WORK PLAN FOR THE SAN DIEGO SHIPYARDS POST-REMEDIAL MONITORING

Cleanup and Abatement Order No. R9-2012-0024

Prepared for

NASSCO, BAE, City of San Diego, San Diego Gas and Electric, Campbell Industries, United States Navy, and San Diego Unified Port District

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CERTIFICATION STATEMENT

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

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Acronyms and Abbreviations

ASTM	American Society for Testing and Materials
BAE	BAE Systems
CAO	Cleanup and Abatement Order
COC	contaminant of concern
COC/SAR	chain-of-custody/sample analysis request (form)
CVAA	cold vapor atomic absorption
CVAFS	cold vapor atomic fluorescence spectrometry
DTR	Detailed Technical Report
EPA	U.S. Environmental Protection Agency
FSP	field sampling plan
GC/FPD	gas chromatography/flame photometric detector
GC/MS	gas chromatography/mass spectrometry
GPS	global positioning system
the Dischargers	NASSCO, BAE, the City of San Diego, San Diego Gas and Electric, Campbell Industries, United States Navy, and San Diego Unified Port District
HPAH	high-molecular-weight polycyclic aromatic hydrocarbon
ICSA/ICSAB	interference check solution
ICP-MS	inductively coupled plasma mass spectrometry
LAET	lowest apparent effects threshold
LCS	laboratory control sample
LOE	line of evidence
MQO	measurement quality objective
MS/MSD	matrix spike/matrix spike duplicate
NASSCO	National Steel and Shipbuilding Company
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
QAPP	quality assurance project plan
QA/QC	quality assurance and quality control
RMP	Remedial Monitoring Plan
RWQCB	San Diego Regional Water Quality Control Board
SD	standard deviation
SIM	selected ion monitoring
the Site	Shipyard Sediment Site
SOP	standard operating procedure
SS-MEQ	Site-specific median effects quotient
SWAC	surface-weighted average concentration
UCL	upper confidence limit
UPL	upper prediction limit

1 Project Overview

This work plan for post-remedial monitoring at the San Diego Bay Shipyards Site was prepared on behalf of National Steel and Shipbuilding Company (NASSCO) and BAE Systems (BAE), in accordance with requirements set out in Cleanup and Abatement Order (CAO) No. R9-2012-0024 and supporting documents, including the Detailed Technical Report (DTR). The activities described below will take place following completion of remediation at the Shipyard Sediment Site (the Site), according to the schedule described in Section 2.10.

1.1 Purpose and Objectives

Post-remedial monitoring is intended to verify that remediation is effective in reducing and maintaining chemical concentrations in sediments to an acceptable level. This post-remedial monitoring plan has been designed to verify that residual pollutant concentrations in the sediments at the Site will not unreasonably impact beneficial uses when remediation has been completed. The long-term beneficial uses identified by the San Diego Regional Water Quality Control Board (RWQCB) at the Site include shellfish harvesting, commercial and sport fishing, contact water recreation, non-contact water recreation, estuarine habitat, marine habitat, wildlife habitat, and migration of aquatic organisms (DTR Section 1.4.2).

Post-remedial monitoring will include sediment sampling for chemistry analysis, bioaccumulation testing, and toxicity testing at specified locations to verify that remedial objectives have been met. Chemistry analysis will verify that the remediation was successful in reducing Site-wide contaminant of concern (COC) concentrations to levels that are protective of all human and wildlife beneficial uses as identified in DTR Section 1.4.2. Sediment toxicity tests will verify that the post-remedial sediment toxicity is not significantly different from conditions at the reference stations described in Finding 17 and in the Technical Report for Cleanup and Abatement Order No. R9-2011-0001 for the Shipyard Sediment Site, San Diego Bay, San Diego, California. Bioaccumulation testing will be used to verify that the average of stations sampled show bioaccumulation levels below the pre-remedial levels. Benthic community assessment will also be performed in the remedial footprint to evaluate post-dredging benthic community development.

1.2 Site Description

The Site is located on the eastern shore of central San Diego Bay, approximately one-half mile south of the Coronado Bridge and half the total distance into the Bay. The NASSCO and BAE Systems leaseholds, portions of which lie in the Site, are adjacent to each other, have a similar range of water depths, and lie within the same hydrologic and biogeographic area. The total combined San Diego Bay water acres included in the NASSCO and BAE Systems leaseholds is approximately 56 acres. The Site encompasses the entire 56 water acres of the NASCCO and BAE Systems leaseholds. Also included in the Site investigation were areas just outside the northwestern boundary of the BAE Systems leasehold and areas west of the leasehold near the

eastern edge of the shipping channel. The vertical and horizontal extent of the Site includes bay bottom marine sediment with pollutant levels greater than "background conditions" found in relatively "clean" regions of San Diego Bay and includes areas that extend beyond the NASSCO and BAE Systems leaseholds (DTR Section 1.1).

1.3 Project Organization

The parties under the CAO for this study (the Dischargers) are NASSCO, BAE, the City of San Diego, San Diego Gas and Electric, Campbell Industries, United States Navy, and San Diego Unified Port District. All activities are being conducted in accordance to the CAO. Table 1 identifies representatives from BAE and NASSCO, RWQCB, key contractors, and laboratories.

1.4 Document Overview

This work plan describes the details of the post-remedial monitoring and is consistent with the guidelines specified by the CAO and the supporting DTR. The work plan includes the following sections:

- Section 2. *Field Sampling Plan*, describes the major components of the field and laboratory studies including sample types, station locations, sample collection techniques, and laboratory methods
- Section 3. *Quality Assurance Project Plan*, describes the necessary quality assurance procedures and quality control activities that will be implemented to ensure quality objectives are achieved for the study
- Section 4. *Data Analysis and Interpretation*, describes how the results of the various chemical and biological analyses will be analyzed and interpreted
- Section 5. *References*, presents references for all documents cited in the work plan.

In addition, the following support documents are provided as appendices:

- Appendix A. Standard Operating Procedures
- Appendix B. Example Field Forms
- Appendix C. Health and Safety Plan

2 Field Sampling Plan

The sediment sample collection will be conducted by a contracted field crew (company to be determined) with oversight by representatives from the Dischargers. Following completion of each sampling event, the field sampling contractor will submit a detailed field report.

Detailed procedures for sample collection, handling, and shipping are described in this field sampling plan (FSP). Procedures are included for the following tasks:

- Documenting the location of stations and establishing sample identifiers
- Collecting and compositing sediment samples
- Processing samples to ensure proper sub-sampling
- Cleaning equipment, work surfaces, and sampling implements prior to commencing sampling and between stations
- Completing standard forms to document the collection effort and field conditions.

The anticipated schedule of sample collection is also discussed in this section.

2.1 Station Locations

The station locations that will be targeted for sediment collection are the 66 stations detailed in the CAO (Attachment 2), based on the original sampling stations from the Detailed Sediment Investigation (Exponent 2003). Station designations and location coordinates of all target sampling stations are shown in Table 2. Depending on conditions encountered in the field, the exact locations sampled may be modified by the field team, but will be located as close to the target coordinates as possible.

2.2 Description of Samples

There will be two distinct sampling events for two different objectives. The first event will include sediment collection for composite chemistry analyses, bioaccumulation testing, discrete sample chemistry analysis for evaluation of benthic exposure, and sediment toxicity testing. Only sediment chemistry analyses are composites. The objective for this activity is to verify that remedial objectives set out in the CAO are protective of all designated beneficial uses by aquatic life, aquatic-dependent wildlife, and human health (DTR Section 1.4.2)

The second sampling event is the benthic community assessment within the footprint. These samples will be used to evaluate the development of the benthic community after the remedy implementation.

2.3 Vessel Operation and Navigation

Sampling will be conducted from a research vessel to be identified by the selected field contractor, in consultation with the Dischargers. The vessel operator will be thoroughly familiar with accurate deployment and retrieval of the sampling gear. Locations will be located using a wide area augmentation system-enabled global positioning system (GPS). The positioning system used for this sampling effort will provide precise latitude and longitude coordinates for the station locations. In the event of GPS failure, stations will be located using a land surveying system, or laser range finder and visual lineups. Water depth will be noted, and all sample locations will be recorded in the field using positions from the GPS or through lineups on the field map.

The leader of the field team, in consultation with the Dischargers' observer, will be responsible for all decisions concerning sample collection. If a significant deviation from this FSP needs to be considered because of conditions encountered during sampling (e.g., repositioning of a station location), the field crew will notify the Dischargers' representative, who may choose to consult with representatives of the Dischargers and RWQCB.

2.4 Sample Identifiers

Sample identifiers will be established before field sampling begins and one will be assigned to each sample as it is collected. Sample identifiers consist of codes designed to fulfill three purposes: 1) to identify related samples (i.e., replicates) to ensure proper data analysis and interpretation, 2) to obscure the relationships between samples so that laboratory analysis will be unbiased by presumptive similarities between samples, and 3) to track individual sample containers to ensure that the laboratory receives all of the material associated with a single sample. To accomplish these purposes, each container is assigned a sample number and a tag number. These codes and their uses are described below:

- **Sample Number—**The sample number is an arbitrary number assigned to each sediment sample collected. All subsamples of a composited field sample will have the same sample number. Each field replicate of a given type will have a different sample number, and the sample numbers of related field replicates will not necessarily have any shared content. The sample number appears on the sample containers and the chain-of-custody/sample analysis request (SAR) forms.

- **Tag Number—**A different sample 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 will appear on the chain-of-custody/SAR forms. 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 numbers will be assigned sequentially in the field; sample tags will be preprinted with tag numbers.

2.5 Sampling Procedures

In this section, procedures are described for collecting the samples described above. Criteria for judging the acceptability of samples are also described. The number and type of samples to be collected during sampling are summarized below and are presented in Table 3. Generally speaking, sampling protocols and procedures are intended to replicate those used in the 2001–2002 detailed sediment investigation as much as possible, to facilitate direct comparison with pre-remedial data.

2.5.1 Surface Sediment Sample Collection

Surface sediment samples (0–2 cm) will be collected using a double Van Veen grab sampler in accordance with standard U.S. Environmental Protection Agency (EPA) methods (U.S. EPA 1986; Bay et al. 2009). The grab sampler will be either stainless-steel or Teflon®-coated. Before sampling begins at a station, the Van Veen grab sampler will be scrubbed with Alconox®, rinsed with site seawater, rinsed with a solvent (e.g., acetone and hexane), air-dried, and rinsed with site seawater. Equipment used for compositing the sediment samples (i.e., stainless-steel or Teflon® bowls and spoons) will follow the same basic decontamination sequence except that the final rinse will be with laboratory-grade distilled/deionized water.

To minimize the potential for cross contamination, the double Van Veen sediment grab sampler will be decontaminated between sampling stations. The decontamination procedure includes the washing of sampling equipment with site water and Alconox® and rinsing with deionized water.

All sample processing equipment (stainless-steel or Teflon® mixing spoons and bowls) will be decontaminated in the laboratory prior to field activities. The decontamination procedure for these apparatus includes the washing with Alconox®, rinsing with deionized water, rinsing with acetone, rinsing with hexane, and then rinsing with deionized water again. These apparatus will then be covered with aluminum foil and packaged for transport to the field collection site. It should be noted in the sample handling section that material in contact with the sides or bottom of the Van Veen will not be collected for chemistry or toxicity analyses. This process further prevents the potential for cross contamination.

If there is a significant lapse of time between decontamination of the sample compositing equipment and collection of the sample, then the decontaminated sample compositing equipment will be covered with foil to protect it from additional contamination. The field team leader will use best professional judgment, with consideration of the conditions during the sampling event, to determine if foil protection is required (Exponent 2001). Any excess solvent rinsates will be collected in a container, and the small volume collected will be allowed to evaporate. Any remaining solvent that does not fully evaporate will be collected for proper disposal at a facility that accepts solvent waste.

After a sediment sample is retrieved and judged to be acceptable for chemical analyses and toxicity testing (see discussion below), the overlying water will be siphoned off and the upper 2 cm of sediment will be collected in accordance with U.S. EPA (1986) guidelines. Stainless-steel spatulas and spoons will be used to collect the sediment. A stainless-steel ruler will be used to ensure that the sampling criterion for adequate penetration depth is met and that the correct amount (i.e., 2 cm) of sediment has been removed. Sediment touching the sides of the grab sampler will not be collected.

At each sampling station, at least two grab samples will be collected for chemical analyses and toxicity testing. The designated field team leader will evaluate the acceptability of each sample collected from the grab sampler based on Bay et al. (2009) and will use best professional judgment to evaluate the acceptability of the sample according to the following criteria:

- The sampler is not overfilled
- Overlying water is present
- The overlying water is not excessively turbid
- A sediment penetration depth of at least 11 cm is attained
- The sediment surface is relatively undisturbed (Exponent 2001).

Due to the nature of activities in active shipyards, there is a significant possibility of sediment disturbance from ship movement. Sediment grabs should be carefully evaluated for signs of physical disturbance. Upon retrieval of the grab, the surface of the sediments will be examined for any evidence of physical disturbance, especially related to potential effects of propeller wash from vessels at the shipyards. Therefore, the sediments will be examined for evidence of fine materials being eroded from the surface of the grab sample. Evidence of physical disturbance may be associated with the presence of loosely-aggregated sands at the surface with little or no component of fine materials. Other evidence may include absence of tubiculous organisms or burrows at the sediment surface. If significant evidence of physical disturbance is evident, the sample location will be moved away from the potential area of disturbance and a new sample location will be established within the target polygon. Any changes in sampling location will be noted in the field notes (Exponent 2001).

The field team leader will evaluate all samples collected. If a sample fails to meet the above criteria, it could be rejected and discarded away from the station.

The surface (top 2 cm) sediment will be collected from each grab sample, and the sediment will be composited (discussed below). The sediment sample at each station will be composited in either a stainless-steel or Teflon® bowl and covered with aluminum foil until a sufficient volume of sediment is collected for both chemical analysis and amphipod toxicity testing. Volumes required for analyses are detailed in Table 6. Sediment in the bowl will then be mixed using a large stainless-steel or Teflon® spoon to achieve a uniform texture and color before subsamples are taken and transferred to pre-cleaned glass containers with Teflon®-lined lids. Immediately after sample containers are filled, they will be placed in a cooler on ice. Samples will be stored at 4±2°C.

Samples will be sent to laboratories for sediment chemistry analysis, bioaccumulation testing, sediment chemistry for benthic exposure, sediment toxicity and benthic community assessment. Only the sediment chemistry analyses are composites. Tables 3 and 4 depict which stations are to be sampled for each test and the COCs that are required for analysis.

2.5.1.1 Sediment Collection for Composite Chemistry, Bioaccumulation Testing, Sediment Chemistry for Benthic Exposure, and Sediment Toxicity Tests

Composite Sediment Samples—The post-remedial surface weighted average concentrations will be confirmed with composite sampling of the entire study site, from the 66 station locations within the six polygon groups (see Figure 1). Discrete samples from each of these 66 stations will be archived for future use if necessary. As stated in the CAO, the volume of each sample will be proportional to the area of the polygon that the station represents. Approximately 1 L of sample will be collected from each station, with 500 mL reserved for archiving. Areas and volumes to be collected are tabulated in Table 5. Individual sediment samples will be combined into six composite samples (representing each polygon group). Three replicates will be taken from each of the six composite samples and sent to the laboratory for analysis. These three replicate sub-samples of the composites will provide an estimate of the variances due to the compositing process. Samples will be placed in appropriate containers for laboratory analyses (see Table 6).

In the laboratory, sediments will be analyzed for the following five primary COCs: copper, mercury, tributyltin, polychlorinated biphenyls (PCBs) (refer to Table 8), and high-molecular-weight polycyclic aromatic hydrocarbons (HPAHs) (refer to Table 7). Details of methods and data handling are provided in Section 3.

Sediment Toxicity—Stations for sediment toxicity testing will be collected from the following five stations: SW04, SW13, SW22, SW23 and NA19. The sediments used for the 10-day amphipod survival toxicity test, using *Eohaustorius estuarius* (ASTM 2008), will be sub-sampled from the sediment homogenate used for chemistry analysis, to ensure that the chemical and toxicity results are related as closely as possible. Approximately 1.5 L will be collected for this test.

Intact, unhomogenized surface sediment will be collected for the 48-hour bivalve development test at the sediment-water interface using *Mytilus galloprovincialis* (ASTM 2004; U.S. EPA/Corps 1994; Anderson et al. 1996, 2001). The top 5 cm of sediment will be collected from each grab sample. Sample integrity will be verified by the presence of sediment overlying water. Polycarbonate core tubes (3-in. diameter by 8-in. high) will be inserted 2 in. into the sediment while the sediment is still in the grab sampler and prior to removal of any overlying water. Six replicates will be collected at each station, five sub-samples for toxicity testing and one sub-sample for interstitial sulfide and ammonia measurements. The intact sediment cores will be transferred to appropriate containers for shipment to the toxicity testing laboratories.

Bioaccumulation Testing—Sediment from nine stations (SW04, SW08, SW13, SW21, SW28, NA06, NA11, NA12, and NA20) will undergo bioaccumulation testing using the 28-day *Macoma nasuta* test (ASTM 2010). Approximately 4 L will be collected at each station for this test. At the end of the 28-day exposure period, the soft tissue of the clam will be removed and

analyzed for the following COCs: arsenic, cadmium, copper, lead, mercury, zinc, HPAHs (Table 7), and PCBs (Table 8).

Sediment Chemistry for Benthic Exposure—Sediments from five stations (SW04, SW13, SW22, SW23, and NA19) will be collected for benthic exposure assessment. Samples will be analyzed for arsenic, cadmium, chromium, copper, lead, mercury, nickel, silver, zinc, tributyltin, PCBs (Table 8), and polycyclic aromatic hydrocarbons (PAHs) (Table 7). Conventional analytes such as grain size, total organic carbon, and ammonia will also be analyzed. Approximately 500 mL will be collected for this analysis.

2.5.1.2 Benthic Infauna Sample Collection for Community Assessment

Sediments for the benthic community assessment will be collected from five stations, randomly selected, with the exclusion of stations NA19, SW04, SW13, SW22, and SW23 (stations where samples will be collected for sediment chemistry for benthic exposure). Collection will occur 3 and 4 years after the completion of the remediation. The samples will be stratified to ensure that two to three samples are collected from each of the two shipyards.

Sediment for benthic infauna community analysis will be collected using a double Van Veen in accordance with standard methods used by U.S. EPA (1987) and Bay et al. (2009). The sediment in the grab sampler will be evaluated for acceptability according to the requirements described in the previous section. All of the sediment (a minimum of 5 cm to a maximum depth of 30 cm) and overlying water collected in each grab sample will be sieved. Five replicates will be collected at each station. Approximately 1 L of sediment will be collected at each station.

Samples collected for benthic community analysis will be gently rinsed over a 1.0-mm sieve with filtered seawater to remove sediment. The remaining sample will be rinsed into a plastic sample jar using a narcotizing solution of magnesium sulfate. After 30 minutes, buffered 10% formalin will be added to the sample jar as a preservative.

The laboratory will prescreen and transfer the sample to 95% ethanol. Debris will be removed and organisms will be sorted by major taxa and the benthic community identified to the lowest feasible taxa level.

2.6 Sample Handling

All sample containers will be provided by the chemical and toxicity testing laboratories and prepared in accordance with EPA guidelines (U.S. EPA 1986) prior to field operations. Table 6 summarizes the types of containers for laboratory analysis. Sample containers for chemical analyses and toxicity testing will be kept closed and in a cooler until used. As they are collected, samples will be fully labeled, recorded in the field logbook along with other pertinent collection data, and returned to coolers as soon as possible. Immediately after they are filled, all sample containers containing sediment for chemical analyses and toxicity testing will be placed on ice in a cooler at 4±2°C. Samples collected for benthic infauna community analysis will be stored in an upright position at a cool temperature and away from direct sunlight. All samples

will be stored in a secure place, where containers are not susceptible to breakage (Exponent 2001).

Sediment samples for all chemical analyses and toxicity testing will be shipped on ice (4±2°C) to the testing laboratories and will be stored at 4±2°C until analysis and final disposition of the samples. All field samples, except archived chemical and benthic infauna samples, will be analyzed as soon as possible after receipt at the laboratory. Maximum sample holding times are stipulated in the quality assurance project plan (QAPP) (Section 3).

Samples in glass containers will be packed in bubble-wrap plastic to prevent breakage, and chain-of-custody seals will be placed across the cooler lids. Chain-of-custody forms will been closed in the coolers with the samples and will be signed at the laboratory upon receipt.

Samples will be shipped or sent by courier after each sampling day to arrive at the participating laboratories the following day. A copy of the signed chain-of-custody form will be returned by the testing laboratory to the Dischargers' consultant and filed in the project file. Sample packaging and shipping requirements are described in Standard Operating Procedure (SOP) GEN-03, *Sample Packaging and Shipping* (Appendix A) (Exponent 2001).

2.7 Field Quality Control Sample Procedures

The following quality control samples will be collected in the field and analyzed by the chemical analytical laboratory with the natural samples:

- **Field Duplicates—**A field duplicate surface sediment sample will be collected and analyzed to assess the variability of chemical concentrations at a location. Field duplicates provide a measure of the total analytical bias (field and laboratory variance) including bias resulting from the heterogeneity of the replicate sample set. Field duplicates will be collected at a minimum frequency of 1 per 20 samples. It is anticipated that three field duplicate sediment samples will be collected from the study sites.

- **Equipment Rinsate Blanks—**An equipment rinsate blank will be collected to help identify possible contamination from the sampling environment or from the sampling equipment (e.g., grab, coring device, bowls, spoons). The rinsate blank will consist of running distilled/deionized water over the sampling equipment after decontamination. One rinsate blank will be collected at a randomly selected station during each sampling event.

- **Standard Reference Materials—**Standard reference material for sediments will be submitted from the field once per sampling event.

2.8 Field Documentation

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 and chain-of-custody procedures will

be implemented to allow samples to be traced from collection to final disposition. The various logs, forms, and labels required to adequately identify and catalogue sampling location and sample information include the following:

- **Field Logbook—**A bound, waterproof field logbook with consecutively numbered pages will be used. All daily field activities will be documented in indelible ink in this logbook; all entries will be signed and dated and no erasures will be made. If an incorrect entry is made, the information will be crossed out with a single strike mark that is signed and dated by the sampler. Field logbooks will be stored in a secure manner when not in use. The field team leader will record the following information daily in the field logbook:
  - Project name, project location, and project number
  - Project start date and end date
  - Date and time of entry (24-hour clock)
  - Time and duration of daily sampling activities
  - Weather conditions
  - Name of person making entries and other field personnel
  - Onsite visitors, if any
  - The sample identifier and analysis code for each sample to be submitted for laboratory analysis
  - The sampling location name, date, gear, water depth, and sampling location coordinates
  - Specific information on each type of sampling activity
  - A description of the sample (source and appearance, such as sediment type, color, and odor)
  - The sample number, analysis code, and tag number for each sediment subsample
  - The number of photographs taken at the sampling location, if any
  - Variations, if any, from specified sampling protocols and reasons for deviation (Exponent 2001).
- **Station/Sample Log—**Each gear deployment event will be recorded on a station/sample log sheet. One or more station/sample log sheets will be completed for each station sampled. The station name, date, gear, cast number, depth, and location coordinates will be recorded on each log sheet (Exponent 2001).

- **Sample Label—**A sample label will be completed for each sample. A sample label will be placed on the outside of all sample containers. An internal label on waterproof paper will also be placed inside each benthic community sample container. All sample label entries will be made with indelible ink, except for the internal label used with the benthic community samples, which will be made with pencil. Sample containers will be labeled at the time of sampling with the following information: sample number, site name, sampling date and time, sampling personnel, preservative (if appropriate), and tag number (Exponent 2001).

The field team leader is responsible for properly completing all logbooks and forms. In addition, a sampling location map will be updated during sampling and will be maintained throughout the sampling event. Station and sample logs must be completed at the time the observations are made. Copies of all logbooks and forms will be appended to the Field Activities Report by the contracted field team. Appendix B contains examples of the forms that are used to record information at each sampling location.

2.9 Field Custody Procedures

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 and chain-of-custody procedures will be implemented to allow samples to be traced from collection to final disposition. The various forms required to adequately identify and catalogue sampling location and sample information include the following:

- **Chain-of-Custody/Sample Analysis Request Form—**The sample identifier and tag numbers of each sample container will be recorded on a chain-of-custody/SAR form (example provided in Appendix B). The signed chain-of-custody/SAR form will be secured to the inside top of each cooler identifying the sample collection date and time, the type of sample, the project, and the field personnel. The chain-of-custody/SAR form will also identify the preservative or other sample pretreatment applied and the analyses to be conducted by referencing a list of specific analytes or the statement of work for the laboratory. The chain-of-custody/SAR form will be sent to the laboratory along with the sample. The chain-of-custody forms will be completed in triplicate, with one copy retained by the field team leader.

- **Custody Seal—**Two custody seals will also be placed across the lid of the cooler (front right and back left) prior to shipping.

At the end of each day and prior to shipping or storage, chain-of-custody entries will be made for all samples. Finally, information on the labels and tags will be checked against field logbook entries and samples will be re-counted (Exponent 2001).

The field team leader is responsible for properly completing all forms. Chain-of-custody/SAR forms will be completed and signed before the end of each sampling day and before the samples pass from the control of the field team leader. Chain-of-custody/SAR forms will be signed at each additional point of transfer of samples between the field and the chemical testing, toxicity testing, and benthic taxonomy laboratories and within each laboratory. Copies of all forms will be retained by the field team leader (Exponent 2001).

2.10 Schedule

Remediation is expected to be completed over three field seasons. The schedule for post-remedial monitoring will begin after the completion of remediation (i.e., year zero) (see Figure 2). Because the first post-remedial monitoring activities are not anticipated to begin until at least 2017 (2 years after completion of all remediation), this work plan should be reviewed and updated at the time that the field sampling contractor and analytical laboratories are selected, in order to ensure consistency with current protocols, and to verify volume requirements for all analyses. To the extent possible, sampling activities in all years should be completed during the same season, preferably the summer months.

2.10.1 Sediment Collection for Composite Chemistry, Bioaccumulation Testing, Sediment Chemistry for Benthic Exposure, and Sediment Toxicity Tests

Sampling and analyses for composite chemistry, bioaccumulation assessment, sediment chemistry for benthic exposure, and toxicity testing will occur 2 and 5 years after completion of remediation. Monitoring will continue in Year 10 after completion of the remedy if the Year 5 remedial goals are not met. A schedule of the sampling activities and their sequencing for each media are shown in Figure 2. The schedules for deliverable submissions (i.e., the Post-Cleanup Monitoring progress reports and final report) are also shown in this figure.

The actual sequence in which the stations will be visited will be determined in the field by the field team leader in order to maximize efficiency while minimizing potential cross-sample contamination.

2.10.2 Benthic Infauna Sample Collection for Community Assessment

Sediment sampling for benthic invertebrate community assessment will occur 3 and 4 years after the completion of the remediation. The actual sequence of sediment collection from each stations will be determined by the field team leader in order to maximize efficiency while minimizing potential cross-sample contamination. A post-remedial monitoring report will be submitted after each of the two sampling events.

2.11 Sampling Safety

Safety hazards are associated with the equipment and supplies that will be used, as well as the general rigors of work on the water. The Health and Safety Plan is provided in Appendix C. Its purpose is to identify potential hazards, institute procedures for minimizing those hazards, document the proper responses in case of accident and injury, and make this information known to all shipboard personnel. Before sampling begins, a health and safety briefing will be held onboard the sampling vessel (Exponent 2001).

3 Quality Assurance Project Plan

This QAPP describes the quality assurance and quality control (QA/QC) procedures that will be used to support the analytical data generated by the post-remedial monitoring activities at the NASSCO and BAE shipyards described above in Section 2. The QA/QC procedures described in this QAPP will also be applied to sediment chemistry monitoring activities described in the Remedial Monitoring Plan (RMP). These QA/QC procedures ensure that the data generated during this site investigation are representative of actual field conditions and meet the project's quality objectives. This QAPP was developed using guidance provided by U.S. EPA (2001, 2002a).

No changes in procedures specified in this QAPP will be permitted without written justification and a detailed explanation of the intended change. All changes are subject to approval by the Dischargers' QA/QC coordinator and project manager, the Dischargers, and RWQCB. A description of all changes, with justification, will be included in applicable data reports.

3.1 Sediment Chemistry

The sediment chemical testing laboratory for this investigation is still to be determined. Selection of this laboratory is subject to change, if for some reason, the laboratory is unable to perform the chemical analysis at the time of sampling.

Site wide post-remedial composite sediment samples will be analyzed for copper, mercury tributyltin, PCB congeners in Table 8, and HPAHs in Table 7. These composite sediment samples will also be analyzed for ammonia, grain-size distribution, total organic carbon, and total solids (i.e., conventional analytes).

3.2 Sediment Toxicity

Sediment toxicity testing will be performed by a laboratory to be determined. Selection of this laboratory is subject to change, if for some reason, the laboratory is unable to perform the toxicity analysis at the time of sampling. Two toxicity tests will be used for assessment of the sediment. The toxicity of whole sediment will be measured using an amphipod (*Eohaustorius estuarius*) for the 10-day survival test. The toxicity of whole sediment will also be measured using mussel (*Mytilus galloprovincialis*) for the 48-hour bivalve larval development test using modifications associated with the sediment interface test (Anderson et al. 1996, 2001).

The amphipod survival test will be conducted according to U.S. EPA (1994) and ASTM E1367-03 (2008) guidelines. This test consists of a 10-day exposure of *Eohaustorius estuarius* to sediment under static conditions. Amphipods are placed in glass chambers containing seawater and a 2 cm layer of test sediment. The number of surviving amphipods is measured at the end of the test and used to calculate the percentage survival relative to the negative control (laboratory generated seawater). A reference toxicant test will be run with every batch of test samples in order to document amphipod relative sensitivity and test precision. This test will

consist of a 96-hour exposure to five different concentrations of ammonia or cadmium chloride dissolved in seawater. Reference toxicant test results that fall outside of control chart limits (two standard deviation [SD] of mean) will trigger a review of test procedures and a possible retest of the corresponding sediment samples.

The mussel embryo development test will be conducted according to U.S. EPA/Corps (1994), ASTM E724-98 (2004), and Anderson et al. (1996, 2001) guidelines. This test consists of a 48-hour exposure of recently fertilized eggs of *Mytilus galloprovinicialis* to test sediment. Mussel embryos are placed in overlying water and are constrained to polyethylene screen tubes anchored in 5 cm of test sediment. The number of surviving normal embryos is measured at the end of the test and used to calculate the percentage normal-alive relative to the negative control (laboratory generated seawater). A reference toxicant test will be run with every batch of test samples in order to document mussel relative sensitivity and test precision. This test will consist of a 48-hour exposure to five different concentrations of ammonium chloride or copper chloride dissolved in seawater. Reference toxicant test results that fall outside of control chart limits (two SD of mean) will trigger a review of test procedures and a possible retest of the corresponding sediment samples.

3.3 Bioaccumulation Testing

The bioaccumulation testing laboratories for this investigation will be performed by laboratories to be determined. Selection of these laboratories is subject to change, if for some reason, the laboratory is unable to perform the bioaccumulation testing or chemical analyses at the time of sampling.

Bioaccumulation of compounds associated with this site will be determined by exposing *Macoma nastua* to post-remedial composite sediment samples collected from the study area. At the end of the 28-day exposure period, the soft tissue of the clam will be removed and sent to the chemical testing laboratory where the tissues will be analyzed for lipids, arsenic, cadmium, copper, lead, mercury, zinc, selected PCB congeners (Table 8), and HPAHs (Table 7).

3.4 Sediment Chemistry of Benthic Exposure

The sediment chemistry of benthic exposure testing laboratory for this investigation is to be determined. Selection of this laboratory is subject to change, if for some reason, the laboratory is unable to perform the chemical analysis at the time of sampling.

Several station locations will be analyzed for arsenic, cadmium, chromium, copper, lead, mercury, nickel, silver, zinc, tributyltin, selected PCB congeners, and PAHs. Tables 7 and 8 show the PAHs and PCB congeners, respectively, to be analyzed for the summed concentrations. These composite sediment samples will also be analyzed for ammonia, grain-size distribution, total organic carbon, and total solids (i.e., conventional analytes).

3.5 Benthic Communities

Laboratory sorting and identification of all benthic samples will be performed by a contractor laboratory to be determined. Selection of this laboratory is subject to change, if for some reason, the laboratory is unable to perform the benthic community sorting and identification at the time of sampling. Prior to sorting, macroinfaunal samples will be transferred to a 70% ethanol solution. Benthic macroinfaunal samples will then be sorted in 100% of the sample volume for each sample and taxonomic identification will be conducted to the lowest practicable taxon.

3.6 Quality Objectives and Criteria for Measurement Data

The primary quality objective for measurement data is to obtain results that are of known and acceptable quality and are representative of the conditions present at the site.

Measurement quality objectives (MQOs) have been established for this project to ensure that chemical, biological, and toxicity data are of known and sufficiently high quality to support the project objectives. Quantitative MQOs for laboratory analyses are provided in Table 9. Quantitative MQOs include precision, accuracy, and completeness. The qualitative goals of representativeness and comparability of the data are ensured by the careful collection of samples according to protocols established in the FSP (Section 2) and the RMP, and the use of standard methodology for testing and analyses.

To confirm that project MQOs for precision and accuracy are achieved, analytical results for field and laboratory quality control samples will be evaluated, as discussed in the following sections. The equations used to assess precision, accuracy, and completeness are provided in Section 3.16 of this QAPP. Quality control results that do not meet target values will be qualified during data validation, and their limitations will be noted in the data quality and usability report for the project. To ensure comparability and representativeness of the laboratory data, standard instrumentation will be used for the analyses and the instruments will be properly calibrated and maintained.

3.7 Special Training and Certification

Procedures to be completed for this study are, for the most part, routine. Standard procedures will be used to collect the sediment samples and to complete laboratory chemical analyses and toxicity testing. Identification and enumeration of benthic macroinvertebrates will be completed by taxonomists and technicians who specialize in this area. All field personnel will have completed the 40-hour Hazardous Waste Operations and Emergency Response training with annual refresher courses as required by the Occupational Safety and Health Administration. The chemical laboratory for this project should be certified by the State of California Department of Health Services' Environmental Laboratory Accreditation Program. The toxicity testing laboratory should be certified by the State of California Department of Health Services' Environmental Laboratory Accreditation Program.

3.8 Documents and Records

Procedures, observations, and test results will be documented for all sample collection, laboratory analysis and reporting, and data validation activities. In addition to data reports provided by the laboratories, reports will be prepared that address data quality and usability, provide tabulated laboratory and field data, and interpret the sediment data. Internal and external reporting procedures for this study are described in this section.

3.8.1 Field Records

Field records will be maintained during all stages of sample collection and preparation for shipment to the laboratories. Field records will include the following items:

- Field logbook to record daily sampling activities and conditions
- Combined station/sample log to document station locations and date/time of collection
- Sample labels
- Combined chain-of-custody/SAR forms
- Custody seals to monitor cooler security during shipment
- Photographic documentation.

In addition to the standard field records, the following reports may be completed if a deviation from the sampling plan or QAPP is encountered or to document an audit:

- Corrective action reports documenting any problems encountered during field activities and corrective actions taken
- System and performance audit reports completed during the investigation
- A summary of any changes made to documented procedures and the rationale for the changes.

3.8.2 Laboratory Data Reports

The laboratories will perform data reduction as described in each test method for this project (Table 9) and submit a complete data package with full documentation for all analyses or other determinations. The laboratory quality assurance officers are responsible for reviewing their respective laboratory data packages and checking data reduction prior to submittal to the Dischargers. Any transcription or computation errors identified during this review will be corrected by the laboratory.

Data reporting requirements for chemical analyses, toxicity tests, bioaccumulation testing, chemistry for benthic exposure, and benthic community enumeration are summarized in the following sections.

3.8.2.1 Composite Sediment Chemical Analyses, Bioaccumulation Testing, and Chemistry for Benthic Exposure

The analytical laboratories will provide all information required for a complete quality assurance review, including the following:

- A cover letter discussing analytical procedures and any difficulties that were encountered
- A summary of compound concentrations (to two significant figures, unless otherwise justified) and method reporting limits
- Laboratory data qualifier codes appended to compound concentrations, as appropriate, and a summary of code definitions
- Initial and continuing calibration data, including instrument printouts and quantification summaries for all compounds
- Results for method and calibration blanks
- Results for all QA/QC checks, including laboratory control samples (LCSs), matrix spike/matrix spike duplicate (MS/MSD) samples, surrogate spikes, laboratory duplicate samples, interelement interference checks (ICSA/ICSAB) samples
- Original data quantification reports for all compounds and samples
- All laboratory worksheets and standards preparation logs (data include final dilution volumes, sample sizes, wet-to-dry ratios, and spiking and standards preparation procedures for all analyses).

3.8.2.2 Toxicity Tests

The quality of test organisms obtained from an outside source, regardless of whether they are from culture or collected from the field should be documented. For cultured organisms, the supplier should provide data with the shipment describing the history of sensitivity for organisms from the same source culture. For field-collected organisms, the supplier should provide data with the shipment describing the collection location, the time and date of collection, the water salinity, and temperature at the time of collection. All organisms should be acclimated to test conditions prior to test initiation. The sediment handling and exposure conditions will be consistent with the appropriate EPA and American Society for Testing and Materials (ASTM) methods. Information such as the type of test chambers (must be identical for all concentration levels), and information on the amount of sediment, overlying water, or pore water in each test chamber (must also be identical for all concentration levels), will be documented and any deviations will be noted in the laboratory case narrative.

The following information will be reported by the toxicity testing and bioaccumulation testing laboratory to allow a complete quality assurance review of the sediment toxicity data:

- A laboratory case narrative cover letter discussing test procedures and any difficulties that were encountered
- Results for all water quality measurements made during testing (i.e., ammonia, dissolved oxygen, pH, temperature, and salinity)
- The test-specific endpoint value (e.g., survival, normality, fertilization) for each exposure chamber and the mean and SD for each treatment
- The test-specific endpoint value (e.g., survival, normality, fertilization) for each exposure chamber and the mean and SD for the negative control (i.e., laboratory negative control sediment)
- The median lethal concentration values and QC limits for the positive control tests
- Information on the source and age of test organisms (i.e., must be from the same source culture)
- Information on sediment handling and exposure chamber preparation
- Electronically scanned laboratory data sheets
- Descriptions of any problems that may have influenced data quality and any corrective actions taken by the laboratory (may only be taken with the project QA/QC officer's concurrence).

3.8.2.3 Benthic Communities Assessment

The following information will be reported by the taxonomic laboratory to allow a complete quality assurance review of the benthic invertebrate enumeration data:

- A cover letter discussing analytical procedures and any difficulties that were encountered
- The number of individuals of each taxon found in each replicate sample (Note: data for each replicate sample will be reported as numbers of individuals per sample for each species [or lowest identifiable taxon])
- Information on standard invertebrate metrics such as taxonomic richness, community evenness, Shannon-Wiener diversity, and percent composition in functional feeding groups
- Information on the sample-sorting efficiency (a minimum of 95% of the total number of individuals in each sample is required [i.e., no more than 5% of the organisms in a given sample can be missed by the original sorter])

- Information on the accuracy of the taxonomic identifications by each taxonomist (i.e., accurate for at least 95% of the total number of species)
- Electronically scanned laboratory data sheets.

3.8.3 Data Quality and Usability Report

A data quality and usability report will be prepared in conjunction with a data report for the chemical analyses, bioaccumulation testing, and chemistry for benthic exposure results. The data quality report will summarize the results of the data validation and data quality review and will describe any significant quality assurance problems that were encountered. The data quality report for the chemical analyses will include the following items:

- Executive summary of overall data quality and recommendations for data use and limitations
- Description of sample collection and shipping, including chain-of-custody and holding time documentation
- Description of analytical methods and detection limits
- Description of data reporting
- Description of completeness relative to QAPP objectives
- Description of precision relative to QAPP objectives, including results for field and laboratory replicate analyses, and if available from RWQCB, results for split samples
- Description of accuracy relative to QAPP objectives, including results of MS/MSD, LCSs, and surrogate recoveries
- Description of any contamination in field and laboratory blanks and implications for bias of the data or false positives
- Identification of all cases where MQOs were not met and summary of the significance of these deviations.

All data and any qualifiers applied to the data as a result of the quality assurance review will be reported in the final data report.

Data for toxicity testing, bioaccumulation testing, and benthic communities will be reviewed and procedures and results will be compared to requirements specified in the methods. The results of these reviews will be included in separate data quality reports.

3.8.4 Location of Records and Reports

The electronic and hard copy data generated for this study will be retained at a designated Dischargers' office in the custody of the project data manager. Field logs, sample records, and chain-of-custody records will be kept with the designated Dischargers' project files for reference purposes.

3.9 Data Acquisition

3.9.1 Sampling Methods

Detailed descriptions of field methods and related quality assurance procedures are provided in the FSP. Samples will be stored on ice or in a refrigerator at 4±2°C until shipment to the laboratories for testing. Requirements for sample containers, preservation, and holding times, as well as the sample mass required by the laboratory for each analysis, are summarized in Table 6. Procedures for labeling, processing, and shipping samples are described in the Appendix A.

3.9.2 Sample Handling and Custody

A continuous record of the possession and proper handling of samples must be maintained so that sample custody and handling is traceable from the time of sample collection until the analytical data have been validated and accepted for use.

3.9.3 Field Operations

Sample custody documentation is initiated in the field as each sample is collected. The designated sampler assumes custody of the samples as soon as they are collected. A sample label is attached to each sample jar as it is filled in the field. The sample information is recorded by the field samplers onto the sample log forms at the time of collection. Sample identifiers will consist of coded information as described in the FSP, Section 2.

At the end of each day and prior to shipping or storage, chain-of-custody/SAR forms will be completed for all samples. Example chain-of-custody/SAR forms are provided in the Appendix B. The information on the sample labels will be rechecked and verified against field logbook entries and the chain-of-custody/SAR forms. Any necessary changes to chain-of-custody/SAR forms, sample container labels, or the field logbook will be made by striking out the error with one line and reentering the correct information. The new entries will be initialed and dated.

3.9.4 Shipment of Samples

All samples will be accompanied by chain-of-custody/SAR forms during shipment. The custodial sampler provides the first signature on the chain-of-custody/SAR form when relinquishing custody to another member of the field team for documentation or packing or to

the shipping company or laboratory courier. The chain-of-custody/SAR forms will be generated using computer spreadsheet software. Sample information from the chain-of-custody/SAR forms will be transferred electronically into the database. Paper or electronically scanned copies of completed chain-of-custody/SAR forms will be provided by the laboratories.

When samples are shipped, the sample containers will be placed in plastic bags, securely packed inside the shipping coolers, and placed on ice as specified in SOP GEN-03 for shipping samples (Appendix A). All glass containers will be wrapped in bubble wrap. The original chain-of-custody/SAR forms will be enclosed in a plastic bag and taped to the inside lid of the cooler. The cooler will be taped closed by wrapping fiber tape completely around it. *This End Up* labels and *Fragile—Glass* labels, as well as any other required shipping labels, will be attached to the cooler, and the cooler will be sealed with two custody seals on adjacent sides of the lid. Packaging will conform to U.S. Department of Transportation regulations. The field personnel will be responsible for sample custody and appropriate sample storage prior to shipment, as well as for packing and shipping samples in a manner that allows the laboratory sufficient time to meet holding time requirements. The technical field personnel will also contact the laboratory project manager and the project manager to notify them of the sample shipment.

3.9.5 Laboratory Procedures for Receipt of Samples

The laboratory project manager will verify receipt of each sample shipment and will contact the sample manager to provide notification that all samples were received and to relay any concerns or observations regarding sample integrity or documentation. The laboratory project manager will also be responsible for ensuring that laboratory chain-of-custody forms and tracking records are completed upon receipt of the samples and maintained through all stages of laboratory analysis. Storage information must be maintained until disposal of the samples. The sample tracking records must show the date of sample extraction or preparation and the date of instrument analysis for each analytical procedure. These records will be used to determine compliance with holding time requirements.

The laboratories will maintain daily temperature logs for all refrigerators and freezers that contain samples for this project. These logs will be stored at the laboratory and copies will need to be provided if requested. The laboratory project manager will notify the project QA/QC coordinator if storage temperatures deviate from those specified in Table 6.

3.10 Analytical Methods

All laboratories for this study will have established protocols and quality assurance procedures that meet or exceed any applicable EPA or ASTM guidelines. Laboratory procedures for chemical analyses, toxicity testing, bioaccumulation testing, chemistry for benthic exposure, and benthic macroinvertebrate enumerations are summarized below.

3.10.1 Chemical Analyses

Chemical analyses will be completed for metals, organic compounds, conventional analytes, and organometallic compounds on sediment and tissue samples. The target method reporting limits for chemical analyses are provided in Table 9. These reporting limits can reasonably be expected from a competent laboratory. The actual detection limits attained during this site investigation may be elevated with respect to target detection limits if interferences are encountered from the sample matrices.

3.10.1.1 Polycyclic Aromatic Hydrocarbons

Analyses for PAHs will be completed using gas chromatography/mass spectrometry (GC/MS) with selected ion monitoring (SIM). The SIM method is more sensitive than the commonly used EPA Method 8270C, typically yielding reporting limits of 5μg/kg in sediment. Samples will be subjected to gel permeation chromatography (EPA Method 3640) to remove interferents. QA/QC procedures will be completed as described in EPA Method 8270C, whenever applicable, with modifications made as necessary to accommodate the greater sensitivity of the SIM method (e.g., lower spiking levels for surrogate compounds, matrix spikes, internal standards). The laboratory method performance criteria for metals analyses are provided in Table 10.

3.10.1.2 Polychlorinated Biphenyl Congeners

PCB congeners (Table 8) will be analyzed by EPA Method 8082. Samples will be extracted using sonication (EPA Method 3550C). Sample extracts will be cleaned up using sulfuric acid and, if necessary, potassium permanganate (EPA Method 3665A). Additional cleanup procedures (e.g., gel permeation chromatography or Florisil® column chromatography) will be used if necessary to remove interferences from the sample extracts. The surrogate hexabromobiphenyl will be used rather than decachlorobiphenyl to avoid potential coelution of PCB congeners with the surrogate. 2,4-Dibromobiphenyl will be used for the internal standard. Analyses for PCB congeners will be completed by simultaneous dual-column gas chromatography with electron capture detection. The temperature program will be modified and the run time extended to allow better separation of individual congeners. Calibration standards, LCS, and MS/MSD spiking solutions will include all congeners of interest. A five-point initial calibration will be completed for each congener. The laboratory method performance criteria for PCB analyses are provided in Table 11.

3.10.1.3 Organometallic Compounds

Analyses for tributyltin will be completed using Stallard et al. (1989). For this method, samples are extracted with methylene chloride and/or *n*-hexane (containing up to 0.2% tropolone). After extraction and concentration, tributyltin is derivatized with hexylmagnesium bromide and analyzed by gas chromatography/flame photometric detector (GC/FPD). The laboratory method performance criteria for tributyltin analyses are provided in Table 12.

3.10.1.4 Metals

Metals analyses will be completed by inductively coupled plasma-mass spectrometry (ICP-MS) according to EPA Method 6020. Analyses for mercury in sediments will be completed by cold vapor atomic absorption (CVAA) spectrometry using EPA Method 7471A and in tissues will be completed by cold vapor atomic fluorescence spectrometry (CVAFS) using EPA Method 1631, Revision E (U.S. EPA 2002b). The laboratory method performance criteria for metals analyses are provided in Table 13.

3.10.1.5 Conventional Analytes

Conventional wet chemistry will be completed according to the methods referenced in Table 9. The laboratory method performance criteria for conventional analyses are provided in Table 14.

3.10.2 Toxicity Testing

3.10.2.1 Amphipod Survival Test

The amphipod survival test using *Eohaustorius estuarius* will be completed according to the methods referenced in ASTM (2008). This test consists of a 10-day exposure of *Eohaustorius estuarius* to sediment under static conditions. Amphipods are placed in glass chambers containing seawater and a 2 cm layer of test sediment. The number of surviving amphipods is measured at the end of the test and used to calculate the percentage survival. A reference toxicant test will be run with every batch of test samples in order to document amphipod relative sensitivity and test precision. This test will consist of a 96-hour exposure to five different concentrations of a reference toxicant such as ammonia or cadmium chloride dissolved in seawater. Reference toxicant test results that fall outside of control chart limits (two SD of mean) will trigger a review of test procedures and a possible retest of the corresponding sediment samples.

3.10.2.2 Bivalve Development Test

The bivalve development test using *Mytilus galloprovinicialis* will be completed according to the methods referenced in U.S. EPA/Corps (1994) and ASTM (2004) with modifications as stipulated in Anderson et al. (1996, 2001). This test consists of a 48-hour exposure of recently fertilized eggs of *Mytilus galloprovinicialis* to test sediment. Mussel embryos are placed in overlying water and are constrained to polyethylene screen tubes anchored in 5 cm of test sediment. The number of surviving normal embryos is measured at the end of the test and used to calculate the percentage normal-alive relative to the negative control (laboratory generated seawater). A reference toxicant test will be run with every batch of test samples in order to document mussel relative sensitivity and test precision. This test will consist of a 48-hour exposure to five different concentrations of ammonium chloride or copper chloride dissolved in seawater. Reference toxicant test results that fall outside of control chart limits (two SD of mean) will trigger a review of test procedures and a possible retest of the corresponding sediment samples.

3.10.3 Benthic Communities

Sediment samples for benthic macroinvertebrate enumeration and identification will be sieved using a mesh size of 1.0 mm and preserved in the field prior to shipment. Taxonomic analyses will be conducted on the organisms retained on the 1.0-mm screen. At the laboratory, detritus will be removed from the 1.0-mm samples by technicians. Benthic taxonomists will sort the invertebrates in each 1.0-mm sample. After sorting has been completed, organisms will be identified to the lowest taxonomic level possible; the target being species level. All taxa will be identified in their entirety. All taxonomic identifications will be made by qualified taxonomists and will be based on published keys. For incomplete specimens, only the anterior or posterior ends will be enumerated, depending upon the taxon. All identifications will be made using binocular-dissecting or compound microscopes. If possible, at least two pieces of literature will be used for each species identification.

Each taxonomist will record initial identifications and counts on sample data sheets. Any pertinent notes and comments on the organisms in each sample will also be recorded. The taxonomist will then sign and date the sample data sheet. All data sheets will be kept in the laboratory at all times so the laboratory supervisor can check questionable identifications and follow the progress of each sample.

3.11 Quality Control

Quality control samples and procedures are used to obtain quantitative information regarding the execution of field sampling and laboratory testing activities. Quality control results may be used to estimate the magnitude of bias and level of precision inherent in the test data. A variety of quality control samples will be collected in the field and initiated by the laboratories for every test.

3.11.1 Field Quality Control

Field quality control samples will include an equipment rinsate blank and a field duplicate sample. These quality control samples will be collected or prepared by sampling personnel in the field and submitted to the laboratory as field samples.

The equipment rinsate blank will be used to identify possible contamination from the sampling environment or from sampling equipment. This blank will be collected by pouring deionized and distilled water over (or through) the decontaminated sampling equipment and into a sample container. One equipment rinsate blank will be collected during the sampling event and will be analyzed for all compounds except conventional analytes.

The field duplicate sample will be collected to assess the homogeneity of the samples collected in the field and the precision of the sampling process. The duplicate will be prepared by collecting two aliquots of sample from the homogenization bowl or sampling equipment and submitting them for analysis as separate samples.

3.11.2 Laboratory Quality Control for Chemical Tests

Each analytical protocol used in this site investigation (Table 9) includes specific instructions for analysis of quality control samples and completion of quality control procedures during sample analysis. These quality control samples and procedures verify that the instrument is calibrated properly and remains in calibration throughout the analytical sequence and that the sample preparation procedures have been effective and have not introduced contaminants into the samples. Additional quality control samples are used to identify and quantify positive or negative interference caused by the sample matrix. Each method protocol provides control limits that indicate acceptable conditions for analysis of samples as well as unacceptable conditions that would necessitate reanalysis of samples. The laboratory method performance criteria for PAHs, PCBs, tributyltin, metals, and conventional analyses are provided in Tables 10–14.

The following laboratory quality control procedures are required for most of the protocols for chemical analyses:

- **Calibration and Verification—**Initial calibration of instruments will be performed at the start of the project and when any ongoing calibration does not meet control criteria. The number of points used in the initial calibration is defined in each analytical method. Continuing calibration will be performed as specified in the analytical methods to track instrument performance. In the event that a continuing calibration does not meet control limits, analysis of project samples will be suspended until the source of the control failure is either eliminated or reduced to within control specifications. Any project samples analyzed while the instrument was out of calibration will be reanalyzed.

- **Method Blanks—**Method blanks are used to assess possible laboratory contamination of samples during all stages of preparation and analysis. Blank corrections will not be applied by the laboratories to the original data. A minimum of one method blank will be analyzed for every analytical batch or one per 20, whichever is more frequent.

- **Laboratory Control Samples—**(standard reference material or spiked blanks) will be used as a check on overall method performance. An LCS will be analyzed for every analytical batch or one per 20, whichever is more frequent.

- **Matrix Spike Samples and Matrix Spike Duplicates—**Matrix spike samples are used to assess the effects of the sample matrix on the accuracy of analytical measurements. For conventional analytes, a minimum of one matrix spike will be analyzed for every analytical batch or one per 20, whichever is more frequent. For metals and organic analyses, duplicate matrix spike samples are used to assess both accuracy and precision. One matrix spike and one matrix spike duplicate will be analyzed for every analytical batch or one per 20, whichever is more frequent. Unspiked laboratory duplicates (described below) are used to assess the precision of data for conventional analytes.

- **Laboratory Duplicates—**Replicate laboratory analyses are indicators of laboratory precision. For conventional analytes, one laboratory duplicate will be analyzed for every analytical batch or one per 20, whichever is more frequent.
- **Surrogate Spike Compounds—**Surrogate spike compounds will be added to all field and quality control samples for organic analyses to evaluate the recovery of compounds from each sample. Recoveries for these surrogate compounds will be reported by the laboratories; however, the laboratories will not correct sample results using these recoveries.

3.11.3 Laboratory Quality Control for Toxicity Tests

Laboratory QA/QC procedures for the toxicity tests include the use of positive and negative controls and daily measurement of water quality conditions (i.e., dissolved oxygen, temperature, salinity, and pH). Appropriate ranges of water quality variables stipulated in the test specific methods (ASTM 1999, 2000, 2004, 2008; U.S. EPA/Corps 1994 with modifications in Anderson et al. 1996, 2001). In addition, ammonia and sulfide will be monitored in the pore water for the amphipod survival test and in the overlying water for the bivalve development test. Ammonia and sulfide concentrations will be monitored throughout the exposure period (at test initiation, every fifth day during the exposure period, and at test termination). The ammonia and sulfide concentrations measured at test initiation provide a baseline of the exposure conditions present in the test chambers. Ammonia and sulfide are monitored to assess whether they may be contributing to toxicity, and not for the purpose of eliminating them. Therefore, if the ammonia or sulfide concentrations at test initiation exceed published threshold values, no corrective action will be taken. Only healthy organisms will be used for testing. Positive and negative controls will be tested concurrently with each toxicity test series. Reference toxicants (i.e., positive controls) will be used to provide insight into mortalities or increased sensitivity that may have occurred as a result of disease or the potential stresses related to handling, acclimation, and testing (e.g., loading density). An invalid reference toxicant test will not invalidate the test data, but will provide an indication of the suitability of the organisms for testing. Negative controls will be used to confirm the viability of the test organisms in the absence of stressors introduced with the test sediment. One set of negative controls (with the appropriate number of replicates) will be run per toxicity test. Performance standards for the negative control sediments are as follows:

Test	Laboratory Negative Control Sediment Performance Standard
Amphipod survival test	10% or greater survival
Bivalve development test	70% or greater survival and 70% or greater shell development
Macoma bioaccumulation test	Adequate mass of organisms at test completion for detection of target compounds

The toxicity tests will be run as a single batch by the respective testing laboratories.

3.11.4 Laboratory Quality Control for Benthic Communities

Organisms are sorted using a dissecting microscope into five main taxonomic groups: polychaetes, crustaceans, molluscs, echinoderms, and miscellaneous minor phyla. While sorting, technicians kept a rough count for QA/QC purposes. This rough count, as well as how many vials are associated with each sample, are listed on an internal sort sheet. Qualified taxonomists identify each organism and keep an actual count. The organisms are identified to the lowest possible taxon for each phylum.

A QA/QC procedure is performed on each of the sorted samples to ensure a 95% sorting efficiency. A 10% aliquot of a sample is re-sorted by a senior technician trained in the QA/QC procedure. The number of organisms found in the aliquot was divided by 10% and added to the total number found in the sample. The original total was divided by the new total to calculate the percent sorting efficiency. When the sorting efficiency of the sample was below 95%, the remainder of the sample (90%) was re-sorted. If a sample fails quality assurance and is resorted, the additional organisms removed are added to the original vials for taxonomic identification. All quality assurance information is written on the original sort sheet associated with the sample.

When taxonomic error or inconsistency is found, all previous results generated by the taxonomist responsible for the error or inconsistency should be evaluated to identify those samples that may be affected. This process, which should be carefully documented by the laboratory, can be very time-consuming. However, upon completion of all taxonomic work, few (if any) taxonomic errors or inconsistencies should remain in the data set. Avoiding errors and inconsistencies through the constant interchange of information and ideas among taxonomists is the best way to minimize time lost from faulty identifications.

When all identification and QA/QC procedures are completed, the jars containing the vials of identified species will be topped off with a solution of 5% glycerin/70% ethyl alcohol. The lids will then be sealed tightly with black electrical tape to prevent evaporation. Each container will be labeled clearly with the survey name, date of collection, and number and type of samples within.

3.12 Instrument and Equipment Testing, Inspection, and Maintenance

Preventive maintenance of field equipment and laboratory instruments is essential if project resources are to be used in a cost-effective manner. Preventive maintenance will take two forms: 1) a schedule of preventive maintenance activities to minimize downtime and ensure the accuracy of measurement systems, and 2) availability of critical spare parts and backup systems and equipment. The performance of these maintenance procedures will be documented in field and laboratory notebooks.

The field team leader will be responsible for ensuring that routine preventive maintenance is performed and documented for all field instrumentation and equipment (e.g., GPS and sampling gear). The laboratory quality assurance officers will be responsible for ensuring that routine preventive maintenance is performed and documented for each analytical instrument and that

spare parts or additional instruments are available in case of instrument breakdown or failure. Instrument quality control procedures (e.g., initial and continuing calibration, LCSs, calibration blanks) will be used to verify the continuing acceptable performance of each instrument.

3.12.1 Instrument and Equipment Calibration

Initial and continuing calibration procedures for laboratory instruments will be completed in accordance with the cited analytical method for each analysis (Table 9). The method descriptions for each analysis specify acceptance criteria for initial and continuing calibration and state the conditions where recalibration is necessary.

All primary chemical standards and standard solutions used in this project will be traceable to National Institute for Standards and Technology or other documented, reliable, commercial sources. At the laboratories, standards are validated prior to use to verify their accuracy by comparison with an independent standard. Reagents are examined for purity by performing method blank analyses.

Field instruments that will be used to measure temperature, dissolved oxygen, and salinity in seawater will be calibrated prior to use each day. Calibration will be completed according to the manufacturer's instructions. Temperature calibration is usually preset at the factory, and if so, will not require additional calibration. Calibration for dissolved oxygen and salinity will be checked at the end of each day of sampling. If calibration is found to drift, the calibration will be checked and the probe recalibrated more frequently, as required. Recalibration will be completed if the calibration changes by 10%. Depth calibration will be completed by zeroing the instrument at the water surface prior to deployment.

Field instruments will not be required for health and safety monitoring.

3.12.2 Inspection and Acceptance of Supplies and Consumables

Supplies and consumables are required for sample collection and laboratory activities. During sample collection, the most critical supplies affecting data quality are those used for decontamination of the sampling equipment. Solvents of appropriate, documented purity will be used for decontamination. Acceptance for all supplies will require an intact seal upon receipt, maintenance at appropriate temperature, and use only prior to the expiration date. The date opened and initials of the individual who opened the container will be written on the solvent bottle and on any smaller containers used to transfer solvent, such as a squirt bottle. This method of documentation allows any contamination problem to be traced to its source and will enable identification of related samples that may have been affected. Acceptance requirements will include a basic inspection of all containers received and rejection of unacceptable supplies.

Reagents of appropriate purity and suitably cleaned equipment must also be used for all stages of laboratory analyses. In addition, the laboratories must ensure that the concentrations of calibration and spiking standard are accurate and that instrumentation is functioning properly. The lot numbers of all standards are routinely tracked by the laboratories, from purchase of

stock standards to preparation of secondary and working calibration standards. All calibration and spiking standards are checked against standards from another source. LCS results provide an additional check for accuracy. Details for acceptance requirements for supplies and consumables at the laboratories are provided in the laboratory SOPs and quality assurance manuals.

3.13 Data Management

Computerized systems will be used to record, store, and sort the technical data that will be generated to support the sediment study. Automated data handling increases data integrity by reducing errors, omissions, and ambiguities that can be introduced by manual procedures. In addition, automated procedures will be used by the laboratories to capture and summarize analytical results. In this case, electronic data files can be imported directly from the laboratory to the project database, minimizing both data entry effort and opportunities for error. Sampling location coordinates will be entered into the database to enable the generation of maps and figures using ArcView® software.

Field logbooks, station/sample forms, and chain-of-custody/SAR forms are prepared by the field team while sample collection activities are in progress. Sample information from the field is entered manually into the database. Each data record will include a unique sample code, station ID, sample type (matrix), compound, compound concentration, and concentration units. Data from the laboratories are entered directly from the electronic disk deliverables. A small portion of the laboratory data may be entered manually if electronic data cannot be supplied. Electronic data summaries are produced to support data validation procedures. Data qualifiers are entered into the database when validation is completed and verified, and the data set is approved as final. All manual and electronic entries are verified by the data manager or validation personnel.

Project data tables and reports are prepared using customized retrievals that filter and sort the data according to criteria specified by the user. The data are automatically formatted for direct use with statistics software packages and various geographic information system software. The maintenance of a single, authoritative database prevents the proliferation of multiple versions of data and the introduction and propagation of errors.

A database query will be developed that will allow the retrieval of data in the standardized data transfer format established for the Southern California Bight 1998 Regional Marine Monitoring Survey.

3.14 Data Verification and Validation

Data verification and validation are conducted to establish the data quality and usability for the project. Data verification is the process of determining whether samples have been collected and analyzed according to procedures prescribed in the FSP, SOPs and method descriptions, and this QAPP. Data verification includes checking for compliance of procedures with the project plan, correctness of protocols used in the field and at the laboratory, comparability of the data

collection and analysis procedures, and completeness of the data set and supporting documentation. Data validation is the process of evaluating the technical quality of the verified data with respect to the project quality objectives. Data validation and verification criteria and procedures for determining data usability procedures are described below.

3.14.1 Data Verification Requirements

Requirements for field and laboratory procedures and data quality are described in this section. Adherence to these procedures by field and laboratory personnel will be verified as described below.

3.14.1.1 Requirements for Verification of Field Procedures

Field procedures will be followed as described in this QAPP, the FSP, and the field SOPs. These procedures will be verified by the field team leader on an ongoing basis while field activities are in progress. Additional verification will be provided through oversight of the field activities by the Dischargers' representative. All protocols related to sample collection, storage, shipping, and handling include requirements for quality assurance procedures and documentation of activities. Any deviations from specified procedures should be documented in detail in the field logbook and fully justified. Specific requirements include, but are not limited to, the following:

- Sampling locations must be fully documented and correct.
- Sample collection, compositing, and homogenization procedures must be completed as planned and fully documented. Difficulties encountered during sampling that may affect the representativeness of the sample should be minimized.
- Sample shipping and handling procedures must be completed as described in the FSP. Maintaining appropriate sample temperatures during field activities and shipping is particularly important.
- Results for field quality control samples (field duplicate, equipment rinsate blank) should meet control limits. The MQO for precision (Table 9) will be used as the control limit for field duplicates. The equipment rinsate blank should be free from contamination. Failure to meet these requirements may result in qualification or rejection of data during data validation.

Planned sampling locations are described in the FSP. If a sample cannot be collected as planned, the Dischargers' representative will be notified and an alternate location or sampling method will be selected if possible. The review process will include immediate evaluation of any sampling difficulties so that an alternate field procedure or location may be established quickly, if necessary.

Sample completeness will be verified at the end of each sampling day and again when samples are packed for shipment to the laboratory. Laboratory personnel will provide an additional completeness check when the samples are received and logged in and checked against the chain-of-custody/SAR forms.

Sample identification information in the sample logs and chain-of-custody/SAR forms will be verified by the data manager or sampling personnel when the field data are entered into the database. Station location information will be verified by the project manager or designee when station coordinates are used to generate project maps. Any discrepancies will be brought to the attention of the field team leader, who will be responsible for resolving the issue. Any deviations that affect data quality or completeness will be discussed in the data quality report, and data will be qualified or rejected, as appropriate.

3.14.1.2 Requirements for Verification of Laboratory Procedures

Laboratory procedures should be followed as described in the analytical methods, this QAPP, the method descriptions cited in Tables 9–14, and the laboratory's quality assurance plan and SOPs. Any deviations from the specified procedures should be documented in detail and fully justified in the case narrative for the data package

Verification of chemical data will be completed at the laboratories. The laboratory will be responsible for the review and verification of all bench sheets, manual entry or transcriptions of data, and any professional judgments made by a chemist (e.g., identification of a PCB congener) during sample preparation, analysis, and calculation and reporting of the final concentrations. The laboratory will also be responsible for the review of quality control results to determine whether data are of usable quality or reanalyses are required. Any nonconformance issues identified during the laboratory's quality assurance checks will be corrected and noted by the laboratory. Close contact will be maintained between the project QA/QC coordinator and the laboratory project manager so that any quality issues can be resolved in a timely manner. Any data quality deviations will be discussed in the laboratory case narrative, including the direction or magnitude of any bias to the data, if possible. The laboratory verification review will include the following:

- Package completeness
- Holding times from collection to extraction and from extraction to analysis
- Instrument calibration, initial and continuing
- Calibration and method blanks
- Instrument performance
- LCS (i.e., standard reference material) results
- Matrix spike samples
- Matrix duplicates or matrix spike duplicates

- Internal standard areas (GC/MS-SIM and ICP-MS analysis)
- Surrogate recovery
- Interference checks (ICP-MS analysis)
- Laboratory duplicate results (conventional analysis)
- Reported detection limits
- Compound quantitation
- Compound identification
- Accurate calculations.

Toxicity data will be reviewed for quality control results that do not meet the criteria specified in the method description. Data deficiencies will be noted if results for any of the following procedures do not meet control limits:

- Sample holding times
- Positive control tests
- Negative control tests
- Water quality conditions.

Data for benthic macroinvertebrate assemblages will be verified and validated primarily by the taxonomic laboratory. Any errors will be corrected at the laboratory and samples will be re-counted or identifications corrected if necessary.

3.14.2 Data Validation Requirements

Validation of all field and laboratory documentation and reports will be conducted after the analyses and tests are completed. The data will be released for interpretation only after validation has been completed and all qualifiers have been correctly entered into the database. Data validation will be completed by the Dischargers' QA/QC contractor prior to finalization of the data.

3.14.2.1 Validation of Chemistry Results

Chemical data will be validated according to EPA Level 4 criteria (U.S. EPA 1995). Level 4 validation includes evaluation of the results for quality control samples (i.e., surrogate recoveries, calibration and method blanks, matrix spikes and matrix spike duplicates, and LCSs) with respect to control limits. Initial and continuing calibration results will be reviewed, but calculations and transcriptions will not be checked on a routine basis because the laboratory is responsible for 100% verification of these results and procedures. These data validation

procedures are consistent with those described in the quality assurance manual for Bight'98 (Bight'98 1998).

Chemical, bioaccumulation testing, and chemistry for benthic exposure data will be evaluated according to procedures described in the EPA Contract Laboratory Program national functional guidelines for data validation (U.S. EPA 2008, 2010) as applicable, with modifications made as appropriate to accommodate method-specific quality control requirements. Data may be qualified as negated, estimated, or rejected if any of the following quality control samples and procedures do not meet control limits:

- Package completeness
- Holding times from collection to extraction and from extraction to analysis
- Instrument calibration, initial and continuing
- Calibration and method blanks
- LCS (i.e. standard reference material) results
- Matrix spike samples
- Matrix duplicates or matrix spike duplicates
- Internal standard areas (GC/MS-SIM and ICP-MS analysis)
- Surrogate recovery
- Interference checks (ICP-MS analysis)
- Laboratory duplicate results (conventional analysis)
- Reported detection limits
- Compound quantitation
- Compound identification.

Upon completion of the validation, a report will be prepared. This report will summarize the samples reviewed, elements reviewed, any nonconformances with the established criteria, and validation actions (including application of data qualifiers). Data qualifiers will be consistent with EPA's national functional guidelines as described in Table 15.

3.14.2.2 Algorithms to Assess Quality Control Results

Data verification includes checking that quality control procedures were performed at the required frequencies and that the quality control results meet control limits defined in the method descriptions or by the project MQOs. The equations that will be used to determine whether measurement targets for project MQOs were met for each quality control procedure are provided below.

Duplicate Analyses—Precision for duplicate chemical analyses will be calculated as the relative percent difference between the duplicate samples. The formula that will be used to assess precision for both laboratory and field duplicate samples is as follows:

$$\mathrm{RPD} = \frac{D_1 - D_2}{(D_1 + D_2)/2} \times 100$$

where:

D1 = sample value

D2 = duplicate sample value.

Matrix Spikes and Surrogate Recoveries—Spiked samples provide an indication of the bias of the analysis system. The recovery of matrix spikes and surrogate spikes will be calculated as the ratio of the recovered spike concentration to the known spiked quantity:

$$\%\mathrm{R} = \frac{A - B}{C} \times 100$$

where:

A = the compound concentration determined experimentally from spiked sample

B = the background level determined by a separate analysis of the unspiked sample

C = the amount of the spike added.

Completeness—Completeness will be calculated for each sample type by dividing the number of valid measurements (all measurements except rejected data) actually obtained by the number of valid measurements that were planned:

$$\%\mathrm{Completeness} = \frac{\text{Valid Data Obtained}}{\text{Total Data Planned}} \times 100$$

To be considered complete, the data sets must also contain all quality control check analyses that verify the precision and accuracy of the results.

3.14.2.3 Detection and Quantification Limits

The detection limit of the sample preparation and analysis process is defined as “the minimum concentration of a substance that can be measured and reported with 99% confidence that the compound is greater than zero” (40 CFR 136B). In other words, it is the point at which qualitative, not quantitative, identification can be made. In practice, the limit of detection is defined as three times the SD of the blank or background response adjusted for the amount of sample typically extracted and the final extract volume of the method.

Best professional judgment is used to adjust the limit of detection upward in cases where high instrument precision (i.e., low variability) results in a calculated limit of detection and equivalent instrument response less than the absolute sensitivity of the analytical instrument. The actual reporting limit for environmental samples is generally higher than the instrument detection limit because the sample matrix tends to contribute to fluctuations in the instrument's background signal. Laboratory personnel will determine reporting limits based on their experience with samples of similar matrix to those collected for this study and on the response of each instrument to samples for this study. The method reporting limits will be verified during data validation.

3.14.2.4 Validation of Toxicity Tests

The following procedures and results will be verified for toxicity test data:

- Use of the correct test procedures
- Identity and source of the test organisms
- Results for positive and negative controls
- Results of measurements for salinity, pH, temperature, dissolved oxygen, sulfide, and ammonia in the test water.

Results from a toxicity test or bioaccumulation test will not be accepted if the QA/QC criteria stipulated in each toxicity test protocol are not met. Results for the positive controls (tests using reference toxicants) will be reviewed to evaluate mortalities or increased sensitivity that may have occurred as a result of disease or the potential stresses related to handling, acclimation, and testing (e.g., loading density). The laboratory will be contacted if errors are found during QA/QC data review. Data may be determined to be unusable if the laboratory is unable to resolve errors.

3.14.2.5 Validation of Benthic Macroinvertebrate Identification

The data validation process for the taxonomic identification of macroinvertebrates includes reviewing the reported data; checking for completeness, consistency of the results, and transcription errors; and recalculating results when feasible. The following information will be reviewed, and verified and validated when feasible:

- Assemblages of species, as determined by visually surveying and mapping the species composition and distribution (i.e., qualitative estimates)
- The results of the taxonomic verification for each taxon as part of the distribution survey
- The number of individuals of each taxon found in each sample.

The laboratory will be contacted if errors are found during the Dischargers' data review. Data may be determined to be unusable if the laboratory is unable to resolve errors.

4 Data Analysis and Interpretation

Two independent post-remedial monitoring programs will be completed, each with a time series of measurements to evaluate conditions in post-remedial conditions:

- Site-wide remedial performance monitoring will ensure that beneficial uses (as cited in the DTR Section 1.4.2.1) are adequately protected by the implemented remedy
- Benthic community recovery monitoring within the remedial footprint will evaluate the benthic community recolonization and development following physical removal by dredging.

The timelines for post-remedial monitoring described below are referenced to the completion of all remediation at the Site (Year zero).

4.1 Monitoring for Remedial Performance

Remedial performance monitoring will consist of three lines of evidence: sediment composite chemistry, sediment toxicity, and bioaccumulation monitoring.

In order to verify that remedial objectives have been met and beneficial uses associated with human and wildlife food web exposure are sufficiently protected, composite chemistry samples will be compared to the post-remedial monitoring triggers specified in the DTR, the reference condition upper prediction limits (UPLs) specified in the DTR, and the site-specific benchmarks developed in the DTR that are protective of aquatic life (Site-specific median effects quotients [SS-MEQs] and lowest adverse effects thresholds [LAETs]). The sample station locations and compositing scheme are described in Section 2.5.1.1.

In order to verify that post-remedial sediments are not significantly toxic to aquatic life, toxicity bioassays will be performed on discrete sediment samples from selected locations within the remedial footprint (see Section 2.5.1.1). Two bioassays (10-day amphipod toxicity and 48-hour bivalve larval development) will be performed, as described in Section 3.10.2.

In order to evaluate the success of remediation in reducing the bioaccumulation potential of sediment COCs, laboratory bioaccumulation testing will be performed on discrete sediment samples collected from selected locations (SW04, SW08, SW13, SW21, SW28, NA06, NA11, NA12, and NA20), as described in Section 2.5.1.1. The bioassay performed will be a 28-day *Macoma nasuta* accumulation test.

At least two rounds of remedial performance monitoring will be performed in Years 2 and 5 post-dredging, with the option of a third round in Year 10, depending on the conditions through Year 5.

4.1.1 Remedial Performance Monitoring Round 1 (Year 2)

Round 1 of the remedial performance monitoring will occur 2 years after the completion of the remediation. Monitoring in this round will consist of evaluations of the composite chemistry (Site-wide surface-weighted average concentration [SWACs]), sediment toxicity, and bioaccumulation.

4.1.1.1 Composite Chemistry (Site-wide SWACs)

The composite chemistry (Site-wide SWACs) will be evaluated to determine if the remediation was successful in reducing COC concentrations in the sediment to levels protective of human and aquatic-dependent wildlife beneficial uses. The calculated Site-wide SWACs will be compared to the post-remedial monitoring trigger concentrations specified in the DTR to determine if the remedy was successful.

Site-wide SWACs represent each of the six polygon groups and will be calculated according to the CAO (Section D.1.c.). Site-wide SWACs will be calculated as the spatially-weighted average of the six composite samples for each COC. Area weighting of each station is accomplished volumetrically within each composite sample (see Table 5). The variance of the sediment compositing can be determined by the three replicate sub-samples of the composite samples.

The Site-wide SWACs will be compared to the trigger concentration, as stated in the DTR (Table 34-1). The remediation will be deemed successful if the Site-wide SWACs are below the trigger concentrations.

A Trigger Exceedance Investigation and Characterization study is warranted for Site-wide SWACs that are greater than the trigger concentrations. This study is intended to determine the causes of the exceedances. The CAO (Section D.4) lists several lines of evidence that can be implemented to determine the causes of exceedances. Depending on the scope and scale of the exceedances, the following approaches can be used:

- Recalculation of the 95% upper confidence limit (UCL) with the incorporation of more recent sampling data.
- Identification of specific areas that caused the exceedance using surrounding post-remediation monitoring data and appropriate historical data.
- Evaluation of any changes in the Site conditions since the previous sampling event.
- Analysis of archived samples to understand which polygons have higher concentrations than expected. Data from this analysis could be used for spatial weighting of data or recalculation of the 95% UCL using various interpolation methods.

If a Trigger Exceedance Investigation and Characterization study is performed, a report will be submitted to the Board that describes the work and results. This Trigger Exceedance Investigation and Characterization report will include a recommended approach for addressing the exceedances with additional sampling, re-dredging, natural recovery, reanalysis after the next monitoring event, or other methods. The CAO requires that the report be submitted within 90 days of the discovery of an exceedance, or as directed by the Board.

4.1.1.2 Discrete Sample Chemistry Analysis for Evaluation of Benthic Exposure

Results of the discrete sample chemistry analysis will be evaluated to verify that the remediation was successful in sufficiently protecting aquatic life beneficial uses. Sediment chemistry results from the selected stations (SW04, SW13, SW22, SW23, and NA19) will be compared to the reference condition to determine whether and the degree to which they are elevated (DTR Table 18-4). To determine if the results are protective of aquatic life, the chemistry results from these stations will be compared to two site-specific benchmarks: SS-MEQs and LAETs.

Chemistry data from the selected stations will be compared to the reference condition according to the Sediment Chemistry Ranking Criteria flow diagram in the CAO (CAO Attachment 8). This evaluation uses the Sediment Quality Guideline Quotient 1 (SQGQ1, as calculated per Fairey et al. 2001) and will categorize each station as having a Low, Moderate, or High ranking that relates to the net COC levels, relative to the reference stations. Note that the weighted average is based on 7 COCs, rather than the full 9 included in the method of Fairey et al. (2001).

The SS-MEQ values calculated for each station will be compared to the 0.9 SS-MEQ threshold derived empirically for the Site. Calculation of the SS-MEQ is detailed in DTR Section 32.5.2. The SS-MEQ threshold is used to address the combined effects of multiple COCs. All stations SS-MEQ values exceeding the 0.9 threshold were included in the remedial footprint.

Sediment chemistry results will also be compared to the 60% LAET (DTR Table 32-19). The LAET is used to identify concentrations in which adverse biological effects are expected, and was also used as a screen (with a 40% safety factor) to identify stations for remediation.

4.1.1.3 Sediment Toxicity Testing

Sediment samples will be collected for toxicity analyses at the following five station locations: SW04, SW13, SW22, SW23, and NA19. Sediment toxicity testing will consist of the 10-day amphipod (*Eohaustorius estuarius*) toxicity bioassay and the 48-hour bivalve (*Mytilus galloprovincialis*) larval development bioassay. The goal of these two tests is to determine whether the post-remedial concentrations in the sediment are toxic to aquatic life, relative to the reference condition.

Mean values will be calculated for survival (*E. estuarius*) and normality (*M. galloprovincialis*) and t-tests will be calculated to determine if samples are significantly different from controls. The mean results will be compared to the reference pool LPL (73% for amphipod survival and 37% for bivalve normal development) (DTR Table 18-8). The Toxicity Ranking Criteria flow diagram (Attachment 9 in CAO) will be used to categorize stations as having Low, Moderate, or High ranking relative to the reference condition.

4.1.1.4 Bioaccumulation Testing

Evaluation of the 28-day laboratory *Macoma nasuta* bioaccumulation test results will determine if the potential for bioaccumulation has decreased since the remedy. The samples collected for bioaccumulation testing will be from stations SW04, SW08, SW13, SW21, SW28, and NA06, NA11, NA12, and NA20. However, bioavailability does not necessarily indicate the presence of or potential for adverse effects. Tissue samples will be analyzed for arsenic, cadmium, copper, lead, mercury, zinc, HPAHs, and PCBs. The replicate chemical concentrations in *Macoma* tissue and in sediment samples will be averaged for each station. A linear regression model will be used to fit relationships to assess statistical significance (at $p = 0.05$). A quantitative comparison of the results will be made to pre-remedial and reference condition tissue concentrations, as tabulated in Section 19 in the DTR.

4.1.2 Summary of Round 1 Monitoring

For each line of evidence evaluated (composite chemistry, toxicity, and bioaccumulation), an assessment in Year 2 will be performed, based on a comparison to pre-remedial conditions described in the DTR. To the extent possible, spatial and temporal patterns in the data should be evaluated to identify factors driving apparent improvement or lack of improvement (e.g., effects of dredging, residual contamination, ongoing shipyard activities, offsite sources, etc.). The results from Round 1 monitoring will be used for comparison in Round 2 and possibly Round 3.

4.1.3 Remedial Performance Monitoring Round 2 (Year 5)

The second round of evaluations for the effectiveness of the remediation will ensure that the beneficial uses associated with human and wildlife food web protection will be performed 5 years after remedy completion. The same analyses and evaluations for sediment composite chemistry, sediment toxicity, and bioaccumulation monitoring performed in Year 2 will also be performed in Year 5.

For each line of evidence evaluated (composite chemistry, toxicity, and bioaccumulation), an assessment of the conditions in Year 5 will be performed, based on a comparison to pre-remedial conditions described in the DTR. To the extent possible, spatial and temporal patterns in the data should be evaluated to identify factors driving apparent improvement or lack of improvement (e.g., effects of dredging, residual contamination, ongoing shipyard activities, offsite sources, etc.). Following this evaluation, a decision should be made, in collaboration with Board staff, on whether Round 3 sampling will be required. A third round of monitoring will be indicated if significant questions remain about the effectiveness of the remedy in achieving the remedial objectives.

4.1.4 Optional Remedial Performance Monitoring Round 3 (Year 10)

In the event that further evaluations are deemed to be warranted after Year 5, a third round of monitoring will occur in Year 10. The analyses and data evaluations will be identical to those performed in Years 2 and 5.

For each line of evidence evaluated (composite chemistry, toxicity, and bioaccumulation), an assessment of the conditions in Year 10 will be performed, based on a comparison to pre-remedial conditions described in the DTR. To the extent possible, spatial and temporal patterns in the data should be evaluated to identify factors driving apparent improvement or lack of improvement (e.g., effects of dredging, residual contamination, ongoing shipyard activities, offsite sources, etc.). Following this evaluation, final conclusions regarding the effectiveness of the remedy should be drawn, in collaboration with Board staff.

4.2 Benthic Community Recovery Monitoring

The benthic community will be completely removed within the dredging footprint. Re-colonization of the disturbed sediments by benthic organisms should begin as soon as dredging is complete. Benthic recovery monitoring will be undertaken to verify that a healthy benthic community is established after dredging, and to monitor the time course of recovery. Two benthic recovery monitoring events are planned in Years 3 and 4 post-dredging.

The benthic community will be assessed using the same four metrics measured during the original sediment investigation (total abundance, number of taxa, Shannon-Weiner diversity index, and Benthic Response Index [BRI]). This sampling will be conducted only to evaluate the development of the benthic community following remediation.

4.2.1 Benthic Recovery Monitoring Round 1 (Year 3)

The benthic community recovery monitoring will evaluate whether the benthic community has successfully re-established in the areas that have been remediated. The benthic community will be assessed with the following evaluations: total abundance (total number of individuals identified in each replicate sample), total taxa richness (total number of distinct taxa identified in each replicate), Shannon-Weiner Diversity Index (a measure of the number of species and distribution of species), and BRI (the abundance-weighted pollution tolerance score of the organisms in the sample).

Calculation of metrics will be performed in accordance with methods specified in the DTR Section 18.4 and associated appendices. For each of the four benthic community metrics evaluated, an assessment of the conditions in Year 3 will be performed, based on a comparison to pre-remedial conditions and the reference condition described in the DTR. Spatial and temporal patterns in the data should be evaluated to identify any factors that might be limiting recovery (e.g., ongoing physical disturbance from shipyard activities).

4.2.2 Benthic Recovery Monitoring Round 2 (Year 4)

A second round of evaluations of the four benthic community metrics (total abundance, total taxa richness, Shannon-Weiner Diversity Index, and BRI) will be completed in Year 4. For each benthic community metric, an assessment of the conditions in Year 4 will be performed, based on a comparison to pre-remedial conditions and the reference condition described in the DTR. Spatial and temporal patterns in the data should be evaluated to identify any factors that

might be limiting recovery (e.g., ongoing physical disturbance from shipyard activities). A final conclusion should be drawn about the status and likely time course of complete benthic recovery within the remedial footprint.

4.3 Summary

A progress report will be submitted in each year during which any post-remedial sampling activity is performed. This report will include all important field observations, analytical results, and data analyses. For each metric calculated or bioassay performed, a finding will be included with respect to the apparent success of the remedy in achieving protection of beneficial uses, and a recommendation will be made to Board Staff for the need for any further action or modification of the monitoring program. Because of the lengthy time course of all post-remedial monitoring activities described above (up to 10 years following completion of remediation), Site conditions may change significantly during the monitoring program. Any changes which could influence data interpretation or beneficial uses should also be noted in the post-remedial monitoring progress reports.

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Figures

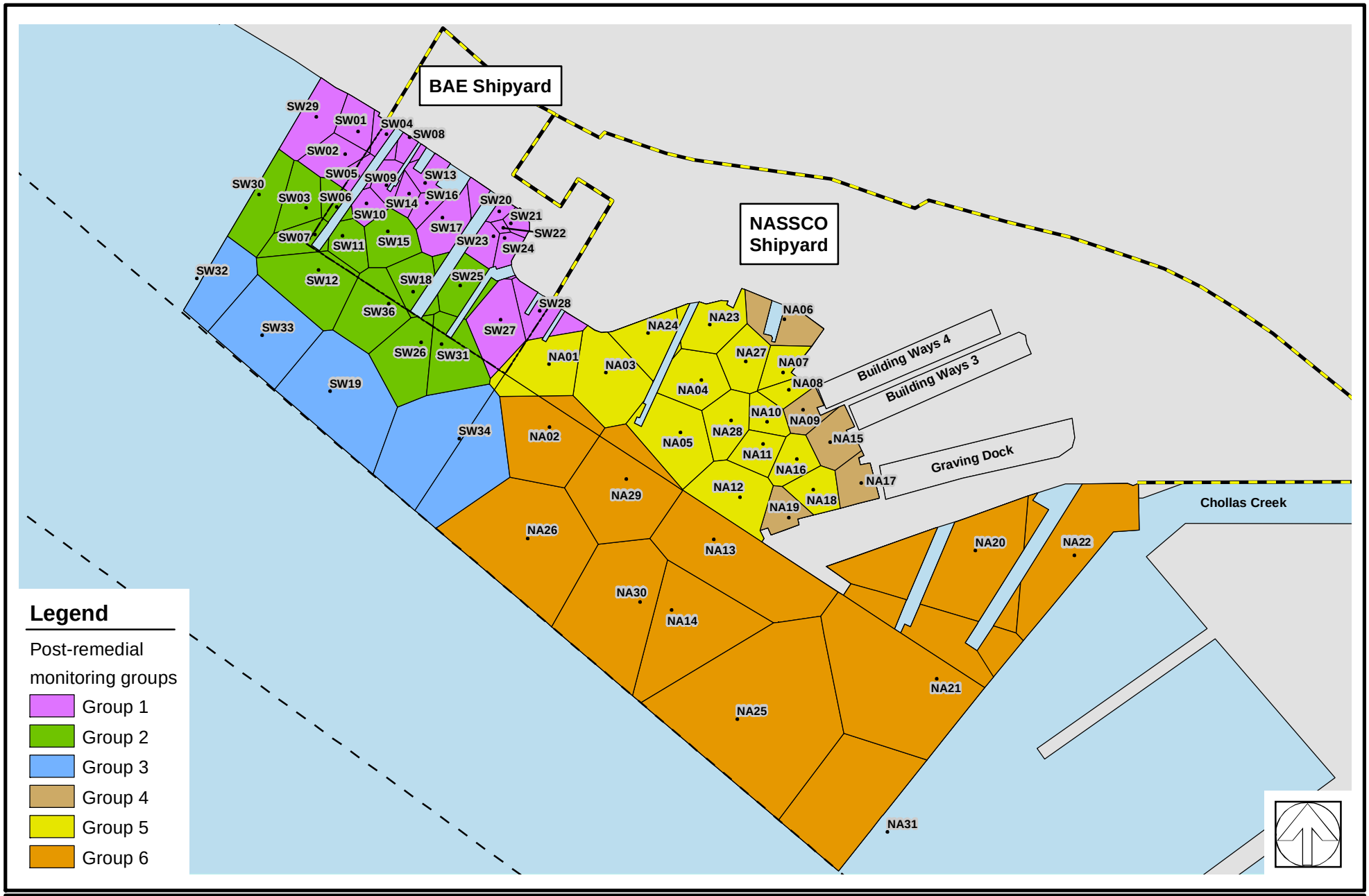

Figure 1. Post-remedial monitoring groups

Exponent®

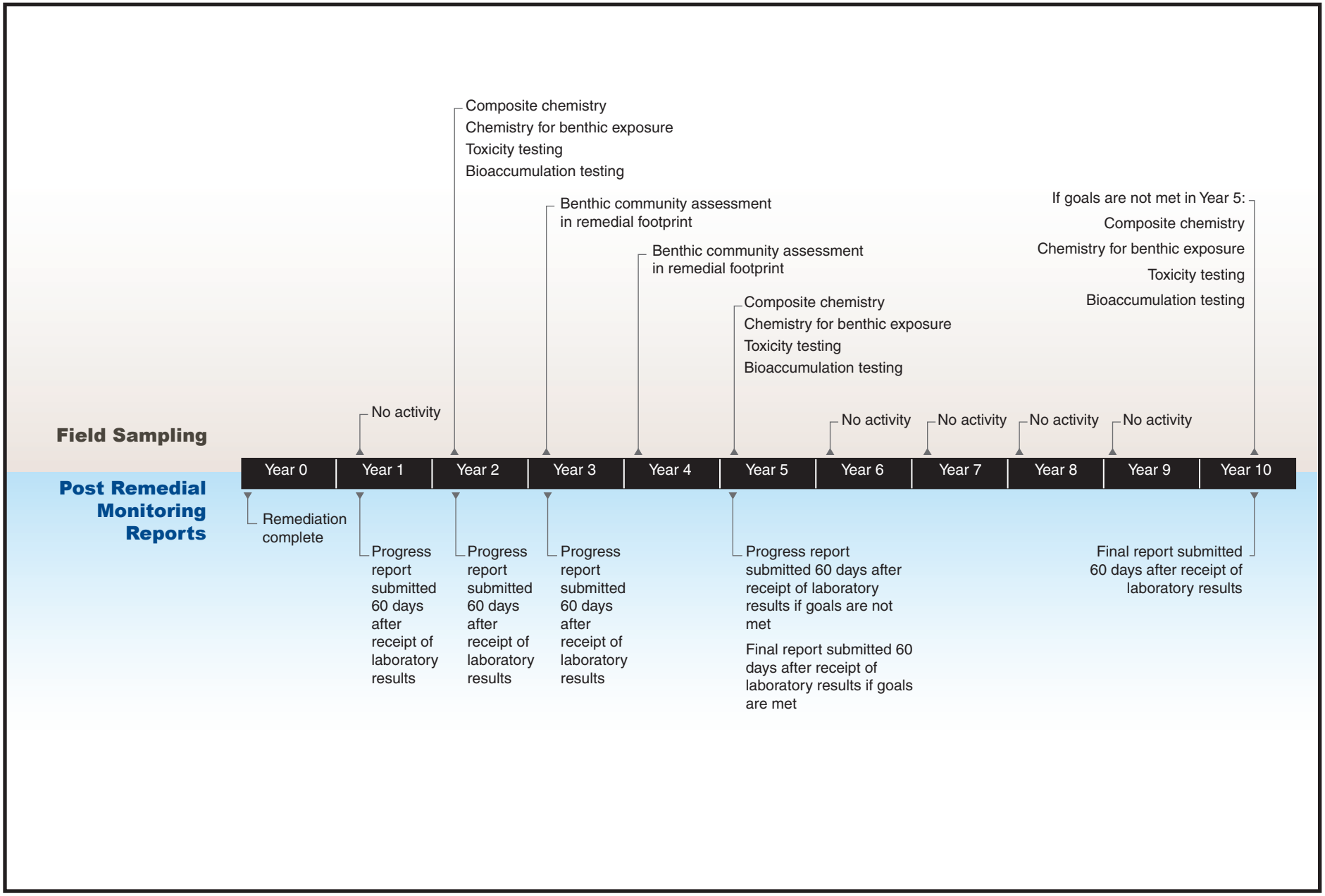

Figure 2. Schedule of post-remediation activities

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Tables

Table 1. Representatives from each responsible party

Company	Representative	Location
Responsible Parties		
BAE Systems	Shaun Halvax	San Diego, CA
NASSCO	Mike Chee	San Diego, CA
Regional Water Quality Control Board		
TBD	TBD	TBD
Sampling Contractors		
TBD	TBD	TBD
Laboratories		
TBD (chemical analysis)	TBD	TBD
TBD (bioaccumulation study)	TBD	TBD
TBD (toxicity tests)	TBD	TBD
TBD (benthic community assessment)	TBD	TBD

Table 2. Station designations and location coordinates

	Latitude			Longitude		
Station	Degrees	Minutes	Seconds	Degrees	Minutes	Seconds
NA01	32	41	21.9516	-118	51	26.0856
NA02	32	41	18.96	-118	51	26.136
NA03	32	41	21.552	-118	51	29.2752
NA04	32	41	21.21	-118	51	34.6284
NA05	32	41	18.726	-118	51	33.462
NA06	32	41	24.09	-118	51	39.2796
NA07	32	41	21.5808	-118	51	39.2112
NA08	32	41	20.742	-118	51	39.5388
NA09	32	41	19.8024	-118	51	40.3344
NA10	32	41	19.2372	-118	51	38.3076
NA11	32	41	18.1896	-118	51	38.0844
NA12	32	41	15.6588	-118	51	36.8028
NA13	32	41	13.6572	-118	51	35.334
NA14	32	41	10.2984	-118	51	32.9832
NA15	32	41	18.2688	-118	51	41.8608
NA16	32	41	17.4804	-118	51	39.978
NA17	32	41	16.3356	-118	51	43.596
NA18	32	41	16.0224	-118	51	40.9212
NA19	32	41	14.6976	-118	51	39.5352
NA20	32	41	13.1388	-118	51	50.0004
NA21	32	41	7.0584	-118	51	47.844
NA22	32	41	12.7536	-118	51	55.3536
NA23	32	41	23.8416	-118	51	35.0928
NA24	32	41	23.4348	-118	51	31.6404
NA25	32	41	5.1468	-118	51	36.6696
NA26	32	41	13.6968	-118	51	24.9156
NA27	32	41	22.0992	-118	51	37.1196
NA28	32	41	19.2876	-118	51	36.2952
NA29	32	41	16.5084	-118	51	30.4416
NA30	32	41	10.6872	-118	51	31.212
NA31	32	40	59.7972	-118	51	45.09
SW01	32	41	32.9784	-118	51	15.372
SW02	32	41	31.902	-118	51	14.6556
SW03	32	41	29.3388	-118	51	12.4812
SW04	32	41	32.8452	-118	51	16.9632
SW05	32	41	30.8652	-118	51	15.39
SW06	32	41	29.3928	-118	51	14.184
SW07	32	41	28.0896	-118	51	12.9744
SW08	32	41	32.7012	-118	51	18.2808
SW09	32	41	30.4188	-118	51	16.9812
SW10	32	41	29.5656	-118	51	15.858
SW11	32	41	28.0212	-118	51	14.5188
SW12	32	41	26.4048	-118	51	13.1724
SW13	32	41	30.5412	-118	51	19.1412
SW14	32	41	30.0228	-118	51	18.2376
SW15	32	41	28.2444	-118	51	17.046
SW16	32	41	29.5908	-118	51	19.2492
SW17	32	41	28.8852	-118	51	20.1276
SW18	32	41	25.3788	-118	51	18.4788
SW19	32	41	20.652	-118	51	13.8384
SW20	32	41	29.1948	-118	51	23.292

Table 2. (cont.)

	Latitude			Longitude		
Station	Degrees	Minutes	Seconds	Degrees	Minutes	Seconds
SW21	32	41	28.6188	-118	51	23.94
SW22	32	41	28.4064	-118	51	23.526
SW23	32	41	28.0212	-118	51	22.9788
SW24	32	41	27.9204	-118	51	23.5944
SW25	32	41	25.674	-118	51	21.1176
SW26	32	41	22.9884	-118	51	18.9396
SW27	32	41	24.0648	-118	51	23.3712
SW28	32	41	24.486	-118	51	25.56
SW29	32	41	33.6696	-118	51	13.0428
SW30	32	41	29.9652	-118	51	9.846
SW31	32	41	22.8984	-118	51	20.0772
SW32	32	41	25.998	-118	51	6.354
SW33	32	41	23.3016	-118	51	10.0332
SW34	32	41	18.42	-118	51	21.0672
SW36	32	41	24.8064	-118	51	17.1144

Table 3. Types of samples to be collected

	Years 2, 5, and 10 (if necessary)			Years 3 and 4
Station	Sediment Chemistry	Bioaccumulation Testing	Sediment Toxicity	Benthic Community Assessment [a]
NA01	C			
NA02	C			
NA03	C			
NA04	C			
NA05	C			
NA06	C	x		Candidate
NA07	C			
NA08	C			
NA09	C			Candidate
NA10	C			
NA11	C	x		
NA12	C	x		
NA13	C			
NA14	C			
NA15	C			Candidate
NA16	C			
NA17	C			Candidate
NA18	C			
NA19	C, D		x	Exclude
NA20	C	x		
NA21	C			
NA22	C			
NA23	C			
NA24	C			
NA25	C			
NA26	C			
NA27	C			
NA28	C			
NA29	C			
NA30	C			
NA31	C			
SW01	C			Candidate
SW02	C			Candidate
SW03	C			
SW04	C, D	x	x	Exclude
SW05	C			Candidate
SW06	C			
SW07	C			
SW08	C	x		Candidate
SW09	C			Candidate
SW10	C			Candidate
SW11	C			
SW12	C			
SW13	C, D	x	x	Exclude
SW14	C			Candidate
SW15	C			
SW16	C			Candidate
SW17	C			Candidate

Table 3. (cont.)

	Years 2, 5, and 10 (if necessary)			Years 3 and 4
Station	Sediment Chemistry	Bioaccumulation Testing	Sediment Toxicity	Benthic Community Assessment [a]
SW18	C			
SW19	C			
SW20	C			Candidate
SW21	C	x		Candidate
SW22	C, D		x	Exclude
SW23	C, D		x	Exclude
SW24	C			Candidate
SW25	C			
SW26	C			
SW27	C			Candidate
SW28	C	x		Candidate
SW29	C			
SW30	C			
SW31	C			
SW32	C			
SW33	C			
SW34	C			
SW36	C			

Notes: C - composite sample. Samples collected for composite sediment chemistry and a discrete sample for archiving.
D - discrete sample. Samples collected for a full suite of sediment chemistry for benthic exposure

[a] Any five randomly selected candidate stations excluding the stations noted in the table.

Table 4. COCs required for chemistry analysis

COC	Sediment Chemistry for Composite Samples	Bioaccumulation Tissue	Sediment Chemistry for Benthic Exposure
Arsenic		x	x
Cadmium		x	x
Chromium		x	x
Copper	x	x	x
Lead		x	x
Mercury	x	x	x
Nickel		x	x
Silver		x	x
Zinc		x	x
HPAHs	x		
Total PAHs		x	x
Total PCBs	x	x	x
TBT	x	x	x
Conventionals [a]			x
Lipid		x	

Note: COC - contaminant of concern

[a] Conventional analyses include grain size, TOC, and ammonia

Table 5. Volumes to be composited for each sampling station

Group	Station	Area (ft^2)	Proportion of Group	Volume (mL)
1	SW01	33,394	0.05	27
1	SW02	39,162	0.06	31
1	SW04	22,682	0.04	18
1	SW05	24,163	0.04	19
1	SW06	25,751	0.04	21
1	SW08	16,829	0.03	13
1	SW09	24,479	0.04	20
1	SW10	21,608	0.03	17
1	SW13	38,257	0.06	31
1	SW14	16,732	0.03	13
1	SW16	17,835	0.03	14
1	SW17	55,898	0.09	45
1	SW20	28,175	0.05	23
1	SW21	11,896	0.02	10
1	SW22	3,762	0.01	3
1	SW23	30,077	0.05	24
1	SW24	21,179	0.03	17
1	SW27	78,889	0.13	63
1	SW28	51,554	0.08	41
1	SW29	62,497	0.10	50
2	SW03	48,811	0.07	33
2	SW25	69,690	0.09	46
2	SW07	40,947	0.05	27
2	SW11	36,689	0.05	24
2	SW12	112,942	0.15	75
2	SW15	55,766	0.07	37
2	SW18	52,601	0.07	35
2	SW26	86,923	0.12	58
2	SW30	72,231	0.10	48
2	SW31	83,498	0.11	56
2	SW36	90,730	0.12	60
3	SW19	214,747	0.29	143
3	SW32	78,477	0.10	52
3	SW33	151,872	0.20	101
3	SW34	304,572	0.41	203
4	NA06	61,035	0.30	148
4	NA09	29,521	0.14	71
4	NA15	47,633	0.23	115
4	NA17	36,471	0.18	88
4	NA19	32,043	0.16	78
5	NA01	99,788	0.11	54
5	NA03	118,384	0.13	63
5	NA04	72,669	0.08	39
5	NA05	112,824	0.12	60
5	NA07	30,298	0.03	16
5	NA08	20,352	0.02	11
5	NA10	29,136	0.03	16
5	NA11	37,813	0.04	20
5	NA12	91,096	0.10	49
5	NA16	38,254	0.04	21
5	NA18	40,452	0.04	22

Table 5. (cont.)

Group	Station	Area (ft^2)	Proportion of Group	Volume (mL)
5	NA23	68,000	0.07	36
5	NA24	65,314	0.07	35
5	NA27	53,889	0.06	29
5	NA28	54,262	0.06	29
6	NA02	164,015	0.06	28
6	NA13	255,727	0.09	43
6	NA14	208,687	0.07	35
6	NA20	311,465	0.10	52
6	NA21	476,122	0.16	80
6	NA25	521,664	0.18	88
6	NA26	302,544	0.10	51
6	NA29	202,964	0.07	34
6	NA30	240,838	0.08	41
6	NA31	229,185	0.08	39
6	NA22	54,670	0.02	9
	Total	6,232,430		

Notes: Approximately 1 L of sediment sample will be collected at each station for chemical analyses. 500 mL of the sample will be reserved for archiving. The remaining 500 mL will be used for the composite sample.

Table 6. Sample preservation and holding time requirements[d]

Analyte	Approximate Laboratory Subsample	Container	Preservation and Handling	Maximum Holding Time (from date of collection)
Sediment				
Conventional Analytes				
Ammonia as N	10 g	125-mL wide-mouth HDPE jar; Teflon®-lined lid	Cool (4°C)	28 days
Total organic carbon	1 g	125-mL wide-mouth HDPE jar; Teflon®-lined lid	Cool (4°C)	28 days
Grain size	250 g	250-mL wide-mouth HDPE jar; Teflon®-lined lid	Cool (4°C)	180 days
Total solids	10 g	125-mL wide-mouth HDPE jar	Cool (4°C)	180 days
Metals				
Metals, except mercury	1 g	125-mL wide-mouth HDPE jar; Teflon®-lined lid	Cool (4°C)	180 days[a]
Mercury	1 g	125-mL wide-mouth HDPE jar; Teflon®-lined lid	Cool (4°C)	28 days[a]
Organometallic Compounds				
Tributyltin	20 g	250-mL wide-mouth glass jar; Teflon®-lined lid	Keep in dark; cool (4°C)	14 days
Organic Compounds				
PCB congeners	30 g	250-mL wide-mouth glass jar; Teflon®-lined lid	Freeze (–20°C)	1 year/ 40 days[b]
PAHs	30 g	250-mL wide-mouth glass jar; Teflon®-lined lid	Keep in dark; cool (4°C)	14 days/ 40 days[b]
Tissue				
Conventional Analytes				
Lipids	1 g	Double plastic self-sealing bags; minimize air space[c]	Freeze (–20°C)	1 year
Metals and organometallic compounds				
Metals	2 g	Double plastic self-sealing bags; minimize air space[c]	Freeze (–20°C)	180 days
Mercury	10 g	Double plastic self-sealing bags; minimize air space[c]	Freeze (–20°C)	1 year
Organotin species	10 g	Double plastic self-sealing bags; minimize air space[c]	Freeze (–20°C)	14 days[a]
Organic compounds		Double plastic self-sealing bags; minimize air space[c]		
PCB congeners	30 g	Double plastic self-sealing bags; minimize air space[c]	Freeze (–20°C)	1 year/ 40 days[b]
PAHs	30 g	Double plastic self-sealing bags; minimize air space[c]	Freeze (–20°C)	1 year/ 40 days[b]
Toxicity Tests				
Amphipod survival test	1.25 L	2´1-L wide-mouth glass jar, Teflon®-lined lid	Keep in dark; cool (4°C)	14 days
Bivalve development	NA[b]	NA[d]	Keep in dark; cool (4°C)	14 days

Table 6. (cont.)

Analyte	Approximate Laboratory Subsample	Container	Preservation and Handling	Maximum Holding Time (from date of collection)
Bioaccumulation Test				
Macoma bioaccumulation test	4 L	4´1-L wide mouth glass jar, Teflon®-lined lid	Keep in dark; cool (4°C)	14 days
Benthic Enumeration				
Macroinvertebrate community	1 L	1-L wide mouth HDPE jar	Sieve sediment in field and add 10 percent formalin; transfer to 70 percent ethanol in lab	5–7 days to transfer to ethanol

Note: PAH - polycyclic aromatic hydrocarbon
PCB - polychlorinated biphenyl

[a] SW-846, Third Edition, Updates I, II, IIA, III and IIIA, Tables 3-2 and 4-1 Sample Containers, Preservation, Techniques, and Holding Times; with additional guidance from EPA Methods 1631 and 1668; and ASTM methods E724-98, E1367-03, and E1688-00a.

[b] Holding time for sample collection to extraction/sample extraction to analysis.

[c] Wide-mouth glass jars with Teflon®-lined lids will be used to store resected and homogenized tissue samples.

[d] Small intact sediment cores will be transferred to the toxicity testing laboratory.

Table 7. Summed list of PAH analytes to be measured in bulk sediments

Naphthalene	Pyrene
C1- Naphthalenes	C1- Fluoranthenes/pyrenes
C2- Naphthalenes	C2- Fluoranthenes/pyrenes
C3- Naphthalenes	C3- Fluoranthenes/pyrenes
C4- Naphthalenes	Benzo[a]anthracne
Acenaphthylene	Chrysene
Acenaphthene	C1- Chrysenes
Biphenyl	C2- Chrysenes
Fluorene	C3- Chrysenes
C1- Flurorenes	C4- Chrysenes
C2- Fluorenes	Benzo[b]fluoranthene
C3- Fluorenes	Benzo[k]fluoranthene
Anthracene	Benzo[e]pyrene
Phenanthrene	Benzo[a]pyrene
C1- Phenanthrenes/anthracenes	Perylene
C2- Phenanthrenes/anthracenes	Indeno[1,2,3,-c,d]pyrene
C3- Phenanthrenes/anthracenes	Dibenzo[a,h]anthracene
C4- Phenanthrenes/anthracenes	Benzo[ghi]perylene
Dibenzothiophene	Total PAH
C1- Dibenzothiophenes	Priority Pollutant PAH
C2- Dibenzothiophenes	Low Molecular Weight PAH
C3- Dibenzothiophenes	High Molecular Weight PAH
Fluoranthene	

Notes: High molecular weight PAH - sum of fluoranthene, pyrene, benzo[a]anthracene, chrysene, benzo[a]pyrene, and dibenzo[a,h]anthracene

Low molecular weight PAH - sum of naphthalene, acenaphtylene, acenaphthene fluorene, anthracene, phenanthrene

PAH - polycyclic aromatic hydrocarbon

Total PAH - sum of all listed PAH analytes

Table 8. Summed list of PCB analytes measured in bulk sediment

PCB Congener	Congener No.	PCB Congener	Congener No.
2,2’,5- Trichlorobiphenyl (C13)	18	2,2’,3,3’,4,4’-Hexachlorobiphenyl (C16)	128
2,4,4’- Trichlorobiphenyl (C13)	28	2,2’,3,4,4’,5’-Hexachlorobiphenyl (C16)	138
3,4,4’- Trichlorobiphenyl (C13)	37	2,2’,3,4’,5’,6-Hexachlorobiphenyl (C16)	149
2,2’,3,5’- Tetrachlorobiphenyl (C14)	44	2,2’,3,5,5’,6 -Hexachlorobiphenyl (C16)	151
2,4,4’,5’- Tetrachlorobiphenyl (C14)	49	2,2’,4,4’,5,5’-Hexachlorobiphenyl (C16)	153
2,2’,5,5’- Tetrachlorobiphenyl (C14)	52	2,3,3’,4,4’,5 -Hexachlorobiphenyl (C16)	156
2,3’4,4’ - Tetrachlorobiphenyl (C14)	66	2,3,3’,4,4’,5’-Hexachlorobiphenyl (C16)	157
2,3’,4’,5- Tetrachlorobiphenyl (C14)	70	2,3,3’,4,4’,6 -Hexachlorobiphenyl (C16)	158
2,4,4’,5 - Tetrachlorobiphenyl (C14)	74	2,3’,4,4’,5,5’-Hexachlorobiphenyl (C16)	167
3,4,4’,5 - Tetrachlorobiphenyl (C14)	81	2,3’,4,4’,5’,6-Hexachlorobiphenyl (C16)	168
3,3’,4,4’ - Tetrachlorobiphenyl (C14)	77	3,3’,4,4’,5,5’-Hexachlorobiphenyl (C16)	169
2,2’3,4,5’- Pentachlorobiphenyl (C15)	87	2,2’,3,3’,4,4’,5 - Heptachlorobiphenyl (C17)	170
2,2’,4,4’,5 -Pentachlorobiphenyl (C15)	99	2,2’,3,3’,4,5’,6’-Heptachlorobiphenyl (C17)	177
2,2’,4,5,5’-Pentachlorobiphenyl (C15)	101	2,2’,3,4,4’,5,5’ -Heptachlorobiphenyl (C17)	180
2,3,3’,4,4’-Pentachlorobiphenyl (C15)	105	2,2’,3,4,4’,5’,6 -Heptachlorobiphenyl (C17)	183
2,3,3’,4’,6-Pentachlorobiphenyl (C15)	110	2,2’,3,4’,5,5’,6 -Heptachlorobiphenyl (C17)	187
2,3,4,4’,5- Pentachlorobiphenyl (C15)	114	2,3,3’,4,4’,5,5’ -Heptachlorobiphenyl (C17)	189
2,3’,4,4’,5-Pentachlorobiphenyl (C15)	118	2,2’,3,3’,4,5,5’-Octachlorobiphenyl (C18)	194
2,3’,4,4’,6-Pentachlorobiphenyl (C15)	119	2,2’,3,3’,4,5’,6,6’-Octachlorobiphenyl (C18)	201
2,3’,4,4’5’-Pentachlorobiphenyl (C15)	123	2,2’,3,3’,4,4’,5,5’,6-Nonachlorobiphenyl (C19)	206
3,3’,4,4’,5-Pentachlorobiphenyl (C15)	126	**Total PCB**	**TPCB**

Note: PCB - polychlorinated biphenyl
Total PCB - sum of all listed PCB congeners

Table 9. Summary of measurement quality objectives

Analysis	Method Reference	Units	Method Reporting Limit	Bias (percent)	Precision (RPD)	Complete-ness (percent)
CHEMICAL ANALYSES						
Sediment						
Conventional Analytes						
Ammonia as N	EPA 350.1	mg/Kg	0.5	75–125	±35	95
Total organic carbon	PSEP (1986)	percent	0.05	75–125	±35	95
Grain size	PSEP (1986)	percent	0.1	NA	±35	95
Total solids	EPA Method 160.3 (NOAA 1998)	weight percent	0.1	NA	±35	95
Metals						
Arsenic	EPA Method 6020 (current revision)	mg/kg	0.5	70–130	±35	95
Cadmium	EPA Method 6020 (current revision)	mg/kg	0.05	70–130	±35	95
Chromium	EPA Method 6020 (current revision)	mg/kg	0.2	70–130	±35	95
Copper	EPA Method 6020 (current revision)	mg/kg	0.1	70–130	±35	95
Lead	EPA Method 6020 (current revision)	mg/kg	0.02	70–130	±35	95
Mercury	EPA Method 7471A (current revision)	mg/kg	0.05	70–130	±35	95
Nickel	EPA Method 6020 (current revision)	mg/kg	0.2	70–130	±35	95
Silver	EPA Method 6020 (current revision)	mg/kg	0.02	70–130	±35	95
Zinc	EPA Method 6020 (current revision)	mg/kg	0.5	70–130	±35	95
Organometallic Compounds						
Tributyltin	Stallard et al. (1989)	µg/kg	1	65–135	±35	95
Organic Compounds						
PCB congeners	EPA Method 8082 (current revision); CAS SOP SOC-8082C	µg/kg	0.5	50–150	±50	95
PAHs	EPA Method 8270C with GC/MS-SIM (current revision)	µg/kg	5	50–150	±50	95
Tissue						
Conventional Analytes						
Lipids	TBD	weight percent	0.1	NA	±35	95
Metals						
Arsenic	EPA Method 6020 (current revision)	mg/kg	0.2	75–125	±35	95
Cadmium	EPA Method 6020 (current revision)	mg/kg	0.005	75–125	±35	95
Copper	EPA Method 6020 (current revision)	mg/kg	0.03	75–125	±35	95
Lead	EPA Method 6020 (current revision)	mg/kg	0.005	75–125	±35	95
Mercury	EPA Method 1631, Rev E (U.S. EPA 2002b)	µg/kg	0.5	75–125	±35	95
Zinc	EPA Method 6020 (current revision)	mg/kg	0.2	75–125	±35	95
Organometallic compounds						
Tributyltin	Stallard et al. (1989)	µg/kg	2	75–125	±35	95

Table 9. (cont.)

Analysis	Method Reference	Units	Method Reporting Limit	Bias (percent)	Precision (RPD)	Complete-ness (percent)
Organic compounds						
PCB congeners	EPA Method 8082 (current revision); CAS SOP SOC-8082C	µg/kg	0.5	50–150	±50	95
PAHs	EPA Method 8270C with GC/MS-SIM (current revision)	µg/kg	10	50–150	±50	95
BIOLOGICAL TESTING						
Toxicity Tests						
Amphipod survival test (*E. estuarius*)	ASTM (2008)	percent survival	NA	--	--	100
Bivalve development (*M. galloprovincialis*)	ASTM (2004); U.S. EPA/USACE (1994); Anderson et al. (1996, 2001)	percent shell development, percent survival	NA	--	--	100
Benthic Enumeration						
Macroinvertebrate community[a]	U.S. EPA (1987)	--[a]	NA	--	--	100
Bioaccumulation Test						
Macoma bioaccumulation test[b]	ASTM (2010)	--[b]	NA	--	--	100

Note: Method reporting limits are on a dry weight basis for sediment samples and on a wet weight basis for tissue samples.

ASTM - American Society for Testing and Materials
CAS - Columbia Analytical Services
EPA - U.S. Environmental Protection Agency
PAH - polycyclic aromatic hydrocarbon
PCB - polychlorinated biphenyl
PSEP - Puget Sound Estuary Program
RPD - relative percent difference
SOP - standard operating procedure
USACE - U.S. Army Corps of Engineers

[a] Benthic macroinvertebrates will be sent to taxonomy laboratory for identification and enumeration.

[b] Tissue from *Macoma* bioaccumulation test will be sent to chemical testing laboratory for chemical analysis.

Table 10. Sediment and tissue samples method performance criteria for PAH compounds

Element or Sample Type	Minimum Frequency	Measurement Quality Objective/ Acceptance Criteria	Corrective Action
Tuning	Prior to every sequence	Tune as specified in laboratory SOP	Resolve before proceeding.
Initial Calibration (All parent PAH and selected alkyl homologue PAHs)	Prior to every sequence, or as needed based on continuing calibration/verification check.	5-point calibration curve over two orders of magnitude %RSD ≤ 20	Resolve before proceeding.
Continuing Calibration (CCAL)	Every 12 hours or every 10 field samples	%D ≤ 25 for 90% of compounds %D ≤ 35 for 10% of compounds	Perform instrument maintenance. Re-analyze affected samples.
Initial Calibration Verification (Second Source or can be met if CCAL is second source)	Per initial calibration	%R target compounds 80-120%	Resolve before proceeding.
Standard Reference Material (if available)	One per batch/every 20 field samples	Within SRM acceptance criteria	Resolve before proceeding.
Matrix Spike/Matrix Spike Duplicate	One per batch/every 20 field samples	50–150%R and 50% RPD	Evaluate impact to data, discuss with manager, and determine if corrective action is needed.
LCS	One per batch/every 20 field samples	50–150%R	Resolve before proceeding.
Method Blank	One per batch/every 20 field samples	All compounds < 5 µg/Kg for sediments and <10 µg/Kg for tissues	Resolve before proceeding. Exponent QA coordinator may be contacted to resolve issues surrounding 'minor exceedances'.
Mass Discrimination	Initial calibration and CCALs (mid-level)	Ratio for the concentration of benzo(g,h,i)perylene to phenanthrene ≥ 0.70	Resolve before proceeding.
Internal Standard (IS)	Every sample	Area within 50–200% and RT within 0.5 minutes of IS in the associated calibration standard	Resolve before proceeding.
Surrogates	Every sample	Refer to laboratory SOP for QC limits.	Re-extract affected samples. Evaluate impact to data, discuss with Exponent QA coordinator, if corrective action is needed.

Table 11. Sediment and tissue samples method performance criteria for PCB congeners

Element or Sample Type	Minimum Frequency	Measurement Quality Objective/ Acceptance Criteria	Corrective Action
Initial Calibration (Standard solution - all target compounds)	Prior to every sequence, or as needed based on continuing calibration/ verification check.	5-point calibration curve %RSD ≤ 20	Resolve before proceeding.
Continuing Calibration (CCAL)	Every 12 hours or every 10 field samples	%D ≤ 15 for 90% of compounds %D ≤ 20 for 10% of compounds	Perform instrument maintenance. Re-analyze affected samples.
Initial Calibration Verification (Second Source or can be met if CCAL is second source)	Per initial calibration	%R target compounds 80–120%	Resolve before proceeding.
Standard Reference Material (if available)	One per batch/every 20 field samples	Within SRM acceptance criteria	Resolve before proceeding.
Matrix Spike/Matrix Spike Duplicate	One per batch/every 20 field samples	50–150%R and 50% RPD	Evaluate impact to data, discuss with manager, and determine if corrective action is needed.
LCS	One per batch/every 20 field samples	50–150%R	Resolve before proceeding.
Method Blank	One per batch/every 20 field samples	All compounds < 0.5 µg/Kg for sediments and tissues	Resolve before proceeding. Exponent QA coordinator may be contacted to resolve issues surrounding 'minor exceedances'.
Surrogates	Every sample	Refer to laboratory SOP for QC limits.	Re-extract affected samples. Evaluate impact to data, discuss with Exponent QA coordinator, if corrective action is needed.

Table 12. Sediment and tissue samples method performance criteria for tributyltin

Element or Sample Type	Minimum Frequency	Measurement Quality Objective/ Acceptance Criteria	Corrective Action
Initial Calibration	Prior to every sequence, or as needed based on continuing calibration/ verification check.	5-point calibration curve %RSD ≤ 20	Resolve before proceeding.
Continuing Calibration (CCAL)	Every 12 hours or every 10 field samples	%D ≤ 15	Perform instrument maintenance. Re-analyze affected samples.
Initial Calibration Verification (Second Source or can be met if CCAL is second source)	Per initial calibration	%R 80–120%	Resolve before proceeding.
Standard Reference Material (if available)	One per batch/every 20 field samples	Within SRM acceptance criteria	Resolve before proceeding.
Matrix Spike/Matrix Spike Duplicate	One per batch/every 20 field samples	65–135 %R and 35% RPD for sediments; 75–125 %R and 35% RPD for tissues	Evaluate impact to data, discuss with manager, and determine if corrective action is needed.
LCS	One per batch/every 20 field samples	65–135 %R for sediments; 75–125 %R for tissues	Resolve before proceeding.
Method Blank	One per batch/every 20 field samples	< 1 µg/Kg for sediments and < 2 µg/Kg for tissues	Resolve before proceeding. Exponent QA coordinator may be contacted to resolve issues surrounding 'minor exceedances'.
Surrogates	Every sample	Refer to laboratory SOP for QC limits.	Re-extract affected samples. Evaluate impact to data, discuss with Exponent QA coordinator, if corrective action is needed.

Table 13. Sediment and tissue samples method performance criteria for metals by ICP-MS and mercury by CVAA and CVAFS

Element or Sample Type	Minimum Frequency	Measurement Quality Objective/ Acceptance Criteria	Corrective Action
ICP-MS Tune	Daily at the beginning of each 24 hour shift and Must start each analytical sequence	Tuning solution must contain elements spanning all the mass regions of interest (see EPA method 6020). Analyze 5 times with RSD ≤ 5% Resolution <0.9amu at 10% peak height Mass calibration < 0.1 amu difference from target mass	Resolve before proceeding
Initial Calibration	Daily prior to sample analysis.	Minimum of a 2 point curve for ICP-ICP-MS (1 blank + 1 standard containing all target compounds) Min 5 point curve for CVAA r>0.995 for multi-point curves	Resolve before proceeding
Independent (Initial) Calibration Verification (ICV)	Analyzed immediately after calibration and prior to samples	Different source than calibration standards Concentration near mid-point of calibration curve Must contain all target compounds to be reported %R = 90– 110%	Resolve before proceeding
Initial Calibration Blank (ICB)	Must be analyzed after each ICV	ICB < RL for all target compounds	Resolve before proceeding
Reporting Limit Standard (CRI)	Daily prior to sample analysis if initial calibration did not contain a low-level standard at the RL for each target compound. If initial calibration includes the RL as the low-level standard in the initial calibration curve, then CRI is not required.	Prepare using same source as calibration standards all target compounds at a concentration = RL %R = 70–130%	Resolve before proceeding unless all target compounds in associated samples are > 10x RL
Interelement Interference Check Standards (ICSA & ICSAB) (ICP-MS only)	Daily prior to sample analysis	See EPA method 6020 for ICSA & ICSAB concentrations of interferents and other compounds For ICP-MS checks on isobaric interference corrections. ICSA & ICSAB: %R = 80–120% Unspiked compounds <RL.	Resolve before proceeding
Continuing Calibration Verification (CCV)	Must be analyzed before samples, after every 10 samples, and at end of each analytical sequence	CCV concentration should be near mid-point of calibration curve and contain all target compounds %R = 90–110%	Perform instrument maintenance. Re-analyze affected samples.

Table 13. (cont.)

Element or Sample Type	Minimum Frequency	Measurement Quality Objective/ Acceptance Criteria	Corrective Action
Continuing Calibration Blank (CCB)	Must be analyzed after each continuing calibration verification (CCV)	CCB < RL for all target compounds Unless: compound not detected in associated sample(s) or sample compound concentrations are >10x the blank value	Resolve before proceeding
Method Blank	Every batch (maximum of 20 field samples).	No compounds to exceed the reporting limit unless compound not detected in associated sample(s) or detected in samples at >10x the blank value	Resolve before proceeding
Laboratory Control Sample or Reference Material	Every batch (maximum of 20 field samples).	Reference Material or laboratory control sample must be matrix-matched to the field samples and prepared/analyzed with the sample batch. Aqueous: %R = 80–120% Sediment: Values must be within manufactor's control limits.	Resolve before proceeding
Matrix Spike (MS)	Every batch (maximum of 20 field samples).	Must be performed on site specific sample from same preparation/analysis batch. Must contain all target compounds to be reported. Sediment %R = 70–130% Tissue %R = 75–125% (For native conc. < 4X spike added)	If a MS %R is <30%, a post digestion spike should be analyzed and fall within 75–125%. See EPA method 6020 for details on spike levels and evaluation. Report QC exceedances in data package narrative.
Sample Duplicate (or matrix spike duplicate)	Every batch (maximum of 20 field samples).	Sediment/Tissue: RPD ≤ 35% if value > RL	Report this QC exceedance in data package narrative.
Internal Standards (ICP-MS only)	Every sample (QC and field samples)	See EPA method 6020 for recommended IS limits. Relative intensity of IS %R = 70–130% compared to IS of standard in calibration curve (or mid-point standard of calibration for multi-level curve).	Check for instrument drift. If IS in associated CCB is acceptable, then dilute sample 5X and re-analyze until IS in control for affected compounds(s). If instrument drift is indicated, recalibrate and re-analyze.

Table 14. Sediment samples method performance criteria for conventional chemistry

QC Element or Sample Type	Minimum Frequency	Acceptance Criteria	Relevant Parameter(s) Reference Methods*
Initial Calibration	Prior to analysis (method and instrument specific procedures and number of standards)	For multipoint calibration, Correlation coefficient (r) >0.995	Ammonia, TOC
Continuing Calibration	Must start and end analytical sequence and every 10 samples	%R 90–110%	Ammonia, TOC
Method Blank	One per batch/every 20 field samples	Not to exceed RL	Ammonia, TOC
LCS	One per batch/every 20 field samples	%R 75–125%	Ammonia, TOC
Matrix Spike Samples	One per batch/every 20 field samples	%R 75–125% If MS/MSD analyzed, RPD ≤ 35%	Ammonia, TOC
Sample Duplicates	One per batch/every 20 field samples	RPD ≤ 35% for analyte concentrations greater than QL	Ammonia, TOC, Grain Size, total solids

Note: Conventional chemistry parameters are **a**mmonia, TOC, grain size, and total solids.

TOC - total organic carbon

Table 15. Data validation qualifier codes

U	Compound concentration is not significantly greater than the associated blank result. The result is judged to be the detection limit.
R	Unreliable result. Data should not be used.
N	The analysis indicates the present of a compound for which there is presumptive evidence to make a “tentative identification”.
NJ	The analysis indicates the presence of a compound that has been “tentatively identified” and the associated numerical value represents its approximate concentration.
J	Reported concentration is an estimate with potentially more bias or less precision than an unqualified result, as determined by the associated quality control results.
UJ	Not detected. Detection limit is an estimate with potentially more bias or less precision than an unqualified detection limit as judged by the associated quality control results

Appendix A

Standard Operating Procedures

Exponent®

SOP BI-12
BENTHIC MACROINVERTEBRATE SAMPLING USING A GRAB SAMPLER

This standard operating procedure (SOP) describes the procedures used to sample benthic macroinvertebrate assemblages by using a grab sampler (e.g., modified van Veen, Ekman, Ponar). Benthic assemblages are typically analyzed for the abundances and biomass of various species and major taxa. The project-specific field sampling plan (FSP) should stipulate the number of replicate samples (i.e., individual grabs) that need to be collected at each station. The personnel performing the benthic macroinvertebrate collection and sample processing will wear protective clothing as specified in the site-specific health and safety plan.

All benthic macroinvertebrate samples will be packaged and shipped in accordance with procedures outlined in SOP GEN-03, *Sample Packaging and Shipping* with consideration of information provided in SOP HS-01, *Restricted Article Shipment*. Sample custody will be maintained in accordance with procedures outlined in SOP GEN-02, *Sample Custody*. Field activities will be recorded in accordance with procedures outlined in SOP GEN-01, *Field Documentation*.

The grab sampler used for benthic infauna studies should be capable of collecting acceptable samples from a variety of substrates, including mud, sand, gravel, and pebbles (APHA 1989). The procedures for sampling benthic macroinvertebrate assemblages by using a grab sampler are described below.

EQUIPMENT REQUIRED

Equipment required for benthic macroinvertebrate sampling includes the following:

- Grab sampler (e.g., modified van Veen, Ekman, Ponar)
- If grab sampler is of considerable weight, then a winch and hydrowire (with load capacities ≥3 times the weight of a full sampler)
- Sample collection table (if vessel deck space allows)
- Sample collection tub
- Ruler
- Sieve(s) (typically with a 0.595-mm mesh for freshwater studies or a 1.0-mm mesh for marine studies; consult project-specific FSP for correct sieve size);

multiple sieves can be stacked on top of each other to capture different size fractions of benthic macroinvertebrates that will be processed separately; consult project-specific FSP for correct number of sieves

- Scoop (for transferring sediment sample aliquots to the sieve)
- Sample containers (clean, 1-L wide mouth plastic jars with plastic screw-on lids)
- Internal labels
- 10 percent buffered formalin
- Rose bengal (depending on study objectives, rose bengal stain may or may not be added; consult project-specific FSP)
- Scrub brush and soft-bristle nylon brush or tooth brush
- If necessary, socket and crescent wrenches (for adding or removing the detachable weights of the van Veen grab sampler)
- Water pump and hose (for sieving samples and for rinsing the grab sampler, sample collection tub, and sample collection table).

GRAB SAMPLER DEPLOYMENT

1. Prior to deployment, clean the inside of the grab sampler with a scrub brush and site water.
2. Depending on the sampling environment and substrate, consult either SOP SD-04 *Surface Sediment Sampling Using a Modified van Veen Grab Sampler*, SOP SD-05, *Surface Sediment Sampling Using an Ekman Grab Sampler*, or SOP SD-06, *Surface Sediment Sampling Using a Ponar Grab Sampler* for the correct deployment techniques for the appropriate grab sampler.
3. Lower the sampler through the water column at a slow and steady speed (e.g., 30 cm/second).

Allow the grab sampler to contact the bottom gently, with only its weight being used to force it into the sediments. The sampler should never be allowed to “free fall” to the bottom because this may result in premature triggering, or improper orientation upon contact with the bottom.

GRAB RETRIEVAL

1. After the grab sampler has rested on the bottom for approximately 5 seconds, begin retrieving it at a slow and steady rate (e.g., 30 cm/second).
2. Ensure that the sampling vessel is not headed into any waves before the sampler breaks the water surface to minimize vessel rolling and potential sample disturbance.
3. After the grab sampler breaks the water surface and is raised to the height of the sample collection table or sample collection tub, rinse away any sediments adhering to the outside of the grab sampler (it is essential that the sediments adhering to the outside of the grab are removed because those sediments and any associated benthic macroinvertebrates are not part of the sample).
4. After rinsing is finished, raise the grab sampler above the height of the collection table or sample collection tub, swing it inboard, and gently lower it into the sample collection tub on the sample collection table while maintaining tension on the hydrowire to prevent the grab sampler from rolling when it contacts the bottom of the tub.
5. When the grab sampler contacts the bottom of the table or tub, insert wedges under both jaws, if necessary, so that the grab sampler will be held in an upright position.
6. Open the doors on the top of the grab sampler, and inspect the sample for acceptability. The following acceptability criteria should be satisfied:
   - The sampler is not overfilled with sample to the point that the sediment surface presses against the top of the sampler or is extruded through the top of the sampler (organisms may have been lost)
   - Overlying water is present (indicating minimal leakage)
   - The overlying water is not excessively turbid (indicating minimal disturbance or winnowing)
   - The sediment surface is relatively undisturbed; the sediment-water interface is intact and relatively flat with no sign of channelling or sample washout
   - The desired penetration depth is achieved (see project-specific FSP); the following penetration depths should be achieved at a minimum:
   - 4–5 cm for medium-coarse sand
   - 6–7 cm for fine sand
   - >10 cm for silty sediment

- There is no sign of sediment loss (incomplete closure of the sampler, penetration at an angle, or tilting upon retrieval).

If a sample fails to meet the above criteria, it will be rejected and discarded away from the station. The location of consecutive attempts should be as close to the original attempt as possible, and if sampling on a river or stream, consecutive attempts should be located in the "upstream" direction of any existing current. Rejected sediment samples should be discarded in a manner that will not affect subsequent samples at that station or other possible sampling stations.

Penetration depth should be determined by placing a ruler against the center of the inside edge of the opening on the top of one side of the grab sampler and extending it into the grab sampler until it contacts the top of the sample. The penetration depth is determined by the difference between that measurement and the total depth of the grab sampler.

SAMPLE REMOVAL AND PROCESSING

1. For each acceptable sample, characterize the sample as specified in the study design. Characteristics that are often recorded include the following:

   - Sediment type (e.g., silt, sand)
   - Texture (e.g., fine-grain, coarse, poorly sorted sand)
   - Color
   - Biological structures (e.g., chironomids, tubes, macrophytes)
   - Approximate percentage of biological structures
   - Presence of debris (e.g., twigs, leaves, wood chips, wood fibers, manmade debris)
   - Approximate percentage of organic debris
   - Presence of shells
   - Approximate percentage of shells
   - Presence of a sheen
   - Odor (e.g., hydrogen sulfide, oil, creosote)
   - Changes is sediment characteristics
   - Presence and depth of redox potential discontinuity layer (if visible)
   - Maximum penetration depth

- Comments relative to sample quality (i.e., leakage, winnowing, disturbance).

2. After the sample is characterized, open the jaws of the grab sampler so that its contents (i.e., sediments and overlying water) are released into the sample collection tub.

3. Rinse any remaining sediment inside the grab into the collection tub, being careful not to overfill the tub with water.

4. Before each sample is sieved, all sieves will be examined for damage and wear. Look for rips in the mesh, irregular mesh spacing, and sand grains caught in the mesh. Use water pressure or a soft nylon brush to dislodge sand. DO NOT use sharp objects or stiff brushes, as the mesh may be damaged or torn.

5. After the entire sample has been collected in the sample collection tub, carefully transfer aliquots of the sample to the sieve by using a scoop.

6. Sieve each sample aliquot by rotating the sieve (in an up-and-down, not swirling, motion) in a bucket of water or by passing a gentle stream of water through the sieve from above or washed using a combination of these techniques. For all methods, it is imperative that the samples be washed gently to minimize specimen damage.

7. After each aliquot has been sieved, carefully rinse all of the retained material into a sample container, and carefully check the sieve to ensure that no organisms are trapped in its mesh (do not fill any sample container more than three-quarters full to ensure that a sufficient amount of space is available for the fixative).

8. If an organism is found to be trapped in the sieve, dislodge it with a gentle stream of water or by using forceps, and transfer it to the sample container.

9. Continue sieving aliquots of the sample until all of the sample has been processed.

10. Any large stones or other debris in the sample too large to fit in the sample jar should be thoroughly and carefully rinsed-off into the sieve, removed, and discarded under the supervision of the field team leader and noted on the field logbook.

11. After the entire sample has been sieved, clean the sieve by turning it over and back-washing it with a high-pressure spray to dislodge any sediment grains or detritus that are lodged in the mesh.

12. Fix each sample by filling each sample container with a 10–15 percent solution of borax-buffered formalin and inverting the container at least five times to ensure that the fixative penetrates all parts of the sample.

13. Depending on the sampling environment and the preferences of the taxonomic laboratory, the samples may be dyed with rose bengal (see project-specific FSP). If required, rose bengal should be added to the formalin solution prior to fixing the samples.

14. Label each sample container (both internal and external labels are required; see below), and store it in a protective container.

INTERNAL LABELS

In addition to the label on the outside of the sample container (i.e., external label, see SOP GEN-01, *Field Documentation*), a complete label must be placed inside each sample container. The internal label must be preprinted and should be made of at least 100 percent waterproof rag paper. The internal labels should be filled out using a pencil (i.e., no ink).

SAMPLE CONTAINERS

Samples can be stored in various containers including glass or plastic jars, and plastic bags. Exponent prefers that plastic jars with plastic screw-on lids (formalin corrodes metal) be used to store benthic macroinvertebrates samples. The use of this kind of sampling container lessens the possibility of formalin leakage during shipping and the breaking or tearing of the sample container. In general, a single 1- or 2-qt container is large enough to hold a sieved sample from a van Veen grab sampler and 1-L container is large enough to hold a sieved sample from a Ekman or Ponar grab sampler. If the sample volume exceeds one half of the container volume, more than one container should be used. Use of multiple containers for single replicates should be recorded in the field logbook.

After the buffered formalin has been added to a sample container, it is critical that the contents be mixed adequately. This usually can be accomplished by inverting the container several times (make sure that the lid is tightly screwed on). After mixing, sample container should be placed in protective containers for storage and transport o the laboratory. After being stored for approximately 1 hour, samples should be inverted several times again to ensure adequate mixing. Onboard the sampling vessel, samples should be stored so as to minimize exposure to sunlight and temperature extremes. They should also be stored in a stable part of the ship to minimize agitation.

BUFFERED FORMALIN PREPARATION

The fixative most commonly used for benthic macroinvertebrate samples is formalin, an aqueous solution of formaldehyde gas. Under no circumstances should ethyl or isopropyl alcohol be used as a preservative in place of the formalin. Penetration of the alcohol into body tissues is too slow to prevent decomposition of the specimens.

Solutions of 10–15 percent buffered formalin are most commonly used. However, samples containing large amounts of organic debris (e.g., peat, woody plant material) may require higher concentrations. The volume of fixative should be at least twice the volume occupied by the sample. If possible, the formalin solution should be added to the sample container until it is completely filled. This will minimize abrasion during shipping and handling. It is recommended that at least 2 L of diluted formalin solution be on hand for each replicate van Veen grab collected and at least 0.75 L of diluted formalin solution be on hand for each replicate Ekman or Ponar grab collected. The formalin solution should always be buffered to reduce acidity. Failure to buffer may result in decalcification of molluscs and echinoderms. Ideally, pH should be at least 8.2, as calcium carbonate dissolves in more acidic solutions. Borax (sodium borate) should be used as the buffer because other buffering agents may hinder identification by leaving a precipitate on body tissues.

To prepare a 10-percent buffered formalin solution, add 4 oz of borax to each gallon of concentrated formalin (i.e., a 40-percent solution of formaldehyde in water). This amount will be in excess, so use the clear supernatant when making seawater dilutions. Dilute the concentrate to a ratio of one part concentrated formalin to nine parts site water (sea water or tap water). If seawater is used, it will further buffer the solution. Fresh buffered formalin should be made prior to each sampling event, because formalin will eventually consume all of the buffering capacity of the borax.

If staining is used (see project-specific FSP), rose bengal is often added to the buffered formalin to facilitate sorting by staining the benthic organisms. The stain colors most infauna and thereby enhances their contrast with the debris from which they are sorted. Taxa that do not always stain adequately include ostracods and gastropods. **BE CAREFUL** when adding rose bengal to the buffered formalin solution. Add only a **VERY SMALL AMOUNT** of rose bengal; a little rose bengal goes a very long way. **REMEMBER**, you can always add more stain to the buffered formalin if you need to, but you can not remove the rose bengal once it has been added.

SOP GEN-01
FIELD DOCUMENTATION

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. Several types of field documents and sample tracking information will be used for this purpose and should be consistently used by field personnel.

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.

A 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 sampler's initials and the date. The sampler will initial and date each page of the field logbook. The sampler 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, site name and location (city and state), Exponent contract number, and the dates (i.e., duration) of sampling activity 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., 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 project 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, wave action, current, tide, vessel traffic, temperature of both the air and water, thickness of ice if present)
- Name of person making entries and other field personnel and their duties, including the times that they are present
- Level of personal protection being used
- Onsite visitors, if any, including the times that they are present
- The name, agency, and telephone number of any field contacts
- Notation of the system used to determine the station location information
- The sample identifier and analysis code for each sample to be submitted for laboratory analysis
- 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
- The type of vessel used (e.g., size, power, type of engine) (for aquatic sampling only)
- The location and description of the work area, including sketches and map references, if appropriate
- Specific information on each type of sampling activity
- The sample type (i.e., groundwater, soil, surface sediment), sample number, and sample tag number
- Preservatives used, if any
- 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

- Estimate of length and appearance of recovered cores
- Photographs (uniquely identified) taken at the sampling location, if any
- Variations, if any, from specified sampling 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 used to record information (e.g., field data sheets, health and safety log).
- The signature of the person making the entry.

Upon completion of the field sampling event, the field 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., Station/Sample Log, Groundwater Monitoring Form, Sediment Core Profile 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 field sampling plan.

Upon completion of the field sampling event, the field 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 will be taken using a camera-lens system with a perspective similar to the naked eye. Photographs may also be taken of sample characteristics and routine sampling activities. Photographs should include a measured scale in the picture, when practical. 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, the date, the time of the photograph, and the general direction faced
2. A brief description of the subject and the field work portrayed in the picture

3. The sequential number of the photograph (filename for digital) and the roll number (disk number for digital, if applicable) on which it is contained.

Upon completion of the field sampling event, the field team leader will be responsible for submitting all photographic materials to be developed (slides, prints) or to be copied (disks), as appropriate. The slides, prints, or disks (as appropriate) and associated negatives will be placed in the project files (at the Exponent Project Manager's location [project-specific]). Photo logs and any supporting documentation from the field logbooks will be photocopied and placed in the project files with the slides, prints, or disks.

SAMPLE LABELS

Exponent sample labels are designed to uniquely identify each sample container that is collected during a sampling event. Field crews will be provided with preprinted sample labels, which must be affixed to each sample container used. The labels should be filled out at the time the samples are collected and should consist of the following information:

1. Sample number
2. Site name or project number
3. Date and time sample is collected
4. Initials of the samplers
5. Preservatives used, if any
6. A unique number (commonly referred to as the "Tag Number") that is preprinted on the label consisting of six digits; used to identify individual containers.

SAMPLE TAGS

Exponent sample tags are designed to be affixed to each container that is used for a sample. Sample tags are only required for environmental samples collected in U.S. Environmental Protection Agency (EPA) Region 5. Field crews will be provided with preprinted sample tags. Sample tags must be attached to each individual sample container with a rubber band or wire through a reinforced hole in the tag. All sample tag entries will be made with indelible ink. The tags should be filled out at the time the samples are collected and should consist of the following information:

1. Sample number
2. Site name or project number

3. Date and time sample is collected
4. Initials of the samplers
5. Preservatives used, if any
6. Type of analysis.

A space for the laboratory sample number (provided by the laboratory at log-in) will also be provided on the sample tag.

INTERNAL SAMPLE LABELS

For benthic infaunal samples, the sediment is washed away from the sample and the remaining benthic infauna are collected into a sample container. A sample label as discussed above is affixed to the outside of the sample container. In addition, an internal sample label is placed inside the sample container. This internal sample label is made of water-proof paper and all internal sample label entries will be made with pencil. The internal sample labels should be filled out at the time the samples are collected and should consist of the following information:

1. Sample number
2. Site name or project number
3. Date and time sample is collected
4. Initials of the samplers
5. Preservative used (i.e., formalin).

CHAIN-OF-CUSTODY/SAMPLE ANALYSIS REQUEST FORMS

Exponent uses a combined chain-of-custody/sample analysis request (COC/SAR) form. The sample number and the unique number at the bottom of each sample label will be recorded on the COC/SAR form. The COC/SAR form will also identify the sample collection date and time, the type of sample, the project, and the field team leader. In addition, the COC/SAR 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/SAR form will be sent to the laboratory along with the sample(s).

The COC/SAR form will be completed in triplicate and consists of three pages: a white sheet, which always remains with the samples; a yellow sheet, which remains with the samples when they are shipped to the laboratory; and a pink sheet, which is removed by field staff prior to shipping to the laboratory or prior to placing the samples into the sample archives. The white sheet and the yellow sheet will be placed into a plastic sealable bag and secured to the inside top

of each sample cooler. The pink sheet will be retained by the field staff for filing at the Exponent Project Manager's location (project-specific).

Exponent also uses computer-generated COC/SAR 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 Exponent Project Manager's location (project-specific).

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 filed logbook entries. Upon completion of the field sampling event, the field team leader will be responsible for submitting all COC/SAR forms to be copied. A discussion of copy distribution is provided below.

CUSTODY SEAL

As security against unauthorized handling of the samples during shipping, two custody seals will be affixed to each sample cooler (example provided in Attachment GEN-03-1). 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 may be prudent.

SHIPPING AIRBILLS

When samples are shipped from the field to the testing laboratory via a commercial carrier (e.g., Federal Express, UPS), an airbill or receipt is provided by the shipper. Upon completion of the field sampling event, the field team leader will be responsible for submitting the sender's copy of all shipping airbills to be copied. A discussion of copy distribution is provided below. The airbill number (or tracking number) should be noted on the applicable COC/SAR forms or alternatively the applicable COC/SAR form number should be noted on the airbill to enable the tracking of samples if a cooler becomes lost.

ACKNOWLEDGMENT 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 Exponent 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/SAR form and the corrected version of the COC/SAR form should be faxed to the laboratory.

The Acknowledgment of Sample Receipt form (and any modified COC/SAR forms) will then be submitted to be copied. A discussion of copy distribution is provided below.

ARCHIVE RECORD FORMS

On rare occasions, samples are archived at an Exponent office. If samples are to be archived at Exponent, 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/SAR form for the samples, and will be placed in a locked file cabinet.

DISTRIBUTION OF COPIES

Two copies of all field logbooks, additional field data forms, COC/SAR forms, and Acknowledgement of Sample Receipt forms will be made at Exponent. 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.

One copy of the shipping airbill will be made and placed in the project file. The original airbill will be given to the respective Exponent receptionist for filing and billing purposes.

Setup 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 charge number. As many as five kinds of files will be included in this folder for each project:

- Field logbook(s)
- Additional field data forms
- COC/SAR forms
- Acknowledgment of Sample Receipt forms
- Archive Record form (to be completed only if samples are archived at the Bellevue field storage facility or at the Boulder laboratory).

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SOP GEN-02
SAMPLE CUSTODY

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 GEN-01, *Field Documentation*, and SOP GEN-03, *Sample Packaging and Shipping*. Chain-of-custody record/sample analysis request (COC/SAR) forms (Attachment GEN-03-1) 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 Exponent 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 Exponent field team member must physically remain with the samples (e.g., at lunch time one team member must remain with the samples).

PROCEDURE

The chain-of-custody record portion of the COC/SAR form is the most critical because it documents sample possession from the time of collection through the final disposition of the sample. The sample analysis request portion of the form provides information to the laboratory regarding what analyses are to be performed on the samples that are shipped.

The COC/SAR 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/SAR form(s), indicating the time and date that the transfer occurs. Copies of the forms will be made and kept by Exponent, and the originals will be included with the samples in the sample cooler. The following guidelines will be followed to ensure consistent shipping procedures and to maintain the integrity of the samples:

1. Each chain-of-custody record/sample analysis request form must be appropriately signed by the sampling personnel. The person who relinquishes custody of the samples must also sign this form.

2. The chain-of-custody record/sample analysis request form should not be signed until the information has been checked for inaccuracies by the field 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/SAR form after corrections are made should be marked out with single lines. This procedure will preclude any unauthorized additions.

3. At the bottom of each COC/SAR 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.

4. If samples are sent by a commercial carrier not affiliated with the laboratory, such as Federal Express or UPS, the name of the carrier should be entered in the "received by" block. Any tracking numbers supplied by the carrier should be also entered in the "received by" block. The time of transfer should be as close to the actual drop-off time as possible. After the COC/SAR forms are signed and copied, they should be sealed inside the transfer container.

5. If errors are found after the shipment has left the custody of Exponent 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.

6. Samples that are archived internally at Exponent must be accompanied by a COC/SAR form and an Archive Record form (see SOP GEN-01).

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SOP GEN-03
SAMPLE PACKAGING AND SHIPPING

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.

EQUIPMENT REQUIRED

Specific equipment or supplies necessary to properly pack and ship environmental samples include the following:

- Ice in doubled, sealable bags (e.g., Ziplocs®), frozen Blue Ice®, or dry ice
- Sealable airtight bags (assorted sizes)
- Large plastic garbage bags
- Paper towels
- Coolers
- Bubble wrap
- Fiber reinforced packing tape
- Duct tape
- Clear plastic packing tape
- Scissors
- Chain-of-custody seals
- "Fragile," "This End Up," or "Handle With Care" labels
- Mailing labels
- Airbills for overnight shipment
- Chain-of-custody record/sample analysis request forms.

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 an overnight courier service. If a courier service is used, then Exponent 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]; see SOP HS-01) prior to shipping the samples. Federal Express service locations can be determined by calling 1-800-463-3339. United Parcel Service locations can be determined by calling 1-800-742-5877.

The following steps should be followed to ensure the proper transfer of samples from the field to the laboratories:

<u>At the sample collection site:</u>

1. Appropriately document all samples using a logbook (see SOP GEN-01), the required sample container identification (i.e., sample labels and sample tags), and a chain-of-custody record/sample analysis request (COC/SAR) form (example provided in Attachment GEN-03-1). Fill out the COC/SAR form as described in SOP GEN-02.

2. Make sure all applicable laboratory quality control sample designations have been made on the COC/SAR form. Samples that will be archived for future possible analysis should be clearly identified on the COC/SAR form by noting the following: "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. Clean the gross contamination from the outside of all dirty sample containers to remove any residual material that may lead to cross-contamination.

4. Store each sample container in an individual sealable plastic bag that allows the sample label (example provided in Attachment GEN-03-1) to be read. Volatile organic analyte (VOA) vials for a single sample must be encased in bubble wrap before being sealed in bags.

5. 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.

<u>At the sample processing area (immediately after sample collection):</u>

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. Samples will be placed in secure storage (i.e., locked room or vehicle) or remain in the possession of Exponent sampling personnel until they are shipped to maintain sample integrity and chain-of-custody requirements.

4. Samples should be stored in the dark (e.g., coolers kept shut).

At the sample processing area (just prior to shipping):

1. Check sample containers against the COC/SAR 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 to prevent leakage.

3. The cooler should be lined with bubble wrap and a large plastic bag should be 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. 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 the samples have a required storage temperature, add enough 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 to fill any empty space to keep the samples from shifting during transport.

6. If possible, consolidate all VOA samples in a single cooler and ship them with (a) trip blank(s) if the quality assurance project plan calls for one.

7. If temperature blanks have been provided by the testing laboratory, include one temperature blank in each sample cooler.

8. Sign, date, and include any tracking numbers provided by the shipper on the COC/SAR form. Remove the back copy of the original COC/SAR form and retain this copy for the project records.

9. Place the rest of the signed COC/SAR 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/SAR 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/SAR 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 GEN-03-1). One seal should be placed on the front of the cooler and one seal should be placed on the side of the cooler opposite the first seal. 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.

12. 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.

13. If an overnight courier is used, fill out the airbill as required and fasten it to either the top of the cooler or to handle tags provided by the shipper. In addition to the adhesive backing on many airbills, the airbill and/or mailing label should also be taped to the lid, because tracking problems can occur if a sticker is removed during shipment.

14. 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. Exponent has arranged with CHEM-TEL (813-248-0573) to provide advisory services (i.e., information on how to label, ship, and package chemicals) for "restricted articles" (e.g., dry ice).

15. 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. Exponent has arranged with CHEM-TEL (813-248-0573) to provide advisory services (i.e.,

information on how to label, ship, and package chemicals) for "restricted articles" (e.g., formalin).

16. If samples are shipped that contain "restricted articles" (e.g., dry ice, formalin), then Exponent personnel must provide a 24-hour emergency number to the shipper. Exponent has arranged with CHEM-TEL to provide a 24-hour emergency contact number for all chemical shipments. Before shipping chemicals (and listing the CHEM-TEL emergency number), Exponent personnel must FAX the shipping document (manifest, declaration of dangerous goods, etc.) to CHEM-TEL informing them of the shipment. The fax number is 813-248-0581.

    For any shipment (air, rail, sea, or ground) within the United States, Canada, Puerto Rico, and the U.S. Virgin Islands, the telephone number to include on the shipping form is 1-800-255-3924. Any shipment outside the North American continent should reference "813-248-0573 (use the AT&T collect call operator)" on the shipping document. On the shipping documents, remember to indicate that the phone number specified is an emergency response contact number.

17. Notify the laboratory contact and the Exponent 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. If possible, fax copies of all chain-of-custody record/sample analysis request forms to the Exponent QA/QC coordinator. **Note:** Prior to faxing, it may be necessary to Xerox the COC/SAR form on a slightly darker setting so that the form is readable after it has been faxed. Never leave the original COC/SAR form in the custody of non-Exponent staff.

ATTACHMENT GEN-03-1

Example Chain-of-Custody Record/Sample Analysis Request Form, and Label and Custody Seal

CHAIN OF CUSTODY RECORD/SAMPLE ANALYSIS REQUEST FORM

Page ____ of ____

Project:
(Name and Number)

Exponent Environmental Group

Bellevue, WA (425) 643-9803
Boulder, CO (303) 444-7270
Lake Oswego, OR (503) 636-4338
Los Angeles, CA (310) 823-2035
Natick, MA (508) 652-8500

Exponent Contact: _____ Office: _____

Ship to: _____

Lab Contact/Phone: _____

Samplers:

Sample No.	Tag No.	Date	Time	Matrix	Analyses Requested						Extra Container	Archive	Remarks

Matrix Code: GW - Groundwater SL - Soil SD - Sediment SW - Surface water

OTHER - Please identify codes _____

Priority: ☐ Normal ☐ Rush Rush time period _____

Shipped via: ☐ FedEx/UPS ☐ Courier Other _____

Condition of Samples Upon Receipt: _____

Custody Seal Intact: ☐ Yes ☐ No ☐ None

Relinquished by: _____ (Signature) Date/Time: _____ Received by: _____ (Signature) Date/Time: _____

Relinquished by: _____ (Signature) Date/Time: _____ Received by: _____ (Signature) Date/Time: _____

Distribution: White and Yellow Copies - Accompany Shipment; Pink Copy - Project File

Chain-of-custody/sample analysis request form.

SOP 05/31/02 WA

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OFFICIAL SAMPLE SEAL

SAMPLE NO.	DATE
SIGNATURE	
PRINT NAME AND TITLE	

Exponent®

SAMPLE NO.

SITE NAME

DATE TIME

SAMPLER PRESERVATIVE

TAG NO. 25101

Example label and custody seal.

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SOP SD-01
DECONTAMINATION OF EQUIPMENT—SEDIMENTS

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, and rinsate blanks will be collected according to SOP SD-02, *Preparation of Field Quality Control Samples—Sediment*. 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 decontaminating sampling and processing equipment contaminated by either inorganic or organic materials. Sampling equipment (e.g., van Veen, Ekman, Ponar, core tubes) used for both analyte groups follow the decontamination order of a detergent wash, site water rinse, organic solvent rinses, and final site water rinse. Sample processing equipment (e.g., bowls, spoons) should have a final distilled/deionized water rinse instead of a site water rinse. If the surface of stainless steel equipment appears to be rusting (possibly due to prolonged contact with organic-rich sediment), it should be given an acid and site water rinse at the end of each sampling day to minimize corrosion.

EQUIPMENT REQUIRED

Equipment required for decontamination includes the following:

- Polyethylene or polypropylene tub (to collect solvent rinsate)
- Plastic bucket(s) (e.g., 5-gal- bucket)
- Tap water or site water
- Carboy, distilled/deionized water (analyte-free; received from testing laboratory or other reliable source)
- Properly labeled squirt bottles
- Funnels
- Alconox®, Liquinox®, or equivalent industrial detergent
- Pesticide-grade ethanol and heptane (consult the project-specific field sampling plan [FSP], as the solvents may vary by EPA region or state)

- 10 percent (v/v) nitric acid (reagent grade) for inorganic contaminants
- Baking soda
- Long handled, hard-bristle brushes
- Extension arm for cleaning core liners
- Plastic sheeting, garbage bags, and aluminum foil
- Core liner caps or plastic wrap and rubber bands
- Personal protective equipment as specified in the health and safety plan.

DECONTAMINATION PROCEDURES FOR FULL SUITE ANALYSIS (ORGANIC, METAL, AND CONVENTIONAL ANALYTES)

Two organic solvents are used in this procedure. The first is miscible with water (e.g., ethanol) and is intended to scavenge water from the surface of the sampling equipment and allow the equipment to dry quickly. This allows the second solvent to fully contact the surface of the sampler. Make sure that the solvent ordered is anhydrous or has a very low water content (i.e., < 1 percent). If ethanol is used, make sure that the denaturing agent in the alcohol is not an analyte in the samples. The second organic solvent is hydrophobic (e.g., heptane) and is intended to dissolve any organic chemicals that are on the surface of the equipment.

The exact solvents used for a given project may vary by EPA region or state (see project-specific FSP). Exponent uses ethanol and heptane as preferred solvents for equipment decontamination. If specified in the project-specific FSP, isopropanol and acetone can be substituted for ethanol, and hexane and methanol can be substituted for heptane in the decontamination sequence. The choice of solvents is also dependent on the kind of material from which the equipment is made (e.g., acetone cannot be used on polycarbonate), and the ambient temperature (e.g., hexane is too volatile in hot climates). In addition, although methanol and hexane are sometimes slightly more effective than other solvents, their use is discouraged due to toxicity to sampling personnel.

The specific procedures for decontaminating sediment sampling equipment and sediment compositing equipment are as follows:

1. Rinse the equipment thoroughly with tap or site water to remove visible sediment. This step should be performed onsite for all equipment, including core liners that will not be used again until the next day of sampling. After removing visible solids, sampling equipment that does not need to be used again that day may be set aside and thoroughly cleaned in the field laboratory at the end of the day.
2. Pour a small amount of concentrated laboratory detergent into a bucket (i.e., about 1–2 tablespoons per 5-gal bucket) and fill it halfway with tap or

site water. If the detergent is in crystal form, all crystals should be completely dissolved prior to use.

3. Scrub the equipment in the detergent solution using a long-handled brush with rigid bristles. For the polycarbonate core liners, use a round brush attached to an extension arm to reach the entire inside of the liners, scrubbing with a back-and-forth motion. Be sure to clean the outside of core liners, bowls, and other pieces that may be covered with sediment.
4. Double rinse the equipment with tap or site water and set right-side-up on a stable surface to drain. The more completely the equipment drains, the less solvent will be needed in the next step. Do not allow any surface that will come in contact with the sample to touch any contaminated surface.
5. If the surface of stainless steel equipment appears to be rusting (this will occur during prolonged use in anoxic marine sediments), the surface requires passivation. Otherwise skip to next step. Using a 10 percent (v/v) nitric acid solution, rinse using a squirt bottle, or wipe all surfaces using a saturated paper towel. Areas showing rust may require some rubbing with the paper towel. If using a squirt bottle, let the excess acid drain into the waste container (which may need to be equipped with a funnel). Double-rinse equipment with tap or site water and set right-side-up on a stable surface to drain thoroughly.
6. Carefully rinse the equipment with ethanol from a squirt bottle, and let the excess solvent drain into a waste container (which may need to be equipped with a funnel). These solvents act primarily as a drying agent by scavenging water from the equipment surface and carrying it away, but they also work as a solvent for some organic contamination. Core liners must be held over the waste container and turned slowly so the stream of solvent contacts all of the surface. The sample apparatus (e.g., grab sampler) may be turned on its side and opened to be washed more effectively. Set the equipment in a clean location and allow it to air dry. Use only enough solvent to scavenge all of the water and flow off the surface of the equipment (i.e., establish sheet flow) into the waste container. Allow equipment to drain as much as possible. Ideally, the equipment will be dry. The more thoroughly it drains, the less solvent will be needed in the next step.
7. Carefully rinse the drained or air-dried equipment with heptane from a squirt bottle, and let the excess solvent drain into the waste container (which may need to be equipped with a funnel). The opening of the squirt bottle may need to be widened to allow enough solvent to run through the core liners without evaporating. Heptane acts as the primary solvent of organic chemicals. Ethanol is soluble in heptane but water is not. If water beading occurs, it means that the equipment was not thoroughly rinsed with ethanol or that the ethanol that was purchased was not free of water. When the equipment has been rinsed with heptane, set it in a clean location and allow the heptane to evaporate before using the equipment for sampling. Use only

enough solvent to scavenge all of the ethanol and flow off the surface of the equipment (i.e., establish sheet flow) into the waste container.

8. The final rinse is with site water for the sampling equipment (i.e., van Veen, Ekman, Ponar, core tubes) and distilled/deionized water for processing equipment (i.e., stainless-steel bowls and spoons). Equipment does not need to be dried before use.
9. If the decontaminated sampling equipment is not to be used immediately, wrap small stainless-steel items in aluminum foil (dull side facing the cleaned area). Seal the polycarbonate core liners at both ends with either core caps or cellophane plastic and rubber bands. Close the jaws of the Ekman and Ponar grab samplers and wrap in aluminum foil.
10. If the sample collection or processing equipment is cleaned at the field laboratory and transported to the site, then the decontaminated equipment will be wrapped in aluminum foil (dull side facing the cleaned area) and stored and transported in a clean plastic bag (e.g., a trash bag) until ready for use, unless the project-specific FSP lists special handling procedures.
11. Rinse or wipe with a wetted paper towel all stainless-steel equipment at the end of each sampling day with 10 percent (v/v) normal nitric acid solution. Follow with a freshwater rinse (site water is okay as long as it is not brackish or salt water).

After decontaminating all of the sampling equipment, the disposable gloves and used foil will be placed in garbage bags and disposed of in a solid waste landfill. When not in use, keep the waste solvent container closed and store in a secure area. The waste should be transferred to empty solvent bottles and disposed of at a licensed facility per the procedures listed in the project-specific FSP. When not in use, keep the waste acid container closed and store in a secure area. The acid waste should be neutralized with baking soda and disposed of per the procedures listed in the project-specific FSP.

DECONTAMINATION PROCEDURES FOR METAL AND CONVENTIONAL ANALYTES ONLY

The specific procedures for decontaminating sediment sampling equipment and sediment processing equipment are as follows:

1. Rinse the equipment thoroughly with tap or site water to remove the visible sediment. This step should be performed onsite for all equipment, including core liners that will not be used again until the next day of sampling. Pieces that do not need to be used again that day may be set aside and thoroughly cleaned in the field laboratory at the end of the day.
2. Pour a small amount of concentrated laboratory detergent into a bucket (i.e., about 1–2 tablespoons per 5-gal bucket) and fill it halfway with tap

or site water. If the detergent is in crystal form, all crystals should be completely dissolved prior to use.

3. Scrub the equipment in the detergent solution using a long-handled brush with rigid bristles. For the polycarbonate core liners, use a round brush attached to an extension arm to reach the entire inside of the liners, scrubbing with a back-and-forth motion. Be sure to clean the outside of core liners, bowls, and other pieces that may be covered with sediment.
4. Double-rinse the equipment with tap or site water and set right-side-up on a stable surface to drain. Do not allow any surface that will come in contact with the sample to touch any contaminated surface.
5. If the surface of stainless steel equipment appears to be rusting (this will occur during prolonged use in anoxic marine sediments), the surface requires passivation. Using a 10 percent (v/v) nitric acid solution, rinse using a squirt bottle, or wipe all surfaces using a saturated paper towel. Areas showing rust may require some rubbing with the paper towel. If using a squirt bottle, let the excess acid drain into the waste container (which may need to be equipped with a funnel). Double-rinse sampling equipment with tap or site water and set right-side-up on a stable surface to drain. Double-rinse processing equipment with distilled/deionized water and allow to drain.
6. If the decontaminated sampling equipment is not to be used immediately, wrap small stainless-steel items in aluminum foil (dull side facing the cleaned area). Seal the polycarbonate core liners at both ends with either core caps or cellophane plastic and rubber bands. Close the jaws of the Ekman and Ponar grab samplers and wrap in aluminum foil.
7. If the sample collecting or processing equipment is cleaned at the field laboratory and transported to the site, then the decontaminated equipment will be wrapped in aluminum foil (dull side facing the cleaned area) and stored and transported in a clean plastic bag until ready for use, unless the project-specific FSP lists special handling procedures.

After decontaminating all of the sampling equipment, the disposable gloves and used foil will be placed in garbage bags and disposed of in a solid waste landfill. When not in use, keep the waste acid container closed and store in a secure area. The acid waste should be neutralized with baking soda and disposed of per the procedures listed in the project-specific FSP.

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SOP SD-02
PREPARATION OF FIELD QUALITY CONTROL SAMPLES—SEDIMENT

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, Exponent'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.

All field quality control samples will be packaged and shipped with other samples in accordance with procedures outlined in SOP GEN-03, *Sample Packaging and Shipping*. Sample custody will be maintained in accordance with procedures outlined in SOP GEN-02, *Sample Custody*.

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.

Table SD-02-1 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 SD-02-1. FIELD QUALITY CONTROL SAMPLE REQUIREMENTS FOR SEDIMENT SAMPLING

Quality Control sample Name	Abbre-viation	Preparation		Frequency[a]
		Location	Method	
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 VOC 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 per SOP GEN-03.

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 per SOP GEN-03.

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). Details on preparation of the standard reference materials can be found in SOP SD-03, *Preparation of Reference Materials—Sediment*.

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SOP SD-04
SURFACE SEDIMENT SAMPLING USING A MODIFIED VAN VEEN GRAB SAMPLER

This SOP describes the procedures used to collect surface sediment with a modified van Veen grab sampler. For the purposes of this SOP, surface sediment is defined as the upper 10 cm of the sediment column, but may vary given the sampling interval specified in the study design. The specific sampling interval will be specified in the project-specific field sampling plan (FSP). Surface sediment is typically analyzed for various physical and chemical variables so the sampling equipment and sampling procedures must be compatible with all analyses.

A modified stainless-steel van Veen grab sampler is capable of collecting acceptable samples from a variety of substrates, such as mud, sand, gravel, and pebbles (APHA 1989; U.S. EPA 2001). The modified van Veen grab sampler incorporates several design improvements over the traditional van Veen grab sampler, which improve the quality of the sediment samples. The modified grab sampler has two doors on top to allow easy access to the sample for visual characterization and subsampling of undisturbed surface sediments. The interiors of the doors are made of screens to minimize the bow wake and the resulting disturbance of the sediment surface when the grab sampler is lowered to the bottom. Rubber flaps cover each screen as the grab sampler is retrieved to prevent disturbing the sediment sample as it is raised through the water column. The arms of the modified grab sampler are lengthened and arced to provide a stronger seal when the grab sampler is closed, thereby minimizing sample leakage when the grab sample is retrieved. Finally, the modified grab sampler has four detachable, epoxy-coated lead weights that allow the weight and penetration of the grab sampler to be optimized with respect to the kind of sediment being sampled. The procedures for collecting surface sediment samples using the modified van Veen grab sampler are described below.

EQUIPMENT AND SUPPLIES REQUIRED

Equipment required for sediment sampling using the van Veen grab sampler includes the following:

- Stainless-steel van Veen grab sampler (typically 0.06 m^2 or 0.1 m^2) and spare parts
- Winch and hydrowire (with load capacities ≥3 times the weight of a full sampler)
- Sample collection table

- Teflon® or polyethylene siphon (inner diameter = 1.27 cm, length = 60–90 cm)
- Stainless-steel ruler
- Stainless-steel spoons/spatulas
- Stainless-steel mixing bowl or pot
- Socket and crescent wrenches (for adding or removing the detachable weights of the grab sampler)
- Water pump and hose (for rinsing the grab sampler, sampling utensils, and sample collection table).

DECONTAMINATION

To prevent potential cross-contamination of samples, all reusable sediment sampling equipment must be decontaminated. Before each station is sampled, decontaminate the inner surfaces of the grab sampler and all stainless-steel sample compositing equipment. Details on correct decontamination procedures can be found in SOP SD-01, *Decontamination of Equipment—Sediment*. The project-specific FSP should also be consulted to determine any project-specific decontamination procedures. The personnel performing the decontamination procedures will wear protective clothing as specified in the site-specific health and safety plan.

All solvent rinsates (if used) will be collected into a bucket or tub and allowed to evaporate over the course of the day. Any rinsate that has not evaporated by the end of the sampling event will be containerized and disposed of in accordance with applicable regulations.

GRAB SAMPLER DEPLOYMENT

1. Attach the grab sampler to the hydrowire with a swivel. The swivel minimizes the twisting forces on the sampler during deployment and ensures that proper contact is made with the bottom. For safety, the hydrowire, swivel, and all shackles should have a load capacity at least 3 times the weight of a full sampler.
2. Place the decontaminated grab sampler on a clean surface (i.e., the sample collection table) and open it.
3. Ensure that the two release chains and the two retrieval chains are hanging free and are not wrapped around the arms of the sampler.
4. Ensure that all doors are firmly latched shut.

5. Attach the ring of the release chains to the release mechanism, and insert the safety pin to prevent the mechanism from being activated prematurely.

6. Start the winch, raise the release mechanism and the sampler, and swing it outboard.

7. Remove the safety pin from the trigger, and lower the sampler through the water column at a slow and steady speed (e.g., 30 cm/second).

8. Allow the grab sampler to contact the bottom gently, with only its weight being used to force it into the sediments. The sampler should never be allowed to "free fall" to the bottom because this may result in premature triggering, an excessive bow wake, or improper orientation upon contact with the bottom.

9. Allow approximately 60 cm of slack in the hydrowire after contact with the bottom is made to ensure that the release mechanism is activated.

GRAB RETRIEVAL

1. After the grab sampler has rested on the bottom for approximately 5 seconds, begin retrieving it at a slow and steady rate (e.g., 30 cm/second). Note: The amount of time that the grab sampler rests on the bottom is dependent upon the kind of substrate (e.g., sediment with a high moisture content will require less time on the bottom to avoid over-penetration).

2. Ensure that the sampling vessel is not headed into any waves before the sampler breaks the water surface to minimize vessel rolling and potential sample disturbance.

3. Care must be taken to avoid loss of fine-grained surface sediments, mixing of sediment layers upon impact, lack of sediment penetration, and loss of sediment from tilting or washout upon ascent.

4. After the grab sampler breaks the water surface and is raised above the height of the sample collection table, swing the grab sampler inboard, keep the sampler in an upright position and gently lower it onto the table, maintaining tension on the hydrowire to prevent the grab sampler from rolling when it contacts the table. Avoid quick movements of the sampler, especially rotation, as this could disrupt the interface.

5. When the grab sampler contacts the table, insert wedges under both jaws so that the grab sampler will be held in an upright position when tension on the hydrowire is relaxed.

6. Relax the tension on the hydrowire, and remove the release and retrieval chains from the surface of the grab sampler.

7. As soon as the grab sampler is secured, open the doors on the top of the grab sampler, and inspect the sample for acceptability. The following acceptability criteria should be satisfied:

   - The sampler is not overfilled with sample to the point that the sediment surface presses against the top of the sampler or is extruded through the top of the sampler
   - Overlying water is present (indicating minimal leakage)
   - The overlying water is not excessively turbid (indicating minimal disturbance of the interface or winnowing)
   - The sediment surface is relatively undisturbed; the sediment-water interface is intact and relatively flat with no sign of channelling or sample washout
   - The desired penetration depth is achieved
   - There is no sign of sediment loss (incomplete closure of the sampler, penetration at an angle, or tilting upon retrieval).

If a sample fails to meet the above criteria, it will be rejected and discarded away from the station. The locations of consecutive attempts and replicate samples (if any) should be as close to the first sample as possible, and if sampling on a river or stream, consecutive attempts should be located upstream of previous samples. Rejected sediment samples should be discarded in a manner that will not affect subsequent samples at that station or other possible sampling stations.

Penetration depth should be determined with a decontaminated stainless-steel ruler by measuring the distance from the top of the sampler to the sediment interface and subtracting this from the inside depth of the sampler. If the sample is fairly level inside the sampler, this measurement can be made at one edge. If the sample is uneven but has an intact interface, then measurements should be made on opposite edges of the sample and the average value used. This observation (i.e., that the sediment surface is slanted) and subsequent calculation of the average penetration depth should be recorded in the field logbook. If penetration depth is inadequate, add auxiliary weights.

SAMPLE REMOVAL AND PROCESSING

1. For acceptable samples, remove the overlying water by slowly siphoning it off near one or more sides of the grab sampler. Ensure that the siphon does not contact the sediments or that fine-grained suspended sediment is not siphoned off. If sediment is suspended in the overlying water, do not proceed with siphoning until the sediment is allowed sufficient time to settle.

2. After the overlying water is removed, characterize the sample as specified in the study design. Characteristics that are often recorded in the field logbook include:

   – Sediment type (e.g., silt, sand)

   – Texture (e.g., fine-grain, coarse, poorly sorted sand)

   – Color

   – Presence/location/thickness of the redox potential boundaries (a visual indication of black is often adequate for documenting anoxia)

   – Approximate percentage of water

   – Presence of biological structures (e.g., amphipods, tubes, macrophytes)

   – Approximate percentage of biological structures

   – Presence of debris (e.g., twigs, leaves)

   – Approximate percentage of organic debris

   – Presence of shells

   – Approximate percentage of shells

   – Stratification, if any

   – Presence of a sheen

   – Odor (e.g., hydrogen sulfide, oil, creosote).

3. After the sample is characterized, remove the top 10 cm using a stainless-steel spatula or spoon (see project-specific FSP for correct sampling interval). Unrepresentative material (e.g., large shells, stones) should be carefully removed without touching the sediment sample, under the supervision of the field team leader. This removal should be noted in the field logbook.

4. Remove subsamples for analysis of unstable constituents (e.g., volatile organic compounds, acid-volatile sulfides), and place them directly into sample containers without homogenization. Sediment must be placed in these containers with no headspace and no entrapped bubbles (i.e., completely fill the sample container).

5. Transfer the remaining surface sediment to a stainless-steel mixing bowl or pot for homogenization. Additional grab samples may be required to collect the volume of sediment specified in the study design. If it is necessary to collect additional grab samples to meet the project-specific volume

requirements, the mixing bowl or pot should be covered with aluminum foil (dull side down) to prevent sample contamination (e.g., from precipitation, splashing water) and placed out of the sun and away from heat.

6. After the surface sediment for a sample has been collected from the grab sampler, move the sampling vessel away from the station, open the jaws of the grab sampler, attach the ring of the deployment chains to the release mechanism, insert the safety pin, start the winch, raise the grab sampler, and allow the remainder of the sediment sample to fall onto the sample collection table or into waste sediment collection buckets/tubs. Discard this material away from the station, and rinse away any sediment adhering to the inside of the grab sampler. The grab sampler is now ready for additional sampling at the same station or decontamination before sampling at a new station.

7. After a sufficient volume of sediment is transferred to the mixing bowl or pot, homogenize the contents of the bowl or pot using stainless-steel spoons until the texture and color of the sediment appears to be uniform.

8. After the sample is homogenized, distribute subsamples to the various containers specified in the study design and preserve the samples as specified in the study design. The sediment in the mixing bowl or pot should be briefly stirred in between the transfer of sediment to each sample container.

9. After all sediment for testing has been placed in the sample containers, if it is suspected that there is a clay component to the sediment, a "ribbon test" should be performed on the sediment to confirm this suspicion. In this "texture-by-feel" test, a small piece of suspected clay is rolled between the fingers while wearing protective gloves. If the piece easily rolls into a ribbon it is clay; if it breaks apart, it is silt. This information should be noted in the field logbook.

FIELD QUALITY CONTROL SAMPLES

Details on collection of field quality control samples and preparation of the certified reference materials can be found in SOP SD-02, *Preparation of Field Quality Control Samples—Sediment* and SOP SD-03, *Preparation of Reference Materials—Sediment*. Not all of the field quality control samples discussed in these SOPs may be required for a given project. The specific field quality control samples will be described in the project-specific FSP and quality assurance project plan (QAPP).

FIELD MEASUREMENTS

A water depth measurement must be collected at every sampling location. For sites where tides affect water depth, the time of collection and depth measurement must be recorded simultaneously. Depending on the specific project objectives, it may be necessary to perform

field measurements of the *in situ* environment. Possible field measurements include temperature and pH of the sediment at the sediment-water interface and concentration of dissolved oxygen, salinity, or conductivity in the overlying water. Details on collection of field measurements can be found in SOP SD-11, *Field Analyses for Sediment.* Required field measurements, if any, will be specified in the project-specific FSP.

STATION LOCATION COORDINATES

Station locations will be determined in accordance with the project-specific FSP. Generally, station locations for all field sampling will be determined using a differential global positioning system (DGPS), which is capable of providing latitude and longitude coordinates with an accuracy of approximately 2 m. The DGPS consists of two satellite receivers linked to each other by a VHF telemetry radio system. The GPS receiver will be on the sampling vessel and positioned above where the grab sampler is deployed. Details on collection of field station coordinates can be found in SOP GEN-04, *Station Positioning Using the Trimble Pathfinder Pro XRS*.

REFERENCES AND OTHER SOURCES

APHA. 1989. Standard methods for the examination of water and waste water. Seventeenth Edition. Prepared and published by American Public Health Association, the American Water Works Association, and the Water Pollutant Control Federation.

U.S. EPA. 2001. Methods for collection, storage, and manipulation of sediments for chemical and toxicological analyses: Technical Manual. EPA-823-B-01-002. U.S. Environmental Protection Agency, Office of Water, Office of Science & Technology, Washington, DC.

Appendix B

Example Field Forms

CHAIN OF CUSTODY RECORD/SAMPLE ANALYSIS REQUEST FORM

Page ____ of ____

Project:
(Name and Number)

Exponent Environmental Group

Bellevue, WA (425) 643-9803
Boulder, CO (303) 444-7270
Lake Oswego, OR (503) 636-4338
Los Angeles, CA (310) 823-2035
Natick, MA (508) 652-8500

Exponent Contact: _____ Office: _____

Ship to: _____

Lab Contact/Phone: _____

Samplers:

Sample No.	Tag No.	Date	Time	Matrix	Analyses Requested						Extra Container	Archive	Remarks

Matrix Code: GW - Groundwater SL - Soil SD - Sediment SW - Surface water

OTHER - Please identify codes _____

Priority: ☐ Normal ☐ Rush Rush time period _____

Shipped via: ☐ FedEx/UPS ☐ Courier Other _____

Condition of Samples Upon Receipt: _____

Custody Seal Intact: ☐ Yes ☐ No ☐ None

Relinquished by: _____ (Signature) Date/Time: _____ Received by: _____ (Signature) Date/Time: _____

Relinquished by: _____ (Signature) Date/Time: _____ Received by: _____ (Signature) Date/Time: _____

Distribution: White and Yellow Copies - Accompany Shipment; Pink Copy - Project File

Chain-of-custody/sample analysis request form.

SOP 05/31/02 WA

Exponent®

OFFICIAL SAMPLE SEAL

SAMPLE NO.	DATE
SIGNATURE	
PRINT NAME AND TITLE	

Exponent®

SAMPLE NO.

SITE NAME

DATE TIME

SAMPLER PRESERVATIVE

TAG NO. 25101

Example label and custody seal.

Appendix C

Health and Safety Plan

Exponent™

HEALTH AND SAFETY PLAN

Site Name San Diego Shipyards (NASSCO and BAE) Contract No. _____

Proposed Activity Post-Remediation Sediment Sampling

Prepared by Sheryl Law Date TBD

Reviewed by TBD Date TBD

1. INTRODUCTION

This site-specific health and safety plan, in conjunction with the Corporate Health and Safety Program, establishes procedures and practices to protect employees of Exponent and its subcontractors from potential hazards posed by field activities at National Steel and Shipbuilding Company (NASSCO) and Southwest Marine shipyards in San Diego, California. In this health and safety plan, measures are provided to minimize potential exposures, accidents, and physical injuries that may occur during daily onsite activities and adverse conditions. Contingency arrangements are also provided for emergency situations.

2. DISCLAIMER

Exponent cannot guarantee the health or safety of any person entering this site. Because of the potentially hazardous nature of this site and the activity occurring thereon, it is not possible to discover, evaluate, and provide protection for all possible hazards that may be encountered. Strict adherence to the health and safety guidelines set forth herein will reduce, but not eliminate, the potential for injury and illness at this site. The health and safety guidelines in this plan were prepared specifically for this site and should not be used on any other site without prior evaluation by trained health and safety personnel.

3. SITE DESCRIPTION

Site name: San Diego Shipyards

Site location or address: Harbor Drive and 28th Street (NASSCO) and Foot of Sampson Street (Southwest Marine)

San Diego, California 92113

Owners/tenants: NASSCO/BAE

Current site use: Marine bay adjacent to active shipyards in San Diego Bay

Past site use (if different): _____

Designated hazardous waste site: No (federal, state, other) _____

Industrial facility _____ Spill _____ Other Marine waters and sediment

Active X Inactive _____

Topography: 126 total acres of tidal property, including 46 acres of water area for NASSCO; 41 total acres of tidal property, including 21 acres of water area for BAE.

Name of and distance to nearest surface water body: Site is in San Diego Bay.

Surrounding land use/nearest population: Shipyards/City of San Diego

Site access: Via sampling vessel.

Nearest drinking water/sanitary facilities: On the sampling vessel and at the shipyards.

Nearest telephone (list number if possible): Cellular phones

All buried utilities must be located prior to drilling or excavating at the site. List procedures to be used to locate utilities or indicate that no subsurface excavation or sampling will occur:

No subsurface sampling will occur

Site map attached: Yes.

4. PROJECT PERSONNEL

	Name/Affiliation	Work Telephone	Home Telephone
Project manager	Tom Ginn	(928) 282-3168	(623) 256-0624
Field team leader	Rick Bodishbaugh	(425) 922-5423	(425) 922-5423
Site safety officer	Rick Bodishbaugh	(425) 922-5423	(425) 922-5423
Exponent field personnel			
Facility contact	Mike Chee (NASSCO)/ Shaun Halvax (BAE)	(619) 544-7778/ (619) 572-6477	(619) 544-7778/ (619) 572-6477
Client contact (if different)			

5. WORK PROPOSED

Description of proposed work: In this supplemental sampling, the collection of surface sediment samples for chemical analysis, toxicity testing, and benthic invertebrate identification and enumeration will be conducted.

Proposed work dates: TBD

Subcontractors	Name	Task	Contact	Telephone
	TBD	Sampling	TBD	TBD

6. HAZARD EVALUATION

Potentially hazardous chemicals known or suspected to be onsite (include preservatives and decontamination chemicals):

Chemical of Concern	Concentration (observed or expected)	Medium	OSHA PEL	OSHA STEL	OSHA IDLH	Odor Threshold	IP(eV)	Carcinogen or Other Hazard
PCBs (as Aroclor® 1254)	Total PCBs = 0.1–3 ppm	sediment	0.5 mg/m^3 (skin)	--	5 mg/m^3	NA	?	C
Acetone	product	decon	1,000 ppm	--	2,500 ppm (10% LEL)	13–100 ppm	9.69	flammable
Hexane	product	decon	500 ppm	50 ppm	1,100 ppm (10% LEL)	130 ppm	10.18	flammable
Formalin	10 percent	preserva-tive	0.75 ppm	2 ppm	20 ppm	0.027–9,770 ppm	10.88	C,P combustible, reactive

Note:
- -- - none established
- C - carcinogen
- IDLH - immediately dangerous to life and health
- IP(eV) - ionization potential
- N/A - not applicable
- NA - not available
- P - poison
- PCB - polychlorinated biphenyl
- PEL - permissible exposure level
- SC - suspected carcinogen
- STEL - short-term exposure level

	Known	Possible	Unlikely
Potential chemical exposure routes at the site:			
Inhalation	X (decon chemicals and preservative)		X (sediment)
Ingestion		X	
Skin absorption		X	
Skin contact		X	
Eye contact		X	
Chemical characteristics:			
Corrosive			X
Ignitable	X (decon chemicals and preservative)		X (sediment)
Reactive	X (acetone and preservative)		X (sediment)
Volatile	X (decon chemicals and preservative)		X (sediment)
Radioactive			X
Explosive			X
Biological agent			X

	Known	Possible	Unlikely
Particulates or fibers			X

If known or likely, describe: Acetone, hexane, and formalin are volatile, and field personnel will stand upwind when using chemicals. These chemicals will not be used unless area is well ventilated.

Possible physical hazards present during site activities:

	Yes	No	Proposed Safety Procedure
Uneven terrain/tripping	X		Keep decks clear, exercise caution, wear properly fitting boots
Heat stress	X		Follow HS-03
Cold/hypothermia		X	
Drowning	X		Wear personal flotation devices when working over the water – follow HS-04.
Falling objects	X		Wear hard hats near overhead hazards (i.e., winch)
Noise		X	
Excavations		X	
Scaffolding		X	
Heavy equipment	X		Stay back from operating equipment (i.e., winch), wear hard hat, coordinate with operator, exercise caution
Material handling	X		Lift properly, do not overload coolers; seek help when moving heavy items.
Compressed air equipment		X	
Confined spaces		X	
Adverse weather	X		Seek shelter during electrical storms; work in adverse conditions only with proper training and equipment
Work in remote areas		X	
Biohazard		X	
Plant/animal hazards		X	
Other Vessel operations	X		Review marine safety SOP HS-04.

Note: If confined space entry is required, personnel must first obtain a confined space entry permit.

Potential physical hazards posed by proposed site activities:

Activity	Potential Hazard
Sediment and invertebrate sampling	Heat; drowning; falling objects; slips, trips, and falls; material handling; adverse weather
Decon of sampling equipment	Dermatitis caused by skin contact with acetone, inhalation of acetone and hexane
Preserving of benthic invertebrate samples	Inhalation of formalin and dermal contact
Sample handling/mobilization	Material handling

7. PERSONAL PROTECTIVE EQUIPMENT

Based on the hazards identified above, the following personal protective equipment will be required for the following site activities (specify both an initial level of protection and a more protective level of protection in the event conditions should change):

	Level of Protection	
	Initial	**Contingency**
Sediment, SPI, pore water, invertebrate, and fish sampling	MD	Leave site
Benthic invertebrate preservation	MD	C
Sample handling	D	MD
Decon	MD	Leave site

Each level of protection will incorporate the following equipment (specify type of coveralls, boots, gloves, respiratory cartridges or other protection, safety glasses, hard hat, and hearing protection):

Level D: [X] Long pants/shirt, work shoes or boots, hard hat (near overhead hazard), safety glasses, nitrile and work gloves (as needed)

Modified D: [X] Same as D, with addition of coated Tyvek coveralls or raingear, and chemical resistant steel-toe boots. Silver shield gloves when handling decon solvents.

Level C: [X] Same as Modified D, with addition of full-face respirator with organic vapor cartridges during chemical decon (only when cross wind or otherwise suitable ventilation is not possible).

Respirator/Respirator Cartridge Information

Is there potential for a respirator to be donned during fieldwork? Yes

If no, proceed to Section 8. If yes, the following section must be completed for each respirator/respirator cartridge combination that will be or potentially will be used during the course of the fieldwork. The Exponent Environmental Group health and safety manager can be contacted for resources to complete this section.

Respirator Manufacturer #1: MSA

Respirator Cartridge Selected for Use: Formaldehyde cartridge

Respirator Cartridge Change Schedule: The cartridge will be changed after 100 minutes of use.

Justify the cartridge change schedule and present all data used to establish this schedule.

Formalin will be added to the benthic invertebrate samples outdoors in a well ventilated area. It is anticipated that a respirator will not be needed for this activity. If, however, the site safety officer deter-

mines that the area is not properly ventilated, then a respirator will be worn for a very limited time while formalin is added to the sample containers. Based on MSA data, this cartridge will last for 3.4 hours (202 minutes) (see attached respirator test data sheet). The cartridge will be changed after 100 minutes of use.

Respirator Manufacturer #2	NA
Respirator Cartridge Selected for Use	NA
Respirator Cartridge Change Schedule	NA

Note: Project personnel are not permitted to deviate from the specified levels of protection without the prior approval of the site safety officer or Exponent Environmental Group health and safety manager.

8. SAFETY EQUIPMENT

The following safety equipment will be onsite during the proposed field activities:

Air Monitoring (check the items required for this project)

- [ ] PID
- [ ] CG/O_2 meter
- [ ] H_2S meter
- [ ] Detector pump and tubes
- [ ] Air sampling pumps
- [ ] Miniram
- [ ] Radiation meter
- [ ] Other: _____

First Aid Kit (mandatory, including adhesive band-aids, gauze, tape, gloves, CPR shield, triangle bandage)
(check additional items required for the site)

- [X] Emergency blanket
- [X] Insect repellent
- [X] Sunscreen
- [ ] Other: _____

Other (check the items required for this project)

- [X] Eyewash
- [X] Drinking water
- [X] Stopwatch for monitoring heart rate
- [X] Thermoscan thermometer for heat stress monitoring
- [ ] Survival kit
- [X] Personal flotation device
- [ ] Cool vests
- [ ] Fit test supplies
- [X] Fire extinguisher (ensure that the sampling vessel is equipped)
- [ ] Windsock
- [X] Cellular phone
- [ ] Radio
- [X] Global positioning system
- [ ] Other: _____

9. SITE CONTROL

Describe location and designation of each zone:

Exclusion zone: The aft deck (i.e., rear deck) of the sampling vessel will be considered to be the exclusion zone. Sample collection and processing will occur in this area. Only properly equipped and trained (i.e., wearing modified D protective clothing) personnel will be allowed in this area. The area will be washed with seawater between sample stations.

Contamination/reduction zone: Chemical decontamination will occur on the aft deck of the sampling vessel on the edge of the exclusion zone, away from other personnel, and in a cross breeze to minimize exposure to volatile decontamination chemicals and preservatives. The rest of the deck will be the contamination reduction zone. Decontamination, sample storage, and other support functions will occur in these areas.

Support zone: The pilot house will be the support zone. No chemical or sample handling activities will occur in this area. Personnel will be required to wash chemicals and sediment from raingear or Tyvek coveralls before entering this area.

Describe controls to be used to prevent entry by unauthorized persons:

No unauthorized personnel will be allowed on the sampling vessel.

10. AIR MONITORING

Air monitoring will be conducted when entering previously uncharacterized sites, when working in the vicinity of uncontaminated chemicals or spills, when opening containers and well casings, and prior to opening and entering confined spaces. Air monitoring must be conducted to identify potentially hazardous environments and determine reference or background concentrations. Air monitoring will be used to define exclusion zones. Air monitoring may also be conducted to evaluate the concentration of chemicals in samples.

The following equipment will be used to monitor air quality in the breathing zone during work activities:

Monitoring Instrument	Calibration Frequency	Parameters of Interest	Sampling Frequency

None. Previous monitoring (data in project file 8600A20.003 and 8600BCH.001) shows that the PEL for formaldehyde was never exceeded while preserving samples. Respirators will be provided if requested by staff, but monitoring data support the fact that there is no danger to exposure above the PEL. Volatile decon chemicals and preservative will be used outdoors to minimize exposure. Previous air monitoring projects have shown that when staff position themselves upwind of the decontamination chemical (acetone and hexane) exposures are below the PEL/TEL. No air monitoring will be performed for PCBs because the sediment will be wet and no dust will be generated.

The following action levels have been established to determine the appropriate level of personal protection to be used during site investigation activities:

Instrument	Reading	Action[a]	Comments
None			

[a] Examples: "upgrade to Level C" or "leave site."

11. DECONTAMINATION

To prevent the distribution of contaminants outside the exclusion zone or cross-contamination of samples, the following procedures will be used to decontaminate sampling equipment:

Sediment sampling equipment (i.e., van Veen grab sampler and core tube liners) will be decontaminated using the following general sequence: site water or tap water rinse, Alconox® scrub using site or tap water, site water or tap water rinse, solvent rinse with acetone and hexane (respectively), and a final site water rinse. Equipment used for compositing the sediment samples (i.e., stainless-steel bowls and spoons) for chemical analysis and toxicity testing will follow the same basic decontamination sequence, except that the final rinse will be with distilled/deionized water.

To prevent the distribution of contaminants outside the exclusion zone and personal exposure to chemicals, vehicles will not be allowed inside the exclusion zone. If vehicles are required in the exclusion zone (e.g., drill rigs), the following procedures will be used to prevent contamination or decontaminate the vehicles:

Chemicals and samples will be packaged in secure containers before placement in a vehicle or vessel pilot house. All sampling equipment and protective equipment will be decontaminated before placement in a vehicle or vessel pilot house.

To minimize or prevent personal exposure to hazardous materials, all personnel working in the exclusion zone and contamination reduction zones will comply with the following decontamination procedures:

All personnel will wash sediment and chemicals from their raingear or Tyvek coveralls before leaving the exclusion zone. All gloves, Tyvek, rain gear, and rubber boots will be removed prior to entering the rental vehicle.

Decontamination equipment required on site will include the following:

Scrub brushes, Alconox® buckets, distilled/deionized water, foil, hexane, acetone, plastic bags, paper towels, garbage bags, plastic tubs.

Decontamination wastewater and contaminated materials will be disposed of in the following manner:

Excess solvent rinsates will be collected in a plastic tub and allowed to evaporate during the course of the decontamination activity. Any rinsates that have not evaporated by the end of the decontamination activity will be containerized and disposed of appropriately.

The following personal hygiene practices will be used:

- Long hair will be secured away from the face so it does not interfere with any activities.
- All personnel leaving potentially contaminated areas will wash their hands and faces prior to entering any clean areas or eating areas.
- Personnel leaving potentially contaminated areas will shower (including washing hair) and change to clean clothing as soon as possible after leaving the site.
- No person will eat, drink, or chew gum or tobacco in potentially contaminated areas. Drink containers and drinking of replacement fluids for heat stress control will be permitted only in areas that are free from contamination. Smoking is prohibited in all areas of the site because of the potential for contaminating samples and for health and safety reasons.

12. VEHICLE SAFETY

Exponent's vehicle safety program requires the following:

- All vehicles are to be operated in a safe manner and in compliance with statutory traffic regulations and ordinances
- Operators are to practice defensive driving and drive in a courteous manner
- Operators are required to have a valid driver's license and liability insurance (per local state laws)
- Seat belts are to be worn by the driver and all passengers
- No persons are allowed to ride in the back of any trucks or vans
- Vehicles are to be driven in conformance with local speed limits
- Personnel who are impaired by fatigue, illness, alcohol, illegal or prescription drugs, or who are otherwise physically unfit, are not allowed to drive
- Personnel are to avoid using cellular phones or engaging in other distractions while driving
- All Exponent-owned field vehicles are to be maintained in a safe and clean condition
- All Exponent-owned field vehicles are to be equipped with the following:
  - First-aid kit
  - Fire extinguisher

- Flares
- Spare tire and jack
- Other equipment as required for the project (e.g., tire chains, towing cable, tools, cellular phone or radio)

- Motor vehicle accidents are to be reported to the responsible law enforcement agency, the Exponent Environmental Group risk manager, and the Exponent Environmental Group health and safety manager
- Employees who have experienced work-related vehicle accidents or citations may be required to complete a defensive driving program.

13. SPILL CONTAINMENT

Provisions must be made for spill containment at any site where bulk liquids will be handled.

Will the proposed fieldwork include the handling of bulk liquids, oil, or chemicals (other than water)? Yes _____ No X

If yes, describe spill containment provisions for the site: _____

14. SHIPMENT OF RESTRICTED ARTICLES

Federal laws and international guidelines place restrictions on what materials may be shipped by passenger and cargo aircraft. In the course of this field investigation, the following items will be shipped to and from the site in the following manner:

Item	Hazardous Constituent	Quantity	Packaging	How Shipped
Samples	None			No special procedures will be required
Solvents (name)	Acetone and hexane	1 gal each	Glass bottles protected against breakage in manufacturers' shipping containers or plastic bottle jackets	Shipped by chemical manufacturer directly to site.
Calibration gas (name)	None			
Preservatives (name)	Formalin	5 gal	Original package	Shipped by chemical manufacturer directly to site.
Other:	None			

Exponent has arranged with CHEM-TEL to provide a 24-hour emergency contact number for all chemical shipments. CHEM-TEL can also provide advisory services (i.e., information on how to label, ship, and package chemicals). EXPONENT PERSONNEL MUST PROVIDE THE 24-HOUR EMERGENCY NUMBER TO THE SHIPPER.

For ANY shipment (air, rail, sea, or ground) within the United States, Canada, Puerto Rico, and the U.S. Virgin Islands that requires a 24-hour emergency response number (on ANY documents, such as Uniform Hazardous Waste Manifests, Shipper's Declaration of Dangerous Goods, etc.), the telephone number to use is 1-800-255-3924. ANY shipment outside the North American continent should reference "813-248-0585 (Please call collect if necessary.)" on the document. Having international users call collect will ensure a bilingual operator is available to identify the call as an emergency. After accepting the call, if needed, CHEM-TEL will network with a translation service to prevent communication difficulties if the caller speaks a language other than English. On the shipping documents, please remember to indicate that the phone number specified is an emergency response contact number.

Before shipping chemicals (and listing the CHEM-TEL emergency number), Exponent personnel must fax the shipping document (manifest, declaration of dangerous goods, etc.) to CHEM-TEL informing them of the shipment. The fax number is 813-248-0581.

Regulatory advisory services are available from CHEM-TEL during business hours: 9 a.m. to 5:30 p.m. at 813-248-0573 (EST). This assistance can include determining the proper packaging, labeling, and shipping requirements for shipping hazardous substances.

15. MEDICAL MONITORING

OSHA requires medical monitoring for personnel potentially exposed to chemical hazards in concentrations in excess of the PEL for more than 30 days per year and for personnel who must use respiratory protection for more than 30 days per year. Exponent requires medical monitoring for all employees potentially exposed to chemical hazards.

Will personnel working at this site be enrolled in a medical monitoring program? Yes _____ No X

16. HEALTH AND SAFETY TRAINING

State and federal laws establish training requirements for workers at uncontrolled hazardous waste sites (including areas where accumulations of hazardous waste create a threat to the health and safety of an individual, the environment, or both).

Exponent and subcontractor personnel will be required to complete the following training requirements:

Duties	No Special Training[a]	24-hour	40-hour	Supervisor	First Aid/CPR	Other
Exponent Personnel						
Rick Bodishbaugh			X	X	X	
Subcontractors						
Vessel operator	X[a]					

[a] Provide explanation or justification: Vessel operator will not be required to have 40-hour training. Vessel operator will stay out of the exclusion zone during sample collection and decon.

17. SITE SAFETY MEETINGS

Site safety meetings must be held before beginning new tasks or when new staff enter a site. Site safety meetings should be held at a minimum of once a week and should be held daily on large projects. Attendance and topics covered must be documented.

18. FACILITY SAFETY PROCEDURES

The client or facility operators require that the following procedures be followed for all personnel at the site:

If required by the NASSCO/BAE facilities, personnel entering restricted areas of the facility will wear hard hats and safety glasses.

19. EMERGENCY PLANNING

In case of fire, spill, or other emergency affecting the site, all affected personnel must immediately evacuate the work area and report to the site safety officer at a predetermined location. Field personnel must also immediately notify facility or community emergency response providers unless facility personnel have already initiated this notification.

Designated assembly point: Field vehicle or vessel cabin

In case of injury, field personnel should take precautions to protect the victim from further harm and notify local or facility emergency services. In remote areas, it will be necessary to have first aid-trained personnel on the field team. The victim may require decontamination prior to treatment—requirements will vary based on site conditions.

Emergency medical care will be provided by:

- [X] Local emergency medical provider (i.e., fire department)
- [ ] Facility emergency medical provider
- [ ] First aid-trained field staff (for remote areas only)

Local Resources	Name	Telephone	Notified Prior to Work (Yes/No)?
Fire	San Diego Fire Department	911	No
Police	San Diego Police Department	911	No
Ambulance	San Diego Fire Department	911	No
Hospital	Sharp Coronado Hospital	(619) 522-3712	No
Site phone	NASSCO/BAE	(619) 997-0095/ (619) 997-7780	Yes

Local Resources	Name	Telephone	Notified Prior to Work (Yes/No)?
Directions to hospital:	The hospital is located at 250 Prospect Place. Start out going southeast on Harbor Drive towards Sampson Street by turning right. Turn left onto Sampson Street. Turn left onto Harbor Drive. Turn right onto Crosby Street. Take the CA-75 ramp. Merge onto CA-75. Turn right onto Glorietta Blvd. Turn left onto 3rd Street. Turn right onto Prospect Place.		

Corporate Resources	Name	Work Telephone	Home Telephone
Exponent Environmental Group Environmental, Health & Safety Specialist	Joseph Sorokach	(623) 587-6752 cell (480) 621-2515	(480) 775-1813
Regional health and safety officer	Scott Shock	(425) 519-8722	
Medical consultant	WorkCare 1320 Harbor Bay Pkwy., Suite #115 Alameda, CA 94502	(800) 455-6155 (510) 748-6900 Fax (510) 748-6915	
CHEM-TEL	Emergency No. 1-800-255-3924		

Any workplace incident that results in a fatality or the hospitalization of three or more employees must be reported immediately to the Exponent Environmental Group delegate at the numbers listed above, and to Human Resources in Menlo Park: (650) 326-9400. Alternate Exponent Environmental Group contact: Kevin Reichelderfer, Director of Quality, and Environmental, Health and Safety, (650) 326-9400, cell phone (650) 823-3031.

In case of accident or emergency the client or facility operators require that the following person be notified immediately: Mike Chee (NASSCO) (619)544-7778; Shaun Halvax (BAE Systems) (619) 238-1000

Other Resources	Agency Name/Location	Telephone
Local OSHA office	U.S. OSHA, San Diego, CA	(619) 767-2280
State OSHA equivalent	Division of Occupational Safety and Health, San Francisco, CA	(415) 703-5100

20. DOCUMENTATION

	Attached	In File	Not Applicable
Exponent site safety acknowledgment forms	X		
OSHA or equivalent state poster		X	
Site safety meeting minutes	X		
Exponent accident/incident report form	X		
Exponent heat stress monitoring form	X		
Exponent confined space entry permit			X

	Attached	In File	Not Applicable
Exponent confined space entry checklist			X
Exponent air monitoring record			X
Exponent air sampling record			X
Site map		X	
Work plan	X		
Material safety data sheets		X	
Hospital route	X		
Health and safety training records		X	
Heat stress standard operating procedure	X		
Confined space entry information			X
Equipment standard operating procedures (list below)			
Other: SOP 423 Safety during Marine Operations	X		

21. LIST OF ATTACHMENTS

Attachment 1. Hospital Map
Hospital route map

Attachment 2. Regulatory Notices
OSHA poster

Attachment 3. Forms
Health and Safety Plan Consent Agreement
Site Safety Meeting Minutes

Attachment 4. Standard Operating Procedures
HS-03, Heat Stress Prevention and Monitoring.
HS-04, Safety during Marine Operations.

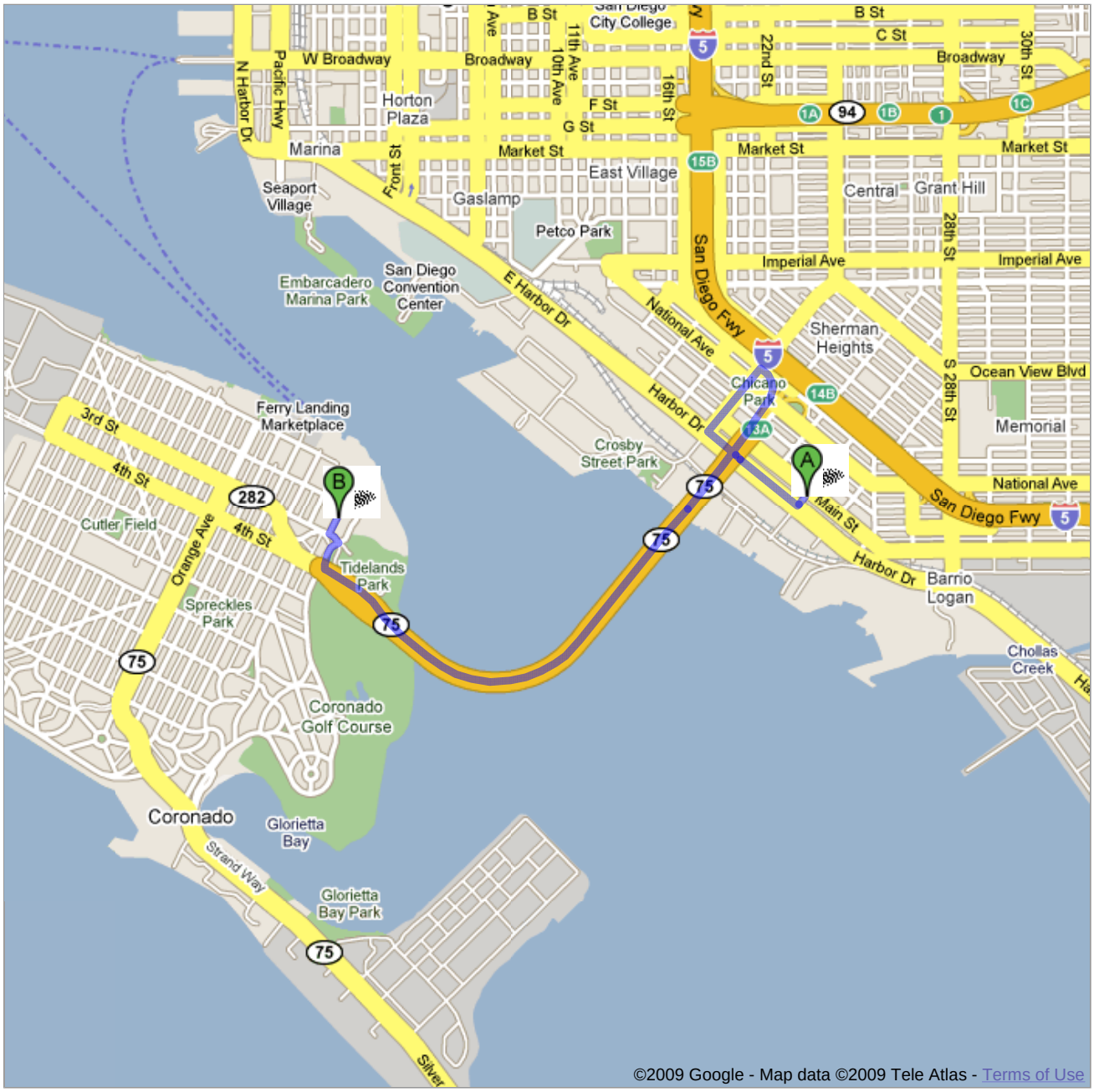
Attachment 1

Hospital Map

Google maps

Directions to 250 Prospect Pl, Coronado, CA 92118
3.0 mi – about **6 mins**

Save trees. Go green!
Download Google Maps on your phone at **google.com/gmm**

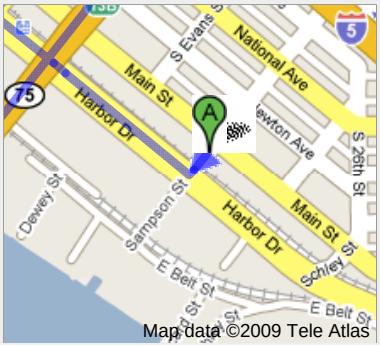


Sampson St

1. Head **southwest** on **Sampson St** toward **Harbor Dr**

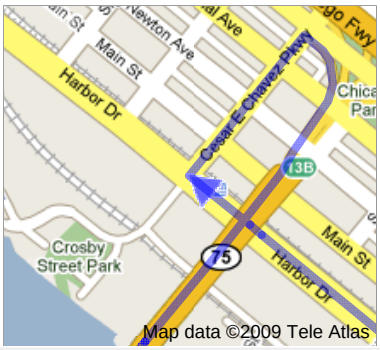
go 217 ft
total 217 ft

2. Turn **right** at **Harbor Dr**
About 1 min



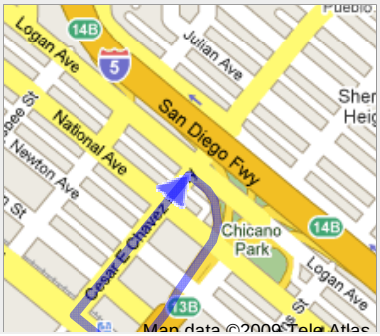
go 0.4 mi
total 0.4 mi

3. Turn **right** at **Cesar E Chavez Pkwy**
About 2 mins



go 0.3 mi
total 0.7 mi

4. Turn **right** to merge onto **CA-75 S**
About 3 mins



go 2.1 mi
total 2.8 mi

5. Take the exit toward **Glorietta Blvd**

go 338 ft
total 2.8 mi

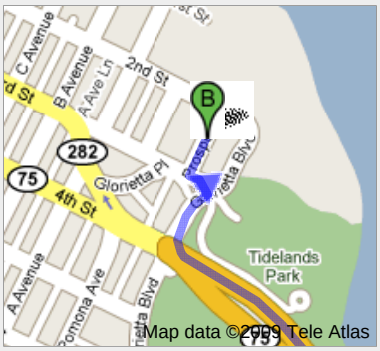
6. Merge onto **Glorietta Blvd**

go 256 ft
total 2.9 mi

7. Turn **left** at **3rd St**

go 223 ft
total 2.9 mi

8. Turn **right** at **Prospect Pl**



go 315 ft
total 3.0 mi

250 Prospect Pl, Coronado, CA 92118

These directions are for planning purposes only. You may find that construction projects, traffic, weather, or other events may cause conditions to differ from the map results, and you should plan your route accordingly. You must obey all signs or notices regarding your route.

Map data ©2009 , Tele Atlas

Attachment 2

Regulatory Notices

Job Safety and Health

It's the law!

OSHA®
Occupational Safety and Health Administration
U.S. Department of Labor

EMPLOYEES:

- You have the right to notify your employer or OSHA about workplace hazards. You may ask OSHA to keep your name confidential.
- You have the right to request an OSHA inspection if you believe that there are unsafe and unhealthful conditions in your workplace. You or your representative may participate in that inspection.
- You can file a complaint with OSHA within 30 days of retaliation or discrimination by your employer for making safety and health complaints or for exercising your rights under the *OSH Act*.
- You have the right to see OSHA citations issued to your employer. Your employer must post the citations at or near the place of the alleged violations.
- Your employer must correct workplace hazards by the date indicated on the citation and must certify that these hazards have been reduced or eliminated.
- You have the right to copies of your medical records and records of your exposures to toxic and harmful substances or conditions.
- Your employer must post this notice in your workplace.
- You must comply with all occupational safety and health standards issued under the *OSH Act* that apply to your own actions and conduct on the job.

EMPLOYERS:

- You must furnish your employees a place of employment free from recognized hazards.
- You must comply with the occupational safety and health standards issued under the *OSH Act*.

This free poster available from OSHA –
The Best Resource for Safety and Health

Free assistance in identifying and correcting hazards or complying with standards is available to employers, without citation or penalty, through OSHA-supported consultation programs in each state.

1-800-321-OSHA (6742)
www.osha.gov

OSHA 3165-12-06R

Attachment 3

Forms

Exponent™

HEALTH AND SAFETY PLAN CONSENT AGREEMENT

I have reviewed the health and safety plan prepared by _____, dated _____, for the _____ _____ site fieldwork. I understand the purpose of the plan, and I consent to adhere to its policies, procedures, and guidelines while an employee of Exponent or its subcontractors.

Employee signature	Firm	Date
Employee signature	Firm	Date
Employee signature	Firm	Date
Employee signature	Firm	Date
Employee signature	Firm	Date
Employee signature	Firm	Date
Employee signature	Firm	Date
Employee signature	Firm	Date

Exponent™

SITE SAFETY MEETING MINUTES

Site Name _____ Contract No. _____

Meeting Location _____

Meeting Date _____ Time _____ Conducted By _____

Pre-fieldwork Orientation ____ Weekly Site Meeting ____ Other _____

Subjects Discussed _____

_____

_____

_____

Safety Officer Comments _____

_____

_____

_____

Name and Signature of Participating Personnel (list company name if subcontractor)

_____

_____

_____

_____

_____

_____

_____

Note: Attach additional pages if necessary. Send this form to the Exponent Environmental Group health and safety manager. Copies will be placed in the appropriate project files.

Attachment 4

Standard Operating Procedures

SOP HS-03
HEAT STRESS PREVENTION AND MONITORING

INTRODUCTION

Heat stress poses a serious threat to the health of workers conducting hazardous material or chemical investigations at industrial and other facilities. This threat is increased for workers wearing chemical protective clothing or personal protective equipment (PPE) because the impermeable clothing does not allow sweat to evaporate and cool the body. Depending on ambient conditions, the work being performed, and other factors, heat stress may affect workers at temperatures as low as 70°F (adjusted for humidity and sunlight; see *Monitoring for Heat Stress*, below) and can occur rapidly, with workers suffering acute symptoms in less than 15 minutes. Even relatively minor symptoms of heat stress can result in impaired functional ability, threatening the safety of the worker and his or her companions. Thus, heat stress can present as great a health risk to workers as chemical hazards or traditional physical hazards such as falling objects and confined spaces. This SOP presents information on heat-related illnesses, factors that influence heat stress, monitoring for heat stress, and heat stress prevention.

HEAT-RELATED ILLNESSES

A common factor in heat-related illnesses is the failure of the worker to recognize the symptoms of heat stress. All personnel should become familiar with the symptoms of heat stress and appropriate first aid precautionary measures.

Table HS-03-1 provides information on the types of heat-related disorders and procedures for treating them. Heat stress can result in minor symptoms such as heat rash, heat cramps, discomfort, and drowsiness. Prolonged heat stress can result in more severe effects, such as heat exhaustion and heat stroke. Heat rash is a relatively minor form of early heat stress that results from prolonged contact with wet clothing. Heat rash can be prevented by allowing the skin to dry completely during rest periods and by showering as soon as possible at the end of the work day. Although heat cramps and drowsiness are generally of minor concern, these symptoms may also result in impaired functional ability, which in turn may threaten the safety of the individual and coworkers.

Heat cramps, heat syncope, heat exhaustion, and heat stroke all result from excessive loss of body fluids and electrolytes. The symptom of heat cramps is spasms in the abdomen or limbs. Heat syncope is a pooling of blood in the lower extremities, which may result in fainting when the worker stands up suddenly or has been immobile. Heat exhaustion, caused by more severe dehydration, has the following symptoms: pale, clammy skin; profuse sweating; weakness;

TABLE HS-03-1. HEAT DISORDERS

Disorder	Cause	Signs	Treatment
Heat rash	Heavy sweating, drinking large volumes of water without replacing salt loss	Profuse tiny raised vesicles, prickly skin	Remove from source of heat; allow skin to dry completely during rest periods; shower as soon as possible after work day
Heat syncope	Lack of acclimatization, pooling of blood in the legs	Fainting while standing, immobile in heat	Remove to cooler area
Heat cramps	Heavy sweating, drinking large volumes of water without replacing salt loss	Painful spasms of muscles used during work; cool, moist skin	Provide fluids that replace salts and protein; allow 1–3 days of rest, depending on the severity of the attack
Heat exhaustion	Sustained exertion in heat, lack of acclimatization, failure to replace water and/or salt	Fatigue, nausea, headache, moist and clammy skin, pale complexion, delirium, diarrhea, cramps	Remove to cooler area; provide cool water and salted fruit or protein drinks
Heat stroke	Sustained exertion in heat, excessive exposure to heat, lack of physical fitness, alcoholism and drug abuse, dehydration, cardiovascular disease	Headache; rapid pulse; dizziness; nausea; confusion; convulsions; flushed, dry skin; high body temperature; loss of consciousness; coma	Call emergency medical services (often 911) immediately; place the worker in a cool, shady area; remove their clothing, then sprinkle their entire body with cool water; also cool by fanning; treat for shock

headache; and nausea. Heat stroke (sometimes called sunstroke) is a life-threatening condition that occurs when the body's temperature-regulating system no longer functions properly. Heat stroke requires immediate medical attention. Symptoms of heat stroke include hot, dry skin; a high fever (often 106°F or more); dizziness; nausea; rapid pulse; and unconsciousness. Brain damage and death may follow if the body temperature is not reduced.

Workers must learn to recognize that dizziness, nausea, headaches, skin rashes, muscle cramps, and pale or clammy skin are symptoms of heat stress and act promptly when suffering these symptoms. Workers may not realize the risk they face by ignoring these symptoms and staying in the work area. If workers ignore the symptoms of heat stress they may risk being overcome or suffer other injuries of heat stress-related impairment. Critical factors in the prevention of heat stress include a proper work regimen and the intake of adequate replacement fluids and electrolytes.

FACTORS INFLUENCING HEAT STRESS

Many factors determine an individual's susceptibility to heat stress. Environmental factors include the ambient temperature, humidity, and presence or absence of cooling breezes or shade. The nature of the work being performed, including the level of physical activity, the degree of permeability and the number of layers of protective clothing, and the time of day that the work is being performed affects the level of heat stress.

Some workers are predisposed toward suffering heat stress. Factors that could increase a worker's susceptibility to heat stress include degree of physical fitness, lack of acclimatization, age, dehydration, obesity, alcohol and drug use, infection, sunburn, diarrhea, and chronic disease.

Workers who have acclimated to working in hot climates or in PPE will be less likely to suffer heat stress. Acclimated individuals typically have lower heart rates and body temperatures than nonacclimated workers. Acclimated workers also sweat sooner and more profusely than those not acclimated to high temperatures or the use of PPE (acclimated individuals may sweat more profusely when wearing PPE than nonacclimated workers, thus increasing their risk of dehydration). The National Institute of Occupational Safety and Health (NIOSH) recommends a progressive 6-day regimen to allow a worker to acclimate to work in a hot environment, especially when wearing PPE (this program begins with 50-percent exposure, then lengthens the staying time by 10 percent each subsequent day). A individual's capacity to work in hot environments generally decreases with age. According to NIOSH, however, an older person in peak physical condition may have a greater work capacity than a less fit, younger worker. Thus, physical fitness is a more significant factor than age when determining an individual's work capacity. Weight is usually a significant factor when determining the ability of an individual to work in a heated environment, because overweight people have a lower surface area to mass ratio and, thus, can not dissipate heat as well as slimmer people. Weight is not as significant a factor when wearing PPE, as the impermeable garments impede the dissipation of body heat regardless of the individual's weight.

MONITORING FOR HEAT STRESS

To ensure the safety of workers wearing impermeable or semipermeable encapsulating PPE, NIOSH recommends that heat stress monitoring be implemented at temperatures above 70°F, using an "adjusted temperature." The adjusted temperature is calculated by determining the ambient temperature (using a standard thermometer, shielded from heat) and adding the total of 13 × the percentage of sunshine (complete overcast = 0 percent sunshine and no cloud cover = 100 percent sunshine). For example, for an ambient temperature of 80°F and 80 percent sunshine, the adjusted temperature would be 90.4°F (80+[13×0.80]=90.4). The effect of heat stress on the body may be monitored using the techniques described below. Recommended intervals for physiological monitoring when wearing permeable or impermeable work clothes are shown in Table HS-03-2.

Heart Rate

To monitor the effect of heat stress on the worker using the heart rate method, the worker must measure his or her heart rate over a 30-second period as soon as possible at the beginning of each rest break. The pulse should be taken at the radial (wrist) artery, not the carotid (neck) artery. When monitoring heart rate, the following guidelines apply:

- If the worker's heart rate does not exceed 110 beats/minute, proceed as before
- If the worker's heart rate exceeds 110 beats/minute at the beginning of the rest period, shorten the next work cycle by one-third and keep the rest period the same
- If the worker's heart rate exceeds 110 beats/minute at the beginning of the next rest period, shorten the next work cycle by another one-third.

Exponent recommends the use of heart rate monitoring as the minimum heat stress monitoring technique.

Oral Temperature

To monitor the effect of heat stress on the worker using the oral temperature method, the worker should use a clinical thermometer (3 minutes under the tongue) at the end of each work period, but before taking a drink. When monitoring oral temperature, the following guidelines apply:

- If the oral temperature does not exceed 99.6°F, no action is needed
- If the oral temperature exceeds 99.6°F at the beginning of the rest period, shorten the next work cycle by one-third and keep the rest period the same

TABLE HS-03-2. SUGGESTED FREQUENCY OF PHYSIOLOGICAL MONITORING FOR FIT AND ACCLIMATIZED WORKERS[a]

Adjusted Air Temperature[b]	Normal Work Ensemble[c]	Impermeable Ensemble
90□F or above (32.2□C)	After each 45 minutes of work	After each 15 minutes of work
87.5□–90□F (30.8□–32.2□C)	After each 60 minutes of work	After each 30 minutes of work
82.5□–87.5□F (28.1□–30.8□C)	After each 90 minutes of work	After each 60 minutes of work
77.5□–82.5□F (25.3□–28.1□C)	After each 120 minutes of work	After each 90 minutes of work
72.5□–77.5□F (22.5□–25.3□C)	After each 150 minutes of work	After each 120 minutes of work

Source: NIOSH (1985).

[a] For work level of 250 kilocalories/hour (moderate work activity).

[b] Calculate the adjusted air temperature (ta adj) by using this equation: ta adj □F = ta □F + (13 □ percent sunshine). Measure air temperature (ta) with a standard, mercury-in-glass thermometer, with the bulb shielded from radiant heat. Estimate percent sunshine by judging what percent of time the sun is not covered by clouds that are thick enough to produce a shadow (100 percent sunshine = no cloud cover and sharp, distinct shadows; 0 percent sunshine = no shadows).

[c] A normal work ensemble consists of cotton coveralls or other cotton clothing with long sleeves and pants.

- If the oral temperature exceeds 99.6°F at the beginning of the next rest period, shorten the following work period by one-third
- If the oral temperature exceeds 100.6°F at the beginning of any rest period, the worker should not be permitted to wear impermeable clothing.

Body Water Loss

To monitor the effect of heat stress on workers by measuring body water loss, the workers must weigh themselves with a scale accurate to within 0.25 lb at the beginning and end of each work day. Their weight for the beginning and the end of the work shift should be taken while wearing similar clothing or, for greatest accuracy, when nude. Fluctuations in weight (between the beginning of the shift and end of the shift) indicate the gain or loss of body fluids, thus revealing if fluid replenishment has been effective. Body weight loss in a work day should not exceed 1.5 percent of total body weight. Where such weight losses occur, more attention should be given to fluid replacement during subsequent work shifts.

Electronic Monitors

Electronic monitors that constantly monitor a worker's heart rate and core temperature have recently been developed. These devices utilize sensors that are held in place on the worker's chest with an elastic band and are programmed to account for the worker's age and type of protective clothing. The worker's heart rate and core temperature are monitored, and lights illuminate on a small pad (worn on the outside of the PPE) to indicate one of the following conditions: the worker may continue as before, the worker has only a limited amount of work time left, or the worker should exit the work area immediately. These devices also include audible alarms and can be set to download heat stress data to a printer at the end of a shift.

Other electronic monitors are designed to measure adjusted (ambient) temperatures and can be programmed to account for the level of worker activity and type of protective clothing. These devices can calculate stay times (the amount of time the workers in the area may remain in that area at the current activity levels) and can also log conditions encountered. These devices do not actually monitor the effects of heat stress on the workers, but may be used to implement heat stress prevention measures.

HEAT STRESS PREVENTION

Several means are available to decrease or prevent the effects of heat stress.

An effective means of preventing heat stress is to schedule work in the cool parts of day—early mornings, evenings, or at night. If the heat source is mechanical (e.g., caused by a power plant or production equipment), it may be possible to schedule the work during hours when the facility is inoperative.

Engineering methods may be used to cool workers regardless of the time of day. These methods frequently involve the use of cool vests (ice packs worn under PPE in a special vest), circulating air (often associated with powered air-purifying respirators that utilize hoods rather than sealed facepieces), or in extreme cases, circulating liquids through specially designed suits. Other engineering controls to prevent heat stress include erecting a shelter to protect workers from direct sunlight or the circulation of air through the workplace. In some instances, deluge showers can be constructed within the exclusion zone or in the decontamination area that allow workers wearing fully encapsulating PPE to stand under a shower of cold water. The deluge shower is an efficient means of providing relief to the worker without requiring the worker to proceed through decontamination and exit from the work area.

A critical element in an effective heat stress prevention program is to ensure that workers maintain a normal level of fluids within their bodies. To prevent heat-related illness, the worker's intake of fluids must approximate the amount of fluid lost (e.g., the worker must drink 8 oz of water for every 8 oz decrease in body weight). The sensation of thirst is not a reliable indicator of fluid loss. When heavy sweating occurs, it is essential that workers increase their fluid intake. The following guidelines may be useful:

- Provide fluid replenishment beverages at the work site, cooled to 50–60°F (appropriate beverages include water and diluted fruit juices or Gatorade®)
- Have workers drink 16 oz of fluid prior to working in a hot environment
- Encourage workers to drink 8–16 oz of liquids every 15–20 minutes, or at each rest break. NIOSH recommends that workers consume a total of 1–1.5 gal of fluids/day, although a greater quantity may be required.

Scheduling rest periods to break up work periods is essential to prevent heat-related illnesses. It is difficult to establish a rigid schedule that spells out the staying time and rest breaks based on temperature alone because other factors, such as the level of physical activity and the type of protective equipment, play a significant role in determining an individual's susceptibility to heat stress. The recommended course of action is to use the guidelines for physiological monitoring provided in Table HS-03-2 to schedule the initial work period, then vary the length of the break and the next work period based on the physiological responses of individual workers to the work load. If the workers are engaged in strenuous activities, are not acclimated to the work environment, or are not in peak physical condition, the work interval should be shortened significantly, and monitoring continued.

INDIVIDUAL RESPONSIBILITIES

In preventing heat stress, it is essential that the individual monitor his or her own symptoms and promptly take steps to remedy any signs of heat stress. Such steps include notifying coworkers of his or her condition and taking whatever measures may be necessary to alleviate the symptoms by taking a break, increasing the intake of fluids, instituting environmental controls

(such as the use of cool vests or circulating air), assuming less strenuous duties, or implementing appropriate first-aid procedures as indicated in Table HS-03-1. No field monitoring program can substitute for the individual's sense of their own health and physical limits.

REFERENCES

NIOSH. 1985. Occupational safety and health guidance manual for hazardous waste site activities. Prepared by the National Institute for Occupational Safety and Health, Occupational Safety and Health Administration, U.S. Coast Guard, and U.S. Environmental Protection Agency. U.S. Department of Human and Health Services, Public Health Service, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, Washington, DC.

SOP HS-04
SAFETY DURING AQUATIC OPERATIONS

INTRODUCTION

Contractor field projects often require the collection of biological, sediment, and surface water samples from vessels. In addition to the physical and chemical hazards associated with all field sampling, there are special hazards associated with vessels. This SOP provides guidance for ensuring the safety of contractor and subcontractor personnel when working on the water. These procedures address inland or protected waters only. Additional procedures are required for working on vessels offshore.

All personnel performing the field sampling will wear protective clothing as specified in the site-specific health and safety plan.

TRAINING

Appropriate training is essential for preventing accidents and ensuring the proper completion of all field duties. The following training requirements apply to all field work conducted on the water:

All contractor and subcontractor personnel must participate in an initial safety briefing prior to beginning the field work, whenever new personnel come aboard, and when conditions or tasks change.

- If the field project is conducted at a designated hazardous materials site or there is any potential for chemical exposure, then all contractor and subcontractor personnel must have the appropriate 40-hour hazardous waste operations training and current 8-hour annual refresher training. Supervisors must have completed the 8-hour supervisors training course.
- The field team leader or site safety officer must have current first aid and cardiopulmonary resuscitation (CPR) training.
- The vessel operator must demonstrate proficiency in the operation of that type of vessel and knowledge of aquatic safety and navigation rules. Personnel without prior experience will be required to complete training in these subjects.

REQUIRED SAFETY EQUIPMENT

To prevent accidents and ensure adequate preparation for any emergencies that may arise, it is the responsibility of the project manager to secure appropriate safety equipment for the duration of the project. This equipment must include the following:

- **Personal Flotation Devices (PFDs)—**There must be one PFD for every person onboard the vessel, plus an additional throwable flotation device for vessels over 16 ft in length.
- **Fire Extinguisher—**Requirements for fire extinguishers vary based on the vessel length and whether the vessel has inboard engines or closed compartments. Fire extinguishers are recommended for all motorized vessels. Additional information regarding requirements for fire extinguishers can be obtained from the U.S. Coast Guard.
- **First-Aid Kit—**A first-aid kit must be provided during all field projects. The contents of the first-aid kit will vary based on the number of persons present, but at a minimum should include a variety of bandages and compresses, disinfectant, gloves, a CPR shield, eyewash, and an emergency blanket. Additional information regarding requirements for first-aid kits can be obtained from the applicable federal or state department responsible for occupational safety and health.
- **Marine Radio with Weather Channel—**A two-way VHF radio is required by law on commercial vessels and is recommended for all work on open waters. The frequency and call sign of local emergency services must be posted on the vessel and be included in the site-specific health and safety plan.
- **Cellular Telephone—**If a two-way VHF marine radio is not available then a cellular telephone must be onboard.
- **Horn or Bell—**U.S. Coast Guard regulations require a signaling device be onboard all vessels longer than 36 ft and require that all vessels, regardless of length, be capable of making audible signals during certain events (i.e., approaching or overtaking other vessels).
- **Navigation Lights—**The requirements for navigation lights vary based on the length and type of vessel. All vessels operated at night must have the appropriate navigation lights.
- **Oars or Paddles—**Small boats must be equipped with alternate means of propulsion.
- **Anchor and Suitable Line—**In most cases, vessels should be equipped with one (or two) anchors and sufficient anchor line for expected water depths and bottom conditions.

- **Reach Pole or Shepherd's Hook—**On larger vessels, a reach pole or shepherd's hook must be available to facilitate rescue of any persons who fall overboard.
- **Other Rescue Gear—**On larger vessels, a block and tackle or other means must be available to pull a person from the water.

HAZARDS AND PREVENTION

There are many physical hazards associated with working onboard a vessel. Potential hazards and appropriate precautions are listed below:

- **Slips/Trips/Falls—**The combination of a moving vessel and wet or slippery decks increases the potential for slips, trips, or falls. These can be prevented by increasing your awareness of the surroundings, keeping one hand free for handholds and support, keeping the deck and working areas clear of unnecessary obstacles or hazards, and wearing nonskid boots or shoes.
- **Drowning—**Even the best swimmer can drown if caught unprepared, tired, or weighted down with bulky clothing and boots. Drowning can be prevented by taking precautions against falling overboard (avoid reaching over the side, beware of slips/trips/falls, avoid ondeck work in heavy seas) and by wearing a PFD. PFDs should be worn underneath chemical protective clothing such as Tyvek® coveralls (thus allowing the wearer to remove the coveralls without first removing the PFD) and should be properly secured or buckled.
- **Crushing/Falling Objects—**The use of hoists to lift coring tools and other equipment could result in crushing or other injuries to field workers. These injuries can be avoided by using properly adjusted and maintained hoists, allowing only experienced personnel to operate the hoist, keeping all personnel out of the way during lifting and hoisting, and wearing hardhats to protect against head injuries or bumps.
- **Gear Deployment and Retrieval—**The deployment and retrieval of sampling gear presents a hazard because of the weight of the gear, its suspension over the deck, and the risk of entanglement or accidental and premature release or closure. Setting the triggering mechanism must always be performed when the equipment is resting on a stable surface. During sample retrieval, at least one crew member is required to watch for the appearance of the sampling gear and alert the winch operator. Failure to observe the sampling gear and stop the winch could lead to breakage of the cable, loss of the sampling gear, and possible injury from either the falling gear or the end of the broken cable. All nonessential personnel should stay clear of the work area during the retrieval and deployment of sampling gear.

All personnel should be knowledgeable in the proper hand signals for guiding the winch operator.

- **Cables—**After repeated use, stainless steel cables may fray or break. Sampling personnel must never take ahold of the moving cable unless they are wearing work gloves. Periodically during the sampling event, the site safety officer should inspect the cable for wear, especially where the wire or cable is attached to the sampling equipment.

- **Climate—**Depending on the climate, field personnel may suffer from hypothermia, dehydration, or heat stress. Climate-related illnesses and injuries can be prevented by dressing appropriately for the expected climate and by having additional clothing onboard should personnel get wet or the weather change suddenly. When working in cold, wet weather, appropriate clothing may include raingear, wool, and modern synthetics. Cotton clothing should only be worn during warm, dry weather. In addition, fluid replenishment beverages (to protect against heat stress and dehydration) or warm beverages (to protect against hypothermia) should be available during field work.

- **Unsecured Gear—**Wherever possible, all ondeck sampling and safety gear should be secured to a deck, rail, or bulkhead to prevent loss from unexpected movement caused by wind or waves.

- **Hatches—**All personnel should be alerted to the presence of an open hatch and hatches should not be left open unnecessarily.

- **Chemical and Sample Storage—**To prevent fire, health hazards, or sample contamination, all field chemicals such as solvents and formalin should be stored on deck or in the hold, and not in the cabin or near samples.

EMERGENCY PROCEDURES

In case of a boating-related injury or fatality, field personnel must:

- Notify emergency medical or rescue personnel immediately (as appropriate). The U.S. Coast Guard emergency frequency is VHF Channel 16.

- Notify the site safety officer, the appropriate project manager, and the Exponent Safety Manager immediately. The project manager and corporate health and safety officer will coordinate notifications to the Occupational Safety and Health Administration and the U.S. Coast Guard.

In case of boating-related property damage exceeding $200, field personnel must:

- Notify police or other legal jurisdiction (as appropriate).
- Notify the site safety officer, the appropriate project manager, and the Exponent Safety Manager within 48 hours of the incident. The project manager and corporate health and safety officer will coordinate notification of the U.S. Coast Guard.
- Notify the Exponent Business Operations Manager to initiate insurance claims.