2.2.1.3 Analytical Strategy

The rationale, analytes, and laboratory methods for the sediment samples are detailed in Table 2-3 and the QAPP (Appendix B). Additional samples may be analyzed based on field observations, including visual observation, odor, and presence of volatile chemicals (e.g., using a photoionization detector). A portion of each sample interval will be archived for possible future chemical analysis. The analytes are grouped into standard and expanded lists.

Most samples will be analyzed for the standard analyte list, which includes the following:

- Conventional analytes (grain size, total solids, and total organic carbon) by American Society for Testing and Materials (ASTM) Method D-422, EPA Method 160.3 modified, and EPA Method SW846-9060A, respectively
- DDx by EPA Method SW846-8081A.

Other samples, as identified in Table 2-3, will be analyzed for an expanded analyte list to better characterize the nature and extent of river-wide COIs inside and adjacent to the preliminary RAA. The expanded analyte list includes the following:

- Standard analyte list (described above)
- Semi-volatile organic compounds (SVOCs) by EPA Method SW846-8270C
- PCB Aroclors by EPA Method SW846-8082
- Volatile organic compounds (VOCs) by EPA Method SW846-8260B
- Organochlorine pesticides by EPA Method SW846-8081A
- Polychlorinated dibenzo-*p*-dioxin and polychlorinated dibenzofuran (PCDD/Fs) by EPA Method 1613B.

² For the purposes of the geotechnical evaluation.

2.2.2 Physical and Engineering Characteristics

2.2.2.1 Rationale

A testing program will be performed to determine the sediment index properties and geotechnical engineering parameters within and adjacent to the RAA boundary. The physical characteristics of sediments are important in the evaluation of dredging, capping, and containment technologies, dredged material transport and disposal, dredged material behavior in a disposal site, potential short-term impacts at the dredge and disposal sites, and the capacity of the sediments to support capping materials.

2.2.2.2 Geotechnical Investigation Sampling Strategy

The geotechnical investigation program will consist of three mud-rotary sediment borings and 13 CPT explorations to evaluate geotechnical properties and subsurface conditions within and adjacent to the RAA boundary (Figure 2-1). CPTs were selected because they are an effective exploratory technique that can be used to collect continuous soil type and property data. Mud-rotary drilling was selected because the drilling mud used for mud-rotary drilling prevents soil heave in the borehole. Heave can obscure the results of SPT.

The CPT measures tip resistance, sleeve friction, and pore pressure essentially continuously to the total depth of the borehole. These three parameters are used to estimate the soil behavior type, which typically correlates well with stratigraphy obtained from drilling and sampling in a collocated mud-rotary borehole. CPT parameters will also be correlated with other important soil parameters used in geotechnical analysis and design, such as sediment shear strength. No sediment samples are collected with the CPT.

The three mud-rotary boreholes (identified as SPT on Figure 2-1) will be collocated with three of the CPTs (identified as CPT on Figure 2-1) to allow development of site-specific correlations between CPT parameters and parameters based on sampling and laboratory testing. The collocated explorations were selected strategically based on existing subsurface information such that correlations for both cohesive and granular soils can be established.

All geotechnical explorations will be advanced to bedrock refusal. Based on existing basalt surface information for the site, bedrock will be encountered at relatively shallow depths. The sediment cover between the shoreline and the existing docks is on the order of 20 to 40 ft. The sediment cover in the channel is only on the order of 2 to 10 ft. Sediment cover is important for the feasibility of installing sheet pile structures.

In the mud-rotary boreholes, SPTs will be performed in the boreholes continuously or at 2.5-ft intervals for the first 20 ft of drilling and at 5-ft intervals thereafter. The SPT is an *in situ* testing technique that is used to estimate soil density of granular material and consistency of cohesive material. Correlations of SPT results with soil parameters are used in geotechnical analysis and

design. Disturbed split spoon samples will be collected for visual soil/sediment classification during SPT. Laboratory testing, consisting of index property testing for soil/sediment classification, will be conducted on selected split spoon samples (refer to Geotechnical Testing Strategy below).

Relatively undisturbed, thin-wall tube samples (Shelby tubes) will also be collected in the mud-rotary boreholes, for advanced laboratory testing (consolidation and shear strength testing) and index property testing on selected samples. Shelby tubes will be collected using a piston sampler (Osterberg Sampler or GUS) to ensure proper sample recovery and minimization of sample disturbance. Shelby tubes will be handled with utmost care so as to minimize further sample disturbance after retrieval. Sample disturbance can obscure the results of advanced geotechnical testing, including shear strength and consolidation parameters.

The preferred sequence for borehole installation is to install CPTs first where a CPT borehole is collocated with a mud-rotary borehole (see CPT -9, CPT-10, and CPT-13 on Figure 2-1). If the CPT is performed first, the stratigraphy at that location is already known prior to mud-rotary drilling, and the Shelby tube sampling depths can be targeted more easily. Shelby tubes will only be collected in cohesive material (i.e., silt and clay). Based on existing subsurface information, relatively thick deposits of cohesive material are expected to be encountered in borings SPT-1 and SPT-3. Shelby tube sampling will, therefore, likely be focused on these two locations. More than one borehole may be required at the mud-rotary locations to allow for undisturbed sampling and/or to provide enough sediment for all proposed tests.

In one of the mud-rotary boreholes (SPT-1; Figure 2-1), rock coring will be performed to 20 ft below the bedrock contact elevation to determine the quality of the rock. The constructability of certain structures may depend on the “rippability” of the bedrock at the site; therefore, unconfined compressive strength and point load index testing of rock samples will be conducted (see Section 2.2.2.3).

The proposed rationale, test parameters, and laboratory methods for each geotechnical boring is presented in Table 2-4 and the QAPP (Appendix B).

2.2.2.3 Geotechnical Testing Strategy

The selection of samples for geotechnical testing will be determined on the basis of observed lithology, as required to characterize the observed range of lithologies and associated geotechnical conditions critical to the selection, evaluation, and design of candidate removal action technologies (Table 2-1). Target sample intervals in the SPT borehole will be determined in the field based on the interpretation of the collocated CPT explorations, which will be advanced prior to the SPT geotechnical boring. The geotechnical testing program will include the following parameters:

- Grain-size analysis by ASTM-D422

- Atterberg limits by ASTM-D4318
- Specific gravity by ASTM-D854
- Moisture content by ASTM-D2216
- Organic content by ASTM-D2974.
- Consolidation by ASTM D 2435 (Method B)
- UU triaxial shear stress by ASTM-D2850
- CU triaxial shear stress by ASTM-D4767
- Unconfined compressive strength (rock) by ASTM D-7012
- Point load index (rock) by ASTM-D5731
- Hydraulic conductivity by ASTM-D5084.

2.2.3 Waste Disposal Evaluation

2.2.3.1 Rationale

Representative large-volume samples are required for disposal design requirements (USEPA/USACE 1998). The assessment of offsite landfill disposal will be performed with landfill-specific acceptance criteria including hazardous waste determinations (i.e., TCLP).

2.2.3.2 Sampling Strategy

Two large-volume samples will be composited from each of seven boreholes located between Dock 1 and Dock 2 (WB-35, WB-36, WB-37, WB-39, WB-41, WB-42, and WB-43; Table 2-3). These areas are within or immediately downstream of the highest DDx concentrations in sediments within the RAA boundary. The composite sample analyses will provide data for sediment that could require disposal as part of the removal action. Figure 2-1 presents the proposed boring locations for each composite sample. Table 2-3 presents the compositing intervals for each large-volume sample. A total of 14 composite samples will be collected—two from each borehole.

2.2.3.3 Analytical Strategy

A representative sample of the composite sediment described above will be analyzed for hazardous waste determination and used to assess landfill disposal options. Composite sediment samples will be analyzed for the following:

- TCLP for standard TCLP VOCs, SVOCs, metals, pesticides, and herbicides (42 individual chemicals using EPA SW-846 methods)

- Asbestos (EPA Method 600/R-93-116).

Additional testing associated with disposal at a solid waste landfill may also be performed. These analyses may include:

- PCB Aroclors by EPA Method SW846-8082
- PCDD/Fs.

2.2.4 Debris Survey, Dock Encumbrances, and Utilities

There are two large docks at the Site within the RAA boundary area, both of which have been out of service since 2001. The docks are primarily timber construction (but each includes four large concrete dolphins), supported by a dense network of timber, steel, and concrete pilings. Three stormwater outfall structures extend into the preliminary RAA boundary. The dock and outfall structures will likely be removed as part of the removal action, as their presence will impact the feasibility of sediment capping or dredging. The site characterization program will include a survey of these structures to verify their condition and catalogue the type and quantity of construction materials. A historical review will be conducted to determine the extent of building and demolition debris in the area currently occupied by the docks and outfalls. In addition, the removal of large obstructions, such as the existing docks, that could affect the implementability of in-water removal and/or remedial actions will be evaluated in the EE/CA.

2.2.5 Future Sampling

The following sections briefly describe future sampling of surface water, groundwater, TZW, and biota. Although the sampling is not part of this FSP, a brief description of the objectives for sampling these media is presented below. The timing and details of these sampling activities will be submitted as addenda to this FSP and the QAPP after the EE/CA as specified below.

2.2.5.1 Water Quality/Chemical Mobility Testing During Dredging and Disposal

Representative sediment from areas that could be dredged will be collected in the future to assess chemical mobility during sediment dredging and disposal. This will consist primarily of elutriate testing (dredging elutriate testing and effluent elutriate testing) on representative dredged material to provide an assessment of contaminant mobility during dredging and disposal operations. However, this sampling will be delayed until after the removal area/removal action is selected so that it is better understood which specific tests, models, and sample locations are required. The water quality and chemical mobility testing will be conducted during the EE/CA design phase.

2.2.5.2 Surface Water

Future sampling of surface water will be conducted to provide baseline conditions and post-removal action monitoring to determine if there are any significant impacts during and after the in-water removal action. In addition, existing and future surface water sample data will provide information on potential Site recontamination from upstream water. The pre- and post-removal action surface water sampling will be included as an element of the removal action work plan. Pre-removal action sampling will be implemented prior to removal action activities.

2.2.5.3 Groundwater and Transition-Zone Water

Future sampling of groundwater and TZW will be required to verify the effectiveness of the Upland Source Control interim remedial measures (IRMs). The future sampling necessary for the NTCRA will depend on the selected removal action. The purpose of the sampling for the Upland Source Control IRMs will be to monitor groundwater conditions upland (upgradient) of the planned cutoff wall and in the shoreline area immediately downgradient of the planned groundwater cutoff wall. The timing and details of this sampling activity will be developed in coordination with the Upland Source Control IRMs and the selected removal action. Post-removal action TZW monitoring will be included as an element of the removal action work plan.

2.2.5.4 Biota

Future biota sampling will be needed for several objectives including, but not limited to, 1) identifying baseline conditions in biota before the removal action; 2) assessing the short term impacts of the removal action on biota contaminant levels; and 3) assessing the long-term effectiveness of the removal action. The details of this sampling activity will be developed in coordination with the selected removal action. Baseline and post-removal action biota monitoring will be included as an element of the removal action work plan.

3 FIELD SAMPLING METHODS

This section presents the field sampling methods to be used by Integral and its subcontractors for the RAA characterization. In general, field sampling methods will follow the standard operating procedures (SOPs) listed in Attachment A. Attachment B contains field forms and examples of chain-of-custody forms, sample labels, custody seals, and logbooks. All sampling will be conducted in accordance with the quality assurance (QA) procedures outlined in the QAPP. Safety guidelines are presented in the site health and safety plan. General guidelines for conducting the field work are described in the following sections.

3.1 HORIZONTAL AND VERTICAL CONTROL METHODS

3.1.1 Utility Survey

Prior to commencing field activities, a utility survey will be conducted to identify all known in-water utilities within the study area. Arkema representatives will be contacted regarding the locations of the private utilities in the study area, including stormwater outfalls and other utilities associated with former plant operations. The Oregon Utility Notification Center (1-800-332-2344) will be contacted to locate public utilities in the study area. If proposed sample locations interfere with utilities, alternate locations will be determined in consultation with the LSS Project Team, as designated in the Final EE/CA Work Plan.

3.1.2 Surface Debris Survey

A visual surface debris survey will be conducted to catalogue and identify the locations of outfalls, pilings, concrete, and other debris within the preliminary RAA boundary. The purpose of the survey is to identify any debris or structures that could affect the implementation of the Final EE/CA Work Plan and potential in-water removal and/or remedial actions.

The survey will be conducted during a low river stage when the riverbank and sediments are most visible. The debris survey in the in-water portion of the Site will be conducted using a small boat equipped with a differential global positioning system (DGPS) unit with an accuracy of approximately ± 1 to 2 meters. The riverbank area will be surveyed using a DGPS unit after blackberries and other vegetation are removed. The DGPS unit will be used in accordance with SOP 1.

The DGPS beacon will be located directly on top of the structure or debris and the horizontal location of the debris will be recorded in latitude and longitude (North American Datum [NAD] 1983) in the field and converted to state plane coordinates (Oregon North, International Feet). Dense areas of debris will be mapped as areas rather than discrete points. Each structure or

piece of debris will be photodocumented and a description (e.g., type of debris, size) will be recorded in the field logbook.

3.1.3 Sample Locations

The horizontal coordinates of each sample station are specified in Tables 2-3 and 2-4. The barge will be guided to the station locations using a DGPS unit with an accuracy of approximately ± 1 meters. The DGPS beacon will be positioned where the drilling will occur (i.e., moon pool). The horizontal location of the station will be recorded in latitude and longitude (NAD 1983) in the field and converted to state plane coordinates (Oregon North, International Feet). Navigation and positioning will follow guidelines in SOP 1.

The mudline elevation at each station will be calculated using a staff gauge attached to one of the docks prior to the field effort (location to be determined). Prior to commencing work, the elevation of the staff gauge will be surveyed relative to the NAVD88 benchmark by an Oregon licensed professional land surveyor. The mudline depth from the water surface will be measured with a sounding device (e.g., weight tied to the end of a fiberglass tape measure) to the nearest 0.1 ft. The water surface elevation will be determined from the staff gauge. The mudline elevation will be calculated as the staff gauge elevation of the river minus the depth to mudline in feet.

The following parameters will be documented in the field logbook at every sample location:

- Horizontal location using a DGPS unit
- Depth to mudline from river level
- River level measured on surveyed tide staff gauge on Arkema dock (measurement must be made within 0.5 hour of the mudline measurement)
- Time and date.

3.2 SAMPLING METHODS

Sampling during this field effort will consist of surface and subsurface sediment sampling and large volume river water samples to be used for dredge material water quality tests.

3.2.1 Sediment Boreholes

3.2.1.1 General Guidelines

A hollow-stem auger (or equivalent) drill rig positioned on a barge will be used to complete the sediment boreholes for sediment quality sampling. The boreholes will be drilled through a moon pool (or equivalent access location) on the barge. Samples will be collected continuously

as detailed in Table 2-3 to bedrock or refusal using a split spoon sampler or a GUS or Osterberg Sampler equipped with a stainless-steel or aluminum Shelby tube. A large-volume split-spoon sampler may also be used for sampling. All chemistry samples that are not identified for analysis will be archived at the analytical laboratory. The drilling and sampling procedures will follow SOP 3, except for the use of conductor casing on selected boreholes, as described below.

A mud-rotary (or equivalent) drill rig positioned on a barge will be used to complete the SPT geotechnical investigation boreholes. The SPT boreholes will be drilled through a moon pool (or equivalent access location) on the barge. SPTs will be performed in the boreholes continuously or at 2.5-ft intervals for the first 20 ft of drilling and at 5-ft intervals thereafter to bedrock or refusal. A GUS or Osterberg Sampler equipped with a stainless-steel or aluminum Shelby tube, or a large-volume split-spoon sampler may be used for sampling. The drilling and sampling procedures will follow SOP 3, except for the use of conductor casing on selected boreholes, as described below.

A CPT (or equivalent) rig positioned on a barge will be used to complete the CPT geotechnical explorations. The CPT explorations will be performed through a moon pool (or equivalent access location) on the barge. CPTs will be performed continuously to bedrock or refusal. The CPT procedures will follow SOP 3, except for the use of conductor casing on selected boreholes, as described below.

Target depths for geotechnical sampling (relatively undisturbed Shelby tube samples) will be based on the lithology observed at the collocated CPT exploration. The preferred sequence for geotechnical explorations is to install CPTs first where a CPT borehole is collocated with a mud-rotary borehole (see CPT -9, CPT-10, and CPT-13 on Figure 2-1). If the CPT is performed first, the stratigraphy at that location is already known prior to mud-rotary drilling, and the Shelby tube sampling depths can be targeted more easily. Shelby tubes will only be collected in cohesive material (i.e., silt and clay). Based on existing subsurface information, relatively thick deposits of cohesive material are expected to be encountered in borings SPT-1 and SPT-3. Shelby tube sampling will, therefore, likely be focused on these two locations. More than one borehole may be required at the mud-rotary locations to allow for undisturbed sampling and/or to provide enough sediment for all proposed tests.

The mudline elevation at each station will be calculated using a tide staff gauge attached to one of the docks, as described in Section 3.1.3. The tide staff gauge will be monitored periodically during drilling activities and adjustments to sample intervals will be made as necessary based on river stage.

3.2.1.2 Conductor Casing

Conductor casing will be employed for all boreholes to recover the majority of the sediment cuttings. Steel conductor casing will be chosen with an inside diameter that is slightly larger

than the outside diameter of the hollow-stem auger (i.e., approximately 1 to 2 in.) so that the majority of the cuttings are extruded to the top of the casing on the barge deck. The conductor casing will be pushed approximately 2 ft into the sediment and will be securely attached to the barge deck using a clamping mechanism so it does not drop when drilling commences.

To contain the sediment cuttings as they surface during drilling activities, the top of the conductor casing will protrude through a 4-ft by 8-ft sheet of $\frac{3}{4}$ -in. plywood that has a 2-in. by 6-in. frame attached. The sediment cuttings will be shoveled into properly labeled, U.S. Department of Transportation (DOT)-approved, 55-gallon steel drums and handled according to specifications in Section 3.8. Care will be taken to minimize any spilling of the sediment. The conductor casing will be retrieved after the augers are retrieved and the borehole has been grouted.

When the borehole is at depth and the augers are ready to be removed from the conductor casing, the augers will be rotated rapidly to bring as much sediment to the top of the conductor casing as possible.

Conductor casing will not be used for CPT boreholes which do not require the removal of sediment during explorations.

3.2.1.3 Logging and Sampling

Sediments from each borehole will be continuously collected and logged by a licensed geologist using ASTM (2000) guidelines, as described in SOP 4. Lithologic logging will include observations of bioturbation, where observed. Each sediment sample that is collected for potential chemical analysis will be processed in accordance with SOP 3. In addition, each sample will be screened for VOCs using an organic vapor meter (OVM) prior to mixing, in accordance with SOP 12. Each sediment sample for potential chemical analysis will be processed (i.e., mixed and composited) in accordance with SOP 2 (Attachment A). After processing³, samples will be placed in the appropriate containers listed in Table 3-1 and labeled in accordance with Sections 3.3 and 3.5 and SOP 5. Samples for potential chemical analysis will be immediately placed in a cooler with ice for preservation. Additional QA guidelines, including sample handling and the collection of duplicate and rinsate blank samples, are presented in the QAPP. Sediment samples collected for the geotechnical investigation will not require mixing nor will they require preservation on ice for shipment.

The large-volume sediment sample for the waste disposal characterization will require the collection of composite samples from seven boreholes (Section 2.2.3). An equal volume of representative sediment will be collected from each composite interval subinterval (approximately 2 ft) and mixed in a large stainless-steel pot using a power mixer or equivalent

³ With the exception of samples collected for VOCs.

device. All materials contacting the sediment will be decontaminated in accordance with Section 3.7 and SOP 9.

3.2.1.4 Borehole Abandonment

The boreholes will be abandoned with a high-solids bentonite grout, mixed according to the manufacturer's specifications, and placed inside the augers through a tremie pipe as the augers are withdrawn. Once the borehole is grouted, the augers will be brought to the barge deck, and any residual sediment left on the augers will be transferred to properly labeled, DOT-approved, 55-gallon drums. The conductor casing (if used) and augers will be decontaminated using a hot pressure-washer in accordance with Section 3.7 and SOP 9.

3.3 SAMPLE IDENTIFICATION

Sediment samples will be assigned an individual sample identification number in the following manner:

- ARK-WB-##-depth

Where:

ARK = Arkema

WB = Boring

= Station number

Depth (e.g., 021 = 0 to 2 ft below mud surface).

Sediment sample processing will occur on the barge as described in the following sections. Sample processing methods are intended to result in high-quality samples that meet the program's QA objectives. Guidelines for sample handling and storage are presented in the QAPP. All samples will be placed immediately in a cooler with ice to preserve them at $4\pm 2^{\circ}\text{C}$ and will be kept at this temperature at all times. All samples will be labeled and identified in accordance with SOP 5.

Field QC samples (i.e., equipment rinsates and field blanks) will be assigned an individual sample identification number in the following manner:

- ARK-EB-## (Equipment Blank - Sample Number starting at 01).

Duplicate sediment samples delivered to the laboratory will be given a blind sample identification (to be determined) that will correspond to the numbering system described above.

3.4 SEDIMENT PROCESSING

Compositing will be performed within individual locations to ensure that adequate sediment is available for the required analyses.⁴ Power Grab and split-spoon samples not used for analysis will be managed in accordance with applicable investigation-derived waste requirements as described in SOP 11.

Sediment composite samples will be processed according to the following step-by-step procedure and SOPs 2 and 3:

1. Screen a representative subsample of all sediment samples collected for volatile organics using an OVM following procedures in SOP 12. Do not composite or homogenize the sample before screening.
2. Transfer sediment from split-spoon to a clean, stainless-steel bowl and cover with aluminum foil.
3. Stir the composite sample until the sample is of uniform color and texture. If any material (e.g., shells, rocks) has to be removed from the sample, note it in the field logbook or on the sample description sheet.
4. Fill jars for physical and chemical analyses.
5. Seal each glass container in a plastic bag in case of breakage. Place in ice chest and pack samples to minimize the chances of breaking.
6. Decontaminate the equipment as described in Section 3.7 and SOP 9.
7. Collect excess sediment from the composite and dispose of as investigation-derived waste, as discussed in Section 3.8 and SOP 11.

3.5 SAMPLE CONTAINERS AND LABELS

Guidelines for sample handling and storage are presented in the QAPP. All samples will be placed immediately in a cooler with ice to preserve them at $4\pm 2^{\circ}\text{C}$ and will be kept at this temperature at all times. All samples will be labeled and identified in accordance with SOP 5.

3.5.1 Sampling Handling Procedures

The following sections describe documentation with sampling and handling procedures. Details are outlined in SOP 6.

⁴ Compositing and homogenizing is not appropriate for the analysis of volatile organics. Discrete samples will be collected only for analysis of volatile organics in soil and sediments.

3.5.1.1 Sample Labels

Sample containers will be clearly labeled with waterproof black ink at the time of sampling. Sample labels will contain the following information:

- Sample identification numbers
- Sample date
- Sample time
- Preservation used, if any (this information will also be included on the chain-of-custody form)
- Initials of sampling personnel.

The sample label will be attached to the sample container prior to, or just after, the container is filled and the lid secured. As an added measure of security, the finished label will be covered with clear packaging tape to protect the ink from moisture and to tightly secure the label to the sample container. Information on the sample label must match the information on the chain-of-custody form and in the site logbook for each sample.

3.5.1.2 Custody Seal

Custody seals will be used on sample shipping containers (coolers) that will either be shipped or sent by messenger to the laboratory as described in SOP 7. Custody seals will be attached to the lid and body of the coolers to detect any tampering during shipment. The custody seals will be signed and dated by the sampler or sample shipper. Custody seals are not required for samples delivered by hand directly to the lab unless left unattended.

3.5.1.3 Sample Summary Log

Sample summary logs will be maintained by the field team leader and used to keep track of all phases of the sampling and analysis process for all individual samples. The sample summary logs will include sample collection date(s), sample delivery date(s), the date(s) analytical results are received, laboratory sample delivery group, and laboratory work order number. The sample summary logs will also identify blind sample numbers given to the laboratory with corresponding numbering in the field.

3.5.1.4 Sample Custody/Tracking Procedures

The samples collected must be traceable from the time they are collected until their derived data are used in the final report. In general, the following provisions apply to sample handling and are described in SOPs 6 and 7:

- The field team leader, or sampler, will be responsible for the care and custody of the samples collected until they are properly transferred or dispatched to the laboratory.
- All appropriate documentation forms will be used, including sample labels, chain-of-custody forms, sample logs, and any other appropriate forms. Documentation will be completed neatly using waterproof black ink.
- When transferring possession of samples, the individuals relinquishing and receiving them will sign, date, and note the time on the chain-of-custody form. Containers shipped by common carrier will have the chain-of-custody form enclosed in a watertight container (e.g., plastic resealable bag) and placed in the container prior to sealing.
- Samples will be packaged properly according to the current DOT requirements and promptly dispatched to the laboratory for analysis. Sample containers will be packed in coolers (or other shipping containers) with a low-density packing material, such as bubble wrap, and Blue Ice[®] or its equivalent. The coolers will be securely sealed.
- Each cooler will be accompanied by its own chain-of-custody form identifying its contents. A copy of the chain-of-custody form will be retained by the field team leader for inclusion in project records.
- For coolers shipped via express delivery service, custody seals will be affixed to the outside of the coolers (shipping containers). The field team leader, sampler, or shipper will sign and date the custody seals.
- All samples will be shipped via express delivery for overnight delivery or hand delivered to the laboratory.

3.6 FIELD DOCUMENTATION PROCEDURES

The primary methods of documentation that will be used for this project include site logbook, photo logs, sample log forms, field change request forms, and sample tracking forms. A description of each of these documentation methods is provided in the following sections. Example field forms are presented in Attachment B.

3.6.1 Field Logbooks

Field logbooks will be used to document all field sampling activities performed at the project site, as described in SOP 8. The logbooks will contain the date, time, and description of all field activities performed; names of personnel; weather conditions; the names of visitors to the Site; areas where photographs were taken; and any other data pertinent to the project. The site logbooks will also contain all sample collection and identification information and (if appropriate) a drawing of each area sampled, along with the exact location (coordinates) of where the sample was collected. The sampling information will be transferred to sample log forms when the sampler returns to the site office. The logbook is the official, legal record of site

activities, and will serve as the key to sample designations and locations. It will include the date, time, river stage, depth to mudline, horizontal DGPS coordinates, site/sample location, sample identification number, sample matrix, how the sample was collected, any comments, and the sampler's name. In addition, the logbook will document deviations from the project plans and health and safety tailgate meeting minutes.

Requirements for logbooks include the following:

- Logbooks will be sturdy, weatherproof, and bound, with consecutively numbered pages. If multiple logbooks are used, they will be numbered sequentially.
- Entries will be made legibly with waterproof, black (or dark) permanent ink.
- Removal of any pages, even if illegible, will be prohibited. Any mistakes will be crossed out with a single line, initialed, and dated.
- Unbiased, accurate language will be used.
- Entries will be made while activities are in progress or as soon afterward as possible (the time of the observation will be noted and the time that the notation is made will be noted if significantly later than the observation time).
- Each consecutive day's first entry will be made on a new, blank page. Each page of the field logbook will be numbered, dated, and signed by the author.
- The date will appear at the top of each page. The time, based on a 24-hour clock (e.g., 0900 for 9:00 a.m. and 2100 for 9:00 p.m.), also will appear for each entry.
- Blank pages, if any, will be marked "page intentionally left blank."

An example of the field logbook can be found in Attachment B.

3.6.2 Photo Documentation

Digital photographs will be taken at sampling locations and of selected samples. These photos will help to identify the sampling locations and will provide an accurate visual record of the material being sampled. All photographs taken will be identified in the field logbooks (preferably in a separate section of the book set aside for that purpose). Photographic logs will contain, at a minimum, the file number, date, time, initials of the photographer, and a description of the image in the photograph.

3.6.3 Sample Collection Information Form

Sampling logs and collection forms will be used to document site and sample characteristic data, which should agree with the information recorded in the site logbooks. Field personnel are required to fill out one sample log form for each sample collected. A copy of these forms will be stored in the field office or field files, with the original stored in the project file. A copy

of these forms will also be included in the final data report and other documents, as appropriate. At a minimum, the log for each sample will contain the sample number, the date and time of sample collection, and a description of the sampling site, as well as the physical characteristics of the sample, the planned analysis, and the initials of the sampler. Example field forms are located in Attachment B.

3.6.4 Field Change

The field team leader will be responsible for all environmental sampling activities, and will occasionally be required to adjust the field program to accommodate site-specific needs after consultation with the project manager and/or QA manager. The field team leader will notify the project manager of any significant field changes. The project manager will immediately notify EPA for approval (verbal or written) of any significant field changes. This notification/approval will typically occur via e-mail or telephone, to avoid suspension of field work. The project manager and/or field team leader will follow up these conversations with an e-mail and field change request form that summarizes the approved changes for EPA signature. When it becomes necessary to modify a program or task, the changes will be documented in the field logbook.

3.6.5 Sample Tracking Forms

Sample tracking is an important aspect of field investigation activities, as it documents the proper handling and integrity of the samples. Sample tracking forms for the project will include chain-of-custody forms, sample labels, custody seals, and sample summary logs. Example forms are located in Attachment B.

3.6.6 Chain-of-custody Form

The chain-of-custody form is used to document the history of each sample and its handling from its collection through all transfers of custody until it reaches the analytical laboratory. Internal laboratory records will document custody of the sample from the time it is received in the lab through its final disposition. The chain-of-custody form will be filled out after the samples have been collected and will be double-checked prior to the transport of the samples to the laboratory. At a minimum, the chain-of-custody form will contain the following information and follow procedures described in SOP 7:

- Name of project
- Names of sampling personnel
- Sample identification numbers
- Collection date and time

- Number and type of containers per sample
- Sample matrix
- Sample preservation, if any
- Analysis requested.

The completed chain-of-custody form will be placed in a large capacity Ziploc® bag and secured to the sample transport container. If coolers are used to transport samples, the chain-of-custody form will be taped to the underside of the cooler lid.

3.7 DECONTAMINATION PROCEDURES

Equipment decontamination will be performed using procedures outlined below and in SOP 9. Site personnel will perform decontamination of all equipment prior to removal from the Site and between sample locations. All decontamination fluids will be containerized in properly labeled, DOT-approved, 55-gallon drums. If any solvents or acids are utilized during the decontamination process, they will be containerized in separate, properly labeled 5-gallon containers. Investigation-derived wastes will be handled in accordance with Section 3.8.

The hollow-stem augers, drill rods, and conductor casing will be decontaminated with a hot water pressure washer.

All non-disposable components of the sediment coring equipment (e.g., split spoons), or other equipment used to collect sediment samples that contacts the sediments, will be decontaminated as follows:

- Potable water rinse
- Alconox™/Liquinox™ detergent wash
- Potable water rinse
- Solvent rinse (if visible contamination is observed)⁵
- Deionized water rinse
- Air dry.

As specified in SOP 10 and the QAPP, rinsate blank samples will be collected once per sampling type (e.g., Power Grab sampling) to document the level of decontamination of sampling equipment. Two equipment rinsate blanks will be collected from the first two cores and will be expedited to the extent practicable (given the number of parameters and low-level methods required) to determine the effectiveness of the procedure. In the event contamination is

⁵ Solvent rinse will include the use of clean paper towels to remove water followed by a hexane rinse. The hexane solvent rinse is only required if visible non-aqueous phase liquid is observed on the sampling equipment.

detected in the rinsate blanks, a field change to the decontamination procedure would be implemented as outlined in Section 3.6.4.

All disposable personal protection equipment (PPE) and liquids generated as a result of decontamination processes will be containerized and handled as investigation-derived wastes, as discussed in Section 3.8 and SOP 11.

3.8 INVESTIGATION-DERIVED WASTES

The primary waste streams to be generated during this project and the proposed storage/disposal methods are described below. LSS is responsible for the proper characterization and disposal of investigation-derived waste streams.

3.8.1 Sediment Cuttings and Excess/Rejected Sediment Samples

Sediment cuttings from drilling activities will be placed in properly labeled, DOT-approved, 55-gallon drums on the barge deck. The drums will be lifted onto one of the docks at the end of the field event, staged on site, and characterized for offsite disposal in accordance with state and federal regulations.

Sediment samples that are rejected and/or determined to be in excess of what is required to conduct analytical sampling will be containerized in 55-gallon drums and managed as described in SOP 11.

3.8.2 Decontamination Wastewaters

Liquid wastes (i.e., decontamination waters) will be potentially contaminated with Site chemicals, including DDx. The presence of any of these constituents in the wastewaters is expected to be diluted; therefore, the wastewaters are not expected to be classified as hazardous waste. Decontamination waters will be containerized in 55-gallon drums as described in SOP 11. The drums will be lifted onto one of the docks at the end of the field event, staged on site, and characterized for offsite disposal in accordance with state and federal regulations.

For solvents (e.g., methanol and hexane), decontamination activities will be conducted so as to minimize the potential for spills/releases of wastewaters. Spent decontamination solvents must be stored in leak-proof container(s) with secured lid(s). The lid will remain closed except when the container is being used for decontamination activities. It is anticipated that liquid wastes will be placed in 5-gallon buckets or similar containers for characterization and offsite disposal.

3.8.3 Personal Protective Equipment/Miscellaneous Debris

Sediment sampling activities will generate PPE and miscellaneous debris. Gross contamination will be removed from these items, and the items will be placed in plastic bags. Interim storage of these materials in plastic bags is acceptable. The bags will be disposed of at a solid waste facility dumpster at the end of each day.

4 REFERENCES

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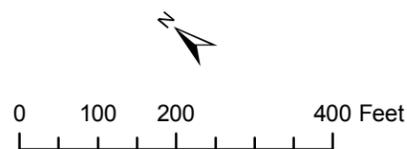
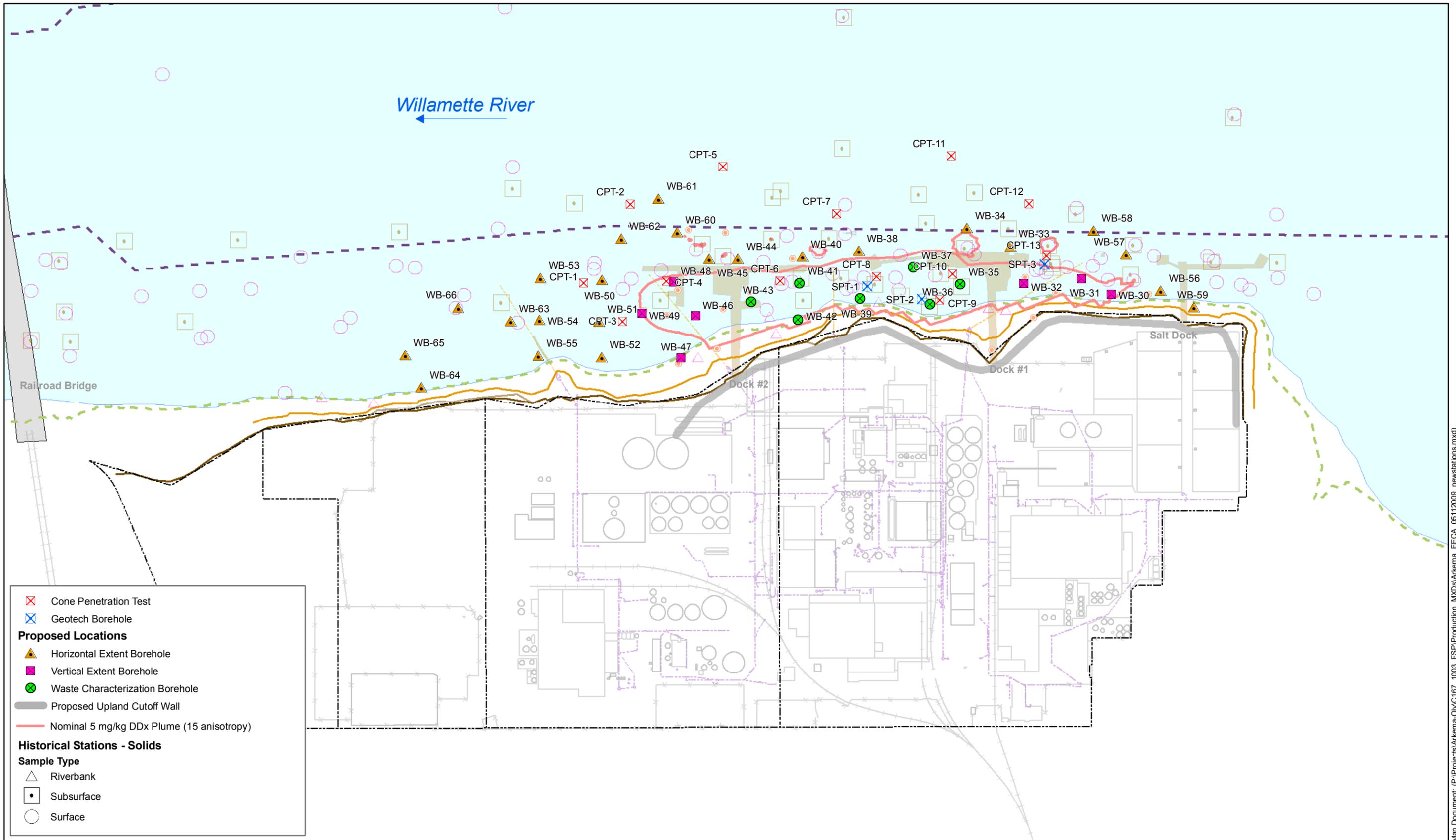
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USEPA. 2000. Methods for measuring the toxicity and bioaccumulation of sediment-associated contaminants with freshwater invertebrates. Second Edition. EPA 600/R-99/064. U.S. Environmental Protection Agency, Office of Research and Development, Duluth, MN.

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FIGURES



FEATURE SOURCES:
 Bathymetric Information: Multibeam bathymetric survey conducted by David Evans and Associates, Inc. from February 6 - March 6, 2004. Contours were derived from a Digital Terrain Model (DTM) based on a three-foot grid of multibeam data.
 Vertical Datum: North American Vertical Datum of 1988 (NAVD88).
 Horizontal Datum: North American Datum of 1983 - 91 adjusted (NAD83/91), State Plane Coordinate System (SPCS), Oregon North Zone.
 Units: International Feet.
 Basemap: Basemap features updated in 2006 by David Evans and Associates. Ordinary high water line, top of bank, and other site features surveyed in April 2006. Most buildings and structures on the Arkema site have been demolished or removed.
 OHW and Top of Slope lines were created from the April 2006 DEA survey, the +12ft contour line was derived from the combined lidar/bathymetry grid.
 Lot Lines: Created by importing pdf file from ERM, georeferencing to CAD lines (RMS error = 2.3042) and heads-up digitizing the lot lines.

- E-Sewer-L
- Storm Drain
- 12ft Contour
- Bridges
- Navigation Channel
- River
- Property and Lot Boundaries
- Docks and Structures 2005
- Ordinary High Water
- Top of Bank

Figure 2-1
Arkema EE/CA
Proposed Sediment
Sampling Locations

TABLES

Table 2-1. Sampling/Analysis Methods – Potential Remedial Action Technologies^a

Sampling/Analysis Tools	Monitored Natural Recovery	Thin-Layer Placement	Isolation Cap	Sediment Dredging/Disposal – Characterization	Hydraulic Containment
Sediment Samples					
Chemical Analyses (COIs, Conventional ^b)	X	X	X	X	--
Physical Analyses (Grain Size)	X	X	X	X	--
Geotechnical Analyses					
Grain Size	--	--	X	X	X
Standard Penetration Test	--	--	X	X	X
Atterberg Limits	--	--	X	X	X
Specific Gravity	--	--	X	X	X
Moisture Content	--	--	X	X	X
Consolidation	--	--	X	X	X
Shear Strength ^c	--	--	X	X	X
Unconfined Compressive Strength (Rock)	--	--	--	X	X
Point Load Index (Rock)	--	--	X	X	X
Hydraulic Conductivity	X	X	X	--	X
Debris Survey	--	X	X	--	X

Notes:

- ^a Once the final RAA boundary is established, several factors pertaining to the area will be examined in the EE/CA report, including constructability, short-term impact, recontamination potential, permanence of the removal action, and proposed institutional controls.
- ^c May include *in situ* vane shear, cone penetration testing, and/or laboratory shear strength testing.
- ^d Suite of conventional and chemical analyses including anions/cations, TOC, COIs.
- ^e The ATT is required by Oregon for all applicable pesticide wastes in determining its acceptability into a Subtitle D Landfill.

- ✓ Sufficient data are available and no additional data and evaluation are needed for the sampling or analysis tool.
- X Insufficient data are available and additional data and evaluation are needed for the sampling or analysis tool.

-- Data not required for the EE/CA.
 ATT – aquatic toxicity test
 COI – constituent of interest

EE/CA – engineering evaluation/cost analysis
 RAA – remedial action area
 TOC – total organic carbon

Table 2-2. Sampling/Analysis Methods – Potential Disposal Alternatives^{a,b}

Sampling/Analysis Tools	Onsite Disposal		Offsite Disposal
	Nearshore CDF	Onsite Landfill	Subtitle C/D Landfill
Sediment Boreholes			
<i>Chemical Analyses (COIs, TOC)</i>	X	X	X
<i>Index Parameters</i>			
Grain Size	X	X	X
SPT	X	X	X
Atterberg Limits	X	X	X
Specific Gravity	X	X	X
Moisture Content	X	X	X
<i>Geotechnical Tests</i>			
Consolidation	X	--	--
Shear Strength ^c	X	--	--
Permeability	X	--	--
Unconfined Compressive Strength (Rock)	X	--	--
Point Load Index (Rock)	X	--	--
<i>Waste Characterization</i>			
RCRA Characteristic/TCLP	--	X	X
ATT	--	X	X

Notes:

^a Once the final RAA boundary is established, several factors pertaining to the area will be examined in the EE/CA report including constructability, short-term impact, recontamination potential, permanence of the removal action, and proposed institutional controls.

^b Chemical analyses that include an evaluation of the leachability of sediment will be conducted on representative composite samples prior to disposal.

^c Includes *in situ* vane shear, cone penetration testing, and/or laboratory shear strength testing.

X – Additional data required for this sampling/analysis tool.

-- Data not required for the EE/CA.

ATT – aquatic toxicity test

CDF – contained disposal facility

COI – constituent of interest

EE/CA – engineering evaluation/cost analysis

RAA – remedial action area

RCRA – Resource Conservation and Recovery Act

SPT - standard penetration test

TCLP – toxicity characteristic leaching procedure

TOC – total organic carbon

Table 2-3. Proposed Sediment Chemistry Boreholes, Analyses, and Rationale^a

Station No.	Proposed X Coordinate	Proposed Y Coordinate	Estimated Sediment Thickness (ft) ^b	Proposed Chemistry Sample Intervals and Parameters ^c	Borehole Rationale
WB-30	7628292.80	701945.99	40	Sample and archive every 2' interval from sediment surface to bedrock. Standard analysis on samples from 8 - 10' bgs interval and below. ^d	Inside horizontal extent of nominal 5 ppm DDx plume, placed to define vertical extent.
WB-31	7628273.94	702029.99	25	Sample and archive every 2' interval from sediment surface to bedrock. Standard analysis on samples from 8 - 10' bgs interval and below. ^d	Inside horizontal extent of nominal 5 ppm DDx plume, placed to define vertical extent.
WB-32	7628169.37	702134.57	25	Sample and archive every 2' interval from sediment surface to bedrock. Standard analysis on samples from 10 - 12' bgs interval and below. ^d	Inside horizontal extent of nominal 5 ppm DDx plume, placed to define vertical extent.
WB-33	7628219.08	702223.72	10	Sample and archive every 2' interval from sediment surface to bedrock. Standard analysis on all samples if WB-34 shows DDx > 5 ppm at any interval.	Outside horizontal extent of nominal 5 ppm DDx plume, placed based on Drill Guide analysis to refine horizontal extent if indicated by WB-34. If location is within horizontal RAA, data will also be used to help define vertical extent in that location.
WB-34	7628183.08	702340.30	5	Sample and archive every 2' interval from sediment surface to bedrock. Standard analysis on all samples.	Outside horizontal extent of nominal 5 ppm DDx plume, placed based on Drill Guide analysis to refine horizontal extent. If location is within horizontal RAA, data will also be used to help define vertical extent in that location.
WB-35	7628063.08	702259.72	40	Sample and archive every 2' interval from sediment surface to 20' bgs, and every 3' interval from 20' bgs to bedrock. Composite and archive one sample using samples from 2' intervals from 0 - 10' bgs and from 10 - 20' bgs. Analyze as follows: Standard analysis for each 3' interval from 20' to bedrock. Expanded analysis + Asb on composite samples from 0 - 10' and 10 - 20'. ^d	Inside horizontal extent of nominal 5 ppm DDx plume, placed to define vertical extent and for waste characterization.
WB-36	7627973.93	702285.44	35	Sample and archive every 2' interval from sediment surface to 22' bgs, and every 3' interval from 22' bgs to bedrock. Composite and archive one sample using samples from 2' intervals from 0 - 10' bgs and from 10 - 22' bgs. Analyze as follows: Standard analysis for each 3' interval from 22' to bedrock. Expanded analysis + Asb on composite samples from 0 - 10' and 10 - 22'. ^d	Inside horizontal extent of nominal 5 ppm DDx plume, placed to define vertical extent and for waste characterization.
WB-37	7628018.50	702379.73	25	Sample and archive every 2' interval from sediment surface to 14' bgs, and every 3' interval from 14' bgs to bedrock. Composite and archive one sample using samples from 2' intervals from 0 - 6' bgs and from 6 - 14' bgs. Analyze as follows: Standard analysis for each 3' interval from 14' to bedrock. Expanded analysis + Asb on composite samples from 0 - 6' and 6 - 14'. ^d	Inside horizontal extent of nominal 5 ppm DDx plume, placed to define vertical extent and for waste characterization.
WB-38	7627960.21	702515.16	5	Sample and archive every 2' interval from sediment surface to bedrock. Standard analysis on all samples if WB-40 shows DDx > 5 ppm at any interval.	Outside horizontal extent of nominal 5 ppm DDx plume, placed based on Drill Guide analysis to refine horizontal extent if indicated by WB-40. If location is within horizontal RAA, data will also be used to help define vertical extent in that location.
WB-39	7627869.35	702432.87	35	Sample and archive every 2' interval from sediment surface to 18' bgs, and every 3' interval from 18' bgs to bedrock. Composite and archive one sample using samples from 2' intervals from 0 - 8' bgs and from 8 - 18' bgs. Analyze as follows: Standard analysis for each 3' interval from 18' to bedrock. Expanded analysis + Asb on composite samples from 0 - 8' and 8 - 18'. ^d	Inside horizontal extent of nominal 5 ppm DDx plume, placed to define vertical extent and for waste characterization.

Table 2-3. Proposed Sediment Chemistry Boreholes, Analyses, and Rationale^a

Station No.	Proposed X Coordinate	Proposed Y Coordinate	Estimated Sediment Thickness (ft) ^b	Proposed Chemistry Sample Intervals and Parameters ^c	Borehole Rationale
WB-40	7627855.64	702616.31	5	Sample and archive every 2' interval from sediment surface to bedrock. Standard analysis on all samples.	Outside horizontal extent of nominal 5 ppm DDx plume, placed based on Drill Guide analysis to refine horizontal extent. If location is within horizontal RAA, data will also be used to help define vertical extent in that location.
WB-41	7627799.06	702576.88	20	Sample and archive every 2' interval from sediment surface to 14' bgs, and every 3' interval from 14' bgs to bedrock. Composite and archive one sample using samples from 2' intervals from 0 - 6' bgs and from 6 - 14' bgs. Analyze as follows: Standard analysis for each 3' interval from 14' to bedrock. Expanded analysis + Asb on composite samples from 0 - 6' and 6 - 14'. ^d	Inside horizontal extent of nominal 5 ppm DDx plume, placed to define vertical extent and for waste characterization.
WB-42	7627725.34	702520.30	35	Sample and archive every 2' interval from sediment surface to 14' bgs, and every 3' interval from 14' bgs to bedrock. Composite and archive one sample using samples from 2' intervals from 0 - 6' bgs and from 6 - 14' bgs. Analyze as follows: Standard analysis for each 3' interval from 14' to bedrock. Expanded analysis + Asb on composite samples from 0 - 6' and 6 - 14'. ^d	Inside horizontal extent of nominal 5 ppm DDx plume, placed to define vertical extent and for waste characterization.
WB-43	7627682.48	702642.03	20	Sample and archive every 2' interval from sediment surface to 18' bgs, and every 3' interval from 18' bgs to bedrock. Composite and archive one sample using samples from 2' intervals from 0 - 8' bgs and from 8 - 18' bgs. Analyze as follows: Standard analysis for each 3' interval from 18' to bedrock. Expanded analysis + Asb on composite samples from 0 - 8' and 8 - 18'. ^d	Inside horizontal extent of nominal 5 ppm DDx plume, placed to define vertical extent and for waste characterization.
WB-44	7627744.20	702739.74	10	Sample and archive every 2' interval from sediment surface to bedrock. Standard analysis on all samples if WB-40 or WB-45 show DDx > 5 ppm at any interval.	Outside horizontal extent of nominal 5 ppm DDx plume, placed based on Drill Guide analysis to refine horizontal extent if indicated by WB-40 or WB-45. If location is within horizontal RAA, data will also be used to help define vertical extent in that location.
WB-45	7627696.20	702796.32	5	Sample and archive every 2' interval from sediment surface to bedrock. Standard analysis on all samples.	Outside horizontal extent of nominal 5 ppm DDx plume, placed based on Drill Guide analysis to refine horizontal extent. If location is within horizontal RAA, data will also be used to help define vertical extent in that location.
WB-46	7627564.19	702727.74	20	Sample and archive every 2' interval from sediment surface to bedrock. Standard analysis on samples from 8 - 10' bgs interval and below. ^d	Inside horizontal extent of nominal 5 ppm DDx plume, placed to define vertical extent.
WB-47	7627456.19	702688.31	30	Sample and archive every 2' interval from sediment surface to bedrock. Standard on all samples.	Between horizontal extent of nominal 5 ppm DDx plume and shoreline, placed to define horizontal and vertical extent.
WB-48	7627593.34	702827.18	15	Sample and archive every 2' interval from sediment surface to bedrock. Standard analysis on samples from 2 - 4' bgs interval and below. ^d	Inside horizontal extent of nominal 5 ppm DDx plume, placed to define vertical extent.
WB-49	7627480.19	702837.46	25	Sample and archive every 2' interval from sediment surface to bedrock. Standard analysis on samples from 6 - 8' bgs interval and below. ^d	Inside horizontal extent of nominal 5 ppm DDx plume, placed to define vertical extent.
WB-50	7627478.47	702972.90	15	Sample and archive every 2' interval from sediment surface to bedrock. Standard analysis on all samples.	Outside horizontal extent of nominal 5 ppm DDx plume, placed based on Drill Guide analysis to refine horizontal extent. If location is within horizontal RAA, data will also be used to help define vertical extent in that location.

Table 2-3. Proposed Sediment Chemistry Boreholes, Analyses, and Rationale^a

Station No.	Proposed X Coordinate	Proposed Y Coordinate	Estimated Sediment Thickness (ft) ^b	Proposed Chemistry Sample Intervals and Parameters ^c	Borehole Rationale
WB-51	7627391.04	702909.47	25	Sample and archive every 2' interval from sediment surface to bedrock. Standard analysis on all samples if WB-50 shows DDx > 5 ppm at any interval.	Outside horizontal extent of nominal 5 ppm DDx plume, placed based on Drill Guide analysis to refine horizontal extent if indicated by WB-50. If location is within horizontal RAA, data will also be used to help define vertical extent in that location.
WB-52	7627325.89	702846.04	30	Sample and archive every 2' interval from sediment surface to bedrock. Standard analysis on all samples if WB-51 shows DDx > 5 ppm at any interval.	Outside horizontal extent of nominal 5 ppm DDx plume, placed based on Drill Guide analysis to refine horizontal extent if indicated by WB-51. If location is within horizontal RAA, data will also be used to help define vertical extent in that location.
WB-53	7627380.75	703096.33	15	Sample and archive every 2' interval from sediment surface to bedrock. Standard analysis on all samples.	Outside horizontal extent of nominal 5 ppm DDx plume, placed based on Drill Guide analysis to refine horizontal extent. If location is within horizontal RAA, data will also be used to help define vertical extent in that location.
WB-54	7627296.75	703029.47	25	Sample and archive every 2' interval from sediment surface to bedrock. Standard analysis on all samples if WB-53 or WB-63 show DDx > 5 ppm at any interval.	Outside horizontal extent of nominal 5 ppm DDx plume, placed based on Drill Guide analysis to refine horizontal extent if indicated by WB-53 or WB-63. If location is within horizontal RAA, data will also be used to help define vertical extent in that location.
WB-55	7627224.75	702972.90	30	Sample and archive every 2' interval from sediment surface to bedrock. Standard analysis on all samples if WB-54 shows DDx > 5 ppm at any interval.	Outside horizontal extent of nominal 5 ppm DDx plume, placed based on Drill Guide analysis to refine horizontal extent if indicated by WB-54. If location is within horizontal RAA, data will also be used to help define vertical extent in that location.
WB-56	7628380.23	701855.13	35	Sample and archive every 2' interval from sediment surface to bedrock. Standard analysis on all samples.	Outside horizontal extent of nominal 5 ppm DDx plume, placed based on Drill Guide analysis to refine horizontal extent. If location is within horizontal RAA, data will also be used to help define vertical extent in that location.
WB-57	7628393.95	701983.71	15	Sample and archive every 2' interval from sediment surface to bedrock. Standard analysis on all samples.	Outside horizontal extent of nominal 5 ppm DDx plume, placed based on Drill Guide analysis to refine horizontal extent. If location is within horizontal RAA, data will also be used to help define vertical extent in that location.
WB-58	7628387.09	702086.57	10	Sample and archive every 2' interval from sediment surface to bedrock. Standard analysis on all samples.	Outside horizontal extent of nominal 5 ppm DDx plume, placed based on Drill Guide analysis to refine horizontal extent. If location is within horizontal RAA, data will also be used to help define vertical extent in that location.
WB-59	7628402.28	701762.98	35	Sample and archive every 2' interval from sediment surface to bedrock. Standard analysis on all samples if WB-56 shows DDx > 5 ppm at any interval.	Outside horizontal extent of nominal 5 ppm DDx plume, placed based on Drill Guide analysis to refine horizontal extent if indicated by WB-56. If location is within horizontal RAA, data will also be used to help define vertical extent in that location.
WB-60	7627695.64	702903.53	10	Sample and archive every 2' interval from sediment surface to bedrock. Standard analysis on all samples.	Outside horizontal extent of nominal 5 ppm DDx plume, placed based on Drill Guide analysis to refine horizontal extent. If location is within horizontal RAA, data will also be used to help define vertical extent in that location.

Table 2-3. Proposed Sediment Chemistry Boreholes, Analyses, and Rationale^a

Station No.	Proposed X Coordinate	Proposed Y Coordinate	Estimated Sediment Thickness (ft) ^b	Proposed Chemistry Sample Intervals and Parameters ^c	Borehole Rationale
WB-61	7627730.35	702995.27	20	Sample and archive every 2' interval from sediment surface to bedrock. Standard analysis on all samples if WB-60 or WB-62 show DDx > 5 ppm at any interval.	Outside horizontal extent of nominal 5 ppm DDx plume, placed based on Drill Guide analysis to refine horizontal extent if indicated by WB-60 or WB-62. If location is within horizontal RAA, data will also be used to help define vertical extent in that location.
WB-62	7627591.50	703002.71	15	Sample and archive every 2' interval from sediment surface to bedrock. Standard analysis on all samples if WB-50 or WB-60 show DDx > 5 ppm at any interval.	Outside horizontal extent of nominal 5 ppm DDx plume, placed based on Drill Guide analysis to refine horizontal extent if indicated by WB-50 or WB-60. If location is within horizontal RAA, data will also be used to help define vertical extent in that location.
WB-63	7627246.85	703084.53	30	Sample and archive every 2' interval from sediment surface to bedrock. Standard analysis on all samples.	Outside horizontal extent of nominal 5 ppm DDx plume, placed based on Drill Guide analysis to refine horizontal extent. If location is within horizontal RAA, data will also be used to help define vertical extent in that location.
WB-64	7626969.15	703151.48	30	Sample and archive every 2' interval from sediment surface to bedrock. Standard analysis on all samples if WB-65 shows DDx > 5 ppm at any interval.	Outside horizontal extent of nominal 5 ppm DDx plume, placed based on Drill Guide analysis to refine horizontal extent if indicated by WB-65. If location is within horizontal RAA, data will also be used to help define vertical extent in that location.
WB-65	7627006.34	703235.78	30	Sample and archive every 2' interval from sediment surface to bedrock. Standard analysis on all samples.	Outside horizontal extent of nominal 5 ppm DDx plume, placed based on Drill Guide analysis to refine horizontal extent. If location is within horizontal RAA, data will also be used to help define vertical extent in that location.
WB-66	7627186.51	703210.09	30	Sample and archive every 2' interval from sediment surface to bedrock. Standard analysis on all samples.	Outside horizontal extent of nominal 5 ppm DDx plume, placed based on Drill Guide analysis to refine horizontal extent. If location is within horizontal RAA, data will also be used to help define vertical extent in that location.

Notes:

^a Separate boreholes will be advanced for geotechnical sampling (see Table 2-4).

^b Sediment thicknesses are estimated based on nearby historical sample stations.

^c Cores will be divided into 2' sections to bedrock or refusal, except for the surface sample that will be collected from 0 - 1'. Composite samples representing the whole length of the 2 - 3' core segments will be collected, mixed to homogeneity (as is possible), and analyzed. In addition, if any field indications of contamination within core sections are noted, discrete samples will be obtained from that portion of core segments that show staining, have odors, show "hits" on a field instrument, etc. All samples that are not analyzed will be archived for possible future analysis.

^d DDx analysis in 2' samples above designated depth interval is not required as it is assumed the upper sediments are within the RAA boundary and will be evaluated in the EE/CA.

Analytes:

Chemistry Standard Analyte List = DDx, conventionals (grain size, total solids, TOC).

Expanded Analyte List = Standard List + SVOCs, PCBs, Dioxins/Furans (D/F), VOCs; full suite of organochlorine pesticides.

Asb = Asbestos

bgs - below ground/sediment surface

DDx - total of 2,4'- and 4,4'-DDD, DDE, and DDT

EE/CA - engineering evaluation/cost analysis

PCB - polychlorinated biphenyl

RAA - removal action area

SVOC - semivolatile organic compound

TOC - total organic carbon

VOC - volatile organic compound

Table 2-4. Proposed Geotechnical Explorations, Analyses, and Rationale

Station No. ^a	Proposed X Coordinate	Proposed Y Coordinate	Estimated Sediment Thickness (ft) ^b	Proposed Geotechnical Parameters	Borehole Rationale
CPT-1	7627443.59	703002.76	20	CPT-tip resistance, sleeve friction, and pore pressure.	Geotechnical evaluation for EE/CA including sheet pile structure & CDF feasibility.
CPT-2	7627675.20	703040.27	10	CPT-tip resistance, sleeve friction, and pore pressure.	Geotechnical evaluation for EE/CA including sheet pile structure & CDF feasibility.
CPT-3	7627431.88	702862.93	25	CPT-tip resistance, sleeve friction, and pore pressure.	Geotechnical evaluation for EE/CA including sheet pile structure & CDF feasibility.
CPT-4	7627583.38	702843.54	20	CPT-tip resistance, sleeve friction, and pore pressure.	Geotechnical evaluation for EE/CA including sheet pile structure & CDF feasibility.
CPT-5	7627902.10	702919.88	10	CPT-tip resistance, sleeve friction, and pore pressure.	Geotechnical evaluation for EE/CA including sheet pile structure & CDF feasibility.
CPT-6	7627771.95	702619.08	20	CPT-tip resistance, sleeve friction, and pore pressure.	Geotechnical evaluation for EE/CA including sheet pile structure & CDF feasibility.
CPT-7	7627997.09	702618.77	5	CPT-tip resistance, sleeve friction, and pore pressure.	Geotechnical evaluation for EE/CA including sheet pile structure & CDF feasibility.
CPT-8	7627939.33	702436.36	25	CPT-tip resistance, sleeve friction, and pore pressure.	Geotechnical evaluation for EE/CA including sheet pile structure & CDF feasibility.
CPT-9	7627998.35	702273.97	35	CPT-tip resistance, sleeve friction, and pore pressure.	Geotechnical evaluation for EE/CA including sheet pile structure & CDF feasibility.
CPT-10	7628070.62	702291.73	30	CPT-tip resistance, sleeve friction, and pore pressure.	Geotechnical evaluation for EE/CA including sheet pile structure & CDF feasibility.
CPT-11	7628300.58	702488.28	10	CPT-tip resistance, sleeve friction, and pore pressure.	Geotechnical evaluation for EE/CA including sheet pile structure & CDF feasibility.
CPT-12	7628334.82	702256.31	10	CPT-tip resistance, sleeve friction, and pore pressure.	Geotechnical evaluation for EE/CA including sheet pile structure & CDF feasibility.
CPT-13	7628260.78	702136.63	20	CPT-tip resistance, sleeve friction, and pore pressure.	Geotechnical evaluation for EE/CA including sheet pile structure & CDF feasibility.
SPT-1	7627905.47	702438.77	25	Various geotechnical tests. See FSP text. ^c	Geotechnical evaluation for EE/CA. Collocated with CPT-8 for development of site-specific correlations of CPT parameters with design soil parameters. Rock coring to 20 ft below bedrock contact to determine rock quality.

Table 2-4. Proposed Geotechnical Explorations, Analyses, and Rationale

Station No. ^a	Proposed X Coordinate	Proposed Y Coordinate	Estimated Sediment Thickness (ft) ^b	Proposed Geotechnical Parameters	Borehole Rationale
SPT-2	7627970.42	702309.76	35	Various geotechnical tests. See FSP text. ^c	Geotechnical evaluation for EE/CA. Collocated with CPT-9 for development of site-specific correlations of CPT parameters with design soil parameters.
SPT-3	7628241.09	702126.03	20	Various geotechnical tests. See FSP text. ^c	Geotechnical evaluation for EE/CA. Collocated with CPT-13 for development of site-specific correlations of CPT parameters with design soil parameters.

Notes:

^a SPT borings will be advanced with mud-rotary equipment. CPTs will be performed with CPT equipment.

^b Sediment thicknesses were estimated based on nearby historical sample stations.

^c Geotechnical tests will be assigned based on conditions encountered during the field program.

CDF - confined disposal facility

CPT - cone penetration testing

EE/CA - engineering evaluation/cost analysis

FSP - field sampling plan

SPT - standard penetration testing

Table 3-1. Sample Containers and Preservation Requirements

Analysis	Laboratory	Container		Preservation	Holding Time
		Type	Size		
Sediment Quality Characteristics					
Grain size	TestAmerica Tacoma or Burlington	WMG	16 oz.	4 ± 2°C	6 months
Total organic carbon	TestAmerica Tacoma	WMG	8 oz.	4 ± 2°C	28 days
Semivolatile organic compounds	TestAmerica Tacoma	WMG	inc.	4 ± 2°C	14 days/40 days ^a
PCBs	TestAmerica Tacoma	WMG	inc.	4 ± 2°C	14 days/40 days ^a
Total solids	TestAmerica Tacoma	WMG	inc.	4 ± 2°C	6 months
Volatile organic compounds	TestAmerica Tacoma	WMG with Septa	2 oz.	No headspace, 4 ± 2°C Do not freeze	14 days
Organochlorine pesticides	TestAmerica Burlington or Knoxville	WMG	8 oz.	4 ± 2°C	14 days/40 days ^a
Chlorinated dioxins/furans	TestAmerica West Sacramento	WMG	8 oz.	4 ± 2°C	1 year
Archive	TestAmerica Tacoma	WMG	16 oz. ^b	Deep frozen (-20°C)	TBD
Physical and Engineering Characteristics					
Subsurface Sediments					
<i>Physical Characteristics</i>					
Grain size	Kleinfelder	WMG	16 oz. ^c	4 ± 2°C	6 months
Atterberg limits	Kleinfelder	WMG		4 ± 2°C	--
Specific gravity	Kleinfelder	WMG		4 ± 2°C	--
Moisture content/density	Kleinfelder	WMG		4 ± 2°C	--
<i>Engineering Characteristics</i>					
Consolidation	Kleinfelder	Sealed Shelby Tube	--	4 ± 2°C	--
Unconsolidated undrained triaxial shear stress	Kleinfelder	Sealed Shelby Tube	--	4 ± 2°C	--
Consolidated undrained triaxial shear stress	Kleinfelder	Sealed Shelby Tube	--	4 ± 2°C	--
Hydraulic conductivity	Kleinfelder	Sealed Shelby Tube	--	4 ± 2°C	--
Torvane shear strength testing	Kleinfelder	Sealed Shelby Tube	--	4 ± 2°C	--
Unconfirmed compressive strength (Rock)	Kleinfelder Redmond	TBD	--	NA	--
Point load index (Rock)	Kleinfelder Redmond	TBD	--	NA	--

Table 3-1. Sample Containers and Preservation Requirements

Analysis	Laboratory	Container		Preservation	Holding Time
		Type	Size		
Sediments for Waste Characterization					
Toxicity Characteristic Leaching Procedure					
TCLP testing ^d	TestAmerica Tacoma	WMG	8 oz.	4 ± 2°C	14 days
Asbestos					
Asbestos	TBD	WMG	8 oz.	--	180 days
Field Blanks					
Total organic carbon	TestAmerica Tacoma	HDPE	250 mL	4 ± 2°C; H ₂ SO ₄ to pH < 2	28 days
Organochlorine pesticides	TestAmerica Burlington or Knoxville	AG	2 x 1 L	4 ± 2°C	7 days/40 days ^e
PCB Aroclors	TestAmerica Tacoma	AG	1 L	4 ± 2°C	7 days/40 days ^e
Semivolatile organic compounds	TestAmerica Tacoma	AG	2 x 1 L	4 ± 2°C	7 days/40 days ^e
Volatile organic compounds	TestAmerica Tacoma	VOA vial	3 x 40 oz. w/ septum	No headspace; HCl to pH < 2; 4 ± 2°C	14 days
Chlorinated dioxins/furans	TestAmerica West Sacramento	AG	2 x 1 L	4 ± 2°C in the dark	1 year

Notes:

^a Holding time is 14 days to extraction and extracts must be analyzed within 40 days from extraction.

^b Two 16 oz jars will be collected for sample intervals chosen for archive.

^c One 16 oz. jar will be collected for all physical characteristics.

^d For standard TCLP VOCs, SVOCs, metals, pesticides, and herbicides (42 individual chemicals) using EPA SW-846 methods.

^e The holding time is 7 days from collection to extraction and 40 days from extraction to analysis.

AG - amber glass

HDPE - high density polyethylene

NA - not applicable

PCB - polychlorinated biphenyl

SVOC - semivolatile organic compound

TBD - to be determined

TCLP - toxicity characteristic leaching procedure

VOA - volatile organic analysis

VOC - volatile organic compound

WMG - wide mouth glass

ATTACHMENT A

STANDARD OPERATING PROCEDURES

STANDARD OPERATING PROCEDURE SOP-1: NAVIGATION AND POSITIONING

Scope and Application

Accurate station positioning is required to help ensure quality and consistency in collecting samples and in data interpretation and analysis. Station positioning must be both absolutely accurate in that it correctly defines a position by latitude and longitude, and relatively accurate in that the position must be repeatable, allowing a user to reoccupy a station location (e.g., long-term monitoring programs).

This SOP describes the most commonly used station positioning method, Differential Global Positioning System (DGPS). Integral owns the following DGPS hardware and software systems for station positioning at many of their field efforts.

- Trimble Pathfinder™ Pro XRS system (TSC1 handheld unit, GPS receiver and GPS antenna)
- Trimble GeoXT
- Trimble Pathfinder Office (Version 4.0)
- Trimble TerraSync Professional (Version 3.05)
- ESRI ArcPad 7.1

The Trimble DGPS offers post-processing sub-meter accuracy often required for documenting sampling station locations and for relocating previously sampled stations. A thorough and comprehensive discussion of the Trimble DGPS is provided in attachments to this SOP.

Summary of Method

Global positioning system (GPS) navigation is used to navigate and position the sampler at the desired location. GPS is a satellite-based system that receives positioning data at 1-second intervals from multiple satellites at known positions in space. Standard GPS is calculated to an accuracy of about ± 50 m.

A higher accuracy of approximately 2 m may be obtained by applying differential corrections to the standard GPS positioning data using DGPS. These differential corrections are applied by sending GPS differential corrections to the GPS receiver via radio transmission. If the sampling location is near the coastal United States, the U.S. Coast Guard generates differential corrections that are transmitted via radio link to the

GPS receiver. If a Coast Guard station is out of range of the sampling area, then a receiver may be set up at a known (i.e., surveyed) reference point on land or real-time satellite differential signals can be purchased from a private company (e.g., OmniSTAR).

With the Trimble GeoXT and Pro XRS systems, GPS data can be gathered to sub-meter accuracy using a choice of differential correction sources (i.e., free beacon differential signals [e.g., Coast Guard or U.S. Forest Service beacons] or OmniSTAR) without establishing a reference station. Correction of data is required to gain sub-meter accuracy. Free beacon or base station signals allow differential corrections to be performed after data collection by using a nearby beacon or base station logging data files. (Note: Station must be within 150 km (93.2 miles) of the data collection location.) For satellite-based signals, a built-in virtual base station allows for real-time data correction, eliminating the need for post-processing data in some cases. However, post-processing data corrections can obtain accuracies in the range of 30–50 cm. These accuracies are for the horizontal (northing and easting) component only. The vertical component (elevation) accuracy ranges from sub meter to three times larger than the horizontal accuracy.

The GPS receiver transmits differentially corrected positioning data to the computer and displays it on the screen using an integrated navigation software package (e.g., HYPACK, TerraSync). The computer data are typically displayed and recorded in World Geodetic System of 1984 (WGS-1984) geographic coordinates (latitude/longitude). However, the integrated navigation system can display and record information in other datums (e.g., UTM, NAD83, etc.). The integrated navigation system, acting as a data manager, displays the sampler's position relative to a target station location in plan view on a video screen. The resulting pictorial screen presentation, as well as numeric navigation data (e.g., range and bearing to the target sampling location) assists the vessel operator (when sampling on-water) in approaching and maintaining the station position while sampling.

Supplies and Equipment

- Cables (antenna to receiver, receiver to computer)
- Trimble Pro XRS GPS antenna
- Trimble Pro XRS GPS receiver with battery charger and batteries
- Trimble TSC1 handheld data logger unit with Asset Surveyor software
- Trimble GeoXT handheld GPS unit (antenna, receiver and computer all-in-one unit) with battery charger/docking station and cables
- Trimble® GeoBeacon™ receiver for precision of real-time differential GPS (use with GeoXT)
- Laptop computer and additional navigational monitor (if needed)
- Navigation software (e.g., Terrasync and Pathfinder Office)

- Laser range finder (use TruPulse™ 200 or 360 Laser Rangefinder - Blue Tooth™ enabled)
- Logbook or log sheets.

Procedures

Latitude and longitude coordinates will be obtained at the locations where surface water samples are collected. An average positioning objective is to accurately determine and record the positions of all sampling locations to within ± 2 m. Positioning accuracies on the order of $\pm 1-3$ m can be achieved by avoiding the few minutes per day when the satellites are not providing the same level of signal. The GPS provides the operator with a listing of the time intervals during the day when accuracies are decreased. Avoidance of these time intervals permits the operator to maintain better positioning accuracy.

On-Land Sampling Event

A Trimble Pro XRS backpack or a handheld Trimble GeoXT (equipped with a GeoBeacon™ receiver) DGPS unit may be used to direct the sampling team to the proposed sampling location. To expedite field activities, the target station coordinates may be entered in the navigation system database prior to beginning sampling. The DGPS antenna is located as close as possible to where the sampling will occur. Once the sample(s) have been collected at the appropriate location, the horizontal coordinates of the station are recorded in the field logbook. If necessary, the vertical elevation may be recorded as well.

On-Water Sampling Event

When collecting samples from a boat, the GPS Pathfinder Pro XRS system is used. The receiver is a real-time GPS mapping receiver combining a GPS receiver, a minimum shift keying (MSK) beacon differential receiver, and a satellite differential receiver in a single housing, the GPS Pathfinder Pro XRS receiver offers the flexibility for choosing a source for real-time differential corrections.

The GPS antenna is mounted right above the location where the sample will be collected. That is, the antenna is mounted vertically at the outboard end of the vessel's boom, at the top middle of an A-frame or at the outboard end of a davit. If this is not possible, the navigator must measure the distance between the sampler location and the antenna and enter an offset in the navigation program (e.g. TerraSync) to correct for that distance. The GPS antenna cable extends along the boom into the cabin where it is connected to the GPS receiver and a laptop. If available, an additional video screen is installed to allow the vessel operator to observe on-screen positioning data from the helm.

Alternatively, if sampling will be done from a different vessel, such as a drilling barge, a backpack or handheld DGPS unit may be used to position the sampling vessel over a proposed sampling location. The DGPS antenna is located as close as possible to where the drilling will occur (i.e., over the moon pool). The person operating the DGPS unit directs the sampling vessel operator to the sample station location.

Once the sampling vessel is at the appropriate location and is anchored, the horizontal coordinates of the station are recorded in the field logbook. To expedite field activities, the target station coordinates may be entered in the navigation system database prior to beginning sampling.

Positioning System Verification

GPS requires no calibration, as all signal propagation is controlled by the U.S. government (the Department of Defense for satellite signals and the U.S. Coast Guard and U.S. Forest Service for differential corrections). Verification of the accuracy of the GPS requires that coordinates be known for one (or more) horizontal control points within the study area. The GPS position reading at any given station can then be compared to the known control point. If possible, GPS accuracy should be verified at the beginning or at the end of each sampling day.

Station Positioning Activities

A consistent routine is used for each day's positioning activities. After successful reception of differential signals, the computer turned on, and the software booted. The accuracy of the system is verified at a horizontal control point, as described in the previous section.

At the beginning of a sampling day, the team leader defines the order in which each sampling station will be visited. The station locations are then selected one at a time from a number of pre-selected station locations that have been entered into the integrated navigation system database. Upon selection of a target station, the positioning data of the sampler is displayed on the computer screen or hand-held unit to assist the operator in proceeding to the station, and if on water work, in maintaining the station position during sampling. A confirmed position is recorded electronically each time a sample collection is attempted (this means that during sediment grab sampling and coring from a boat, the locations of both accepted and rejected grabs or cores are recorded). Upon recovery of the sampling device, the station position coordinates (i.e. northing (y) and easting (x) or latitude and longitude) are read from the archived computer file and recorded in the field logbook or on log sheets as a backup to the computer record. Time and water depth (if applicable) are also recorded. Ancillary information recorded in the field logbook may include personnel operating the GPS system, tidal phase or river stage for on-water work,

elevation for on-land work, type of sampling activity, and time when coordinates were collected.

References

Trimble Navigation Limited. 2001. TSC1 Asset Surveyor operation manual. Version 5.20. <http://trl.trimble.com/dscgi/ds.py/Get/File-8145/Oper.pdf>

Trimble Navigation Limited. 2007. GPS tutorial. Accessed on January 12, 2007. <http://www.trimble.com/gps/index.shtml>

ATTACHMENT 1

TRIMBLE PRO XRS AND TSC1 DESCRIPTION

The Trimble Pathfinder™ Pro XRS combines a high-performance GPS receiver and antenna, beacon differential receiver, and satellite differential receiver (Wide Area Augmentation System [WAAS]) capabilities in one compact unit. The Pro XRS also includes Trimble's advanced Everest™ technology, which allows users to collect accurate position data near walls, water, vehicles, or other surfaces that reflect satellite signals. Reflected signals, also called multipath signals, make it difficult for GPS receivers to accurately determine position. Everest uses a patented technique to remove multipath signals before measurements are used to calculate position.

Equipment Required

The GPS Pro XRS with a TSC1 data logger consists of the following:

- GPS receiver in backpack casing (with system batteries and cables)
- Hand-held data logger (TSC1) and cable, OR Laptop with Terrasync software installed and cable. (Note: Terrasync procedures are covered under Attachment 5.)
- Pro XRS antenna, range poles, and cable
- Compass and tape measure
- Spare 12-volt camcorder and 9-volt batteries (minimum of 2 each) (use only Kodak, Duracell, or Energizer 9-volt batteries)
- Battery charger and power cord.

Pro XRS and TSC1 Setup

Follow these procedures for the proper setup of the Pro XRS:

1. Ensure connections between batteries, receiver and data logger are correct and secure. The coaxial antenna cable connects from the GPS receiver port "ANT" to the base of the antenna. The TSC1 cable (a "pig-tail"-type cable) connects from the bottom or top of the TSC1 to the receiver port "B", where a 9-pin serial port dongle is attached. The dual Y-clip cables should be connected from the receiver to the batteries. Alternatively, if AC power is available (e.g., aboard a vessel), then the power cable for the battery charger can be attached directly to the receiver on some models.

2. Screw the three long antenna poles together (the shorter pole may be added if necessary for taller users). Screw on the antenna and connect its cable.
3. Put backpack and/or shoulder strap on. The pouch for the data logger should be in place around the waist strap/in backpack.
4. Screw antenna to the attachments on the top of the back-pack. Wind cord around pole, and use ensure the antenna is secure. Please be aware of overhead hazards, especially if working near low hanging power lines. Severe injury or death can result.

Basic Operation of the Pro XRS

Recording a Feature

Before beginning field use, ensure that all GPS configurations and settings are set correctly for the particular use of the Pro XRS and that an appropriate data dictionary is loaded onto the TSC1 (See Attachment 4 and 5 for typical settings). These steps outline the basic use of the GPS to document a sample position or any other defined "feature." Note that the TSC1 has both hard-keys and soft-keys that allow for its operation. The hard-keys are all the keys (e.g., letters and numbers) on its surface. The soft-keys are the F1 through F5 hardkeys. The function of these changes depending upon the context. These keys will be referred to with arrows around them (<soft-key>).

1. Turn data logger on outside in an open area. Wait for antenna to receive satellite signals. The display will read "Recording Almanac," "Too few SVs," and "PDOP too high." Continue to wait until enough satellites (a minimum of 4) are acquired, and the PDOP is below 5.0.
2. Ensure that the real-time settings are correct according to the parameters listed in Attachment 1.
3. Select DATA COLLECTION, and create a new rover file or open an existing file. This file should be named according to the format specified by the project GIS analyst. Note: If opening an existing file press <NEW> to access the "Antenna options" menu and "Start Feature" menu.
4. Enter the height of the antenna from the ground to the "Measurement Method" reference point shown in the "Antenna Options" menu and then press ENTER to bring up the "Start Feature" menu.

5. Pick the appropriate data dictionary to use with the rover file. Only one dictionary can be used with a rover file. Please consult with the project GIS analyst to formulate the most appropriate data dictionary for the type of sampling you wish to perform. The data dictionary entitled “Generic,” contains only a comment field, and is appropriate for simple navigation tasks. If using a data dictionary, make sure to become familiar with its attributes before recording information in the field.
6. Move to the location of the first feature for which you want to record the GPS position. Select the appropriate feature and press ENTER to begin logging. Log data points in accordance with the feature type. Point features should have at least 10 points collected at a stationary location. Line features should be collected while moving. If movement is stopped, press the <PAUSE> key. When movement starts again, press the <RESUME> key. Area features should be collected with enough points to define the outline of the area (e.g., a square building would have four single points, collected on each corner, and the <PAUSE> key would be used between each of the points).
7. Depending on the setup of the data dictionary, each feature may have one or more feature attributes. An attribute is used to record additional data associated with the feature. For example, the attributes assigned to a sediment sampling station could be sample number, station ID, sampling gear, sediment color, odor, etc. (The <PAUSE> key should be used while recording feature attributes to avoid too many data points being collected at one point feature. [Body movements while logging attributes for an extended time can decrease the accuracy of collection.] The <PAUSE> key must be used when recording attributes of a line or area feature because only one data point should be collected in a single location.) Once all attributes are entered and the feature data points are logged, press ENTER to complete and save the feature and move on to a new feature. Pressing ESC instead of ENTER will allow the user to abandon the logged feature without saving.
8. When all features in a given area have been recorded, from the “Data Collection” menu press ESC to exit data capture and then press <YES> to close the file. Features are appended and saved to the file after each collection, so there is no need to “save” the file. When the Pro XRS system is not in use, it should be turned off. If you need to come back to the same rover file later in the day, the rover file may be reopened at that time. Rover files may not be edited after 7 days from the first feature was created. Please consult the project GIS analyst for the best way to handle multi-week sampling projects. Ideally, files should be saved and sent to the GIS daily for differential corrections. Files older than a week will require access to archived base station files for differential corrections and will require additional GIS time for post-processing.

Post-processing may be done in the field if the appropriate software and internet connections are available.

9. At the end of each day, the rover file should be downloaded to a PC by using Pathfinder Office software and if possible, sent to the GIS team for post-processing and QA/QC checks.

Feature Collection Options

Offsets—The TSC1 can collect a point or line feature while standing at a set distance away from the feature. This option may be necessary because of obstructions such as tree cover, buildings, or car traffic. For a point feature, measure the distance between the object you want recorded and the Pro XRS antenna. Use the compass to determine the bearing (e.g., west is 270°). The bearing is the direction the point should be moved for it to be located in the correct place (e.g., if you are due north of the feature, the bearing is south or 180°; i.e., the position you want recorded is south of where you are standing). Estimate the inclination from the feature to the GPS antenna (if height determination is critical, a clinometer should be used). The inclination is the degree angle up from the feature to the antenna (e.g., if the feature is 5° below the antenna position, -5° would be entered). During data capture, from within the feature, press the <OFFSET> button, and enter the distance, bearing, and inclination. Press OK to complete the feature.

Note: This procedure describes an offset of a single feature. A constant offset may be applied to all features collected as well.

Nesting—While recording a line feature or an area feature, a point feature may be collected to avoid backtracking. While recording the line or area feature, press <PAUSE> and then <NEST>. The TSC1 will prompt for collection of a new feature. Move to the feature, and collect data as for any other point feature. When the feature is complete, press OK. The Pro XRS is ready to resume collecting data as part of the line/area feature: press <RESUME>. (Remember to continue moving before pressing resume to avoid having multiple positions recorded in the same place in the line or area feature.)

Segmenting—While moving along a line feature, changing the attributes of that line may be necessary (e.g., because of a change in surface type from paved to dirt road, dropping a benthic sledge at the bottom of a river and marking when the benthic tow starts). This change may be done without having to begin a new feature by pressing <PAUSE> and then <SEGMENT>. Change the appropriate attributes and then press <RESUME> to continue recording.

Repeat—The function allows the collection of a new feature with the same feature attributes as the previous feature. If features are not exactly the same, it also allows editing of the attributes.

Quickmark— Allows collection of point features while moving (e.g., from a car or a boat) by estimating the exact location. The use of this feature will not result in positionally accurate locations and is not recommended for most sampling operations.

Reviewing and Editing Features

It is possible to review or edit features collected in the field while still in the data capture mode. For example, it may be necessary to document the GPS location in the field logbook or to edit one of the feature's attributes. Without exiting data capture, press <REVIEW>. (If data capture is already complete, just press REVIEW and then select the appropriate rover file.) This step will display a list of data points including each feature collected. Scroll to the appropriate feature, and follow the steps below depending on the required action:

- To view the GPS location (e.g., lat/long), press <POS>
- To edit the attributes, press ENTER. Make any necessary edits to the attributes by scrolling through.
- To change or add an offset, press <POS>, then press <OFFSET>. Make any necessary changes.
- To delete a feature collected in error, press .

Navigating to an Existing Location

Waypoints

To use the Pro XRS to navigate to a previously established position, this position must be loaded into the TSC1 data logger as a waypoint, be present as a feature position in the data files, or must be generated in the field using the GPS unit. Waypoints may be entered into the TSC1 by:

- Manually entering coordinates
- Choosing previously recorded locations and importing them into the TSC1 by using Pathfinder Office
- Defining a location stored in a rover file saved to the TSC1 as a waypoint (see *Reviewing/Editing Features*, above)
- Creating a way point from the current position being shown by the operating GPS unit in the field.

Navigating

Usually the *Navigation* module (accessed by pressing MENU followed by Navigation) will be used to guide yourself to a target (waypoint or feature). You can also use the *Map* module (accessed by pressing MENU followed by Map) to:

- Orient yourself in the area you are working in
- Get a general indication of the location of a feature or waypoint that you want to find
- Find or select features or waypoints that you want to navigate to
- Plot a course from one place to another.

While in the Map screen, the GPS cursor x shows the current position reported by the receiver and is always shown on the Map screen (note: it may not always be within the visible part of the screen when panning or scrolling). The <OPTIONS> key can be used to hide or display the GPS trail (line of dots showing up to 60 previous positions), the heading showing the direction of travel, and other options on the map display.

A feature can be selected by pressing MENU, Data Collection to reach the “Start Feature” screen, and then REVIEW to access all features contained in the data file. The desired feature can then be highlighted and selected by pressing the <Target> key which adds a crossed flag to the feature. The Map screen can be re-accessed by selecting MENU, then Map, which will now show the highlighted feature with a crossed flag symbol on the Map screen. The user can then start moving toward the feature and the current position (shown by the x) will move closer to the target position as the user approaches.

There are two graphical modes of navigation with the Pro XRS in the TSC1 *Navigation* module. On both modes text information appears on the right of the screen in the *Info* panels, which can be configured by the user. The graphic modes available are the *Directional Dial* screen or the *Road* screen, which can be toggled between using the <Mode> key.

To navigate you need to select a target and then a start position. Each of these positions can be features from an open data file or a waypoint. A list of available features or waypoints can be accessed by pressing <TARGET> or <START>. Once the item has been chosen as a target it will show the crossed flags symbol in the list. Once a target has been selected, the Distance to Go appears at the bottom of the Navigation screen, which indicates the distance from the current GPS position to the target. Select a start position (not required but useful for calculating crosstrack error and other navigation information) by pressing <START>. A waypoint of the current GPS position can be created for use as the Start point by selecting <CREATE>. Once the Start position is selected, a flag symbol will appear next to the item in the list.

In the *Directional Dial* mode an arrow will appear that will always point at the target. This is the bearing to go (Note: you need to be moving for this to be accurate as it will lock if you are moving too slowly or are stopped). The triangle at the top of the circle represents the direction that you are going or heading. This triangle never moves, but by changing directions you can line up the arrow with the triangle. When the two are aligned you are heading in the direction of the target. When you are close to the target a bull's-eye (two concentric circles) will appear at the edge of the screen. This is warning you that the unit will be switching to the close up screen. A proximity alarm will sound and the directional arrow will be replaced by the bull's-eye on the close up screen. Your current position will be shown by an x and the target by the bull's-eye. Move so that the x is in the same location as the bull's-eye.

In the *Road* mode you navigate by walking down a road. Your position is shown by a stick figure and is always positioned in the center of the screen. The target (crossed flags) shows the point that you are navigating to. Your heading is shown by the top center of the screen and the bearing to go is shown by the direction of the road, which will rotate as you change your heading. Change your heading until the road is pointing at the top of the screen (Target is also at the top of the screen) and the edges are parallel to the sides of the screen. As you move toward the target the screen zooms in, so the road appears to get wider.

Downloading Rover Files

Upon returning to the office, all rover files should be downloaded from the TSC1 to a PC for post-processing. You will need the Trimble Pathfinder Office software installed on your computer. If not using a field laptop that already has the program installed, please contact your project GIS analyst for instructions on how to install the software.

Connect the TSC1 to your computer using the appropriate cables. In addition to the "pigtail" cable, you will also need a null modem, which is a 9-pin female to female cable, in order to plug into a PC serial port. Once connected, power up the TSC1 unit and navigate to MENU, File Manager, File Transfer. Then, open the Pathfinder software and navigate to the *Utilities>Data Transfer...* window from the menu bar. Select GIS Datalogger on COM1 (for most computer systems), and press the green connect button. Files can be downloaded from the TSC1 by selecting the Receive tab and choose the data file type from the Add pulldown menu. After downloading, all rover files and waypoints should be removed from the TSC1 to conserve memory. Rover files may be deleted from the File Manager menu.

1. Select MENU, File Manager, then delete file(s).
2. Select the rover file to be deleted, and press <ENTER>.
3. Confirm the deletion of this file by pressing <YES>.

Data dictionaries can be deleted in the same manner by selecting Data dictionaries from the File Manager menu. Waypoints may be deleted by selecting Utilities from the Main menu and then by selecting Waypoints followed by .

ATTACHMENT 2

TSC1 SETTINGS

The following are lists of menus that can be accessed through the TSC1 keypad. Please ensure that settings are correct before proceeding. Please do not make changes to the settings unless necessary. Each menu will list all available subheadings, the correct setting, and the available <soft-keys> to access additional menus. Comments are included only where necessary.

GPS Rover Options

Access this menu by selecting Configuration from the main menu and then select GPS Rover Options.

Logging Options	Setting	Comment
<u>Logging intervals</u>		
Point feature	1s	
Line/area feature	2s–5s	depending upon speed of movement
Not in feature	None	
Velocity	None	
Confirm end feature	No	
Minimum pos	10	
Carrier Mode	Off	
Carrier phase min time	10 min	
Dynamics code	Land	may be changed to sea or air, as appropriate
Audible click	Yes	
Log DOP data	Yes	
Log PPRT data	Yes	
Log QA/QC data	Yes	
Allow GPS update	Warn First	
Warning Distance	Any	
Position Mode Manual	3D	
Elevation Mask	15°	Should not go below 15° (accuracy decreases)
SNR Mask	6.0	Can raise to 7 if multi-path filtering is poor
PDOP Mask	5.0	Can be raised up to 8 – reduces accuracy
PDOP Switch	6.0	

Real-Time Input Options

This menu can be accessed from the GPS Rover options menu by selecting real-time input.

Option	Setting	Comment
Preferred Correction Source	Choice 1	Integrated Beacon
	Choice 2	Integrated WAAS
	Choice 3	Use uncorrected GPS
Correction age limit	20s	

Antenna Options

This menu can be accessed from the GPS Rover options menu by selecting Antenna Options.

Option	Setting	Comment
Height (from ground)	in m or ft	Enter correct user antenna height using measurement method indicated below
Measure Type	Uncorrected Integrated GPS/Beacon/Satellite	
Confirm	Per file	Can be changed to "Per feature" if antenna height varies and elevation is critical
Part Number	33580-50	Auto selected based on TYPE selected
Measurement Method	Bottom of Antenna Mount	

ATTACHMENT 3

ADDITIONAL SETTINGS FOR THE TSC1

Additional TSC1 settings can be found in the configuration menu. Items of particular importance are indicated in italics.

Configuration

This menu can be accessed by selecting Configuration from the main menu.

Configuration	Description
GPS base station options	For using a land base station or beacon for real time corrections
NMEA/TSIP output	Consult manual
Coordinate system	Changes coordinate system among latitude/longitude, UTM, and other coordinate systems. System can be converted, if necessary, after data capture by using Pathfinder Office software.
Map Display options	Change layers, scale, background files and items shown on the TSC1 screen during data collection
Navigation options	Changes Navigation parameters
Units and display	Changes various units, for example: length (e.g., feet, meters), elevation reference (e.g., MSL), <i>North reference</i> (i.e., true or magnetic). Units can be converted, if necessary, after data capture by using Pathfinder Office software.
Time and date	Changes to <i>local time</i> , 24 hour clock, date format, etc.
Quickmarks	Set-up parameters for use with quickmarks.
Constant offset	Set-up parameters for use with a constant offset.
External sensors	Connections with external sensors.
Hardware (TSC1)	TSC1 settings such as beep volume, contrast, <i>internal and external battery status</i> , software version, free space.

Contrast and Backlighting

The TSC1 display can be viewed in various light settings. Pressing FUNC, then L turns on the display backlight for viewing in dim lighting. In addition, the contrast can be adjusted by pressing FUNC, then E or F.

ATTACHMENT 4

PRE-SAMPLING ACTIVITIES BEFORE USE OF THE PRO XRS DGPS UNIT

Determination of Optimal Satellite-Use Time

Positioning accuracies on the order of $\pm 1-3$ m can be achieved by avoiding the few minutes per day when the satellites are not providing the same level of signal. The GPS provides the operator with a listing of the time intervals during the day when accuracies are decreased. Avoidance of these time intervals using Trimble's Mission Planning software permits the operator to maintain better positioning accuracy.

Mission Planning

Trimble's Planning software is a stand-alone software tool supporting any form of analysis to determine visibility for GPS and geostationary satellites. It can be downloaded for free at:

http://www.trimble.com/planningsoftware_ts.asp

The location can be picked from a list of cities from all over the world, select a location from the world map or type in the local WGS84 position to do more precise mission planning.

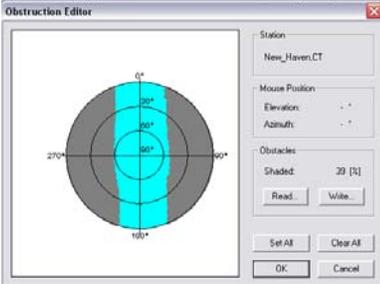
- Put in multiple station locations to determine the best time to observe these stations simultaneously.
- Get detailed sky plots (including obstructions) of the site for any time of the day to aid in determining the best available occupation times.
- Chart out the different DOP values by time
- Get a quick overview on the number of satellites available for the site, for any time of the day.

Using the Mission Planning Software

1. First, download the latest version of the Trimble Planning Software from the web site listed above. Be sure to download the latest Ephemeris file from the same page.

2. Install the software to a computer on which you have the appropriate permissions.
3. Start the Trimble Planning Software.
4. On the Main Menu, go to Almanac > Import > SSF...
5. Browse through the same folder where the Ephemeris file was saved. Select it and click Open.

Setting the GPS Survey Parameters

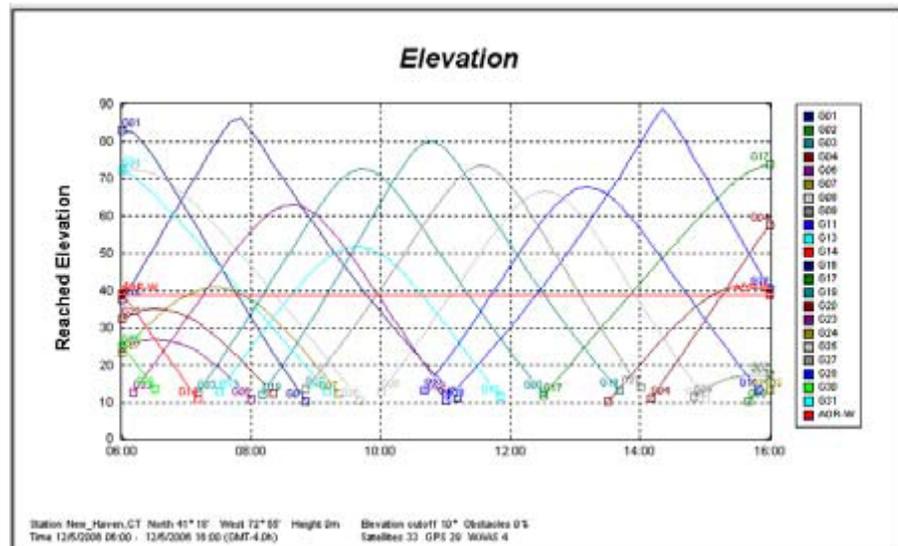
1. On the Main Menu, go to File>Station.
2. Click on the City name button to open the City Selector.
3. There are a number of options for selecting the area to survey. Depending upon the area to be surveyed, it may be more appropriate to manually enter Latitude/Longitude coordinates, or to use the Map Button to search for a station visually.
4. Select the city that is closest to the area to where the survey will be conducted.
5. If there are significant obstacles that will be confronted in the survey, click on the obstacles button and use the Obstruction Editor to define any obstructions that will be a factor in the survey (will the survey be in a canyon, the shadow of a mountain, etc?...).

6. Define the starting date/time and duration of the survey work.
7. Set the time zone for report format

Creating Planning Graphs

Once the survey parameters have been entered use the Toolbar to produce all the graphs created by the planning survey.

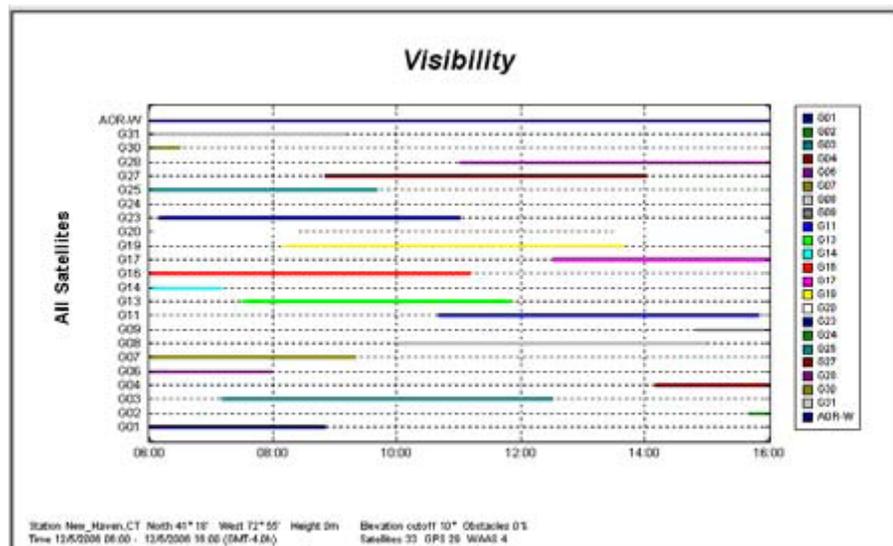
Elevation Graphs

The elevation graph will show satellites at very low elevations that do not significantly contribute to positioning calculations because of atmospheric interferences. It will also show the elevation in the sky for each satellite visible by the GPS receiver in the area across the time period defined. Note that this graph may be the most important for planning surveys in vertically developed urban environments.



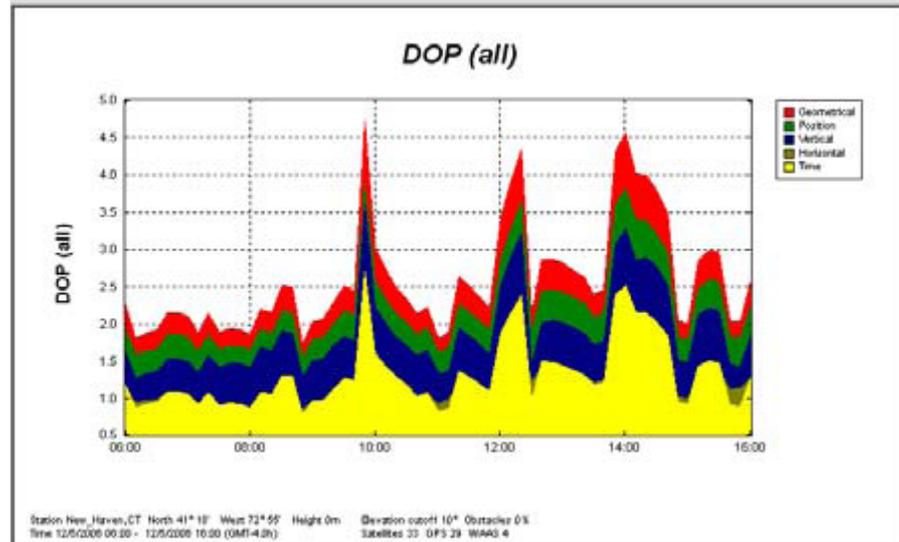
Visibility Graphs

This graph displays the visibility of satellites as a function of time.



DOP Graphs

Dilution of Precision (DOP) maps shows the satellite signal quality in relation to the number of satellites and their position in the sky and relative to each other. The lower the DOP value the better signal quality and the higher the positioning precision. This map is probably the best to use for a survey planning.



ATTACHMENT 5

MANAGING GPS DATA FROM TERRASYNC—A TUTORIAL

Introduction

Currently, positional data collected in the field is most often done with a Trimble GPS unit (see Integral's equipment list at the beginning of the SOP) interfaced with a laptop via Trimble's TerraSync software. This short tutorial is meant to serve as a guide to field personnel who need to understand how to retrieve and collect geographic data in the most efficient way possible with existing software.

Scope

This document is intended to be a reference for procedures involving:

1. Fixing files containing target stations that are more than 7 days old so that they can be updated
2. Adding features in GPS Pathfinder software (companion to TerraSync) and then importing them as base files in TerraSync.

This document is **not** intended to be a comprehensive manual for using Terrasync or Pathfinder software. It is assumed that the reader has received at least some training on how to use the basic features of Terrasync and is comfortable using MS Windows.

The Basics

GPS data collection at Integral currently utilized two pieces of complementary software: Terrasync – the interface for GPS navigation and data collection; and Pathfinder Office – a multi-use piece of software that acts as a conduit between GIS data files (shape files) and Terrasync GPS files. Pathfinder can also be used as a simple map editor in a pinch.

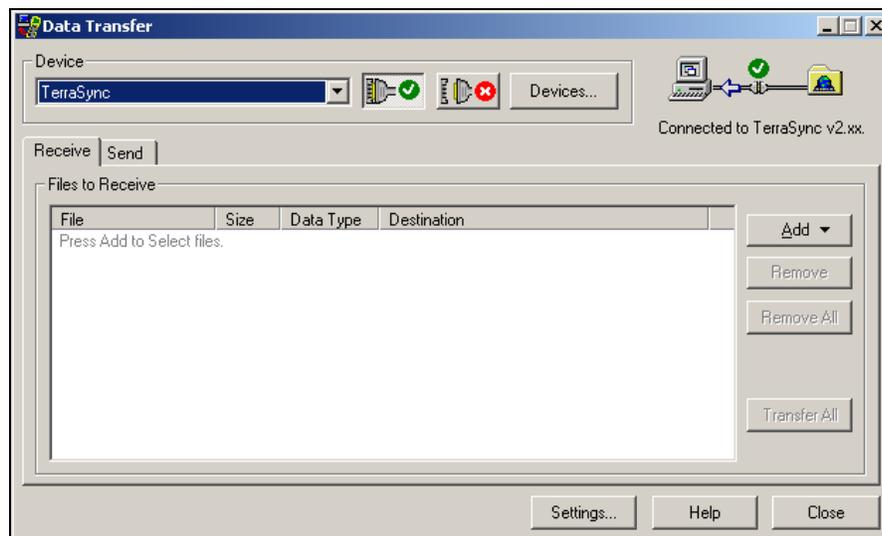
Installing the Correct Versions of Terrasync and Pathfinder

**** Important note *** : This tutorial uses Pathfinder Office version 4.00 and TerraSync version 3.05. It is very important to use the proper versions of this software due to compatibility issues. Licenses for TerraSync are reserved to one per computer or handheld GPS device. A floating license is available for Pathfinder Office and can be installed in several office computers .Please obtain installation instructions from GIS staff.*

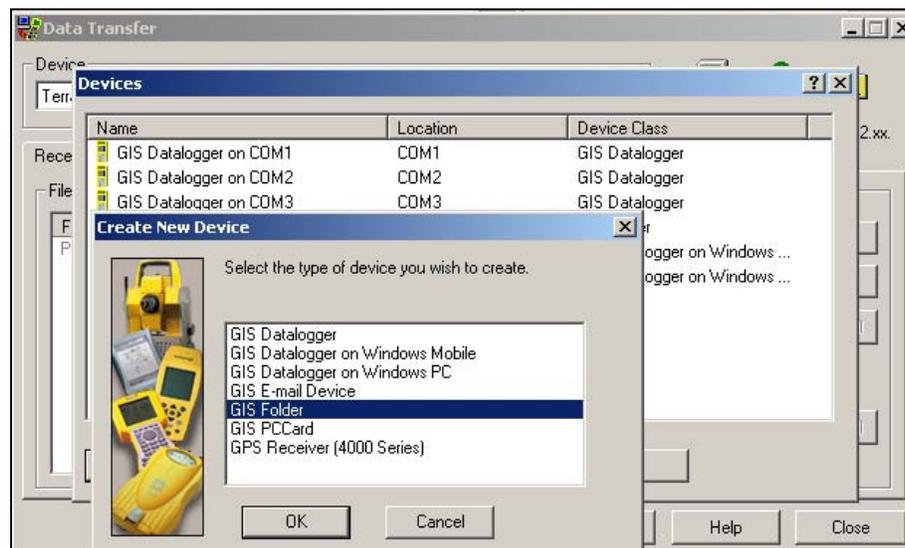
Initial Setup of TerraSync and Pathfinder Office

There are certain settings and configuration setups that are needed before Pathfinder Office can talk to TerraSync. Whether you are newly installing this software or have an existing installation, it is good to check to make sure these settings are in place.

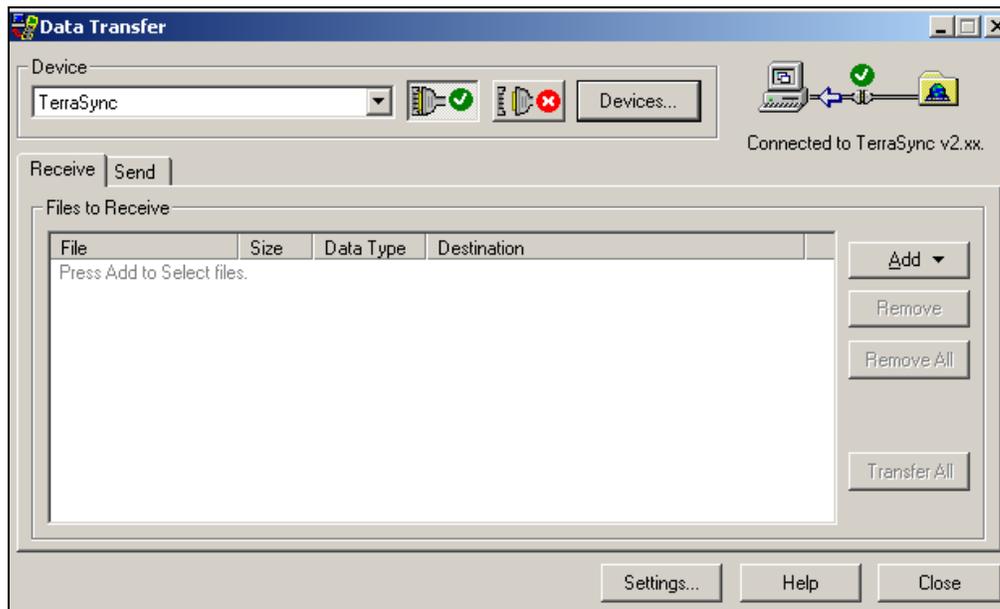
1. Open Pathfinder Office and go to the **>Utilities>Data Transfer...** menu. A dialog box similar to Figure 1 should greet you. This is the interface for communicating with TerraSync.



2. Click the **Devices** button, and then **New...**
3. You are then presented with a list of options, and you want 'GIS Folder'



4. Browse to the Terrasync data folder on your computer, which in most cases will be **C:\My Documents\TerraSync**
5. In the next box, 'Type' will be **TerraSync**, and 'Version' will be **v. 3.05**.
6. The next box prompts you for a name that will display in the device list. Shorten it to simply say **TerraSync**.
7. Now you should be able to go back to the Data Transfer dialog box, select TerraSync from the dropdown menu, press the 'connect' icon, and get a rewarding green check mark indicating success.



If this procedure does not work for you, it is likely that you have the wrong version of Pathfinder or TerraSync. For some reason, with each version upgrade of Pathfinder, connectivity to older versions of Terrasync is lost. You can check what version of Pathfinder you have installed by going to the **>Help>About GPS Pathfinder Office...** menu. To find out what version of Terrasync you have, you need to go to **C:\Program Files\TerraSync**, right-click on TerraSync.exe, and choose the version tab.

Common Issues

Handling Expired Files in Terrasync

One of the most common things that field personnel will have to deal with is the one week expiration date when trying to collect data with Terrasync (Figure 1). This is a safety feature of Terrasync to prevent too many days of logged in data being saved in a

single file, and unfortunately there is no solution that we know of. The following instructions will guide you through the process to make the files useable.

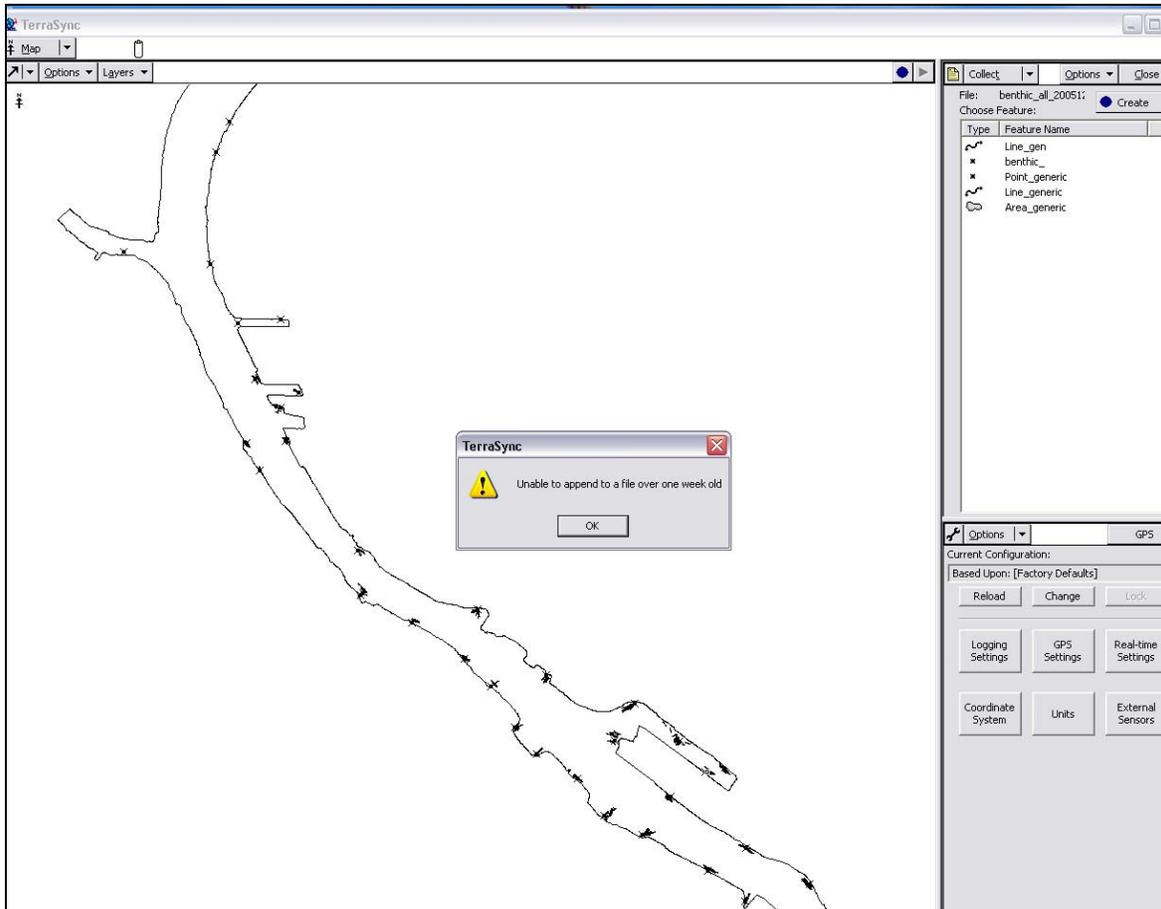


Figure 1: TerraSync file that is over one week old will not allow user to collect features. Note, the clock starts ticking when you collect your first feature in the field (not when the file was created)

Basically, there are two options depending on your needs. If you don't need to see your previously logged locations and just need to see the targets, you can use the original files provided by GIS staff (option 1). If you need to see previously occupied locations in order to make decisions about where to go next, then you will need to transfer the file to Pathfinder and back again (option 2).

Option 1: Move and replace logged files with original targets.

At the beginning of the field effort, you should receive a set of files with your target locations, most likely in a zip archive (.zip file extension). There will be six to eight files with the same name but with different extensions (see Figure 2). These files will have to

go into the C:\My Documents\TerraSync\ folder in order to be available to Terrasync.

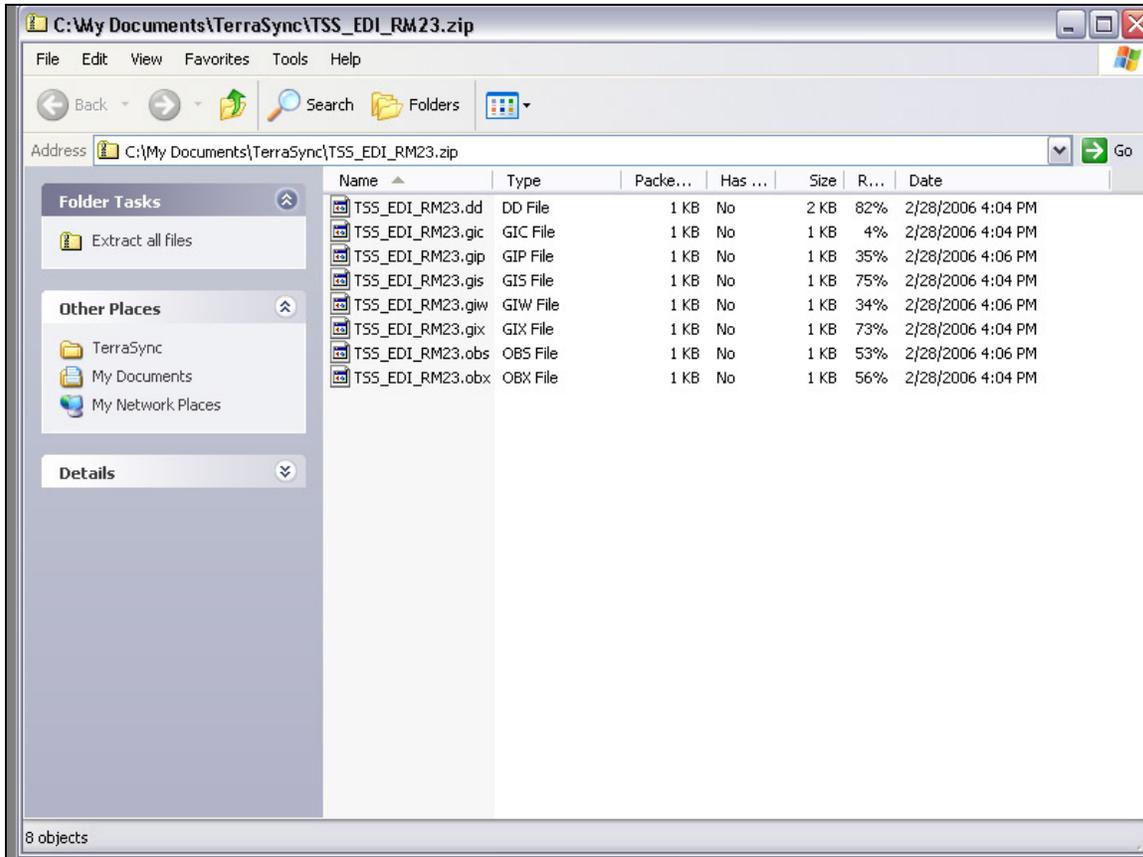


Figure 2: Example of file set to be unzipped into the TerraSync folder.

After you unzip these files to Terrasync, keep this zip archive around in an easy to find place (i.e. the Desktop or project GPS folder). The reason for this is that the one week clock does not start ticking until you begin collecting your first point in the field. Therefore, you can use this unadulterated file again, so long as you make a copy of the work you did the previous week. Here are the detailed steps to take:

1. Make sure you have the original files with the target locations available in a handy place. This will probably be the original zip archive. Also, **be sure to close TerraSync** while performing this process.
2. Navigate to C:\My Documents\TerraSync\ in Windows Explorer. Locate the files that you have been using the previous week. Make sure to get all the little files associated with the dataset. Note, that while it is useful to sort the files by date modified, you can miss some of the little files – it is highly recommended that you sort the files alphabetically.

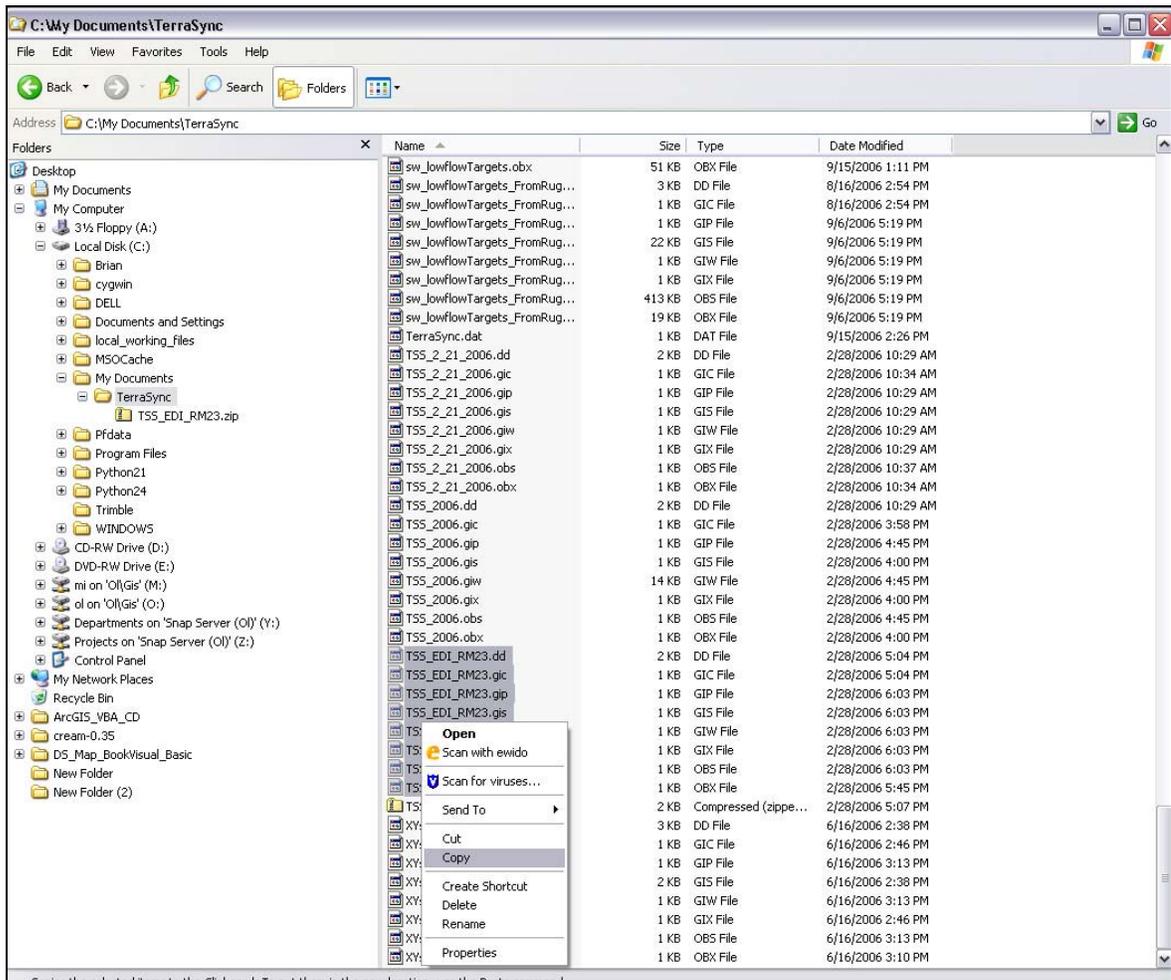


Figure 3: Selecting files to copy to a different directory

3. Copy all of these files to a different directory, preferably one that is named appropriately to reflect the data and time period that you were collecting. For example C:\Documents and Settings\bpointer\Desktop\lampreyTargets_20060925. These files contain the data you have collected the previous week and should be backed up and/or emailed to the appropriate project manager or GIS staff.
4. First, make sure you have made a copy of the original files. You can now safely replace the files you just copied with the ones from the original zip file. Simply right-click the zip archive, click “Extract All...”, and when prompted to “Select a folder to extract files to”, browse to C:\My Documents\TerraSync. If prompted about replacing existing files, select yes to all.

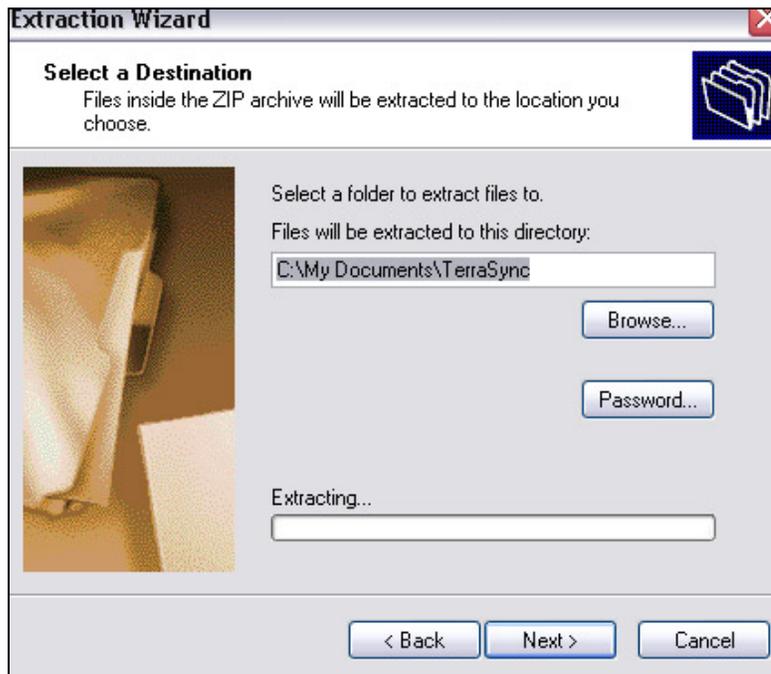


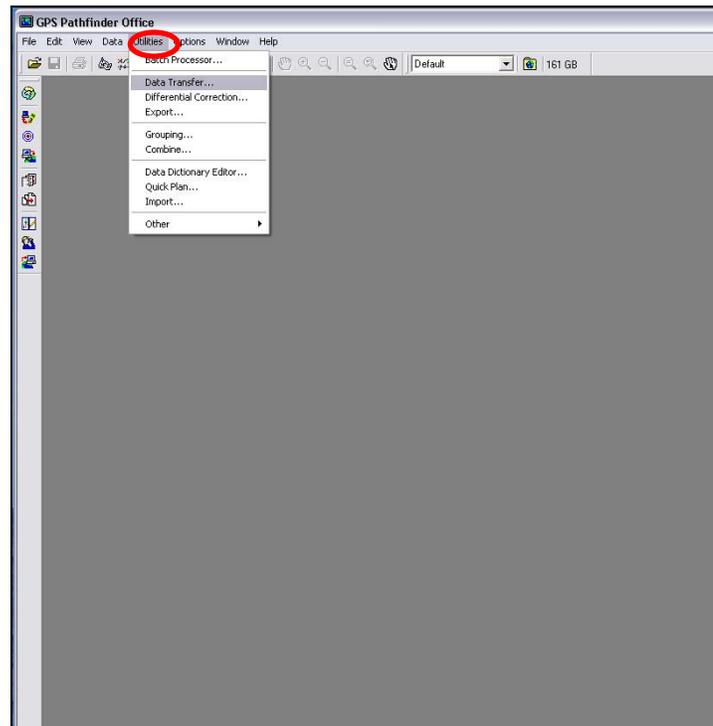
Figure 4: Extract (or copy) original target files into the TerraSync directory.

5. You should now be able to open the file in TerraSync and begin logging as normal.

Option 2: Transfer files back and forth from TerraSync.

If you need to be able to see the previously occupied positions from last week while positioning this week, you need to use Pathfinder to reset the file. This process will essentially combine the targets and actuals from last week into one file. This has its drawbacks though – once converted the actuals from last week will not be able to be corrected, so a backup procedure similar to the one in the previous option should be carried out to maintain data integrity. Here are the details.

1. For good data management, please backup the data files from the previous week using the procedure laid out in steps 1-3 in Option 1 above.
2. Close TerraSync and open up Pathfinder Office.
3. Go to the >Utilities>Data Transfer menu or just click the icon on the left.



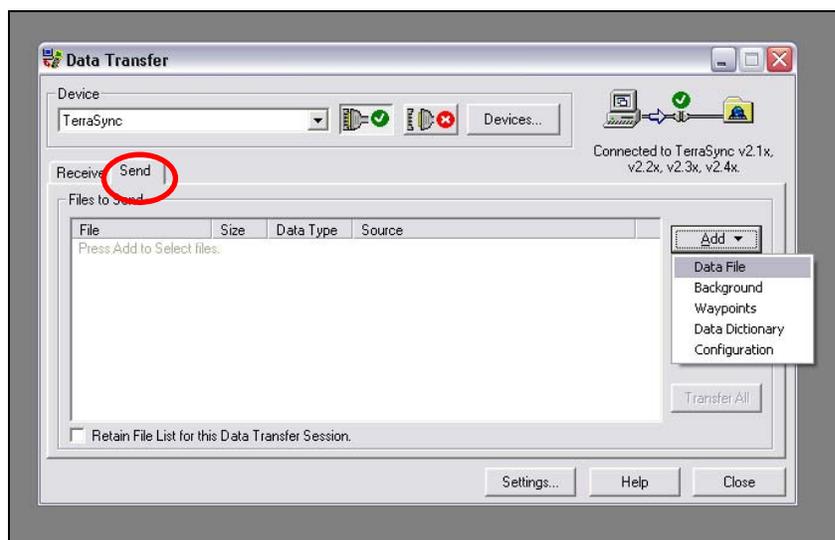
4. Ensure that the device listed is TerraSync. If not, follow the initial setup instructions at the beginning of this document. Most of the computers used for GPS logging are already setup for this.

There are two tabs, Receive and Send. Make sure that Receive is selected and then go to Add>Data File. Select the file(s) that you are using and select Open. The file should now be in the "Files to Receive" box. Click Transfer All and wait for the transfer to take place. If you have made the recommended backups, it is fine to replace any files.



Figure 5: Transferring file from TerraSync.

- Now select the Send tab, and go to Add>Data File. Select the file you just transferred (it will have the same name as the TerraSync file) and click Open. Now click Transfer All to move the file back to TerraSync.



By transferring the file back and forth from Terrasync to Pathfinder you have “reset the clock” and you may now update the file for an additional 7 days. This file will have your targets and actual positions from the last week, so it is important to be aware of the features you are selecting for navigation.

STANDARD OPERATING PROCEDURE SOP-2: SURFACE SEDIMENT SAMPLING

Scope and Application

The purpose of this SOP is to define and standardize the methods for collecting surface sediment samples from freshwater or marine environments. Surface sediments are defined as those from 0 to at most 1 ft (30 cm) below the sediment-water interface. The actual definition of surface sediments is typically program-specific and is dependent on the purpose of the study and the regulatory criteria (if any) to which the data will be compared.

This SOP utilizes and augments the procedures outlined in Puget Sound Estuary Program (PSEP; USEPA 1996) guidelines. A goal of this SOP is to ensure that the highest quality, most representative data be collected, and that these data are comparable to data collected by different programs that follow PSEP guidelines.

Summary of Method

Sediment samples for chemical and toxicity analysis are collected using a surface sediment sampling device (e.g., grab sampler). If a sample meets acceptability guidelines, overlying water is carefully siphoned off the surface, and the sediment is described in the field log. Sediment samples for chemical analysis may be collected directly from the sampler (e.g., volatile organic compounds and sulfides) or sediment from the sampler may be homogenized using decontaminated, stainless-steel containers and utensils prior to being placed in sample jars. Sediment from several sampler casts may also be composited and homogenized prior to being placed in sample jars.

Supplies and Equipment

A generalized supply and equipment list is provided below. Additional equipment may be required depending on project requirements.

- Grab sampler or box corer (see examples below in *Procedures for Sediment Sample Collection*)
- Field equipment:
 - Siphoning hose
 - Stainless-steel bowls or containers

- Stainless-steel spoons, spatulas, and/or mixer
- Decontamination supplies
- (Alconox™ detergent, 0.1 N nitric acid, methanol, hexane, deionized water)
- Personal protective equipment for field team (rain gear, safety goggles, hard hats, nitrile gloves)
- Photoionization detector (PID) and/or flame ionization detector (FID)
- First Aid kit
- Cell phone
- Camera
- Sample containers
- Bubble wrap
- Sample jar labels
- Clear tape
- Permanent markers
- Indelible black-ink pens
- Pencils
- Coolers
- Ice
- Documentation
 - Waterproof field logbook
 - Field Sampling Plan (FSP)
 - Health and Safety Plan (HASP)
 - Correction forms
 - Request for change forms
 - Waterproof sample description forms.

Procedures

Sediment Sample Collection

To collect sediment for chemical and biological analyses, a sampler that obtains a quantifiable volume of sediment with minimal disturbance of the sediments must be

employed. Additionally, the sampler should be composed of a material such as stainless-steel or aluminum, or have a non-contaminating coating such as Teflon™. Samplers capable of providing high-quality sediment samples include grab-type samplers (e.g., van Veen, Smith-McIntyres, Young grab, Power Grab and ponar grab) and box cores (Soutar, mini-Soutar, Gray-O'Hara, spade core). Some programs require a sampler that collects from a specific area (e.g., 0.1 m²). Most sampling devices are typically a standard size; however, some non-standard sizes are available to meet the requirements of specific programs. Grab samplers, especially the van Veen grab, are the most commonly used samplers to collect surface sediment. Power Grab samplers are often used for programs requiring collection of sediment deeper than 10 cm (4 in) or in areas with debris.

A hydraulic winch system should be used to deploy the sampler at a rate not exceeding 1 m/sec to minimize the bow wake associated with sampler descent. Once the sampler hits the bottom, the jaws are slowly closed and the sampler is brought to the deck of the vessel at a rate not exceeding 1 m/sec to minimize any washing and disturbance of the sediment within the sampler. At the moment the sampler hits the bottom, the time, depth, and location of sample acquisition are recorded in the field logbook.

Once onboard, the sampler is secured, any overlying water is carefully siphoned off, and the sample is inspected to determine acceptability. Criteria used to determine acceptability are those detailed in PSEP (1986), except when noted in the project-specific FSP. These criteria include but are not limited to:

- There is minimal or no excessive water leakage from the jaws of the sampler.
- There is no excessive turbidity in the water overlying the sample.
- The sampler is not over-penetrated.
- The sediment surface appears to be intact with minimal disturbance.
- The program-specified penetration depths are attained.

If the sample meets acceptability criteria, the sample is recorded and observations entered onto a sample description form or log. Once the sample has been characterized, the sediment is then subsampled for chemical and biological analyses.

Sample Processing

Sediment for chemical and/or toxicity analyses is removed from the sampler using a stainless-steel spoon. Depending on programmatic goals, the upper 30 cm (1 ft) of sediment is removed. To prevent possible cross contamination, sediments touching the margins of the sampler are not used.

Sample logs, labels, custody seals, and chain-of-custody forms are completed, and sample information is recorded in the field notebook.

Samples for volatile compounds (either organics or sulfides) are collected using a decontaminated stainless-steel spoon while sediment is still in the sampler. These sediments are not homogenized. The volatile organics sample jar should be tightly packed with sediment (to eliminate obvious air pockets) and filled so that there is no headspace remaining in the jar. Alternatively, if there is adequate water in the sediment, the container may be filled to overflowing so that a convex meniscus forms at the top, and the cap carefully placed on the jar. Once sealed, there should be no air bubbles. The sulfides sample is preserved with 0.2 N zinc acetate.

The remaining sediment is then placed into a pre-cleaned, stainless-steel bowl. Typically, sediment from a minimum of three separate casts of the sampler is composited at each station. Once a sufficient amount of sediment has been collected, the sediment is homogenized until it is of uniform color and has obtained a smooth consistency. It is then dispensed into pre-cleaned sample jars for the various chemical or biological analyses. Sample jars for biological analyses should be filled to the top with sediment to minimize available headspace. This procedure will minimize any oxidation reactions within the sediment. Sample jars for chemical analysis may be frozen for storage, leaving enough headspace left in the container to allow for expansion of the sediment upon freezing. Sample jars collected for VOC analysis will not be frozen.

After dispensing the sediment, the containers are then placed into coolers with ice and are either shipped directly to the analytical laboratories or transported to a storage facility. Excess sediment will be placed in Department of Transportation-approved 55 gallons drums and handled in accordance with SOP-11.

Sediment is described in accordance with ASTM D-2488 (SOP 4) on the sample log form.

Sampling equipment decontaminated in accordance with SOP-9, Equipment Decontamination.

Reference

USEPA. 1996. Puget Sound Estuary Program: Recommended protocols for measuring selected environmental variables in Puget Sound. Prepared for U.S. Environmental Protection Agency, Region 10, and Puget Sound Estuary Program, Seattle, WA. Tetra Tech and HRA, Inc., Bellevue, WA.

STANDARD OPERATING PROCEDURE SOP-3:

SUBSURFACE SEDIMENT SAMPLING USING A SPLIT- SPOON SAMPLER AND A GUS OR OSTERBERG SAMPLER EQUIPPED WITH A SHELBY TUBE

Scope and Application

This SOP describes Integral procedures for the collection of subsurface sediment samples using a split-spoon sampler and a Gregory Undisturbed Sampler (GUS) or Osterberg sampler equipped with a Shelby Tube. Sediment cores will be collected following ASTM Method D-1586-84, Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils.

Supplies and Equipment

A generalized supply and equipment list is provided below. Additional equipment may be required depending on the project.

- Sampling device:
 - Hollow-stem auger drill rig (or equivalent Sonic rig)
 - Stainless-steel, 1.5-ft-long, 2-in-diameter split spoon; *or* 2.5-ft-long, 3-in-diameter split-spoon sampler or Shelby tubes
 - Stainless-steel or other liners, if required
 - Stainless-steel core catchers (as necessary)
 - Core extruder device, drill, ratchet, plugs
 - 55-gallon drums (if required)
- Field equipment:
 - Aluminum foil
 - Duct tape
 - Hack saw
 - Plastic sheeting
 - Pipe cutter

- Plunger (if necessary)
- Table or tray
- Ice (if storing cores)
- Stainless-steel bowls
- Stainless-steel spoons, spatulas, and/or mixer
- Assorted geology supplies (e.g., hand lens, grain-size card, scales, etc.)
- Decontamination equipment (SOP-9)
- Personal protective equipment for field team (rain gear, safety goggles, hard hats, nitrile gloves)
- Photoionization detector (PID)
- First Aid kit
- Cell phone
- Camera
- Sample containers
- Ziploc® bags
- Bubble wrap
- Clear tape
- Permanent markers
- Indelible ink pen
- Pencils
- Coolers
- Documentation:
 - Core description forms
 - Waterproof field logbook
 - Field Sampling Plan (FSP)
 - Health and Safety Plan (HASP)
 - Chain-of-custody seals
 - Sample labels
 - Correction forms

Procedures

Hollow-stem auger or equivalent (e.g., Sonic) drilling is used to obtain sediment cores using both split-spoon and GUS or Osterberg samplers equipped with a Shelby tube. Both split-spoons and Shelby tubes can collect similar-sized cores (2-ft-long, 3-in-diameter), although the methods of obtaining the cores differ. Split-spoons are hammered into the sediment, while Shelby tubes are hydraulically or pneumatically (with nitrogen gas) driven into the sediment. In addition, each half of a split-spoon sample is simply pulled apart to expose the core, while the sediment must be extruded from the Shelby tube. Once the core is exposed, the processing and handling of the core sample is identical.

The following sections describe the methods of collecting and "extruding" split-spoon and Shelby tube cores, respectively. Methods for processing and sampling the cores are also included.

Collection of Cores Using a Split-Spoon Sampler

1. Decontaminate the split-spoon sampler, liners (if used), and other equipment in accordance with SOP-9. If a stainless-steel split-spoon sampler without liners is used, the sampler should be fully decontaminated between all samples collected. If liners are used, liners should be fully decontaminated, while the split-spoon should be cleaned with Alconox[®], tap or seawater, and a distilled water rinse.
2. Insert stainless-steel liners into the split-spoon sampler, along with sand catchers, if required.
3. Attach the split-spoon sampler to the bottom end of a string of drill rod which extends from the top of the auger, through the hollow stem, and to the bottom of the borehole.
4. Attach a 140-pound (or other appropriate weight) hammer to the top of the drill rod string and drive the sampler into the soil at the bottom of the borehole.

NOTE: Record the hammer weight and blow counts in the field log. The blow counts are generally recorded for each 6-inch interval.

5. To drive the sampler into the sediment, alternately raise the hammer on a rope, which passes around a rotating cathead, and allow the hammer to free-fall 30 inches by suddenly releasing the tension on the cable.
6. Pull the sampler up from the bottom of the borehole on the drive rods and remove from the bottom of the drive rod string.

7. Remove the top assembly and the drive shoe from the sampler and open the tube by removing one-half of the split barrel. If liners are used, push the sediment from the liner, and arrange the liner sections in the appropriate order, taking care to maintain the integrity of the core.
8. If field organic vapor monitoring is required, immediately collect a representative sample from the sampler and place in a new, labeled Ziploc® bag for screening. The Ziploc® bag should be closed and allowed to sit in ambient air for 10 minutes prior to monitoring with an OVM or PID.
9. Process and subsample the core as described in sections below.
10. Advance the auger and repeat steps 1-9.

Collection of Cores Using GUS or Osterberg Samplers Equipped with Shelby Tubes

1. Decontaminate the Shelby tubes and other equipment in accordance with SOP-9. The Shelby tubes should be fully decontaminated between all samples collected. Core caps should be washed with Alconox® and water, and rinsed with distilled water, in accordance with SOP-9.
2. Attach the GUS or Osterberg sampler equipped with a Shelby tube to the bottom end of a string of drill rod that extends from the top of the auger, through the hollow stem, and to the bottom of the borehole.
3. Lower the coring assembly (rod with GUS or Osterberg sampler) until it is positioned at the sediment/water interface.
4. Hydraulically (or pneumatically) drive the core tube into the sediment until a 2-ft core is obtained.
5. Once the core is brought onboard, remove it from the rod, and immediately cap and tape both ends. It is preferable to put a layer of foil on each end prior to capping. Label the core with station, sampling depth interval, time of collection, and core orientation (top of core).
6. Place the core in an upright box or stand with ice until it is processed. Cover the cores in the holding box with a tarp to prevent sample contamination from airborne particles (e.g., vessel engine gases) and to keep them out of direct sunlight.
7. The Shelby tube cores may be processed on the barge or onshore near the site. During transit, the tubes must remain upright and cool.

8. When prepared to process a core, remove the cap from the upper end of the core (holes present where the core is attached to the sampler and rod). Place the core horizontally in the extruder core holder so that the open end is toward the extruder. Secure the core in the holder and remove the other cap at the bottom of the core. Place an appropriate-sized plug wrapped in foil into the top end of the core, insert the extruder rod and screw, and wind the plug until it touches the top end of the sediment. A tray wrapped in aluminum foil should be placed at the bottom end of the core, and a person wearing nitrile or polyethylene gloves should be present to catch and guide the core as it is extruded. Use a drill or ratchet (depending on how stiff the core is) to wind the screw, pushing the core from the Shelby tube. If the core is particularly stiff, it may be necessary to hit the side of the core tube with a rubber hammer or other device while winding the extruder. Alternatively, if the core is particularly soft, the core may be readily extruded by simply pushing the plug with a rod by hand.
9. If field organic vapor monitoring is required, immediately collect a representative sample from the sampler and place it in a new, labeled Ziploc® bag for screening. The Ziploc® bag should be closed and allowed to sit in ambient air for 10 minutes prior to monitoring with an OVM or PID.
10. Process and subsample the core as described in the following sections.
11. Advance the auger, and repeat steps 1-10.

Sampling and Processing the Subsurface Sediment Cores

1. Once the core is exposed, split the core lengthwise using a decontaminated knife or spoon.
2. If subsamples are to be collected for volatile organics, total sulfides, or acid volatile sulfides, collect them immediately after the core has been split. Use a decontaminated spoon to remove sediment along the entire length of the core for each subsample collected. Place the subsample into the appropriate jar according to the procedures described in SOP-6, label the jar, and place it in a cooler with ice (or blue ice). The volatile organics sample jar should be tightly packed with sediment (to eliminate obvious air pockets) and filled so that there is no headspace remaining in the jar. Alternatively, if there is adequate water in the sediment, the container may be filled to overflowing so that a convex meniscus forms at the top, and the cap carefully placed on the jar. Once sealed, there should be no air bubbles.
3. If required by the field sampling plan, place a sign above the sample, including station number, core depth, and date and time of core collection. In addition, place a measuring stick along the length of the core, and photograph the sediment core. Avoid touching the core with the scale or sign.

4. Describe the core, including such information as the vertical changes in sediment characteristics (e.g., texture, density, and moisture) and distribution of visible contamination, color and odor of the sediments, sediment texture, presence of debris (wood chips, wood fibers, human artifacts), presence of oily sheen, and visible fauna or biological structures in accordance with ASTM Method D2488 (SOP-4). This information should be recorded in the sediment coring log, along with other information listed in SOP-4, Sediment Borehole Logging.
5. Transfer sediment selected for chemical analyses to a decontaminated stainless-steel mixing bowl. Cover the bowl if more sediment from another core is composited with the sample.
6. Mix the sediment in the bowl until well homogenized (visibly uniform) and transfer it into the appropriately sized sample containers for the individual analyses (see SOP-2, Surface Sediment Sampling).
7. Verify that samples have been properly labeled and store them onsite in a cooler at 4°C until they are packaged for shipping (see SOPs 5 and 6).
8. Generally, at completion of sediment sampling activities at a station, collect all spilled and excess material and dispose of overboard at the original sampling location. However, dispose of material in accordance with applicable regulations and any directives issued by the client. It may be required to place excess material into DOT-approved 55-gallon drums (depending on level and type of contamination).
9. Decontaminate all sampling equipment, including internal components, prior to use, between sampling events, stations and depth intervals, and prior to demobilization in accordance with SOP-9, Equipment Decontamination.

STANDARD OPERATING PROCEDURE SOP-4: BOREHOLE LOGGING AND FIELD CLASSIFICATION OF SOILS AND SEDIMENT

Scope and Application

The following procedures establish the minimum information that must be recorded in the field to adequately document soil borehole advancement activities performed during field exploration. The borehole log form must be filled out completely.

This SOP presents the field classification of soils to be used by Integral field staff. In general, Integral has adopted the procedures provided in ASTM Method D-2488-00 attached, Standard Practice for Description and Identification of Soils. ASTM D-2488-00 uses the Unified Soil Classification System (USCS) for naming soils. Field personnel are encouraged to study these procedures prior to initiation of field work.

Soil descriptions should be precise and comprehensive without being verbose. The overall impression of the soil should not be distorted by excessive emphasis on minor constituents. In general, the similarities of consecutive soil samples should be emphasized and minor differences de-emphasized. These descriptions will be used to interpret aquifer properties and other potential contaminant transport properties, rather than interpret the exact mineralogy or tectonic environment. Integral is primarily interested in engineering and geochemical properties of the soil.

Soil descriptions should be provided in the Soil Description column of the soil boring log for each sample collected. If there is no difference between consecutive soil samples, subsequent descriptions can be noted as "same as above" or minor changes such as "increasing sand" or "becomes dark brown" can be added.

The format and order of soil descriptions should be as follows:

- Group symbol—Place in the Unified Symbol column
- USCS group name—Make identical to the ASTM D-2488-00 Group Name with the appropriate modifiers.
- Minor components
- Color
- Moisture
- Additional descriptions

Supplies and Equipment

- Soil log form
- Munsell® (or equivalent) soil color chart

Procedures

1. The USCS is an engineering properties system that uses grain size to classify soils. The first major distinction is between fine-grained soils (more than 50 percent passing the No. 200 sieve [75 µm/0.029 in.]) and coarse-grained soils (more than 50 percent retained by the No. 200 sieve). Small No. 200 sieves are necessary to classify soils that are near the cutoff size.
2. Fine-grained soils are classified as either silts or clays. Field determinations of silts and clays are based on observations of dry strength, dilatancy, toughness, and plasticity. Field procedures for these tests are included in ASTM D-2488-00. If these tests are used, the results should be included in the soil description. At least one complete round of field tests should be performed for a site if these materials are encountered, preferably at the beginning of the field investigation. The modifiers “fat” and “lean” are used by ASTM to describe soils of high and low plasticity. The soil group symbols (i.e., CL, MH) already indicate plasticity characteristics, and these modifiers are not necessary in the description. Soils with high plasticity can be emphasized by describing them as “silty CLAY with high plasticity.” Plasticity is an important descriptor because it is often used to interpret whether an ML soil is acting as either a leaky or a competent aquitard. For example, an ML soil can be dilatent/nonplastic and serve as a transport pathway, or it can be highly plastic and very impervious.
3. Coarse-grained soils are classified as either predominantly gravel or sand, with the No. 4 sieve (4.75 mm/0.19 in.) being the division. Modifiers are used to describe the relative amounts of fine-grained soil, as noted below:

Description	Percent Fines	Group Symbol
Gravel (sand)	<5 percent	GW, GP (SW, SP)
Gravel (sand) with silt (clay)	5–15 percent	Hyphenated names
Silty (clayey) gravel (sand)	>15 percent	GM, GC (SM, SC)

The gradation of a coarse-grained soil is included in the specific soil name (i.e., fine to medium SAND with silt). Estimating the percent of size ranges following the group name is encouraged for mixtures of silt, sand, and gravel. Use of the modifiers “poorly graded” or “well graded” is not necessary as they are indicated by the group symbol.

A borderline symbol is shown with a slash (GM/SM). This symbol should be used when the soil cannot be distinctly placed in either soil group. A borderline symbol should also be used when describing interbedded soils of two or more soil group names when the thickness of the beds are approximately equal, such as “interbedded lenses and layers of fine sand and silt.” The use of a borderline symbol should not be used indiscriminately. Every effort should be made to place the soil into a single group. (One very helpful addition to the soil log form description is the percentage of silt/sand/gravel. Even if the geologist did not have sufficient time to properly define the soil, this percentage breakdown allows classification at a later date.)

4. Minor components such as cobbles, roots, and construction debris should be preceded by the appropriate adjective reflecting relative percentages: trace (0–5 percent), few (5–10 percent), little (15–25 percent), and some (30–45 percent). The word “occasional” can be applied to random particles of a larger size than the general soil matrix (i.e., occasional cobbles, occasional brick fragments). The term “with” indicates definite characteristics regarding the percentage of secondary particle size in the soil name. It will not be used to describe minor components. If a nonsoil component exceeds 50 percent of an interval, it should be stated in place of the group name.
5. The basic color of a soil, such as brown, gray, or red, must be given. The color term can be modified by adjectives such as light, dark, or mottled. Especially note staining or mottling. This information may be useful to establish water table fluctuations or contamination. The Munsell® soil color chart designation is the Integral color standard. These charts are readily available and offer a high degree of consistency in descriptions between geologists.
6. The degree of moisture present in the soil should be defined as dry, moist, or wet. Moisture content can be estimated from the criteria listed in Table 3 of ASTM D-2488-00.

7. Features such as discontinuities, inclusions, joints, fissures, slickensides, bedding, laminations, root holes, and major mineralogical components should be noted if they are observed. Anything unusual should be noted. Additional soil descriptions may be made at the discretion of the project manager or as the field conditions warrant. The Soil Boring Log Form lists some optional descriptions, as does Table 13 of the ASTM standard. The reader is referred to the ASTM standard for procedures of these descriptions.
8. The contact between two soil types must be clearly marked on the soil boring log. The field geologist, who has the advantage of watching the drilling rate and cuttings removal and can talk with the driller in real time has a much better chance of interpreting the interval than someone in the office. If the contact is obvious and sharp, draw it in with a straight line. If it is gradational, a slanted line over the interval is appropriate. In the case where it is unclear, a dashed line over the most likely interval is used.



Standard Practice for Description and Identification of Soils (Visual-Manual Procedure)¹

This standard is issued under the fixed designation D 2488; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope *

1.1 This practice covers procedures for the description of soils for engineering purposes.

1.2 This practice also describes a procedure for identifying soils, at the option of the user, based on the classification system described in Test Method D 2487. The identification is based on visual examination and manual tests. It must be clearly stated in reporting an identification that it is based on visual-manual procedures.

1.2.1 When precise classification of soils for engineering purposes is required, the procedures prescribed in Test Method D 2487 shall be used.

1.2.2 In this practice, the identification portion assigning a group symbol and name is limited to soil particles smaller than 3 in. (75 mm).

1.2.3 The identification portion of this practice is limited to naturally occurring soils (disturbed and undisturbed).

NOTE 1—This practice may be used as a descriptive system applied to such materials as shale, claystone, shells, crushed rock, etc. (see Appendix X2).

1.3 The descriptive information in this practice may be used with other soil classification systems or for materials other than naturally occurring soils.

1.4 The values stated in inch-pound units are to be regarded as the standard.

1.5 *This standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. For specific precautionary statements see Section 8.*

1.6 *This practice offers a set of instructions for performing one or more specific operations. This document cannot replace education or experience and should be used in conjunction with professional judgment. Not all aspects of this practice may be applicable in all circumstances. This ASTM standard is not*

intended to represent or replace the standard of care by which the adequacy of a given professional service must be judged, nor should this document be applied without consideration of a project's many unique aspects. The word "Standard" in the title of this document means only that the document has been approved through the ASTM consensus process.

2. Referenced Documents

2.1 ASTM Standards:

D 653 Terminology Relating to Soil, Rock, and Contained Fluids²

D 1452 Practice for Soil Investigation and Sampling by Auger Borings²

D 1586 Test Method for Penetration Test and Split-Barrel Sampling of Soils²

D 1587 Practice for Thin-Walled Tube Sampling of Soils²

D 2113 Practice for Diamond Core Drilling for Site Investigation²

D 2487 Classification of Soils for Engineering Purposes (Unified Soil Classification System)²

D 3740 Practice for Minimum Requirements for Agencies Engaged in the Testing and/or Inspection of Soil and rock as Used in Engineering Design and Construction³

D 4083 Practice for Description of Frozen Soils (Visual-Manual Procedure)²

3. Terminology

3.1 *Definitions*—Except as listed below, all definitions are in accordance with Terminology D 653.

NOTE 2—For particles retained on a 3-in. (75-mm) US standard sieve, the following definitions are suggested:

Cobbles—particles of rock that will pass a 12-in. (300-mm) square opening and be retained on a 3-in. (75-mm) sieve, and

Boulders—particles of rock that will not pass a 12-in. (300-mm) square opening.

3.1.1 *clay*—soil passing a No. 200 (75- μ m) sieve that can be made to exhibit plasticity (putty-like properties) within a range of water contents, and that exhibits considerable strength when air-dry. For classification, a clay is a fine-grained soil, or the

¹ This practice is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.07 on Identification and Classification of Soils.

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² *Annual Book of ASTM Standards*, Vol 04.08.

³ *Annual Book of ASTM Standards*, Vol 04.09.

*A Summary of Changes section appears at the end of this standard.

fine-grained portion of a soil, with a plasticity index equal to or greater than 4, and the plot of plasticity index versus liquid limit falls on or above the “A” line (see Fig. 3 of Test Method D 2487).

3.1.2 *gravel*—particles of rock that will pass a 3-in. (75-mm) sieve and be retained on a No. 4 (4.75-mm) sieve with the following subdivisions:

coarse—passes a 3-in. (75-mm) sieve and is retained on a ¾-in. (19-mm) sieve.

fine—passes a ¾-in. (19-mm) sieve and is retained on a No. 4 (4.75-mm) sieve.

3.1.3 *organic clay*—a clay with sufficient organic content to influence the soil properties. For classification, an organic clay is a soil that would be classified as a clay, except that its liquid limit value after oven drying is less than 75 % of its liquid limit value before oven drying.

3.1.4 *organic silt*—a silt with sufficient organic content to influence the soil properties. For classification, an organic silt is a soil that would be classified as a silt except that its liquid limit value after oven drying is less than 75 % of its liquid limit value before oven drying.

3.1.5 *peat*—a soil composed primarily of vegetable tissue in various stages of decomposition usually with an organic odor, a dark brown to black color, a spongy consistency, and a texture ranging from fibrous to amorphous.

3.1.6 *sand*—particles of rock that will pass a No. 4 (4.75-mm) sieve and be retained on a No. 200 (75-µm) sieve with the following subdivisions:

coarse—passes a No. 4 (4.75-mm) sieve and is retained on a No. 10 (2.00-mm) sieve.

medium—passes a No. 10 (2.00-mm) sieve and is retained on a No. 40 (425-µm) sieve.

fine—passes a No. 40 (425-µm) sieve and is retained on a No. 200 (75-µm) sieve.

3.1.7 *silt*—soil passing a No. 200 (75-µm) sieve that is nonplastic or very slightly plastic and that exhibits little or no strength when air dry. For classification, a silt is a fine-grained soil, or the fine-grained portion of a soil, with a plasticity index less than 4, or the plot of plasticity index versus liquid limit falls below the “A” line (see Fig. 3 of Test Method D 2487).

4. Summary of Practice

4.1 Using visual examination and simple manual tests, this practice gives standardized criteria and procedures for describing and identifying soils.

4.2 The soil can be given an identification by assigning a group symbol(s) and name. The flow charts, Fig. 1a and Fig. 1b for fine-grained soils, and Fig. 2, for coarse-grained soils, can be used to assign the appropriate group symbol(s) and name. If the soil has properties which do not distinctly place it into a specific group, borderline symbols may be used, see Appendix X3.

NOTE 3—It is suggested that a distinction be made between *dual symbols* and *borderline symbols*.

Dual Symbol—A dual symbol is two symbols separated by a hyphen, for example, GP-GM, SW-SC, CL-ML used to indicate that the soil has been identified as having the properties of a classification in accordance with Test Method D 2487 where two symbols are required. Two symbols are required when the soil has between 5 and 12 % fines or when the liquid

limit and plasticity index values plot in the CL-ML area of the plasticity chart.

Borderline Symbol—A borderline symbol is two symbols separated by a slash, for example, CL/CH, GM/SM, CL/ML. A borderline symbol should be used to indicate that the soil has been identified as having properties that do not distinctly place the soil into a specific group (see Appendix X3).

5. Significance and Use

5.1 The descriptive information required in this practice can be used to describe a soil to aid in the evaluation of its significant properties for engineering use.

5.2 The descriptive information required in this practice should be used to supplement the classification of a soil as determined by Test Method D 2487.

5.3 This practice may be used in identifying soils using the classification group symbols and names as prescribed in Test Method D 2487. Since the names and symbols used in this practice to identify the soils are the same as those used in Test Method D 2487, it shall be clearly stated in reports and all other appropriate documents, that the classification symbol and name are based on visual-manual procedures.

5.4 This practice is to be used not only for identification of soils in the field, but also in the office, laboratory, or wherever soil samples are inspected and described.

5.5 This practice has particular value in grouping similar soil samples so that only a minimum number of laboratory tests need be run for positive soil classification.

NOTE 4—The ability to describe and identify soils correctly is learned more readily under the guidance of experienced personnel, but it may also be acquired systematically by comparing numerical laboratory test results for typical soils of each type with their visual and manual characteristics.

5.6 When describing and identifying soil samples from a given boring, test pit, or group of borings or pits, it is not necessary to follow all of the procedures in this practice for every sample. Soils which appear to be similar can be grouped together; one sample completely described and identified with the others referred to as similar based on performing only a few of the descriptive and identification procedures described in this practice.

5.7 This practice may be used in combination with Practice D 4083 when working with frozen soils.

NOTE 5—Notwithstanding the statements on precision and bias contained in this standard: The precision of this test method is dependent on the competence of the personnel performing it and the suitability of the equipment and facilities used. Agencies that meet the criteria of Practice D 3740 are generally considered capable of competent and objective testing. Users of this test method are cautioned that compliance with Practice D 3740 does not in itself assure reliable testing. Reliable testing depends on several factors; Practice D 3740 provides a means for evaluating some of those factors.

6. Apparatus

6.1 *Required Apparatus:*

6.1.1 *Pocket Knife or Small Spatula.*

6.2 *Useful Auxiliary Apparatus:*

6.2.1 *Small Test Tube and Stopper (or jar with a lid).*

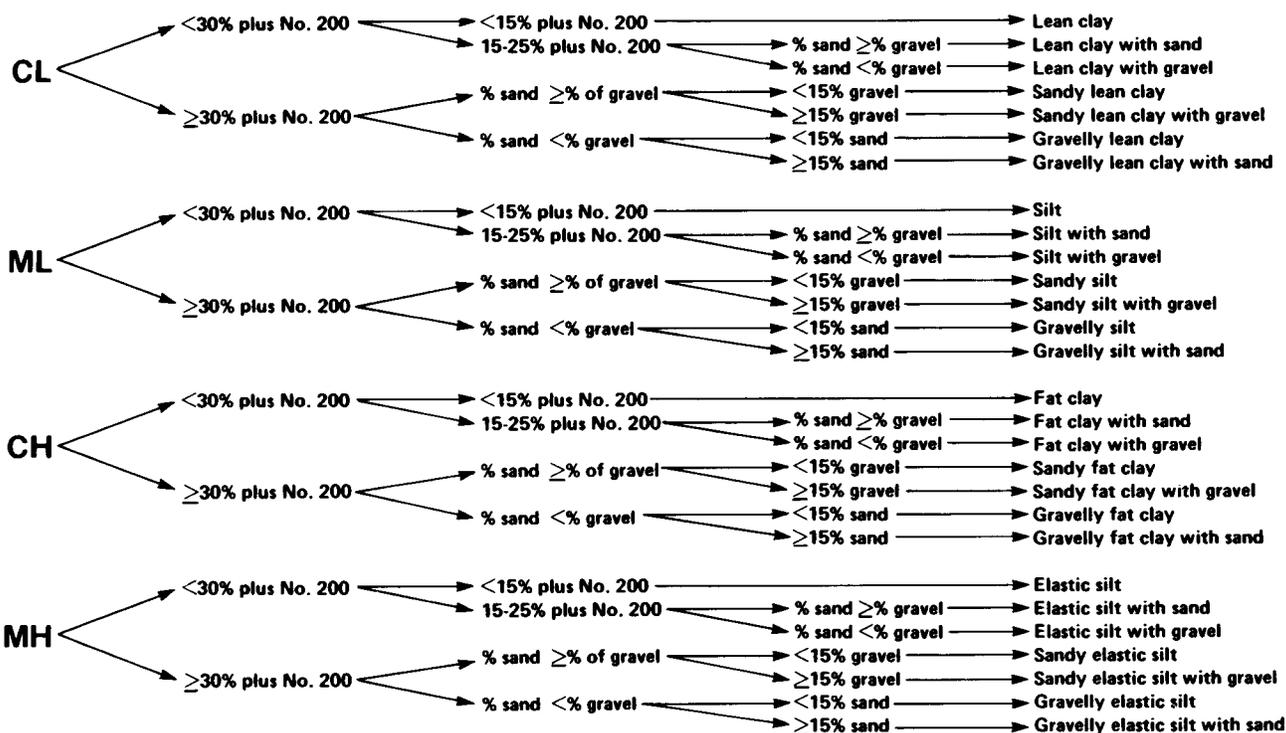
6.2.2 *Small Hand Lens.*

7. Reagents

7.1 *Purity of Water*—Unless otherwise indicated, references

GROUP SYMBOL

GROUP NAME

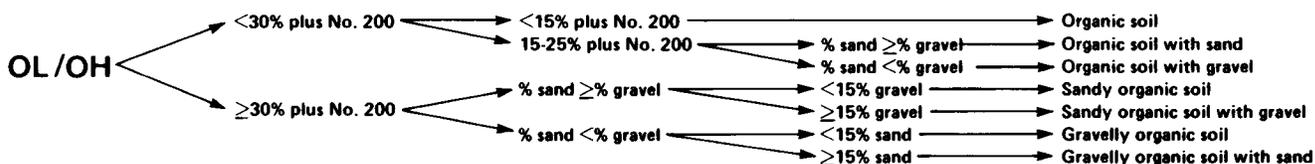


NOTE 1—Percentages are based on estimating amounts of fines, sand, and gravel to the nearest 5 %.

FIG. 1a Flow Chart for Identifying Inorganic Fine-Grained Soil (50 % or more fines)

GROUP SYMBOL

GROUP NAME



NOTE 1—Percentages are based on estimating amounts of fines, sand, and gravel to the nearest 5 %.

FIG. 1 b Flow Chart for Identifying Organic Fine-Grained Soil (50 % or more fines)

to water shall be understood to mean water from a city water supply or natural source, including non-potable water.

7.2 *Hydrochloric Acid*—A small bottle of dilute hydrochloric acid, HCl, one part HCl (10 N) to three parts water (This reagent is optional for use with this practice). See Section 8.

8. Safety Precautions

8.1 When preparing the dilute HCl solution of one part concentrated hydrochloric acid (10 N) to three parts of distilled water, slowly add acid into water following necessary safety precautions. Handle with caution and store safely. If solution comes into contact with the skin, rinse thoroughly with water.

8.2 **Caution**—Do not add water to acid.

9. Sampling

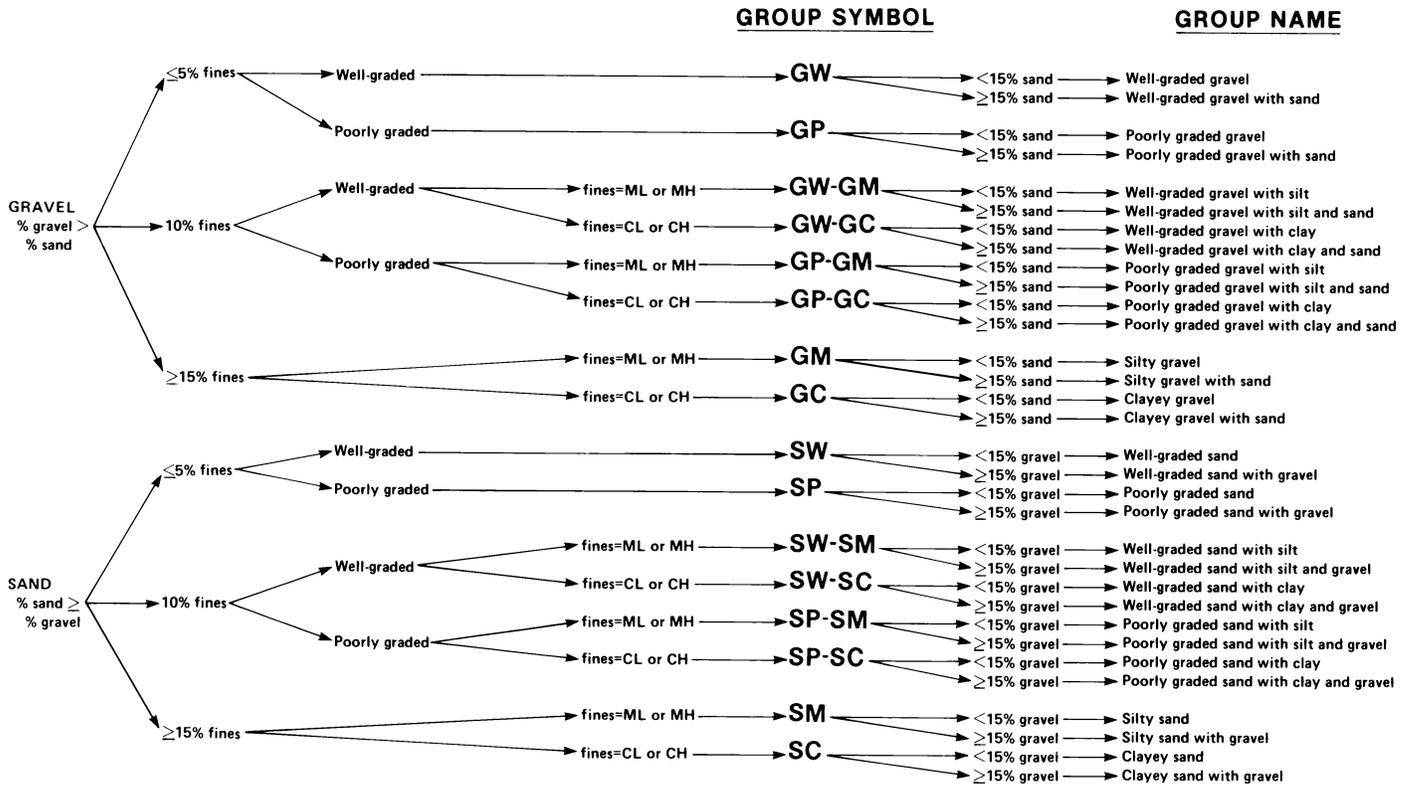
9.1 The sample shall be considered to be representative of the stratum from which it was obtained by an appropriate, accepted, or standard procedure.

NOTE 6—Preferably, the sampling procedure should be identified as having been conducted in accordance with Practices D 1452, D 1587, or D 2113, or Test Method D 1586.

9.2 The sample shall be carefully identified as to origin.

NOTE 7—Remarks as to the origin may take the form of a boring number and sample number in conjunction with a job number, a geologic stratum, a pedologic horizon or a location description with respect to a permanent monument, a grid system or a station number and offset with respect to a stated centerline and a depth or elevation.

9.3 For accurate description and identification, the minimum amount of the specimen to be examined shall be in accordance with the following schedule:



NOTE 1—Percentages are based on estimating amounts of fines, sand, and gravel to the nearest 5 %.

FIG. 2 Flow Chart for Identifying Coarse-Grained Soils (less than 50 % fines)

Maximum Particle Size, Sieve Opening	Minimum Specimen Size, Dry Weight
4.75 mm (No. 4)	100 g (0.25 lb)
9.5 mm (¾ in.)	200 g (0.5 lb)
19.0 mm (¾ in.)	1.0 kg (2.2 lb)
38.1 mm (1½ in.)	8.0 kg (18 lb)
75.0 mm (3 in.)	60.0 kg (132 lb)

NOTE 8—If random isolated particles are encountered that are significantly larger than the particles in the soil matrix, the soil matrix can be accurately described and identified in accordance with the preceding schedule.

9.4 If the field sample or specimen being examined is smaller than the minimum recommended amount, the report shall include an appropriate remark.

10. Descriptive Information for Soils

10.1 *Angularity*—Describe the angularity of the sand (coarse sizes only), gravel, cobbles, and boulders, as angular, subangular, subrounded, or rounded in accordance with the criteria in Table 1 and Fig. 3. A range of angularity may be stated, such as: subrounded to rounded.

10.2 *Shape*—Describe the shape of the gravel, cobbles, and boulders as flat, elongated, or flat and elongated if they meet the criteria in Table 2 and Fig. 4. Otherwise, do not mention the shape. Indicate the fraction of the particles that have the shape, such as: one-third of the gravel particles are flat.

10.3 *Color*—Describe the color. Color is an important property in identifying organic soils, and within a given locality it may also be useful in identifying materials of similar geologic origin. If the sample contains layers or patches of

TABLE 1 Criteria for Describing Angularity of Coarse-Grained Particles (see Fig. 3)

Description	Criteria
Angular	Particles have sharp edges and relatively plane sides with unpolished surfaces
Subangular	Particles are similar to angular description but have rounded edges
Subrounded	Particles have nearly plane sides but have well-rounded corners and edges
Rounded	Particles have smoothly curved sides and no edges

varying colors, this shall be noted and all representative colors shall be described. The color shall be described for moist samples. If the color represents a dry condition, this shall be stated in the report.

10.4 *Odor*—Describe the odor if organic or unusual. Soils containing a significant amount of organic material usually have a distinctive odor of decaying vegetation. This is especially apparent in fresh samples, but if the samples are dried, the odor may often be revived by heating a moistened sample. If the odor is unusual (petroleum product, chemical, and the like), it shall be described.

10.5 *Moisture Condition*—Describe the moisture condition as dry, moist, or wet, in accordance with the criteria in Table 3.

10.6 *HCl Reaction*—Describe the reaction with HCl as none, weak, or strong, in accordance with the criteria in Table 4. Since calcium carbonate is a common cementing agent, a report of its presence on the basis of the reaction with dilute hydrochloric acid is important.

10.7 *Consistency*—For intact fine-grained soil, describe the

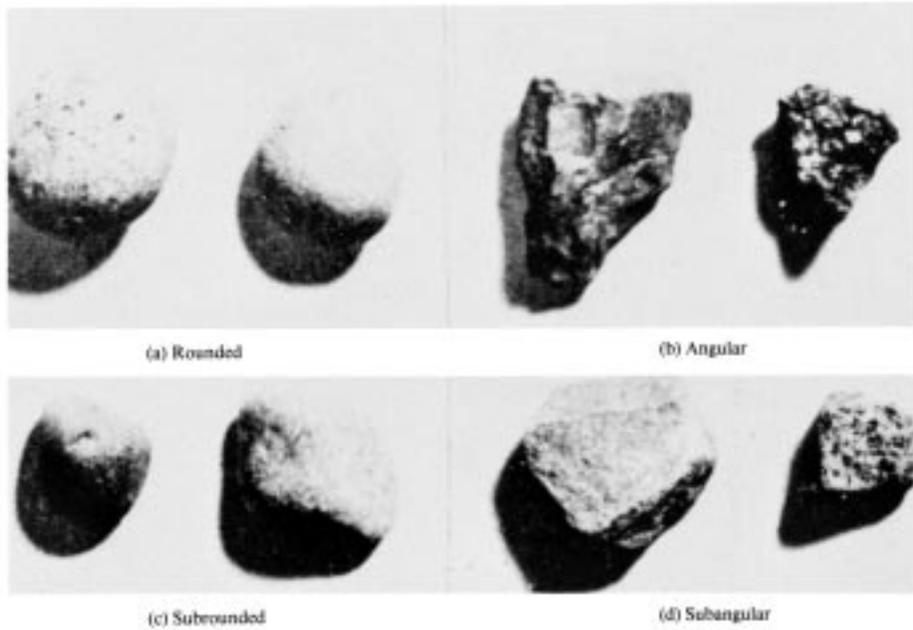


FIG. 3 Typical Angularity of Bulky Grains

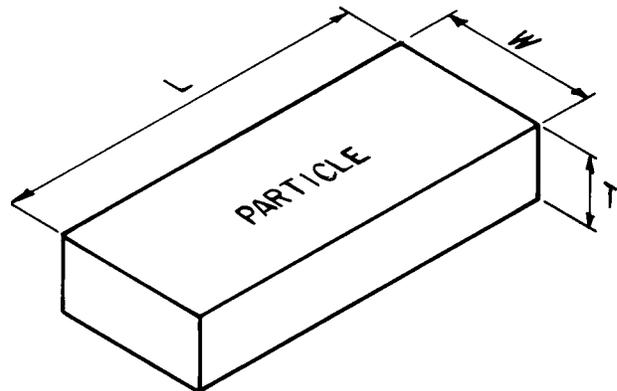
TABLE 2 Criteria for Describing Particle Shape (see Fig. 4)

The particle shape shall be described as follows where length, width, and thickness refer to the greatest, intermediate, and least dimensions of a particle, respectively.

Flat	Particles with width/thickness > 3
Elongated	Particles with length/width > 3
Flat and elongated	Particles meet criteria for both flat and elongated

PARTICLE SHAPE

W = WIDTH
T = THICKNESS
L = LENGTH



FLAT: $W/T > 3$
 ELONGATED: $L/W > 3$
 FLAT AND ELONGATED:
 - meets both criteria

FIG. 4 Criteria for Particle Shape

consistency as very soft, soft, firm, hard, or very hard, in accordance with the criteria in Table 5. This observation is inappropriate for soils with significant amounts of gravel.

10.8 *Cementation*—Describe the cementation of intact coarse-grained soils as weak, moderate, or strong, in accordance with the criteria in Table 6.

10.9 *Structure*—Describe the structure of intact soils in accordance with the criteria in Table 7.

10.10 *Range of Particle Sizes*—For gravel and sand components, describe the range of particle sizes within each component as defined in 3.1.2 and 3.1.6. For example, about 20 % fine to coarse gravel, about 40 % fine to coarse sand.

10.11 *Maximum Particle Size*—Describe the maximum particle size found in the sample in accordance with the following information:

10.11.1 *Sand Size*—If the maximum particle size is a sand size, describe as fine, medium, or coarse as defined in 3.1.6. For example: maximum particle size, medium sand.

10.11.2 *Gravel Size*—If the maximum particle size is a gravel size, describe the maximum particle size as the smallest sieve opening that the particle will pass. For example, maximum particle size, 1½ in. (will pass a 1½-in. square opening but not a ¾-in. square opening).

10.11.3 *Cobble or Boulder Size*—If the maximum particle size is a cobble or boulder size, describe the maximum dimension of the largest particle. For example: maximum dimension, 18 in. (450 mm).

10.12 *Hardness*—Describe the hardness of coarse sand and larger particles as hard, or state what happens when the

TABLE 3 Criteria for Describing Moisture Condition

Description	Criteria
Dry	Absence of moisture, dusty, dry to the touch
Moist	Damp but no visible water
Wet	Visible free water, usually soil is below water table

TABLE 4 Criteria for Describing the Reaction With HCl

Description	Criteria
None	No visible reaction
Weak	Some reaction, with bubbles forming slowly
Strong	Violent reaction, with bubbles forming immediately

TABLE 5 Criteria for Describing Consistency

Description	Criteria
Very soft	Thumb will penetrate soil more than 1 in. (25 mm)
Soft	Thumb will penetrate soil about 1 in. (25 mm)
Firm	Thumb will indent soil about ¼ in. (6 mm)
Hard	Thumb will not indent soil but readily indented with thumbnail
Very hard	Thumbnail will not indent soil

TABLE 6 Criteria for Describing Cementation

Description	Criteria
Weak	Crumbles or breaks with handling or little finger pressure
Moderate	Crumbles or breaks with considerable finger pressure
Strong	Will not crumble or break with finger pressure

TABLE 7 Criteria for Describing Structure

Description	Criteria
Stratified	Alternating layers of varying material or color with layers at least 6 mm thick; note thickness
Laminated	Alternating layers of varying material or color with the layers less than 6 mm thick; note thickness
Fissured	Breaks along definite planes of fracture with little resistance to fracturing
Slickensided	Fracture planes appear polished or glossy, sometimes striated
Blocky	Cohesive soil that can be broken down into small angular lumps which resist further breakdown
Lensed	Inclusion of small pockets of different soils, such as small lenses of sand scattered through a mass of clay; note thickness
Homogeneous	Same color and appearance throughout

particles are hit by a hammer, for example, gravel-size particles fracture with considerable hammer blow, some gravel-size particles crumble with hammer blow. “Hard” means particles do not crack, fracture, or crumble under a hammer blow.

10.13 Additional comments shall be noted, such as the presence of roots or root holes, difficulty in drilling or augering hole, caving of trench or hole, or the presence of mica.

10.14 A local or commercial name or a geologic interpretation of the soil, or both, may be added if identified as such.

10.15 A classification or identification of the soil in accordance with other classification systems may be added if identified as such.

11. Identification of Peat

11.1 A sample composed primarily of vegetable tissue in various stages of decomposition that has a fibrous to amor-

phous texture, usually a dark brown to black color, and an organic odor, shall be designated as a highly organic soil and shall be identified as peat, PT, and not subjected to the identification procedures described hereafter.

12. Preparation for Identification

12.1 The soil identification portion of this practice is based on the portion of the soil sample that will pass a 3-in. (75-mm) sieve. The larger than 3-in. (75-mm) particles must be removed, manually, for a loose sample, or mentally, for an intact sample before classifying the soil.

12.2 Estimate and note the percentage of cobbles and the percentage of boulders. Performed visually, these estimates will be on the basis of volume percentage.

NOTE 9—Since the percentages of the particle-size distribution in Test Method D 2487 are by dry weight, and the estimates of percentages for gravel, sand, and fines in this practice are by dry weight, it is recommended that the report state that the percentages of cobbles and boulders are by volume.

12.3 Of the fraction of the soil smaller than 3 in. (75 mm), estimate and note the percentage, by dry weight, of the gravel, sand, and fines (see Appendix X4 for suggested procedures).

NOTE 10—Since the particle-size components appear visually on the basis of volume, considerable experience is required to estimate the percentages on the basis of dry weight. Frequent comparisons with laboratory particle-size analyses should be made.

12.3.1 The percentages shall be estimated to the closest 5 %. The percentages of gravel, sand, and fines must add up to 100 %.

12.3.2 If one of the components is present but not in sufficient quantity to be considered 5 % of the smaller than 3-in. (75-mm) portion, indicate its presence by the term *trace*, for example, trace of fines. A trace is not to be considered in the total of 100 % for the components.

13. Preliminary Identification

13.1 The soil is *fine grained* if it contains 50 % or more fines. Follow the procedures for identifying fine-grained soils of Section 14.

13.2 The soil is *coarse grained* if it contains less than 50 % fines. Follow the procedures for identifying coarse-grained soils of Section 15.

14. Procedure for Identifying Fine-Grained Soils

14.1 Select a representative sample of the material for examination. Remove particles larger than the No. 40 sieve (medium sand and larger) until a specimen equivalent to about a handful of material is available. Use this specimen for performing the dry strength, dilatancy, and toughness tests.

14.2 Dry Strength:

14.2.1 From the specimen, select enough material to mold into a ball about 1 in. (25 mm) in diameter. Mold the material until it has the consistency of putty, adding water if necessary.

14.2.2 From the molded material, make at least three test specimens. A test specimen shall be a ball of material about ½ in. (12 mm) in diameter. Allow the test specimens to dry in air, or sun, or by artificial means, as long as the temperature does not exceed 60°C.

14.2.3 If the test specimen contains natural dry lumps, those that are about 1/2 in. (12 mm) in diameter may be used in place of the molded balls.

NOTE 11—The process of molding and drying usually produces higher strengths than are found in natural dry lumps of soil.

14.2.4 Test the strength of the dry balls or lumps by crushing between the fingers. Note the strength as none, low, medium, high, or very high in accordance with the criteria in Table 8. If natural dry lumps are used, do not use the results of any of the lumps that are found to contain particles of coarse sand.

14.2.5 The presence of high-strength water-soluble cementing materials, such as calcium carbonate, may cause exceptionally high dry strengths. The presence of calcium carbonate can usually be detected from the intensity of the reaction with dilute hydrochloric acid (see 10.6).

14.3 *Dilatancy:*

14.3.1 From the specimen, select enough material to mold into a ball about 1/2 in. (12 mm) in diameter. Mold the material, adding water if necessary, until it has a soft, but not sticky, consistency.

14.3.2 Smooth the soil ball in the palm of one hand with the blade of a knife or small spatula. Shake horizontally, striking the side of the hand vigorously against the other hand several times. Note the reaction of water appearing on the surface of the soil. Squeeze the sample by closing the hand or pinching the soil between the fingers, and note the reaction as none, slow, or rapid in accordance with the criteria in Table 9. The reaction is the speed with which water appears while shaking, and disappears while squeezing.

14.4 *Toughness:*

14.4.1 Following the completion of the dilatancy test, the test specimen is shaped into an elongated pat and rolled by hand on a smooth surface or between the palms into a thread about 1/8 in. (3 mm) in diameter. (If the sample is too wet to roll easily, it should be spread into a thin layer and allowed to lose some water by evaporation.) Fold the sample threads and reroll repeatedly until the thread crumbles at a diameter of about 1/8 in. The thread will crumble at a diameter of 1/8 in. when the soil is near the plastic limit. Note the pressure required to roll the thread near the plastic limit. Also, note the strength of the thread. After the thread crumbles, the pieces should be lumped together and kneaded until the lump crumbles. Note the toughness of the material during kneading.

14.4.2 Describe the toughness of the thread and lump as

TABLE 8 Criteria for Describing Dry Strength

Description	Criteria
None	The dry specimen crumbles into powder with mere pressure of handling
Low	The dry specimen crumbles into powder with some finger pressure
Medium	The dry specimen breaks into pieces or crumbles with considerable finger pressure
High	The dry specimen cannot be broken with finger pressure. Specimen will break into pieces between thumb and a hard surface
Very high	The dry specimen cannot be broken between the thumb and a hard surface

TABLE 9 Criteria for Describing Dilatancy

Description	Criteria
None	No visible change in the specimen
Slow	Water appears slowly on the surface of the specimen during shaking and does not disappear or disappears slowly upon squeezing
Rapid	Water appears quickly on the surface of the specimen during shaking and disappears quickly upon squeezing

low, medium, or high in accordance with the criteria in Table 10.

14.5 *Plasticity*—On the basis of observations made during the toughness test, describe the plasticity of the material in accordance with the criteria given in Table 11.

14.6 Decide whether the soil is an *inorganic* or an *organic* fine-grained soil (see 14.8). If inorganic, follow the steps given in 14.7.

14.7 *Identification of Inorganic Fine-Grained Soils:*

14.7.1 Identify the soil as a *lean clay*, CL, if the soil has medium to high dry strength, no or slow dilatancy, and medium toughness and plasticity (see Table 12).

14.7.2 Identify the soil as a *fat clay*, CH, if the soil has high to very high dry strength, no dilatancy, and high toughness and plasticity (see Table 12).

14.7.3 Identify the soil as a *silt*, ML, if the soil has no to low dry strength, slow to rapid dilatancy, and low toughness and plasticity, or is nonplastic (see Table 12).

14.7.4 Identify the soil as an *elastic silt*, MH, if the soil has low to medium dry strength, no to slow dilatancy, and low to medium toughness and plasticity (see Table 12).

NOTE 12—These properties are similar to those for a lean clay. However, the silt will dry quickly on the hand and have a smooth, silky feel when dry. Some soils that would classify as MH in accordance with the criteria in Test Method D 2487 are visually difficult to distinguish from lean clays, CL. It may be necessary to perform laboratory testing for proper identification.

14.8 *Identification of Organic Fine-Grained Soils:*

14.8.1 Identify the soil as an *organic soil*, OL/OH, if the soil contains enough organic particles to influence the soil properties. Organic soils usually have a dark brown to black color and may have an organic odor. Often, organic soils will change color, for example, black to brown, when exposed to the air. Some organic soils will lighten in color significantly when air dried. Organic soils normally will not have a high toughness or plasticity. The thread for the toughness test will be spongy.

NOTE 13—In some cases, through practice and experience, it may be possible to further identify the organic soils as organic silts or organic clays, OL or OH. Correlations between the dilatancy, dry strength, toughness tests, and laboratory tests can be made to identify organic soils in certain deposits of similar materials of known geologic origin.

TABLE 10 Criteria for Describing Toughness

Description	Criteria
Low	Only slight pressure is required to roll the thread near the plastic limit. The thread and the lump are weak and soft
Medium	Medium pressure is required to roll the thread to near the plastic limit. The thread and the lump have medium stiffness
High	Considerable pressure is required to roll the thread to near the plastic limit. The thread and the lump have very high stiffness

TABLE 11 Criteria for Describing Plasticity

Description	Criteria
Nonplastic Low	A 1/8-in. (3-mm) thread cannot be rolled at any water content. The thread can barely be rolled and the lump cannot be formed when drier than the plastic limit.
Medium	The thread is easy to roll and not much time is required to reach the plastic limit. The thread cannot be rerolled after reaching the plastic limit. The lump crumbles when drier than the plastic limit.
High	It takes considerable time rolling and kneading to reach the plastic limit. The thread can be rerolled several times after reaching the plastic limit. The lump can be formed without crumbling when drier than the plastic limit.

TABLE 12 Identification of Inorganic Fine-Grained Soils from Manual Tests

Soil Symbol	Dry Strength	Dilatancy	Toughness
ML	None to low	Slow to rapid	Low or thread cannot be formed
CL	Medium to high	None to slow	Medium
MH	Low to medium	None to slow	Low to medium
CH	High to very high	None	High

14.9 If the soil is estimated to have 15 to 25 % sand or gravel, or both, the words “with sand” or “with gravel” (whichever is more predominant) shall be added to the group name. For example: “lean clay with sand, CL” or “silt with gravel, ML” (see Fig. 1a and Fig. 1b). If the percentage of sand is equal to the percentage of gravel, use “with sand.”

14.10 If the soil is estimated to have 30 % or more sand or gravel, or both, the words “sandy” or “gravelly” shall be added to the group name. Add the word “sandy” if there appears to be more sand than gravel. Add the word “gravelly” if there appears to be more gravel than sand. For example: “sandy lean clay, CL”, “gravelly fat clay, CH”, or “sandy silt, ML” (see Fig. 1a and Fig. 1b). If the percentage of sand is equal to the percent of gravel, use “sandy.”

15. Procedure for Identifying Coarse-Grained Soils (Contains less than 50 % fines)

15.1 The soil is a *gravel* if the percentage of gravel is estimated to be more than the percentage of sand.

15.2 The soil is a *sand* if the percentage of gravel is estimated to be equal to or less than the percentage of sand.

15.3 The soil is a *clean gravel* or *clean sand* if the percentage of fines is estimated to be 5 % or less.

15.3.1 Identify the soil as a *well-graded gravel*, GW, or as a *well-graded sand*, SW, if it has a wide range of particle sizes and substantial amounts of the intermediate particle sizes.

15.3.2 Identify the soil as a *poorly graded gravel*, GP, or as a *poorly graded sand*, SP, if it consists predominantly of one size (uniformly graded), or it has a wide range of sizes with some intermediate sizes obviously missing (gap or skip graded).

15.4 The soil is either a *gravel with fines* or a *sand with fines* if the percentage of fines is estimated to be 15 % or more.

15.4.1 Identify the soil as a *clayey gravel*, GC, or a *clayey sand*, SC, if the fines are clayey as determined by the procedures in Section 14.

15.4.2 Identify the soil as a *silty gravel*, GM, or a *silty sand*,

SM, if the fines are silty as determined by the procedures in Section 14.

15.5 If the soil is estimated to contain 10 % fines, give the soil a dual identification using two group symbols.

15.5.1 The first group symbol shall correspond to a clean gravel or sand (GW, GP, SW, SP) and the second symbol shall correspond to a gravel or sand with fines (GC, GM, SC, SM).

15.5.2 The group name shall correspond to the first group symbol plus the words “with clay” or “with silt” to indicate the plasticity characteristics of the fines. For example: “well-graded gravel with clay, GW-GC” or “poorly graded sand with silt, SP-SM” (see Fig. 2).

15.6 If the specimen is predominantly sand or gravel but contains an estimated 15 % or more of the other coarse-grained constituent, the words “with gravel” or “with sand” shall be added to the group name. For example: “poorly graded gravel with sand, GP” or “clayey sand with gravel, SC” (see Fig. 2).

15.7 If the field sample contains any cobbles or boulders, or both, the words “with cobbles” or “with cobbles and boulders” shall be added to the group name. For example: “silty gravel with cobbles, GM.”

16. Report

16.1 The report shall include the information as to origin, and the items indicated in Table 13.

NOTE 14—*Example: Clayey Gravel with Sand and Cobbles, GC*—About 50 % fine to coarse, subrounded to subangular gravel; about 30 % fine to coarse, subrounded sand; about 20 % fines with medium plasticity, high dry strength, no dilatancy, medium toughness; weak reaction with HCl; original field sample had about 5 % (by volume) subrounded cobbles, maximum dimension, 150 mm.

In-Place Conditions—Firm, homogeneous, dry, brown

Geologic Interpretation—Alluvial fan

TABLE 13 Checklist for Description of Soils

1. Group name
2. Group symbol
3. Percent of cobbles or boulders, or both (by volume)
4. Percent of gravel, sand, or fines, or all three (by dry weight)
5. Particle-size range:
Gravel—fine, coarse
Sand—fine, medium, coarse
6. Particle angularity: angular, subangular, subrounded, rounded
7. Particle shape: (if appropriate) flat, elongated, flat and elongated
8. Maximum particle size or dimension
9. Hardness of coarse sand and larger particles
10. Plasticity of fines: nonplastic, low, medium, high
11. Dry strength: none, low, medium, high, very high
12. Dilatancy: none, slow, rapid
13. Toughness: low, medium, high
14. Color (in moist condition)
15. Odor (mention only if organic or unusual)
16. Moisture: dry, moist, wet
17. Reaction with HCl: none, weak, strong
<i>For intact samples:</i>
18. Consistency (fine-grained soils only): very soft, soft, firm, hard, very hard
19. Structure: stratified, laminated, fissured, slickensided, lensed, homogeneous
20. Cementation: weak, moderate, strong
21. Local name
22. Geologic interpretation
23. Additional comments: presence of roots or root holes, presence of mica, gypsum, etc., surface coatings on coarse-grained particles, caving or sloughing of auger hole or trench sides, difficulty in augering or excavating, etc.

NOTE 15—Other examples of soil descriptions and identification are given in Appendix X1 and Appendix X2.

NOTE 16—If desired, the percentages of gravel, sand, and fines may be stated in terms indicating a range of percentages, as follows:

Trace—Particles are present but estimated to be less than 5 %

Few—5 to 10 %

Little—15 to 25 %

Some—30 to 45 %

Mostly—50 to 100 %

16.2 If, in the soil description, the soil is identified using a classification group symbol and name as described in Test Method D 2487, it must be distinctly and clearly stated in log

forms, summary tables, reports, and the like, that the symbol and name are based on visual-manual procedures.

17. Precision and Bias

17.1 This practice provides qualitative information only, therefore, a precision and bias statement is not applicable.

18. Keywords

18.1 classification; clay; gravel; organic soils; sand; silt; soil classification; soil description; visual classification

APPENDIXES

(Nonmandatory Information)

X1. EXAMPLES OF VISUAL SOIL DESCRIPTIONS

X1.1 The following examples show how the information required in 16.1 can be reported. The information that is included in descriptions should be based on individual circumstances and need.

X1.1.1 *Well-Graded Gravel with Sand (GW)*—About 75 % fine to coarse, hard, subangular gravel; about 25 % fine to coarse, hard, subangular sand; trace of fines; maximum size, 75 mm, brown, dry; no reaction with HCl.

X1.1.2 *Silty Sand with Gravel (SM)*—About 60 % predominantly fine sand; about 25 % silty fines with low plasticity, low dry strength, rapid dilatancy, and low toughness; about 15 % fine, hard, subrounded gravel, a few gravel-size particles fractured with hammer blow; maximum size, 25 mm; no reaction with HCl (Note—Field sample size smaller than recommended).

In-Place Conditions—Firm, stratified and contains lenses of silt 1 to 2 in. (25 to 50 mm) thick, moist, brown to gray; in-place density 106 lb/ft³; in-place moisture 9 %.

X1.1.3 *Organic Soil (OL/OH)*—About 100 % fines with low plasticity, slow dilatancy, low dry strength, and low toughness; wet, dark brown, organic odor; weak reaction with HCl.

X1.1.4 *Silty Sand with Organic Fines (SM)*—About 75 % fine to coarse, hard, subangular reddish sand; about 25 % organic and silty dark brown nonplastic fines with no dry strength and slow dilatancy; wet; maximum size, coarse sand; weak reaction with HCl.

X1.1.5 *Poorly Graded Gravel with Silt, Sand, Cobbles and Boulders (GP-GM)*—About 75 % fine to coarse, hard, subrounded to subangular gravel; about 15 % fine, hard, subrounded to subangular sand; about 10 % silty nonplastic fines; moist, brown; no reaction with HCl; original field sample had about 5 % (by volume) hard, subrounded cobbles and a trace of hard, subrounded boulders, with a maximum dimension of 18 in. (450 mm).

X2. USING THE IDENTIFICATION PROCEDURE AS A DESCRIPTIVE SYSTEM FOR SHALE, CLAYSTONE, SHELLS, SLAG, CRUSHED ROCK, AND THE LIKE

X2.1 The identification procedure may be used as a descriptive system applied to materials that exist in-situ as shale, claystone, sandstone, siltstone, mudstone, etc., but convert to soils after field or laboratory processing (crushing, slaking, and the like).

X2.2 Materials such as shells, crushed rock, slag, and the like, should be identified as such. However, the procedures used in this practice for describing the particle size and plasticity characteristics may be used in the description of the material. If desired, an identification using a group name and symbol according to this practice may be assigned to aid in describing the material.

X2.3 The group symbol(s) and group names should be placed in quotation marks or noted with some type of distinguishing symbol. See examples.

X2.4 Examples of how group names and symbols can be incorporated into a descriptive system for materials that are not naturally occurring soils are as follows:

X2.4.1 *Shale Chunks*—Retrieved as 2 to 4-in. (50 to 100-mm) pieces of shale from power auger hole, dry, brown, no reaction with HCl. After slaking in water for 24 h, material identified as “Sandy Lean Clay (CL)”; about 60 % fines with medium plasticity, high dry strength, no dilatancy, and medium toughness; about 35 % fine to medium, hard sand; about 5 % gravel-size pieces of shale.

X2.4.2 *Crushed Sandstone*—Product of commercial crushing operation; “Poorly Graded Sand with Silt (SP-SM)”; about 90 % fine to medium sand; about 10 % nonplastic fines; dry, reddish-brown, strong reaction with HCl.

X2.4.3 *Broken Shells*—About 60 % gravel-size broken

shells; about 30 % sand and sand-size shell pieces; about 10 % fines; “Poorly Graded Gravel with Sand (GP).”

X2.4.4 *Crushed Rock*—Processed from gravel and cobbles in Pit No. 7; “Poorly Graded Gravel (GP)”; about 90 % fine,

hard, angular gravel-size particles; about 10 % coarse, hard, angular sand-size particles; dry, tan; no reaction with HCl.

X3. SUGGESTED PROCEDURE FOR USING A BORDERLINE SYMBOL FOR SOILS WITH TWO POSSIBLE IDENTIFICATIONS.

X3.1 Since this practice is based on estimates of particle size distribution and plasticity characteristics, it may be difficult to clearly identify the soil as belonging to one category. To indicate that the soil may fall into one of two possible basic groups, a borderline symbol may be used with the two symbols separated by a slash. For example: SC/CL or CL/CH.

X3.1.1 A borderline symbol may be used when the percentage of fines is estimated to be between 45 and 55 %. One symbol should be for a coarse-grained soil with fines and the other for a fine-grained soil. For example: GM/ML or CL/SC.

X3.1.2 A borderline symbol may be used when the percentage of sand and the percentage of gravel are estimated to be about the same. For example: GP/SP, SC/GC, GM/SM. It is practically impossible to have a soil that would have a borderline symbol of GW/SW.

X3.1.3 A borderline symbol may be used when the soil could be either well graded or poorly graded. For example: GW/GP, SW/SP.

X3.1.4 A borderline symbol may be used when the soil could either be a silt or a clay. For example: CL/ML, CH/MH, SC/SM.

X3.1.5 A borderline symbol may be used when a fine-grained soil has properties that indicate that it is at the boundary between a soil of low compressibility and a soil of high compressibility. For example: CL/CH, MH/ML.

X3.2 The order of the borderline symbols should reflect similarity to surrounding or adjacent soils. For example: soils in a borrow area have been identified as CH. One sample is considered to have a borderline symbol of CL and CH. To show similarity, the borderline symbol should be CH/CL.

X3.3 The group name for a soil with a borderline symbol should be the group name for the first symbol, except for:

CL/CH lean to fat clay
ML/CL clayey silt
CL/ML silty clay

X3.4 The use of a borderline symbol should not be used indiscriminately. Every effort shall be made to first place the soil into a single group.

X4. SUGGESTED PROCEDURES FOR ESTIMATING THE PERCENTAGES OF GRAVEL, SAND, AND FINES IN A SOIL SAMPLE

X4.1 *Jar Method*—The relative percentage of coarse- and fine-grained material may be estimated by thoroughly shaking a mixture of soil and water in a test tube or jar, and then allowing the mixture to settle. The coarse particles will fall to the bottom and successively finer particles will be deposited with increasing time; the sand sizes will fall out of suspension in 20 to 30 s. The relative proportions can be estimated from the relative volume of each size separate. This method should be correlated to particle-size laboratory determinations.

X4.2 *Visual Method*—Mentally visualize the gravel size particles placed in a sack (or other container) or sacks. Then, do the same with the sand size particles and the fines. Then, mentally compare the number of sacks to estimate the percentage of plus No. 4 sieve size and minus No. 4 sieve size present.

The percentages of sand and fines in the minus sieve size No. 4 material can then be estimated from the wash test (X4.3).

X4.3 *Wash Test (for relative percentages of sand and fines)*—Select and moisten enough minus No. 4 sieve size material to form a 1-in (25-mm) cube of soil. Cut the cube in half, set one-half to the side, and place the other half in a small dish. Wash and decant the fines out of the material in the dish until the wash water is clear and then compare the two samples and estimate the percentage of sand and fines. Remember that the percentage is based on weight, not volume. However, the volume comparison will provide a reasonable indication of grain size percentages.

X4.3.1 While washing, it may be necessary to break down lumps of fines with the finger to get the correct percentages.

X5. ABBREVIATED SOIL CLASSIFICATION SYMBOLS

X5.1 In some cases, because of lack of space, an abbreviated system may be useful to indicate the soil classification symbol and name. Examples of such cases would be graphical logs, databases, tables, etc.

X5.2 This abbreviated system is not a substitute for the full name and descriptive information but can be used in supplementary presentations when the complete description is referenced.

X5.3 The abbreviated system should consist of the soil classification symbol based on this standard with appropriate lower case letter prefixes and suffixes as:

Prefix:

Suffix:

s = sandy
g = gravelly

s = with sand
g = with gravel
c = with cobbles
b = with boulders

X5.4 The soil classification symbol is to be enclosed in parenthesis. Some examples would be:

<i>Group Symbol and Full Name</i>	<i>Abbreviated</i>
CL, Sandy lean clay	s(CL)
SP-SM, Poorly graded sand with silt and gravel	(SP-SM)g
GP, poorly graded gravel with sand, cobbles, and boulders	(GP)scb
ML, gravelly silt with sand and cobbles	g(ML)sc

SUMMARY OF CHANGES

In accordance with Committee D18 policy, this section identifies the location of changes to this standard since the last edition (1993^{e1}) that may impact the use of this standard.

(1) Added Practice D 3740 to Section 2.

(2) Added Note 5 under 5.7 and renumbered subsequent notes.

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STANDARD OPERATING PROCEDURES SOP-5: SAMPLE LABELING

Scope and Application

This SOP describes the general Integral procedures for sample labeling. The project-specific sampling and analysis plan (SAP) should be consulted to determine the exact sample identifiers and sample labels are required for a given project. If they are not specified in the SAP, the designations listed below should be followed.

Supplies and Equipment

- Site logbook
- Chain-of-custody form(s)
- Sample labels.

Procedures

Environmental samples will be labeled using a unique designation system consisting of:

- Sample identification number
- Tag number
- Sample location identification.

The following describes each of the numbers.

Sample ID Number

The sample ID number is a unique number that is generally assigned six digits, including a two-digit media code and a four-digit number. The media code may be site-specific, but the Integral default codes are as follows:

- SS—Surface soil
- BH—Subsurface soil or rock (typically from borehole)
- GW—Groundwater
- SW—Surface water

- PW—Pore water
- BT—Biota or biological tissue

The exact sample ID numbering scheme may vary from project to project. Variances in the sample numbering scheme will be described in the field sampling plan for the field effort. Each sample will be assigned a unique sample number. Note that in cases where samples consist of multiple bottles from the same location, each bottle will be assigned the same sample number and time. Replicates from the same location, however, will be assigned a different sample number and time, and the sample numbers of related field replicates will not necessarily have any shared content. Each field split of a single sample will also have a different sample number and time. The sample number is recorded on the sample label, the chain-of-custody form, and the field logbook.

Sample Tag Number

A different tag number is attached to each sample container. If the amount of material (i.e., everything associated with a single sample number) is too large for a single container, each container will have the same sample number and a different sample tag. A sample will also be split between containers if a different preservation technique is used for each container (i.e., because different analyses will be conducted).

The sample tag number is a unique five- or six-digit number assigned to each sample label (or “tag”) for multiple bottles per sample. Integral sample labels come with a pre-printed sample tag number. The purpose of the tag number is to provide a unique tracking number to a specific sample bottle. This allows for greater flexibility in tracking sample bottles and assists in field quality control when filling out documentation and shipping. Sample tags are not used by many other consultants, and there may be resistance from such firms during teaming situations. However, experience has shown that tags can be very valuable, both in the field and while processing data from field efforts.

Sample tag numbers will be recorded on the sample label (typically pre-printed), the chain-of-custody form, and the field logbook. Tag numbers are used by laboratories only to confirm that they have received all of the containers that were filled and shipped. Data are reported by sample number.

Sample Location ID

The sample location ID is a unique designation that identifies where the sample was collected. For sediment samples, this number is frequently the station ID (e.g., WB-10). The sample ID will also indicate if the sample is a field quality control sample (e.g., WB-10-DUP). The sample ID is recorded in the field logbook *only* and is not provided on the sample label or chain-of-custody form.

Sample Documentation

The SAP, or an appendix to the SAP, presents examples of how sample labeling information should be documented in the field logbook or borehole log. More or less information may be required on a site-specific basis.

STANDARD OPERATING PROCEDURE SOP-6: SAMPLE PACKAGING AND SHIPPING

Scope and Application

Specific requirements for sample packaging and shipping must be followed to ensure the proper transfer and documentation of environmental samples collected during field operations. Procedures for the careful and consistent transfer of samples from the field to the laboratory are outlined herein. This SOP presents the method to be used when packing samples that will either be hand delivered or shipped by commercial carrier to the laboratory.

Equipment and Supplies Required

Specific equipment or supplies necessary to properly pack and ship environmental samples include the following:

- Project-specific sampling and analysis plan (SAP)
- Project-specific field logbook
- Sealable airtight bags (assorted sizes) (e.g., Ziplocs[®])
- Wet ice in doubled, sealable bags; frozen Blue Ice[®]; or dry ice
- Coolers
- Bubble wrap
- Fiber reinforced packing tape and duct tape
- Clear plastic packing tape
- Scissors or knife
- Chain-of-custody (COC) forms
- Chain-of-custody seals
- Large plastic garbage bags (preferably 3 mil [0.003 inch] thick)
- Paper towels
- “Fragile,” “This End Up,” or “Handle With Care” labels
- Mailing labels
- Airbills for overnight shipment

Procedure

The logistics for sample packaging and shipping should be specifically tailored to each study. In some cases, samples may be transferred from the field to a local storage facility where they can be either frozen or refrigerated. Depending on the logistics of the operation, field personnel may transport samples to the laboratory themselves or utilize a commercial courier or shipping service. If a courier service is used, then Integral field personnel need to be aware of any potentially limiting factors to timely shipping (e.g., availability of overnight service and weekend deliveries to specific areas of the country, shipping regulations “restricted articles” [e.g., dry ice, formalin]) prior to shipping the samples.

Sample Preparation

The following steps should be followed to ensure the proper transfer of samples from the field to the laboratories:

At the sample collection site:

1. Appropriately document all samples using the proper logbooks or field forms (see SOP-8), required sample container identification (i.e., sample labels with tag numbers), and chain-of-custody (COC) form. Fill out the COC form as described in SOP-7, and use the sample labeling techniques provided in SOP-5.
2. Make sure all applicable laboratory quality control sample designations have been made on the COC forms. Samples that will be archived for future possible analysis should be clearly identified on the COC form and should be also be labeled as “Do Not Analyze: Hold and archive for possible future analysis” as some laboratories interpret “archive” to mean continue holding the residual sample after analysis.
3. Notify the laboratory contact and the Integral project quality assurance/quality control (QA/QC) coordinator that samples will be shipped and the estimated arrival time. Send copies of all COC forms to Integral’s project QA/QC coordinator or project manager, as appropriate.
4. Ensure that samples remain in the possession of the sampling personnel at all times. Any temporary onsite sample storage areas will be locked and secured to maintain sample integrity and chain-of-custody requirements.
5. Clean the outside of all dirty sample containers to remove any residual material that may lead to cross-contamination.

6. Fill out the chain-of-custody form as described in SOP-7, and retain the back (pink) copy of the form for the project records prior to sealing the cooler. Check sample containers against the chain-of-custody form to ensure all of the samples that were collected are in the cooler.
7. Store each sample container in an individual sealable plastic bag that allows the sample label to be read. Volatile organic analyte (VOA) vials must be encased in a foam sleeve or in bubble wrap before being sealed in bags.
8. If the samples have a required storage temperature, place a sufficient amount of ice in the sample cooler to maintain the temperature inside the cooler (e.g., 4°C) throughout the sampling day.

At the sample processing area (immediately after sample collection):

1. If the samples have a required storage temperature, then the samples should be cooled to and maintained at that temperature prior to shipping. For example, a sufficient amount of ice must be present in each sample cooler to maintain the temperature inside the cooler at 4°C until processing begins to ship the samples to the testing laboratory.
2. Be aware of holding time requirements for project-specific analytes and arrange the sample shipping schedule accordingly.
3. Place samples in secure storage (i.e., locked room or vehicle) or ensure they remain in the possession of Integral sampling personnel before shipment. Lock and secure any sample storage areas to maintain sample integrity and chain-of-custody requirements.
4. Store samples in the dark (e.g., keep coolers shut).

At the sample processing area (just prior to shipping):

1. Check sample containers against the COC form to ensure all samples intended for shipment are accounted for.
2. Choose the appropriate size cooler (or coolers) and make sure that the outside and inside of the cooler is clean of gross contamination. If the cooler has a drain on the outside at the bottom of the cooler, the drain should be capped and thoroughly taped shut with duct tape.
3. Ensure the cooler is lined with bubble wrap and a large plastic bag (preferably a bag with a thickness of 3 mil) is opened and placed inside the cooler.

4. Individually wrap each glass container (which at the sample collection site had already been placed in an individual sealable plastic bag) in bubble wrap using either tape or a rubber band to hold the bubble wrap in place. Place the wrapped samples into the large plastic bag in the cooler, leaving sufficient room for ice to keep the samples cold (i.e., 4°C).
5. If temperature blanks have been provided by the testing laboratory, include one temperature blank in each sample cooler.
6. If the samples have a required storage temperature, add enough wet ice or Blue Ice® to keep the samples refrigerated during overnight shipping (i.e., 4°C). Always over-estimate the amount of ice that you think will be required. Ice should be enclosed in a sealable plastic bag and then placed in a second sealable plastic bag to prevent leakage. Avoid separating the samples from the ice with excess bubble wrap because it will insulate the containers from the ice. After all samples and ice have been added to the cooler, use bubble wrap (or other available clean packing material) to fill any empty space to keep the samples from shifting during transport.
7. If possible, consolidate all VOA samples in a single cooler and ship them with (a) trip blank(s) if the project-specific quality assurance project plan calls for one.
8. Sign, date, and include any tracking numbers provided by the shipper on the COC form. Remove the back (pink) copy of the original COC form and retain this copy for the project records.
9. Place the rest of the signed COC form in a sealable bag and tape the bag containing the form to the inside of the cooler lid. Each cooler should contain an individual COC form for the samples contained in each respective cooler. If time constraints impact sample shipping and it becomes necessary to combine all of the samples onto a single set of COC forms and the shipment contains multiple coolers, indicate on the outside of the respective cooler "Chain-of-Custody Inside."
10. After the cooler is sufficiently packed to prevent shifting of the containers, close the lid and seal it shut with fiber-reinforced packing tape. The cooler should be taped shut around the opening between the lid and the bottom of the cooler and around the circumference of the cooler at both hinges.
11. As security against unauthorized handling of the samples, apply two chain-of-custody seals across the opening of the cooler lid (example provided in Attachment 2-1). One seal should be placed on the front right portion of the cooler and one seal should be placed on the back left portion of the cooler. Be sure the seals are properly affixed to the cooler so they are not removed during shipment. Additional tape across the seal may be necessary if the outside of the cooler is wet.

Sample Shipping

Hand-Delivery to the Testing Laboratory

1. Notify the laboratory contact and the Integral project QA/QC coordinator that samples will be delivered to the laboratory and the estimated arrival time.
2. All environmental samples that are hand-delivered to the testing laboratory will be received by the laboratory on the same day that they were packed in the coolers.
3. Fax or scan and email copies of all COC forms to the Integral project QA/QC coordinator. Note: Prior to faxing, it may be necessary to photocopy the COC form on a slightly darker setting so that the form is readable after it has been faxed. Never leave the original COC form in the custody of non-Integral staff.

Shipped by Commercial Carrier to the Laboratory

1. Use a mailing label and label the cooler with destination and return addresses, and add other appropriate stickers, such as "This End Up," "Fragile," and "Handle With Care." If the shipment contains multiple coolers, indicate on the mailing label the number of coolers that the testing laboratory should expect to receive (e.g., 1 of 2; 2 of 2). Place clear tape over the mailing label to firmly affix it to the outside of the cooler and to protect it from the weather. This is a secondary label in case the airbill is lost during shipment.
2. Fill out the airbill as required and fasten it to handle tags provided by the shipper (or the top of the cooler if handle tags are not available).
3. If samples need to be frozen (-20°C) during shipping, then dry ice will need to be placed in the sample cooler. Be aware of any additional shipping, handling, and special labeling requirements that may be required by the shipper for these samples.
4. Benthic infauna samples will need to be preserved with formalin in the field prior to shipping. Be aware of any additional shipping, handling, and special labeling requirements that may be required by the shipper for these samples.
5. Notify the laboratory contact and the Integral project QA/QC coordinator that samples will be shipped and the estimated arrival date and time. All environmental samples that are shipped at 4°C or -20°C will be shipped overnight for next morning delivery. Fax or scan and email copies of all COC forms to the Integral project QA/QC coordinator. Note: Prior to faxing, it may be necessary to photocopy the COC form on a slightly darker setting so that the form is readable after it has been faxed. Never leave the original COC form in the custody of non-Integral staff.

STANDARD OPERATING PROCEDURE SOP-7: SAMPLE CUSTODY

Scope and Application

This SOP describes Integral procedures for custody management of environmental samples.

A stringent, established program of sample chain-of-custody will be followed during sample storage and shipping activities to account for each sample. The procedure outlined herein will be used with SOP-6, which covers sample packaging and shipping; SOP-8, which covers the use of field logbooks and other types of field documentation; and SOP-5, which covers sample labeling. Chain-of-custody (COC) forms ensure that samples are traceable from the time of collection through processing and analysis until final disposition. A sample is considered to be in a person's custody if any of the following criteria are met:

1. The sample is in the person's possession
2. The sample is in the person's view after being in possession
3. The sample is in the person's possession and is being transferred to a designated secure area
4. The sample has been locked up to prevent tampering after it was in the person's possession.

At no time is it acceptable for samples to be outside of Integral personnel's custody unless the samples have been transferred to a secure area (i.e., locked up). If the samples cannot be placed in a secure area, then an Integral field team member must physically remain with the samples (e.g., at lunch time one team member must remain with the samples).

Chain-of-Custody Forms

The COC form is the critical because it documents sample possession from the time of collection through the final disposition of the sample. The form also provides information to the laboratory regarding what analyses are to be performed on the samples that are shipped.

The COC form will be completed after each field collection activity and before the samples are shipped to the laboratory. Sampling personnel are responsible for the care and custody of the samples until they are shipped. When transferring possession of the

samples, the individuals relinquishing and receiving the samples must sign the COC form(s), indicating the time and date that the transfer occurs.

The COC forms each consist of 3-part carbon-less paper with white, yellow, and pink copies. The pink copy is kept by the sampling team leader. The white sheet and the yellow sheet will be placed into a plastic sealable bag and secured to the inside top of each transfer container (e.g., cooler). The pink sheet will be retained by the field staff for filing at the Integral Project Manager's location. Each COC form has a unique 4-digit number. This number and the samples on the form shall be recorded in the field logbook. Integral also uses computer-generated COC forms. If computer-generated forms are used, then the forms must be printed in triplicate and all three sheets signed so that two sheets can accompany the shipment to the laboratory and one sheet can be retained on file at the Integral Project Manager's location. Alternatively, if sufficient lead time is available, the computer-generated forms will be printed on 3-part carbon-less paper.

The project-assigned sample number and the unique tag number at the bottom of each sample label will be recorded on the COC form. The COC form will also identify the sample collection date and time, the type of sample, the project, and the sampling personnel. In addition, the COC form provides information on the preservative or other sample pretreatment applied in the field and the analyses to be conducted by referencing a list of specific analyses or the statement of work for the laboratory. The COC form will be sent to the laboratory along with the sample(s).

Procedures

The following guidelines will be followed to ensure the integrity of the samples:

1. Each COC form must be appropriately signed and dated by the sampling personnel. The person who relinquishes custody of the samples must also sign this form.
2. At the end of each sampling day and prior to shipping or storage, chain-of-custody entries will be made for all samples. Information on the labels and tags will be checked against field logbook entries.
3. The COC form should not be signed until the information has been checked for inaccuracies by the sampling team leader. All changes should be made by drawing a single line through the incorrect entry and initialing and dating it. Revised entries should be made in the space below the entries. Any blank lines remaining on the COC form after corrections are made should be marked out with single lines that are initialed and dated. This procedure will preclude any unauthorized additions.

4. At the bottom of each COC form is a space for the signatures of the persons relinquishing and receiving the samples and the time and date that the transfer occurred. The time that the samples were relinquished should match exactly the time they were received by another party. Under no circumstances should there be any time when custody of the samples is undocumented.
5. If samples are sent by a commercial carrier not affiliated with the laboratory, such as Federal Express (FedEx) or United Parcel Service (UPS), the name of the carrier should be recorded on the COC form. Any tracking numbers supplied by the carrier should be also entered on the COC form. The time of transfer should be as close to the actual drop-off time as possible. After the COC forms are signed and the “pink” copy has been removed, they should be sealed inside the transfer container.
6. If errors are found after the shipment has left the custody of sampling personnel, a corrected version of the forms must be made and sent to all relevant parties. Minor errors can be rectified by making the change on a copy of the original with a brief explanation and signature. Errors in the signature block may require a letter of explanation.
7. Samples that are archived internally at Integral must be accompanied by a COC form and an Archive Record form.
8. Upon completion of the field sampling event, the sampling team leader will be responsible for submitting all COC forms to be copied. A discussion of copy distribution is provided in SOP-AP2.

Custody Seal

As security against unauthorized handling of the samples during shipping, two custody seals will be affixed to each sample cooler. The custody seals will be placed across the opening of the cooler (front right and back left) prior to shipping. Be sure the seals are properly affixed to the cooler so they cannot be removed during shipping. Additional tape across the seal and around the cooler may be prudent.

Shipping Air Bills

When samples are shipped from the field to the testing laboratory via a commercial carrier (e.g., Federal Express, UPS), an air bill or receipt is provided by the shipper. The air bill number (or tracking number) should be noted on the applicable COC forms or alternatively the applicable COC form number should be noted on the air bill to enable the tracking of samples if a cooler becomes lost.

Acknowledgement of Sample Receipt Forms

In most cases, when samples are sent to a testing laboratory, an Acknowledgment of Sample Receipt form is faxed to the project QA/QC coordinator the day the samples are received by the laboratory. It is the responsibility of the person receiving this form to review the form and make sure that all the samples that were sent to the laboratory were received by the laboratory and that the correct analyses were requested. If an error is found, the laboratory must be called immediately. Decisions made during the telephone conversation should be documented in writing on the Acknowledgment of Sample Receipt Form. In addition, corrections should be made to the COC form and the corrected version of the COC form should be faxed to the laboratory.

Archive Record Forms

On rare occasions, samples are archived at an Integral office. If samples are to be archived at Integral, it is the responsibility of the project manager to complete an Archive Record form. This form is to be accompanied by a copy of the COC form for the samples, and will be placed in a locked file cabinet. The original COC form will remain with the samples in a sealed Ziploc bag.

STANDARD OPERATING PROCEDURE SOP-8: FIELD DOCUMENTATION

Scope and Application

The integrity of each sample from the time of collection to the point of data reporting must be maintained throughout the study. Proper record keeping will be implemented in the field to allow samples to be traced from collection to final disposition.

All information relevant to field operations must be properly documented to ensure that activities are accounted for and can be reconstructed from written records to the extent that someone not present at the site can reconstruct the activity without relying on the memory of the field crew. Several types of field documents will be used for this purpose and should be consistently used by field personnel. Field documentation should include only a factual description of site-related activities and observations made. Field personnel should not include superfluous comments or speculation regarding the field activities or observations made.

Field Logbooks

During field sampling events, field logbooks are used to record all daily field activities. The purpose of the field logbook is to document events that occur and record data measured in the field to the extent that someone not present at the site can reconstruct the activity without relying on the memory of the field crew.

The field logbook is issued by the Project Manager (or designee) to the appropriate site personnel for the direction of onsite activities (e.g., Reconnaissance Survey Team Leader, Sampling Team Leader). It is the responsibility of this person (or designee) to keep the site logbook current while in his or her possession, and return it to the Project Manager or turn it over to another field team.

A separate bound, waterproof field logbook with consecutively numbered pages will be completed using indelible ink for each sampling event. All daily field activities will be documented in indelible ink in this logbook and no erasures will be made. All corrections should consist of a single line-out deletion, followed by the author's initials and the date. The author will initial and date each page of the field logbook. The author will sign and date the last page at the end of each day, and a line will be drawn through the remainder of the page.

The project name, dates of the field work, site name and location (city and state), and Integral contract number should be written on the cover of the field logbook. If more than one logbook is used during a single sampling event, then the upper right hand corner of the logbook will be annotated (e.g., Volume 1 of 2, 2 of 2) to indicate the number of logbooks used during the field event. Field logbooks will be stored in a secure manner when not in use in the field. At a minimum, the sampler will record the following information in the field logbook:

- Project name, project location, and contract number
- Purpose and description of the field task
- Project start date and end date
- Date and time of entry (24-hour clock)
- Time and duration of daily sampling activities
- Weather conditions at the beginning of the field work and any changes that occur throughout the day, including the approximate time of the change (e.g., wind speed and direction, rain, thunder, wave action, current, tide, vessel traffic, temperature of both the air and water, thickness of ice if present)
- Name and affiliation of person making entries and other field personnel and their duties, including the times that they are present
- The location and description of the work area, including sketches, map references, and photograph log, if appropriate
- Level of personal protection being used
- Onsite visitors (names and affiliations), if any, including the times that they are present
- The name, agency, and telephone number of any field contacts
- Notation of the coordinate system used to determine the station location information
- The sample identifier and analysis code for each sample to be submitted for laboratory analysis, if not included on separate field data sheets
- All field measurements made (or reference to specific field data sheets used for this purpose), including the time that the measurement was collected and the date of calibration, if appropriate
- The sampling location name, date, gear, water depth (if applicable), and sampling location coordinates, if not included on separate field data sheets
- The type of vessel used (e.g., size, power, type of engine) (for aquatic sampling only)

- Specific information on each type of sampling activity
- The sample type (e.g., groundwater, soil, surface sediment), sample number, sample tag number, and preservatives used (if any), if not included on separate field data sheets
- Sample storage methods
- Cross-references of numbers for duplicate samples
- A description of the sample [source and appearance, such as soil or sediment type, color, texture, consistency, presence of biota or debris, presence of oily sheen, changes in sample characteristics with depth, presence/location/thickness of the redox potential discontinuity (RPD) layer, and odor] and penetration depth, if not included on separate field data sheets
- Estimate of length and appearance of recovered cores, if not included on separate field data sheets
- Photographs (uniquely identified) taken at the sampling location, if any
- Details of the work performed
- Variations, if any, from the project-specific sampling and analysis plan (SAP) or standard operating protocols and reasons for deviation
- Details pertaining to unusual events which might have occurred during sample collection (e.g., possible sources of sample contamination, equipment failure, unusual appearance of sample integrity, control of vertical descent of the sampling equipment)
- References to other logbooks or field forms used to record information (e.g., field data sheets, health and safety log)
- Any field results not appearing the field data sheets (if used), including station identification and location, date, and time of measurement
- Sample shipment information (e.g., shipping manifests, COC form numbers, carrier, air bill numbers, time addresses)
- A record of quantity of investigation derived wastes (if any) and storage and handling procedures.

During the field day, as listed above, a summary of all site activities should be recorded in the logbook. The information need not duplicate anything recorded in other field logbooks or field forms (e.g., Site Health and Safety Officer's logbook, calibration logbook, field data sheets), but should summarize the contents of the other logbooks and refer to the page locations in these logbooks for detailed information.

If measurements are made at any location, the measurements and equipment used must either be recorded in the field logbook or reference must be made to the logbook and page number(s) on which they are recorded. All maintenance and calibration records for equipment should be traceable through field records to the person using the instrument and to the specific piece of instrumentation itself.

Upon completion of the field sampling event, the sampling team leader will be responsible for submitting all field logbooks to be copied. A discussion of copy distribution is provided below.

Field Data Forms

Occasionally, additional field data forms are generated during a field sampling event (e.g., groundwater monitoring form, sediment core profile form, water quality measurement form) to record the relevant sample information collected during a sampling event. For instructions regarding the proper identification of field data forms, sampling personnel should consult the project-specific SAP.

Upon completion of the field sampling event, the sampling team leader will be responsible for submitting all field data forms to be copied. A discussion of copy distribution is provided below.

Photographs

In certain instances, photographs (print or digital) of sampling stations may be taken using a camera-lens system with a perspective similar to the naked eye. Photographs should include a measured scale in the picture, when practical. Photographs may also be taken of sample characteristics and routine sampling activities. Telephoto or wide-angle shots will not be used because they cannot be used in enforcement proceedings. The following items should be recorded in the field logbook for each photograph taken:

1. The photographer's name or initials, the date, the time of the photograph, and the general direction faced (orientation)
2. A brief description of the subject and the field work portrayed in the picture
3. For print photographs, the sequential number of the photograph and the roll number on which it is contained
4. For digital photographs, the sequential number of the photograph, the file name, the file location, and back-up disk number (if applicable).

Upon completion of the field sampling event, the sampling team leader will be responsible for submitting all photographic materials to be developed (prints) or to be copied (disks), as appropriate. The prints or disks (as appropriate) and associated negatives will be placed in the project files (at the Integral Project Manager's office). Photo

logs and any supporting documentation from the field logbooks will be photocopied and placed in the project files with the prints or disks.

Equipment Calibration Records

Equipment calibration records, including instrument type and serial number, calibration supplies used, calibration methods and calibration results, date, time, and personnel performing the calibration, should be recorded in the field logbook. At a minimum, equipment used during the investigation should be calibrated daily in accordance with the manufacturers' recommendations.

Distribution of Copies

Two copies of all field logbooks and additional field data forms will be made at Integral. The first copy will be stamped with a "COPY" stamp. This copy will be placed in the project file and will be available for general staff use. The second copy will be stamped with a "FILE" stamp. This copy will be placed in the data management file with the laboratory data packages and will be used by the data management and quality assurance staff only. The original field logbooks and forms will be placed in a locked file cabinet.

Set-up of Locking File Cabinet

Each project will have its own file folder in a locking file cabinet. The folder label will include the project name and contract number. As many as six kinds of files will be included in this folder for each project:

- Field logbook(s)
- Additional field data forms
- Photographs
- COC forms
- Acknowledgment of Sample Receipt forms
- Archive Record form (to be completed only if samples are archived at an Integral field storage facility or Integral laboratory).

STANDARD OPERATING PROCEDURE SOP-9: EQUIPMENT DECONTAMINATION

Scope and Application

To prevent potential cross contamination of samples, all reusable sediment sampling and processing equipment will be decontaminated before each use. At the sample collection site, a decontamination area will be established in a clean location, upwind of actual sampling locations, if possible. This is where all sediment sampling and processing equipment will be cleaned. Decontaminated equipment will be stored away from areas that may cause recontamination. When handling decontamination chemicals, field personnel will follow all relevant procedures and will wear protective clothing as stipulated in the site-specific health and safety plan.

This SOP describes procedures for decontamination of sampling equipment, drilling equipment, and other tools that could come in contact with contaminated media (Ecology 2003, PSEP 1997).

Supplies and Equipment

- Plastic sheeting
- Steam cleaner and collection basin (if required)
- 55-gallon, DOT-approved drums (if required)
- Non-phosphate detergent (e.g., Alconox® or Liquinox®)
- Acid rinses (inorganic constituents), either reagent-grade diluted nitric or hydrochloric acid (if required)
- Solvent rinses (organic constituents), either pesticide-grade methanol, hexane, isopropanol or acetone (if required)
- Polyethylene or polypropylene tub (to collect solvent rinsate)
- Deionized or distilled water rinse available from retail stores. Note that distilled water generally contains low levels of organic contaminants and can not be used for field blanks (must receive reagent-grade from laboratory).
- Tap water rinse from local tap water.
- 5-gallon buckets, or other appropriate containers
- Scrub brushes

- Teflon™ squirt bottles
- Gloves (e.g., nitrile or polyethylene)
- Personal protective clothing (as specified in the site-specific health and safety plan)

Procedures

Drill Rig or Test Pit Sampling Equipment Decontamination Procedures

1. Decontaminate sampling equipment before use, between samples and stations, and upon completion of sampling operations.
2. Equipment used during drilling/test pit operations should be decontaminated in the Exclusion Zone prior to transport to the Support Zone (refer to site-specific HASP).
3. If the steam-cleaning location is in an area outside of the Exclusion Zone, remove loose sediment on the drill rig, augers, drill pipe, and rods, and other large equipment at the drill site, then move the equipment directly to the steam-cleaning decontamination area for more thorough cleaning.
4. To decontaminate a drill rig or backhoe, pressure wash with a steam cleaner using potable water rinse upon mobilization, between drilling locations, and upon demobilization. Cleaning water can generally be allowed to drain directly on the ground near the station (refer to the field sampling plan [FSP]).
5. To decontaminate auger, drill rods, and other downhole tools, pressure wash with a steam cleaner and potable water rinse upon mobilization, between drilling locations, and upon demobilization. All decontamination fluids are to be containerized for proper disposal.
6. To decontaminate split-spoon and hand-auger samplers, wash with laboratory-grade detergent/water solution, rinse with tap water and a final distilled water rinse. If the samplers were exposed to visibly contaminated sediments (e.g., creosote, diesel, etc), dry the sampler off with clean paper towels and carefully rinse the equipment with hexane from a squirt bottle, letting the excess solvent drain into a waste container (which may need to be equipped with a funnel). A hexane rinse should be followed by another distilled water rinse. To the extent possible, allow to air dry prior to sampling. If the split-spoon is not used immediately, wrap it in aluminum foil. All decontamination fluids are to be containerized for proper disposal.

Decontamination of Sampling Implements and Processing Materials

1. Decontaminate sampling implements (e.g., spoons and knives) and other processing materials such as mixing bowls and pans before use, between samples, and upon completion of sampling operations.
2. To decontaminate sampling spoons, mixing bowls, and other hand-held tools, wash with a scrub brush using a laboratory-grade detergent/water solution (Liquinox® or Alconox® solution), rinse with tap water, followed by distilled water or ASTM Type II reagent-grade water. As described above, if the sediment is visibly contaminated, a hexane rinse may be necessary. This is followed by another distilled water rinse. To the extent possible, allow to air dry. Once decontaminated, this equipment will be wrapped in aluminum foil to prevent contamination by airborne contaminants during transportation to the sampling site. Containerize all decontamination fluids for proper disposal.
3. To decontaminate sampling spoons used to collect volatile organics, wash the spoon with a scrub brush using a laboratory-grade detergent/water solution, and rinse with distilled water. Wrap the spoon in aluminum foil. The solvent rinse is eliminated in order to avoid interference with the analysis. Containerize all decontamination fluids for proper disposal.
4. If necessary, to decontaminate wash buckets, pressure wash with a steam cleaner using a laboratory-grade detergent/water solution and potable water rinse upon mobilization, between station locations, upon demobilization, or as needed during sampling operations.

After decontaminating all of the sampling equipment, the disposable gloves and used foil will be placed in garbage bags and disposed of in an appropriate solid waste landfill.

References

Ecology. 2003. Sediment sampling and analysis plan appendix. Guidance on the development of sediment sampling and analysis plans meeting the requirements of the sediment management standards (Chapter 173-204 WAC). Washington State Department of Ecology, Olympia, WA.

PSEP. 1997. Puget Sound Estuary Program: recommended guidelines for sampling marine sediment, water columns, and tissue in Puget Sound. Final report. Prepared for the Puget Sound Estuary Program, U.S. Environmental Protection Agency, Region 10, Office of Puget Sound, Seattle, WA, and Puget Sound Water Quality Authority, Olympia, WA.

STANDARD OPERATING PROCEDURE SOP-10: PREPARATION OF FIELD QUALITY CONTROL SAMPLES FOR SEDIMENTS

Scope and Application

This SOP describes the purpose, preparation, and collection frequency of field duplicate samples, field replicate samples, matrix spike/matrix spike duplicates, equipment rinsate blanks, bottle blanks, trip blanks, temperature blanks, environmental blanks, and reference materials (i.e., a standard reference material, a certified reference material, or other reference material; for the purposes of this document the acronym SRM will be used for all types of reference materials) for sediment samples. Not all of the field quality control (QC) samples discussed in this SOP may be required for a given project. The specific field quality control samples will be identified in the project-specific field sampling and analysis plan (FSP) and quality assurance project plan (QAPP). For most projects, Integral's recommended field QC samples are: an equipment rinsate blank, a field duplicate, and trip blanks if volatile organic compounds (VOCs) are to be analyzed. Definitions of all potential QC samples are described below.

As part of the quality assurance/quality control (QA/QC) program, all field QC samples will be sent to the laboratories blind. To accomplish this, field QC samples will be prepared and labeled in the same manner as regular samples, with each QC sample being assigned a unique sample number that is consistent with the numbering for regular samples. All of the containers with preservatives that are required to complete the field QC sample for the applicable analyte list shall be labeled with the same sample number. The sample ID for field quality control samples should allow data management and data validation staff to identify them as such and should only be recorded in the field logbook. Under no circumstances should the laboratory be allowed to use reference materials, rinsate blanks, or trip blanks for laboratory QC analysis (i.e., duplicates, matrix spike, and matrix spike duplicates). To prevent this from happening, regular samples should be selected and marked on the chain-of-custody/sampling analysis request (COC/SAR) form or the laboratory should be instructed to contact the project QA/QC coordinator to select appropriate samples for each sample group.

Field quality control samples will be prepared at least once per sampling event, and certain types will be prepared more often at predetermined frequencies. If the number of samples taken does not equal an integer multiple of the intervals specified in this SOP, the number of field quality control samples is specified by the next higher multiple. For example, if a frequency of 1 quality control sample per 20 is indicated and 28 samples are

collected, 2 quality control samples will be prepared. The text below describes the preparation and frequency of field quality control samples required for sediment sampling activities, and shall be followed, unless different frequency requirements are listed in the FSP and QAPP.

The following table lists the quality control sample types and suggested frequencies for sediment sampling programs. Because sediment quality control sampling may require assessment of site cross-contamination, additional blanks may be required. A detailed explanation of each quality control sample type with the required preparation follows.

Table 1. Field Quality Control Sample Requirements

Quality Control Sample Name	Abbreviation	Location	Preparation Method	Frequency ^a
Duplicate	DUP	Sampling site	Additional natural sample	One per 20 samples. May not be applicable if REP is being collected.
Replicate	REP	Sampling site	Additional natural sample	One replicate per 20 samples. May not be applicable if DUP is being collected.
Matrix spike/matrix spike duplicate	MS/MSD	Sampling site	Additional sample bottles filled for laboratory quality control requirements	One per 20 samples.
Equipment rinsate blank	ER	Sampling site	Deionized water collected after pouring through and over decontaminated equipment	Minimum of one per sampling event per type of sampling equipment used and then 1:20 thereafter.
Bottle blank	BB	Field	Unopened bottle	One per sample episode or one per bottle type.
Trip blank	TB	Laboratory	Deionized water with preservative	One pair per each VPC sample cooler shipment
Temperature blank	TMB	Laboratory	Deionized water	One per sample cooler.
Environmental blank	EB	Field	Bottle filled at sample site with DI water	One per 20 samples.
Standard reference material	SRM	Field laboratory or Sampling site	SRM ampules or other containers for each analyte group	One set per 50 samples or one per episode.

^a Frequencies provided here are general recommendations; specific frequencies should be provided in the project-specific FSP or QAPP.

Field Duplicate Samples

Field duplicate (or split) samples are collected to assess the homogeneity of the samples collected in the field and the precision of the sampling process. Field duplicates will be prepared by collecting two aliquots for the sample and submitting them for analysis as separate samples. Field duplicates will be collected at a minimum frequency of 1 per 20 samples or once per sampling event, whichever is more frequent. The actual number of field duplicate samples collected during a sampling event will be determined on a case-by-case basis by the project QA/QC coordinator (consult the project-specific FSP and QAPP, as the requirements on frequency of field duplicate collection may vary by EPA region or state).

Field Replicate Samples

Field replicate samples are co-located samples collected in an identical manner over a minimum period of time to provide a measure of the field and laboratory variance, including variance resulting from sample heterogeneity. Field replicates will be prepared by collecting two completely separate samples from the same station and submitting them for analysis as separate samples. Field replicates will be collected at a minimum frequency of 1 per 20 samples or once per sampling event, whichever is more frequent. If field duplicate samples are collected, then it is unlikely that field replicate samples will also be collected during a sampling event. The actual number of field replicate samples collected during a sampling event will be determined on a case-by-case basis by the project QA/QC coordinator (consult the project-specific FSP and QAPP, as the requirements on frequency of field duplicate collection may vary by EPA region or state).

Matrix Spike/Matrix Spike Duplicates

The matrix spike/matrix spike duplicate (MS/MSD) analyses provide information about the effect of the sample matrix on the design and measurement methodology used by the laboratory. To account for the additional volume needed by the laboratory to perform the analyses, extra sample volumes may be required to be collected from designated sediment stations. MS/MSDs may be collected at a minimum frequency of 1 per 20 samples or once per sampling event, whichever is more frequent. The actual number of extra bottles collected during a sampling event will be determined on a case-by-case basis by the project QA/QC coordinator (consult the project-specific FSP and QAPP, as the requirements may vary by analyte group).

Equipment Rinsate Blanks

Equipment rinsate blanks will be used to help identify possible contamination from the sampling environment and/or from decontaminated sampling equipment. Equipment

rinsate blanks will be prepared by pouring laboratory distilled/deionized water through, over, and into the decontaminated sample collection equipment, then transferring the water to the appropriate sample containers and adding any necessary preservatives. Equipment rinsate blanks will be prepared for all inorganic, organic, and conventional analytes at least once per sampling event per the type of sampling equipment used. The actual number of equipment rinsate blanks prepared during an event will be determined on a case-by-case basis by the project QA/QC coordinator (consult the project-specific FSP and QAPP, as the requirements on frequency of equipment rinsate blank collection may vary by EPA region or state).

Bottle Blanks

The bottle blank is an unopened sample bottle. Bottle blanks are submitted along with sediment samples to ensure that contaminants are not originating from the bottles themselves because of improper preparation, handling, or cleaning techniques. If required, one bottle blank per lot of prepared bottles will be submitted for analysis. If more than one type of bottle will be used in the sampling (e.g., HDPE or glass), then a bottle blank should be submitted for each type of bottle and preservative. The actual number of bottle blanks analyzed during a project will be determined on a case-by-case basis by the project QA/QC coordinator (consult the project-specific FSP and QAPP as the requirements on frequency of bottle blank analysis may vary by EPA region or state).

To prepare a bottle blank in the field, set aside one unopened sample bottle from each bottle lot sent from the testing laboratory. Label the bottle as "Bottle Blank" on the sample label (and in the "Remarks" column on the COC/SAR form), and send the empty bottle to the laboratory with the field samples.

Trip Blanks

Trip blanks will be used to help identify whether contaminants may have been introduced during the shipment of the sediment samples from the field to the laboratory for VOC analyses only. Trip blanks are prepared at the testing laboratory by pouring distilled/deionized water into two 40-mL VOC vials and tightly closing the lids. Each vial will be inverted and tapped lightly to ensure no air bubbles exist.

The trip blanks will be transported unopened to and from the field in the cooler with the VOC samples. A trip blank shall be labeled and placed inside the cooler that contains newly collected VOC samples and it shall remain in the cooler at all times. A trip blank must accompany samples at all times in the field. One trip blank (consisting of a pair of VOC vials) will be sent with each cooler of samples shipped to the testing laboratory for VOC analysis.

Temperature Blanks

Temperature blanks will be used by the laboratory to verify the temperature of the samples upon receipt at the testing laboratory. Temperature blanks will be prepared at the testing laboratory by pouring distilled/deionized water into a vial and tightly closing the lid. The blanks will be transported unopened to and from the field in the cooler with the sample containers. A temperature blank shall be included with each sample cooler shipped to the testing laboratory.

Field Blanks

The field blank is prepared in the field to evaluate potential background concentrations present in the air and in the distilled/deionized water used for the final decontamination rinse. If unpreserved bottles are to be used, then the appropriate preservative (i.e., for metals samples use a 10-percent nitric acid solution to bring sample pH to 2 or less) must be added, as may be required. Field blanks should be collected at a minimum frequency of 1 in 20 samples. The actual number of field blanks analyzed during a project will be determined on a case-by-case basis by the project QA/QC coordinator (consult the project-specific FSP and QAPP, as the requirements on frequency of field blank analysis may vary by EPA region or state).

To prepare a field blank in the field, open the laboratory-prepared sample bottle while at a sample collection site, fill the sample bottle with distilled/deionized water and then seal. Assign the field blank a unique sample number, label the bottle, and then send the bottle to the laboratory with the field samples.

Reference Materials

Reference materials (i.e., a standard reference material, a certified reference material, or other reference material; for the purposes of this document the acronym SRM will be used for all types of reference materials) are samples containing known analytes at known concentrations that have been prepared by and obtained from EPA-approved sources. The SRMs have undergone multilaboratory analyses using a standard method which provides certified concentrations. When available for a specific analyte, SRM samples provide a measure of analytical performance and/or analytical method bias (i.e., accuracy) of the laboratory. Several SRMs may be required to cover all analytical parameters. For all analytes where available, one SRM will be analyzed at a frequency of one per 50 samples. The actual number of SRMs analyzed during a project will be determined on a case-by-case basis by the project QA/QC coordinator (consult the project-specific FSP and QAPP, as the requirements on frequency of SRM analysis may vary by EPA region or state).

STANDARD OPERATING PROCEDURE SOP-11: INVESTIGATION-DERIVED WASTE HANDLING

Scope and Application

This SOP presents the method to be used when handling investigation-derived wastes during field sampling activities.

Supplies and Equipment

- 55-gallon drums
- Paint markers
- Tools (to open and close drum)
- Drum labels.

Procedures

1. Containerize solid wastes by placing them in properly labeled, Department of Transportation (DOT)-approved, 55-gallon drums or other approved containers. Do not combine solid residues known to be from a contaminated area with other residues.
2. Label drums as "NON-CLASSIFIED WASTE MATERIAL: LABORATORY ANALYSIS IN PROGRESS". Include on the labels a drum number, the type of material, site address, accumulation date, and generator name and phone number.
3. Properly close, seal, and stage all filled or partially filled drums before demobilization.
4. Profile the drums based on the analytical results from corresponding borehole samples, or waste characterization samples collected from the drums. Once the drums are profiled, dispose of them in accordance with applicable regulations.
5. Maintain a drum inventory in the field logbook.

6. Sampling activities will generate personal protective equipment and miscellaneous debris that need to be disposed of. Remove gross contamination from these items, and place the items in plastic bags. Interim storage of these materials in plastic bags is acceptable. Dispose of the bags at an appropriate solid waste facility dumpster at the end of each day.

STANDARD OPERATING PROCEDURE SOP-12: HYDROCARBON FIELD SCREENING FOR SOIL AND SEDIMENT

Scope and Application

This SOP presents the qualitative field screening methods for hydrocarbons in soil.

Equipment/Reagents Required

- Clean, stainless-steel or plastic pan
- Camera (if necessary)
- Ziploc® bags
- Photo-ionization detector (PID)

Procedures

Headspace Field Screening

1. Calibrate PID in accordance with the manufacturer's specifications.
2. Label Ziploc® bag with the sample number.
3. Place representative soil sample in Ziploc® bag until bag is approximately one-quarter full (if sample recovery is sufficient). Seal Ziploc® bag and homogenize sample.
4. Allow bag to sit at ambient temperature for approximately 10 minutes. Place PID wand into bag, being careful not to contact soil with PID probe. Also be careful not to let any ambient air in the bag as this may cause dilution.
5. Gently shake Ziploc® bag and record highest sustained reading in the field logbook or borehole log.

Visual Screening

Visual screening consists of inspecting the soil or sediment for the presence of stains indicative of residual petroleum hydrocarbons. Visual screening is generally more

effective in detecting the presence of heavier petroleum hydrocarbons, such as motor oil, or when hydrocarbon concentrations are high.

1. Visually inspect soil or sediment sample.
2. Look for indications of the presence of hydrocarbons, which typically include a mottled appearance or dark discoloration of the soil.
3. Record observations in logbook. Note: Visual observations do not definitively indicate the presence of hydrocarbons.

Sheen Testing

Sheen testing involves immersion of the soil or sediment sample in water and observing the water surface for signs of a sheen.

1. Place a representative soil or sediment sample into a clean, stainless-steel or plastic pan filled with deionized water with as little disturbance as possible.
2. Record observations in the logbook. Visual evidence of a sheen forming on the surface of the water is classified as follows:
 - **No sheen (NS)**—No visible sheen on the water surface.
 - **Colorless Sheen (CS)**—Light, nearly colorless sheen; spread is irregular, not rapid; film dissipates rapidly (**Note:** light colorless sheens can be confused with sheens produced by organic content). Note that this sheen may or may not indicate the presence hydrocarbons.
 - **Heavy Sheen (HS)**—Light to heavy colorful film with iridescence; stringy, spread is rapid; sheen flows off the sample; most or all of water surface is covered with sheen.

ATTACHMENT B

FIELD FORMS

Sample Label

Site: _____	integral <small>consulting inc.</small>
Sample No.: _____	
Matrix: _____	Date: _____
Filtered (Y/N): _____ <small>(if applicable)</small>	Time: _____
Analysis: _____ <small>(optional)</small>	Pres: _____
Sampler: _____	
Tag Number: <u>1813</u>	

Custody Seal

CUSTODY SEAL		integral <small>consulting inc.</small>
Date: _____	Time: _____	
Sampler Signature: _____		

FIELD CHANGE REQUEST (FCR) FORM

Project Name: _____

Project No.: _____

Client: _____

Request No.: FCR-_____

To: _____

Date: _____

Field Change Request Title: _____

Description:

Recommended Change:

Field Operations Lead (or designee)

Signature

Date

Approval:

Project Manager

Signature

Date

Distribution:

LSS Project Manager

Integral Project Manager

Field Operations Lead

QA Officer

Project File

Other:



"Rite in the Rain"[®]
ALL-WEATHER
ENVIRONMENTAL
No. 550F