EAST WATERWAY OPERABLE UNIT
SUPPLEMENTAL REMEDIAL INVESTIGATION/ FEASIBILITY STUDY
FINAL QUALITY ASSURANCE PROJECT PLAN CLAM STUDIES

For submittal to:

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Region 10
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Prepared by:

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EAST WATERWAY CLAM STUDIES
FINAL QUALITY ASSURANCE PROJECT PLAN

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Acronyms

ACRONYM	Definition
%RSD	percent relative standard deviation
ACG	analytical concentration goal
ANSETS	Analytical Services Tracking System
ARI	Analytical Resources, Inc.
BHR-AA	borohydride reduction-atomic absorption
CAS	Columbia Analytical Services, Inc.
CFR	Code of Federal Regulations
COC	chain of custody
CVAA	cold vapor atomic absorption spectrophotometry
DCM	dichloromethane
DGPS	differential global positioning system
DQI	data quality indicator
DQO	data quality objective
EPA	US Environmental Protection Agency
ERA	ecological risk assessment
EW	East Waterway
EWG	East Waterway Group
FC	field coordinator
FS	feasibility study
GC/ECD	gas chromatography/electron capture detection
GC/FPD	gas chromatography/flame photometric detection
GC/MS	gas chromatography/mass spectrometry
GC/MS/MS	gas chromatography/mass spectrometry/mass spectrometry
GFAAS	graphite furnace atomic absorption spectrophotometry
HAZWOPER	hazardous waste operations and emergency response
HG-AFS	hydride generation-atomic fluorescence spectrometry
HHRA	human health risk assessment
HRGC/HRMS	high-resolution gas chromatography/high-resolution mass spectrometry
HSP	health and safety plan
ICP-AES	inductively coupled plasma-atomic emission spectrometry
ICP-MS	inductively coupled plasma-mass spectrometry

ACRONYM	Definition
LCS	laboratory control sample
MDL	method detection limit
MLLW	mean lower low water
MSA	method of standard additions
MS	matrix spike
MSD	matrix spike duplicate
NAD 83	North American Datum 1983
NOAA	National Oceanic and Atmospheric Administration
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PM	project manager
PSEP	Puget Sound Estuary Program
QA/QC	quality assurance/quality control
QAPP	quality assurance project plan
RL	reporting limit
ROV	remotely operated video
RPD	relative percent difference
SDG	sample delivery group
SIM	selective ion monitoring
SPI	sediment profile imaging
SRI	supplemental remedial investigation
SRM	standard reference material
SVOC	semivolatile organic compound
TM	task manager
TOC	total organic carbon
Windward	Windward Environmental LLC

1 Introduction

This quality assurance project plan (QAPP) describes the sampling design and quality assurance objectives and protocol for characterizing clam habitat and collecting and analyzing clam tissue and co-located sediment in the East Waterway (EW). Details about project organization and management, field data collection methods, sample handling, laboratory analytical protocols, and data management and documentation are also provided. This QAPP was prepared in accordance with guidance for preparing QAPPs from the US Environmental Protection Agency (EPA 2002).

Data from these studies will be used to support the ecological (ERA) and human health (HHRA) risk assessments for the supplemental remedial investigation (SRI) and feasibility study (FS) for the EW. Three (of four) clam studies are described in this QAPP:

- Characterization of intertidal clam habitat and collection and analysis of intertidal clam tissue and co-located sediment
- Characterization of subtidal benthic habitats and identification of potential geoduck (*Panopea abrupta*) beds
- Collection and analysis of geoduck tissue and co-located sediment

A fourth study for the purpose of collecting and analyzing small (i.e., less than 2 cm) subtidal clams (and co-located sediment) will be conducted as part of infaunal tissue characterization, which is covered in a separate QAPP.

This QAPP is organized as follows:

- Section 2 – project management
- Section 3 – data generation and acquisition
- Section 4 – assessment and oversight
- Section 5 – data validation and usability
- Section 6 – references
- Section 7 – maps

A health and safety plan (HSP) designed for the protection of onsite personnel from physical, chemical, and other hazards posed during field sampling activities is included as Appendix A. Field collection forms are included as Appendix B. The derivation of risk-based analytical concentration goals (ACGs) for tissue is presented in Appendix C. The derivation of ACGs for sediment collected at clam sampling locations is presented in Appendix D. Data management procedures are presented in Appendix E. The deployment and analytical SOPs for the sediment profile imaging (SPI) are presented in Appendix F

2 Project Management

This section describes the overall management of the project, identifies key personnel, and describes their responsibilities, including field coordination, quality assurance and quality control (QA/QC), laboratory management, and data management.

2.1 Project Organization and Team Member Responsibilities

The East Waterway Group (EWG), which comprises the Port of Seattle, City of Seattle, and King County, and EPA will be involved in all aspects of this project, including discussion, review, and approval of the QAPP and the interpretation of the results of the investigation. Windward Environmental LLC (Windward) will be responsible for the management and implementation of the effort described in this QAPP and coordination with EPA and the EWG. Figure 2-1 shows the overall project organization for the clam studies described in this QAPP.

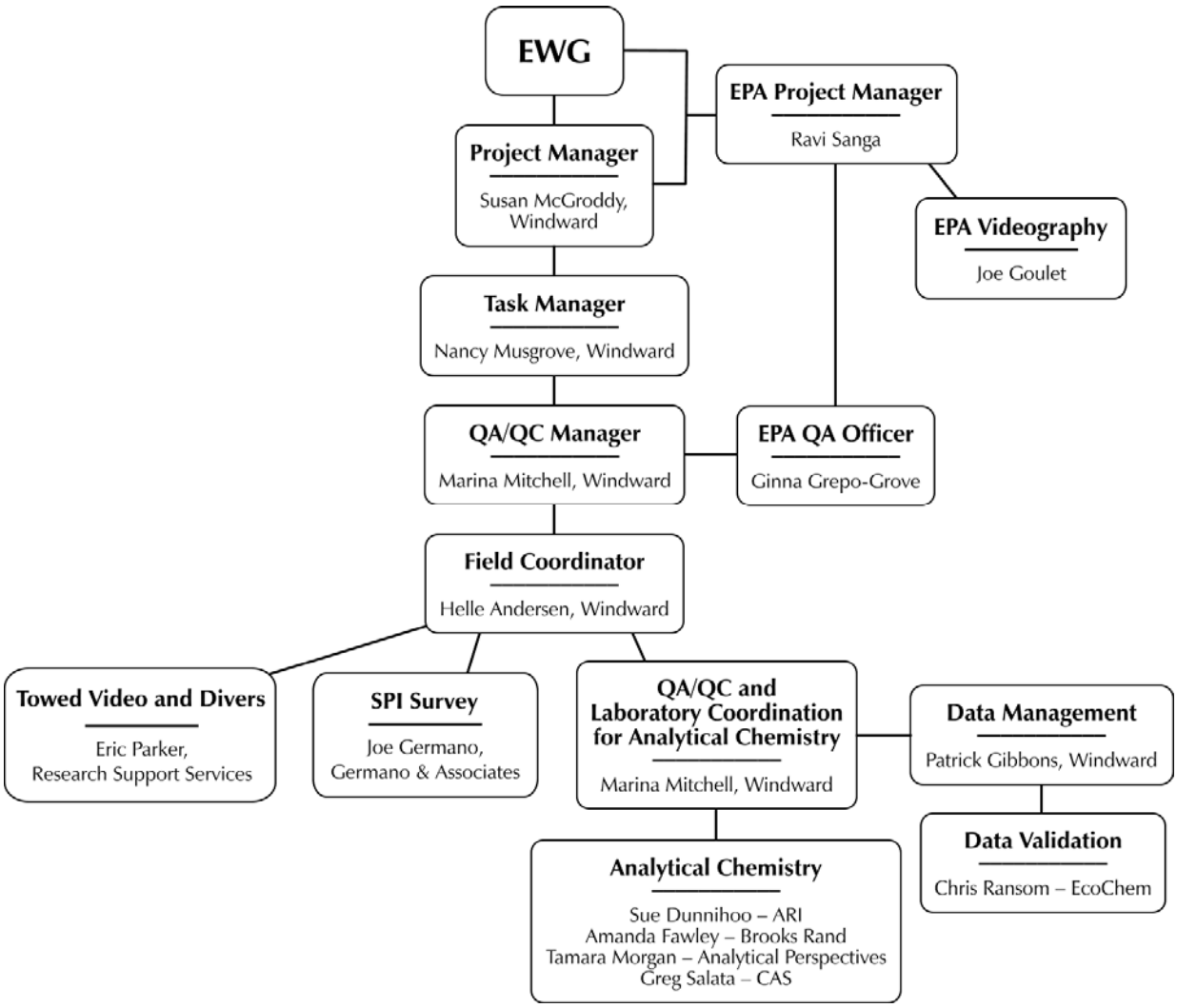

Figure 2-1. Project organization

2.1.1 Project Management

EPA will be represented by its project manager (PM) for this project, Ravi Sanga. Mr. Sanga can be reached as follows:

Mr. Ravi Sanga
US Environmental Protection Agency, Region 10
1200 Sixth Avenue, Suite 900
ECL-111
Seattle, WA 98101-3140
Telephone: 206.553.4092
Facsimile: 206.553.0124
E-mail: Sanga.Ravi@epamail.epa.gov

Susan McGroddy will serve as the Windward PM and will be responsible for overall project coordination and providing oversight on planning and coordination, work plans, all project deliverables, and performance of the administrative tasks needed to

ensure timely and successful completion of the project. She will also be responsible for coordinating with EWG and EPA on schedule, deliverables, and other administrative details. Dr. McGroddy can be reached as follows:

Dr. Susan McGroddy
Windward Environmental LLC
200 W Mercer Street, Suite 401
Seattle, WA 98119
Telephone: 206.812.5421
Facsimile: 206.217.0089
Email: susanm@windwardenv.com

Nancy Musgrove will serve as the Windward task manager (TM). The TM is responsible for project planning and coordination, production of work plans, production of project deliverables, and performance of the administrative tasks needed to ensure timely and successful completion of the project. The TM is responsible for communicating with the Windward PM on the progress of project tasks and any deviations from the QAPP. Significant deviations from the QAPP will be further reported to EWG and EPA. Ms. Musgrove can be reached as follows:

Ms. Nancy Musgrove
Windward Environmental LLC
200 W Mercer Street, Suite 401
Seattle, WA 98119
Telephone: 206.812.5431
Facsimile: 206.217.0089
Email: nancym@windwardenv.com

2.1.2 Field coordination

Helle Andersen will be the Windward field coordinator (FC). The FC is responsible for managing the field activities and for general field QA/QC oversight. She will ensure that appropriate protocols for sample collection, preservation, and holding times are observed and oversee the delivery of environmental samples to the designated laboratories for chemical analysis. Ms. Andersen can be reached at:

Ms. Helle Andersen
Windward Environmental LLC
200 W Mercer Street, Suite 401
Seattle, WA 98119
Telephone: 206.812.5402
Facsimile: 206.217.0089
Email: helleb@windwardenv.com

2.1.3 Quality assurance/quality control

Marina Mitchell of Windward will serve as QA/QC manager for the project. As the QA/QC manager, she will provide oversight for the coordination of the field sampling and laboratory programs and will ensure compliance with the QAPP. She will also supervise data validation and project QA coordination, including coordination with the EPA QA officer, Ginna Grepo-Grove. Ms. Mitchell can be reached as follows:

Ms. Marina Mitchell
Windward Environmental LLC
200 W Mercer Street, Suite 401
Seattle, WA 98119
Telephone: 206.812.5424
Facsimile: 206.217.0089
Email: marinam@windwardenv.com

Ms. Grepo-Grove can be reached as follows:

Ms. Ginna Grepo-Grove
US Environmental Protection Agency, Region 10
1200 Sixth Avenue, Suite 900 (OEA-095)
Seattle, WA 98101
Telephone: 206.553.1632
Email: grepo-grove.gina@epa.gov

EcoChem, Inc., will provide independent third-party review and validation of analytical chemistry data. Chris Ransom will act as the data validation PM and can be reached as follows:

Ms. Chris Ransom
EcoChem, Inc.
Dexter Horton Building
710 Second Avenue, Suite 600
Seattle WA 98104
Telephone: 206.233.9332
Email: cranson@ecochem.net

2.1.4 Laboratory project management

Ms. Mitchell of Windward will also serve as the laboratory coordinator for the analytical chemistry laboratories. Analytical Resources, Inc. (ARI), Analytical Perspectives, Brooks Rand Labs LLC (Brooks Rand), and Columbia Analytical Services, Inc. (CAS), will perform chemical analyses on the tissue and sediment samples. ARI will be responsible for analysis of all analytes, with the exception of inorganic arsenic (provided by Brooks Rand) and congener analyses of polychlorinated biphenyls and dioxins and furans (provided by Analytical Perspectives). CAS will provide confirmatory analyses of organochlorine pesticides. The laboratory PMs can be reached as follows:

Ms. Susan Dunnihoo
Analytical Resources, Inc.
4611 S 134th Place, Suite 100
Tukwila, WA 98168
Telephone: 206.695.6207
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Ms. Amanda Fawley
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Ms. Tamara Morgan
Analytical Perspectives
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Mr. Greg Salata
Columbia Analytical Services, Inc.
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Kelso, WA 98626
Telephone: 360.577.7222
Facsimile: 360.636.1068
Email: gsalata@kelso.cas.com

The laboratories will do the following:

- Adhere to the methods outlined in this QAPP, including the methods referenced for each procedure
- Adhere to documentation, custody, and sample logbook procedures
- Implement QA/QC procedures defined in this QAPP
- Meet all reporting requirements
- Deliver electronic data files as specified in this QAPP
- Meet turnaround times for deliverables as described in this QAPP
- Allow EPA and the QA/QC third-party auditors to perform laboratory and data audits

2.1.5 Data management

Mr. Patrick Gibbons will oversee data management to ensure that analytical data are incorporated into the EW database with appropriate qualifiers following acceptance of the data validation. QA/QC of the database entries will ensure accuracy for use in the ERA and HHRA.

2.2 PROBLEM DEFINITION/BACKGROUND

The Duwamish River discharges to Elliott Bay (Map 2-1) in Seattle, Washington. The river forms two branches approximately 1 mile from its mouth. The EW is the eastern branch of the Duwamish River along the east side of Harbor Island. This site has been designated as an operable unit of the Harbor Island Superfund site.

Windward is conducting and ERA and HHRA as part of the SRI and FS of the EW sediments. The objective of this sampling effort is to further characterize the EW environment and use data gathered from these efforts to assess risks from contaminated sediments posed to the organisms living in the EW and to humans using the EW (i.e., recreation activities in the waterway and consumption of organisms from the waterway). Risk estimates for humans and ecological receptors will be calculated from chemical concentrations in sediment, water, and biota from the EW. Cleanup of sediment contamination will occur in the EW as part of the Superfund process to address identified risks to human health and ecological receptors.

The draft conceptual site model and data gaps analysis report (Anchor et al. 2008) identified a need for additional information to determine the presence and extent of clams and clam habitat in the EW in support of the HHRA and ERA. Four field studies and sample collection events are proposed to help resolve the following questions associated with use of site-specific clam tissue residues in the estimation of dietary exposures of receptors of concern:

- What is the extent, distribution, and quality of potential clam habitat in intertidal and subtidal areas of the EW?
- Are clams that may be targeted by recreational or tribal shellfish harvesters present in the intertidal and subtidal areas of the EW?
- Are clams sufficiently abundant in either intertidal or subtidal areas such that field-collected clams (i.e., site-specific samples) can be used to derive exposure point concentrations for human or ecological receptors based on their clam dietary fraction?[1]
- At what concentrations are human and ecological receptors exposed to chemicals through the ingestion of clams?

[1] Clams will be included as a dietary component for human shellfish harvesters and ecological receptors that are known to prey on clams regardless of the abundance of clams in the EW.

Some data that would contribute to resolution of these questions are available; however, they are incomplete. Existing data (i.e., grain size, sediment total organic carbon [TOC] content, bottom depth, and areal extent of dredging) reported in the existing information summary report (Anchor and Windward 2008) will be compiled in the ERA to describe the distribution of potential clam habitat. Data gaps with respect to the distribution of habitats, aquatic vegetation, and in-water structures and debris will be addressed through the collection of additional information as part of the clam studies. Habitat information and observations will be used to support restoration planning in the development of FS alternatives for EW. Seafood from the Duwamish estuary, including the EW, is known to be consumed by various user groups, including recreational and tribal fishers and shellfish gatherers. Although it is generally known where intertidal areas occur within the EW, the potential for these areas to support clam harvest or clamming activities (at a minimum) under current and future conditions[2] has not been investigated. The presence of subtidal geoduck populations that may be of interest to the Tribes is currently unknown, as is the potential for any future production (either natural or cultured).

A number of ecological receptors of concern (i.e., crabs, pigeon guillemot, and river otter) that use the EW for foraging may eat small clams as part of their diet. It is currently unknown if clams exist in sufficient quantities in EW sediments such that field-collected clams can be relied upon to represent the clam portion of the diet of these ecological receptors.

Intertidal and subtidal studies are proposed to establish the presence and distribution clams and their habitat in the EW. Clam tissue will also be collected, where possible, to provide estimates of exposure point concentrations of chemicals of interest for EW human and ecological receptors.

2.3 PROJECT/TASK DESCRIPTION AND SCHEDULE

The habitat characterization and clam sampling will be initiated following EPA's approval of this QAPP. This section provides an overview of the sampling and analysis activities and schedule for three of the four studies designed to address the objectives outlined in Section 2.2. Detailed sampling designs are presented in Section 3.1.

2.3.1 Intertidal habitat observations and clam and sediment sampling

Approximately six intertidal beaches were identified based on bathymetric elevations and a field reconnaissance conducted in early June 2008. During an EPA survey in July several other beaches were discovered and shoreline characteristics were observed that resulted in identification of 11 potential sampling areas. Proposed areas for investigation are shown on Map 2-2. Habitat characteristics will be described and

[2] The restoration potential of various locations will be addressed in the development of alternatives that will be evaluated in the FS.

photographed, and evidence of clams will be investigated at each beach area. In areas where clams are found, clams and co-located surface sediments will be sampled. Clam samples will be archived until decisions about compositing across species or sampling areas or the prioritization of analyses are made in consultation with EPA. The intertidal clam study will take place from July 29 to August 2, 2008, based on the low tide schedule for this period (Table 2-1).

Table 2-1. Low tide schedule for proposed sampling period

Date	Time	Tidal Height (ft MLLW)[a]
July 29	8:47 a.m.	-2.3
July 30	9:41 a.m.	-2.8
July 31	10:32 a.m.	-3.0
August 1	11:20 a.m.	-2.9
August 2	12:05 p.m.	-2.3

[a] Based on Lockheed, Harbor Island tide station.

MLLW – mean lower low water

2.3.2 Subtidal habitat remote observations

Observations of subtidal habitat characteristics will rely on a remotely operated video (ROV) camera, a towed video camera, and ship-deployed sediment profile camera. The ROV survey will be conducted by EPA on July 15 and 16, 2008 and will investigate potential geoduck habitat and areas not accessible by other equipment (e.g., shallow, nearshore areas, underpier areas, between bridges). Interpretation of the EPA ROV images will follow within 2 weeks of collection, in coordination with Windward and EPA and its partners. Additional towed video work will be conducted in late August, to address spatial data gaps regarding subtidal habitat conditions that remain after the EPA ROV survey. The SPI camera work is tentatively scheduled for early October 2008. SPI images will be analyzed in late fall 2008.

2.3.3 Subtidal habitat diver observations and geoduck sampling

Videos of bottom habitat collected by the ROV camera will be evaluated by Windward, EPA, and Tribal biologists to identify potential geoduck habitat areas that will be further investigated by divers. To the extent practicable, dives will be coordinated with the rockfish sampling effort scheduled in late summer (August). Divers will observe and photograph habitat conditions and provide written descriptions for each dive location. Areas that cannot be observed by the ROV or towed video (e.g., under bridges) will also be target areas for diver observations. Dive schedules have not been set, but dives are anticipated to occur in August.

2.3.4 Subtidal sediment sampling

Shallow (i.e., 1 m below mudline) core samples representing geoduck exposures will be collected as part of the subsurface sediment sampling program scheduled for early

2009. Shallow cores will be collected in areas where geoducks or their potential habitat has been found based on diver observations. Other details regarding these samples will be documented in the subsurface sediment QAPP.

2.3.5 Sample analysis, validation, and reporting

Intertidal clam tissues and co-located beach sediments will be analyzed within 4 weeks following approval by EPA regarding tissue sample compositing strategies based on the amount of tissue biomass available from each beach area. Geoduck tissue (as individual samples, not composites) will be analyzed within 4 weeks of collection. Data will be validated within 5 weeks of receipt of the final data packages from the laboratories. A draft data report presenting the chemical data for all the clam tissue and co-located sediment samples will be submitted to EPA within 8 weeks of Windward's receipt of validated data. This report will be finalized within 4 weeks of receiving comments from EPA on the draft report. Intertidal and subtidal habitat descriptions and an assessment of habitat quality based on SPI image analysis will be submitted separately, within 4 weeks of receipt of the SPI analysis and report, assuming all other habitat observational data are available (i.e., diver observations and photos and ROV images).

2.3.6 Summary schedule

The tentative schedule for all field work is summarized below (Table 2-2). Field conditions or subcontractor availability may affect the actual schedule.

Table 2-2. Project schedule for clam studies

Activity	Tentative Date Start	Tentative End Date
ROV survey	7/15/2008	7/16/2008
ROV survey interpretation	717/2008	7/31/2008
Intertidal clam tissue and co-located beach sediment sampling	July 29, 2008	August 2, 2008
Consultation with EPA on clam tissue compositng followed by EPA approval	August 8, 2008	
Analysis of clam tissue and co-located sediment	August 18, 2008	September 19, 2008
Data validation	September 22, 2008	October 31, 2008
Additional towed video work	August 2008	
SPI camera work	October 6, 2008	October 10, 2008
SPI images evaluation/interpretation	Late fall	
Subtidal clam sampling	August 2008	
Geoduck chemistry analysis	September 2008	

Data Report	November 3, 2008	December 31, 2008
Habitat Report		Within 4 weeks of receipt of SPI data
Subsurface sediment sampling	Early 2009	

2.4 DATA QUALITY OBJECTIVES AND CRITERIA

The overall data quality objective (DQO) for this project is to develop and implement procedures that will ensure the collection of representative data of known, acceptable, and defensible quality. Parameters used to assess data quality are precision, accuracy, representativeness, comparability, completeness, and sensitivity. These parameters are discussed, and specific data quality indicators (DQIs) for tissue and sediment laboratory analysis are presented, in Section 3.4.2.

2.5 SPECIAL TRAINING/CERTIFICATION

The Superfund Amendments and Reauthorization Act of 1986 requires the Secretary of Labor to issue regulations providing health and safety standards and guidelines for workers engaged in hazardous waste operations. The federal regulation 29CFR1910.120 requires training to provide employees with the knowledge and skills enabling them to perform their jobs safely and with minimum risk to their health. All sampling personnel will have completed the 40-hour hazardous waste operations and emergency response (HAZWOPER) training course and 8-hour refresher courses, as necessary, to meet Occupational Safety and Health Administration regulations.

2.6 DOCUMENTATION AND RECORDS

The following sections describe documentation and records needed for field observations and laboratory analyses.

2.6.1 Field observations

All field activities will be recorded in a field logbook maintained by the FC. The field logbook will provide a description of all sampling activities, conferences associated with field sampling activities, sampling personnel, and weather conditions, plus a record of all modifications to the procedures and plans identified in this QAPP and the HSP (Appendix A). The field logbook will consist of bound, numbered pages. All entries will be made in indelible ink. The field logbook is intended to provide sufficient data and observations to enable participants to reconstruct events that occurred during the sampling period.

The following field data collection sheets (included as Appendix B) will also be used to record pertinent information after sample collection:

- Intertidal habitat observations and photo log
- Subtidal habitat observations and photo log

- Surface sediment collection form
- Clam tissue collection form
- Protocol modification form
- Corrective action form

2.6.2 Laboratory records

The various laboratory record requirements for the co-located tissue and sediment chemistry data are described in this section. The chemistry laboratory will be responsible for internal checks on sample handling and analytical data reporting and will correct errors identified during the QA review. The laboratory data package will be submitted electronically and will include the following:

- **Project narrative**: This summary, in the form of a cover letter, will present any problems encountered during any aspect of analysis. The summary will include, but not be limited to, a discussion of QC, sample shipment, sample storage, and analytical difficulties. Any problems encountered by the laboratory, and their resolutions, will be documented in the project narrative.
- **Records**: Legible copies of the chain-of-custody (COC) forms will be provided as part of the data package. This documentation will include the time of receipt and the condition of each sample received by the laboratory. Additional internal tracking of sample custody by the laboratory will also be documented.
- **Sample results**: The data package will summarize the results for each sample analyzed. The summary will include the following information, as applicable:
  - Field sample identification code and the corresponding laboratory identification code
  - Sample matrix
  - Date of sample extraction/digestion
  - Date and time of analysis
  - Weight and/or volume used for analysis
  - Final dilution volumes or concentration factor for the sample
  - Percent moisture in the samples
  - Identification of the instruments used for analysis
  - Method detection limits (MDLs) and reporting limits (RLs)
  - All data qualifiers and their definitions
- **QA/QC summaries:** These summaries will contain the results of all QA/QC procedures. Each QA/QC sample analysis will be documented with the same information as that required for the sample results (see above). The laboratory

will make no recovery or blank corrections. The required summaries are listed below.

- The calibration data summary will contain the concentrations of the initial calibration and daily calibration standards and the date and time of analysis. The response factor, percent relative standard deviation (%RSD), relative percent differences (RPDs), and retention time for each analyte will be listed, as appropriate. Results for standards analyzed at the RL to determine instrument sensitivity will be reported.
- The internal standard area summary will report the internal standard areas, as appropriate.
- The method blank analysis summary will report the method blank analysis associated with each sample and the concentrations of all compounds of interest identified in these blanks.
- The surrogate spike recovery summary will report all surrogate spike recovery data for organic analyses. The names and concentrations of all compounds added, percent recoveries, and QC limits will be listed.
- The matrix spike (MS) recovery summary will report the MS or MS duplicate (MSD) recovery data for analyses, as appropriate. The names and concentrations of all compounds added, percent recoveries, and QC limits will be included in the data package. The RPD for all MS/MSD analyses will be reported.
- The laboratory replicate summary will report the RPD for all laboratory replicate analyses. The QC limits for each compound or analyte will be listed.
- The standard reference material (SRM) analysis summary will report the results and recoveries of the SRM analyses and list the accuracy, as defined in Section 3.4.2, for each analyte, when available.
- The laboratory control sample (LCS) analysis summary will report the results of the analyses of the LCS. The QC limits for each compound or analyte will be included in the data package.
- The relative retention time summary will report the relative retention times for the primary and confirmational columns of each analyte detected in the samples, as appropriate.

- **Original data:** Legible copies of the original data generated by the laboratory will be provided, including the following:
  - Sample preparation, extraction/digestion, and cleanup logs
  - Instrument analysis logs for all instruments used on days of calibration and analysis

- Chromatograms for all samples, blanks, calibration standards, MS/MSD, laboratory replicate samples, LCS, and SRM samples for all gas chromatography analyses
- Reconstructed ion chromatograms of target chemicals detected in the field samples and method blanks for all gas chromatography/mass spectrometry (GC/MS) analyses
- Enhanced and unenhanced spectra of target chemicals detected in field samples and method blanks, with associated best-match spectra and background-subtracted spectra, for all GC/MS analyses.
- Quantitation reports for each instrument used, including reports for all samples, blanks, calibrations, MS/MSD, laboratory replicates, LCS, and SRMs

The contract laboratories for this project will submit data electronically, in EarthSoft EQuIS® standard four-file or EZ_EDD format. Guidelines for electronic data deliverables for chemical data is provided on the EarthSoft website, http://www.earthsoft.com/en/index.html, and additional information will be communicated to the laboratories by the project QA/QC coordinator or data manager. All electronic data submittals must be tab-delimited text files with all results, MDLs, and RLs reported to the appropriate number of significant figures. If laboratory replicate analyses are conducted on a single submitted field sample, the laboratory sample identifier must distinguish among the replicate analyses.

2.6.3 Data reduction

Data reduction is the process by which original data (analytical measurements) are converted or reduced to a specified format or unit to facilitate data analysis. Data reduction requires that all aspects of sample preparation that could affect the test result, such as sample volume analyzed or dilutions required, be taken into account in the final result. It is the laboratory analyst's responsibility to reduce the data, which are subjected to further review by the laboratory data review specialists, laboratory PM, project QA/QC coordinator, project PM, and independent data reviewers. The data will be generated in a form amenable to review and evaluation. Data reduction may be performed manually or electronically. If performed electronically, all software used must be demonstrated to be true and free from unacceptable error.

2.6.4 Data report

A data report will be prepared to document all activities associated with the collection, handling, and analysis of samples. At a minimum, the following will be included in the data report:

- Summary of all field activities, including descriptions of any deviations from the approved QAPP

- All photographs of benthic habitat (either as pictures in the report or submitted on a CD)
- Summary spreadsheet containing information from field forms
- Extent of the sediment and clam sampling areas (i.e., individual beaches) reported in latitude and longitude to the nearest one-tenth of a second and in northing and easting to the nearest foot
- Plan view of the project showing the actual sampling locations
- Summary of the QA/QC review of the analytical data including a comparison of RLs with ACGs.
- Results from the analysis of field samples included as summary tables in the main body of the report, data forms submitted by the laboratories, and cross-tab tables produced from Windward's database
- Summary statistics (mean, minimum, maximum, frequency of detection) will be provided to EPA to characterize the results.

Once the data report has been approved by EPA, a database export will be created from Windward's database. The data will be exported in a format compatible with Ecology's Environmental Information Management System, which consists of separate tables for events, locations, samples, and results. Data will also be provided to EPA in MS Access. Any relevant geographic information system (GIS) files will also be transmitted to EPA.

3 Data Generation and Acquisition

This section describes the collection and processing of clam tissue samples and sediment samples for chemical analysis. Elements include sampling design, sampling methods, sample handling and custody requirements, analytical methods, QA/QC, instrument/equipment testing and frequency, inspection and maintenance, instrument calibration, supply inspection/acceptance, non-direct measurements, and data management. Three of the four studies detailed in this QAPP is described in the sampling design and sampling methods sections.

3.1 Sampling Design

Separate sampling designs have been developed for each clam study in order to address the study objectives defined in Section 2.2.

3.1.1 Intertidal clam habitat observations and clam and co-located sediment sampling

Approximately 11 intertidal areas have been identified to date, based on field reconnaissance performed in early June and during the ROV survey in July 2008 (Map 2-2). Intertidal beach locations will be confirmed during the first sampling day of the intertidal clam survey. Non-riprapped areas (i.e., beaches consisting of sand, gravel,

cobble, or shell hash) will be the focus of this survey because they are the preferred habitat of clams. Under-pier areas, or intertidal areas that represent a hazard to field workers (e.g., under condemned piers), will not be visited (the two under-pier areas scheduled for demolition are exceptions where safe access is possible).

Observations and sample collection will be conducted during low tide along the entire length of each beach between the uppermost elevation with intertidal sediment and the lowest extent of the exposed beach. A low tide of at least -2.0 ft MLLW is required to provide sufficient beach area for investigation. Elevation ranges will be estimated based on times relative to the published low tide..

Habitats present at each beach will be described and documented using digital photos. Clams and sediment will be sampled at points with evidence of clam presence (e.g., siphons showing or dimples) or from quadrats placed randomly along transects paralleling the beach.

Assuming sufficient biomass of clams is found, clams will be sorted by species. The overall goal is to create at least one composite sample for each beach area sampled; however, compositing strategies will be approved by EPA. Prior to compositing whole (in-shell) clams will be frozen until such decisions are made. Transects that characterize the entire beach will be executed and clam tissue will be collected from as broad an area as possible. Clams that are typically targeted for recreational shellfish harvest will be the preferred species (i.e., butter, native and Japanese littleneck, and softshell clams), although any clam will be collected. Surface sediment will be collected and composited from each beach at locations where clams are sought. Tissue compositing decisions will be made by EPA following field collection and discussions with EWG.

3.1.2 Subtidal clam habitat observations

Subtidal clam studies will be conducted to evaluate the distribution and characteristics of available clam habitat and to collect (if possible) geoduck that may be harvested by tribal members. Subtidal studies will focus on areas of the EW that have not been dredged within the past 2 years (recently disturbed sediments are unlikely to support populations of geoduck because of their longevity and their response to the presence of other geoduck as a trigger for larval settlement).

Clam habitat distribution will be investigated using photographic techniques and diver observations. Videography (ROV and/or towed video) and SPI will make up the photographic techniques. Real-time observations are possible using video. Field notes will document any unique habitat features as well as discrete shifts in habitat features. Windward, EPA, and Tribal biologists will evaluate images following collection by EPA to select areas for additional diver observations. Potential geoduck sampling areas will be identified based on the presence of likely habitat (i.e., silt, sand, or gravel substrates; low slope; limited debris or physical disturbance; and aquatic vegetation) or evidence of clam occurrence based on the video survey.

Use of the SPI camera will be limited to soft sediment areas (i.e., areas in where the equipment can penetrate the sediment); successful deployment in steep areas may also be limited. The SPI camera will be used to investigate Slips 27 and 36, as well as the restoration south of the Spokane Street and West Seattle Bridges.

3.1.3 Subtidal geoduck and co-located sediment sampling

Geoducks will be collected by divers (if possible) for chemical analysis; sediment samples will be subsequently collected by means of shallow core sampling from the top 3 ft (90 cm), the extent of geoduck burrowing, in the vicinity of any geoduck collection areas. Proposed geoduck sampling areas will be documented in an addendum to this QAPP following the review of visual information.

Following the selection of sampling areas in consultation with EPA and Tribal biologists, divers will be deployed to the potential geoduck sampling areas. Divers will provide habitat observations, estimate geoduck density, and will attempt to sample geoduck using hand tools (use of hydraulic tools is not proposed). If geoduck are not present (or cannot be sampled) but horse clams are, this surrogate species will be collected to represent geoduck tissue residues. Shallow core sampling protocols will be the subject of a separate QAPP.

3.2 SAMPLING METHODS

The sampling methods for each of the studies are described in separate sections below. During field activities, there may be contingencies that require modification of the general procedures outlined below. Modifications will be at the discretion of the FC after consultation with the Windward PM and the boat operator, if applicable. EPA will be consulted in the event that significant deviations from the sampling design are required. All modifications will be recorded in the logbook.

3.2.1 Identification scheme for all locations and samples

Each beach will be assigned a unique alpha-numeric location ID number. The first two characters of the location ID are "EW" to identify the East Waterway project area. The sampling locations for the overall project are divided into intertidal and subtidal groups, as indicated by a single character following the project area: B for an intertidal beach; S for a subtidal location. The specific location is indicated by a two-digit number that follows the intertidal/subtidal notation (beaches will be number 01-11, per Figure 2-2; subtidal sampling areas will be numbered separately).

The next characters indicate the sample medium to be collected at that location, SS for surface sediment, JL for Japanese littleneck clam tissue, MA for macoma clam tissue, BC for butter clam tissue, BN for bent-nose clam tissue, or GD for geoduck tissue[3] (HC if only horse clam are found). When more than one sample of a specific medium is

[3] Sediment samples co-located with geoduck samples will be collected as part of the subsurface sediment sampling program. Details will be provided in the subsurface sediment QAPP.

collected at a given location, a two-digit numeric suffix greater than -01 will be added (original samples are all labeled -01). Sample names for surface sediment samples will also contain the depth of collection (i.e., -030 to indicate the sediment was collected from 0 to 30 cm). Examples of sample naming conventions for the clam studies follow:

- EW-B01-JL-01 (East Waterway, Beach 1, Japanese littleneck clam tissue, first bag of clams)
- EW-B01-JL-02 (East Waterway, Beach 1, Japanese littleneck clam tissue, second bag of clams)
- EW-B01-SS-030 (East Waterway, Beach 1, surface sediment, collected from 0 to 30 cm)
- EW-S03-GD-01 (East Waterway, Subtidal location 3, first geoduck)

Once clams have been composited, a unique sample identifier will be assigned to the composite sample. Since composite samples may include clams collected from multiple beaches, the number of the beach may not be appropriate to include in a sample label. In cases where clams have been composited across beaches, the numbers of the individual beaches contributing to the composite will be identified. It is recognized that compositing across beaches is highly undesirable, and that compositing decisions will be made in discussions with EWG, EPA and stakeholders. The suffix "-comp" will be added to the sample identifier to indicate that it is a composite sample followed by sequential numbers. An example of the sample naming conventions for the clam samples is EW-B123-CT-comp01 (East Waterway, composite from beaches 1, 2, and 3, first composite sample)

Geoduck will not be combined into composite samples so each sample will be identified using the individual geoduck specimen identifiers.

3.2.2 Location positioning

Sampling locations will be documented using a differential global positioning system (DGPS). A handheld DGPS unit will be used during intertidal sampling, and a DGPS unit mounted on the winch arm will be used with equipment deployed from a sampling vessel (e.g., SPI camera). The DGPS unit is wide-area augmentation system enabled and will receive DGPS signals from satellites to both triangulate a position and provide a locational correction factor, resulting in positioning accuracy of within 3 m. Washington State Plane coordinates North (NAD 83) will be used for the horizontal datum.

3.2.3 Habitat observations

Visual observations of intertidal clam habitat will be made during visits to beaches that are exposed during low tides (including two areas of current or planned pier demolition where safe access is possible). Observations will include apparent grain size/sediment texture; beach slope; degree of exposure to wind- or ship-generated

wave action; presence of macroalgae, debris, or man-made structures; and the presence and type of other organisms (e.g., worms, amphipods, crab) on or within the sediment. Observations will be documented using digital photography of beach characteristics and further described in field notes. DGPS coordinates will be taken at points of observations whenever possible. Areas identified for piling and planking removal that cannot be accessed as part of this survey will be evaluated for habitat in the SRI.

Subtidal clam habitat will be investigated using photographic techniques and diver observations. Subtidal studies will primarily rely on EPA's ROV or a towed video camera (in the event of incomplete ROV observations) and an SPI camera (plan and profile photos) to characterize benthic habitats.

In areas where a towed camera may not be successfully deployed (potentially Slip 27, Slip 36, or the restoration area south of the West Seattle/Spokane Street bridges), ROV and SPI equipment will be used to provide habitat information. Areas that are inaccessible to either a video camera or the SPI camera, and where over- or in-water structures do not represent a hazard, will be visited by divers. One exception is under-pier areas, which are assumed to be poor clam habitat as a result of the presence of riprap and will not be included in the habitat survey. Divers will also be used to collect detailed observations in areas of likely geoduck habitat, as suggested by EPA's video results or based on the best professional judgment of Windward, EPA, and Tribal shellfish biologists. Bottom conditions will be documented by deploying the ROV in the narrow upstream entrance to the waterway, under the Spokane Street, West Seattle, and railroad bridges, in shoreline areas with limited vessel access and at the mouth of the waterway. Estimates of the locations of discrete changes in habitat type, unique habitat features, or evidence of geoducks (or other large clams) will be made based on the DGPS coordinates of sampling vessel plus the wire length and heading of the ROV (actual DGPS coordinates of the ROV are not available with EPA's current equipment setup). Additional video or still photos will be collected in areas that indicate the potential presence of geoduck (primarily evidence of large clam siphons). EPA currently plans to provide two days of field effort with the ROV. Additional remote investigations using a towed video camera operated by a subcontractor to Windward will complete the spatial evaluation of benthic habitat in the waterway. The subcontractor will provide an additional field day for this effort.

The SPI equipment will provide sediment surface (plan view) and profile images on a regular grid (up to 180 images each) throughout the waterway. It is anticipated that these visual studies will each require two days of field effort. Deployment and analytical protocol are provided in a QAPP prepared by the SPI subcontractor and included as an appendix to this QAPP. Still photos and SPI images will be geo-referenced and will be used to map the extent of subtidal riprap placement and unique habitat features within the EW. Where evident, the presence of large clams, other macrofauna, or macroalgae will be noted. SPI images will be evaluated to assess of the

degree of physical disturbance, biological activity, successional stage of the invertebrate community dwelling within the sediment, and the overall habitat quality.

3.2.4 Clam tissue and co-located sediment collection

Clams will be collected using a variety of methods, including digging with hand tools in intertidal areas and hand removal of large subtidal clams by divers. Sampling of small subtidal clams from either a benthic sledge or van Veen grab sampler deployed from a boat will occur as part of the benthic invertebrate prey tissue collection and will be described in the QAPP associated with that effort.

Intertidal sampling will focus on, but not be limited to, clams larger than approximately 4 cm (1.5 in.[4]); however, all clams will be retained to ensure that sufficient tissue is collected for the purposes of the ERA and HHRA. Diver collection will specifically target geoduck that would be a Tribal resource, if they are present (horse clam may be used as a surrogate for geoduck).

Sediments will be collected by hand from intertidal clam sampling areas. Co-located sediment in geoduck sampling areas will be collected as part of the subsurface sediment sampling program; details will be provided in a separate QAPP. Sediments associated with small clams that will represent infaunal prey for higher-order receptors will be collected using a van Veen grab as part of the infaunal tissue collection effort and will be described in that QAPP.

3.2.4.1 Intertidal Clam Collection

Beaches present in the EW are typically small pocket beaches, with the exception of Slip 27 (#5), the under-bridge areas (#8 and #10), and the restoration beach (#9) south of the Spokane St. Bridge. Intertidal beaches that may support clam populations or clamming activities are identified in Map 2-2; under-pier intertidal areas will not be sampled (with the exception of the current pier demolition area near Terminal 25 and the planned pier demolition near the USCG facility).

At each sampling location, the entire beach will be canvassed for the presence of clams by looking for siphons, dimples, or siphon holes (clam "shows"). Sample quadrats (0.25 square meter [m^2]) will be placed at clam shows for purpose of excavating clams and identifying the area that co-located sediment will be sampled. Representative tissue and sediment samples will be collected from the entire beach area to avoid spatially biasing the characterization of the beach and potential exposure estimates.

If no clam shows are evident, transects will be laid out along the beach to represent upper, mid- and lower tidal levels (the upper tidal level may not be present at some of the beaches due to the presence of riprap). A survey tape will be run along each beach stratum; each meter marker will represent a potential sampling point. Random numbers will be generated to represent at least 5 sampling points along each transect

[4] 1.5 in. is the regulatory limit for several recreationally harvested clam species and is used here as a surrogate for the size of clams may be targeted by recreational or Tribal shellfish gatherers.

or 10 percent of each transect (whichever is greater) to direct the intertidal sampling. Sample quadrats will be placed at the identified points that will be excavated along each transect.

Sediment within each quadrat will be excavated to a depth of 30 cm (1 ft) below the sediment surface at each sampling point using a small shovel or hand trowel. Any clams encountered will be removed by hand. The remaining sediment will be screened through a 2-mm mesh screen; clams larger than (or equal to) approximately 4 cm will be sorted by species and retained for potential analysis (broken clams will not be included in the sample). Smaller (less than 4 cm and retained on the sieve screen) clams that may represent invertebrate exposures or possible subsistence consumption will also be retained.

Field personnel will wear nitrile powder-free examination gloves; all sampling equipment will be stainless steel and will be rinsed with site water between samples to avoid contaminating tissue specimens during collection and handling.

Clams will be rinsed with site water, large clams will be separated by species (small clams will not be sorted in the field), wrapped in the shell in clean foil (shiny side out), and double bagged in plastic zip-lock bags. Samples will be held on ice until transport to the laboratory. Undepurated clams (whole body) will be frozen until a tissue compositing strategy is finalized by EPA. Removal of the clam tissue from the shell will be performed by ARI.

One surface sediment sample will also be collected and composited at each beach. The top 30 cm of sediment will be used to represent clam exposures. Sediment will be collected from each location where digging for clams takes place; a total volume of 68 ounces will be collected from each beach. Sediment will be homogenized in the laboratory by Windward personnel and placed in two 16-oz glass jars, two 8-oz glass jars, one 4-oz glass jar, and one 16-oz high density polyethylene jar prior to relinquishing custody to the lab.

There will only be one opportunity to perform the intertidal survey in the summer of 2008, based on remaining low tides. There are 5 days of low tides, lasting about 4 to 6 hours each day in late July and early August. In order to maximize the level of effort to determine clam presence, two field crews will be deployed.

Sampling efforts will be coordinated with outgoing and incoming tides to maximize the time available and amount of beach exposed. An estimate of the duration of daily available sampling periods has been made assuming an equal rate of tidal rise and fall; the available sampling periods are presented in Table 3-1.

Table 3-1. Available sampling periods for intertidal clam collection

DATE	Dropping			Time at LOW	Rising		
	Time at +2 ft	Time at 0.0 ft	Time at -2.0 ft		Time at -2.0 ft	Time at 0.0 ft	Time at +2 ft
29-Jul	6:28 am	7:35 am	8:41 am	8:48 am	8:55 am	10:01 am	11:08 am
30-Jul	7:02 am	8:09 am	9:15 am	9:42 am	10:51 am	11:15 am	12:22 pm
31-Jul	7:47 am	8:53 am	10:00 am	10:33 am	11:39 am	12:13 pm	1:13 pm
1-Aug	8:38 am	9:44 am	10:51 am	11:21 am	11:51 am	12:58 pm	2:25 pm
2-Aug	9:43 am	10:49 am	11:54 am	12:06 pm	12:16 pm	1:23 pm	2:29 pm

The level of effort invested in clam sampling will depend on beach size. A three-person crew will spend approximately two hours at a small pocket beach; a crew will spend an entire low tide cycle at a larger beach. There are 11 beaches to be sampled in 5 days; the goal will be to complete sampling at 2 to 3 beaches per day using 2 crews.

3.2.4.2 Subtidal Clam Collection

Divers will be deployed to areas of likely geoduck habitat, as identified in video survey records and in consultation with EPA and Tribal biologists. If geoducks are present, divers will document the occurrence by taking digital images of the siphon shows and recording the spatial coordinates of the sampling location. If substrates are soft enough at a given location to allow hand collection, a geoduck will be removed from the substrate for subsequent tissue analyses[5] (tissue samples will represent individual samples, rather than composites). If geoducks are not present, but other large clams (e.g., horse clams) are present, these clams will be collected as a surrogate to represent geoduck exposures.

Small hand tools may also be used to assist in removal. If the substrates are compacted such that hand removal is not possible, no samples will be collected at that location. To further support the benthic habitat assessment in the EW, divers will also take digital images of habitat conditions in the vicinity of their dive, regardless of the success in locating geoducks.

Divers will not be used to collect sediment samples at geoduck sampling locations because of the potential loss of sediment associated with diving techniques. Rather, the sampling vessel that will be mobilized for subsurface sediment chemistry sampling will reoccupy the geoduck sampling area and collect sediment to a depth of

[5] Geoducks are currently not harvested for human consumption in the EW and are not assumed to represent a component of the diet of ecological receptors of concern for the EW. If present, these clams represent a potential resource for Tribes.

1 m at that time. This effort will be described in greater detail in the subsurface sediment QAPP.

3.2.5 Field equipment

The following items will be needed in the field for all three studies:

- QAPP
- Field collection forms
- Study area maps
- Tide tables
- COC forms
- Field notebooks and pens/pencils/Sharpies®
- Digital camera
- DGPS
- Batteries
- 200-mL beaker
- Stainless steel bowls and spoons
- Garden sprayer
- Alconox® detergent
- Scrub brushes
- Distilled water
- Coolers
- Powder-free nitrile exam and rubber work gloves
- Boots (or waders)
- Duct tape
- Aluminum foil
- Paper towels
- First aid kit

Study-specific field equipment for the intertidal survey is as follows:

- 50-m survey tape
- Survey stakes
- 0.25 m^2 quadrat
- Clam identification key

- Ice
- Stainless steel shovel or trowels
- Zip-lock bags for clams
- Buckets

EPA will provide its own equipment for the ROV. Subcontractors will provide survey-specific equipment for the towed video, SPI, and diver studies. Intertidal tissue and sediment collection/handling equipment will be provided by Windward; sampling equipment for small subtidal clams and sediment will be specified in separate QAPPs associated with the infaunal prey assessment and subsurface sediment sampling efforts. Geoduck tissue handling equipment is included in the above lists.

Prior to mobilization, these lists will be consulted to ensure all equipment is available and pre-cleaned. As part of the mobilization process, each item will be double-checked by the FC (see Section 3.6).

3.3 Sample Handling and Custody Requirements

This section describes how individual samples will be processed, labeled, tracked, stored, and transported to the laboratory for analysis. In addition, this section describes decontamination procedures, procedures for the disposal of field-generated wastes, sample custody procedures, and shipping requirements. Sample custody is a critical aspect of environmental investigations. Sample possession and handling must be traceable from the time of sample collection, through laboratory and data analyses, to delivery of the sample results to the recipient.

3.3.1 Sample handling procedures

Whole-body clams and geoducks will be sorted by species in the field and wrapped in clean aluminum foil, shiny side out. Each foil package will be double-bagged in sealed zip-lock bags and stored on ice (or frozen gel packs) while in the field. Sediment for chemical analyses will be placed in several large pre-cleaned, wide-mouth glass jars and capped with Teflon®-lined lids for transport to the lab. All sediment and clam sample containers will be filled leaving a minimum of 2.5 cm of head space to prevent breakage during shipping and storage. Prior to transfer to the laboratory, each glass container will be wrapped in bubble wrap, individually placed in a zip-lock bag, and placed in a sturdy cooler with frozen gel packs or ice. Each jar or bag will be sealed, labeled, and stored under appropriate conditions, as outlined in Section 3.3.1.

Sediment will be homogenized by Windward personnel at the lab using stainless steel bowls and spoons and transferred into containers as specified in Tables 3-2 and 3-3; sediment for grain size analysis may be held in high density polyethylene (HDPE) jars. Tissue samples will be composited and homogenized at ARI according to their standard operating procedures, following agreement between EPA and EWG regarding a compositing strategy. Once the tissue samples are composited and

homogenized, the homogenate will be stored in appropriately sized, pre-cleaned, wide-mouth glass jars and capped with Teflon®-lined lids. All samples will be stored frozen at the laboratories, with the exception of sediment sample for grain size analysis which will be refrigerated.

Table 3-2. Container requirements for tissue samples

PARAMETER	CONTAINER TYPE
PCBs (as Aroclors), organochlorine pesticides, SVOCs (including PAHs)	aluminum foil and double bagged in zip-lock bags (whole specimen including shell); glass jar (homogenate)[a]
Total metals, including mercury, butyltins, total solids, lipids	aluminum foil and double bagged in zip-lock bags (whole specimen including shell); glass jar (homogenate)[a]
PCB congeners, dioxins and furans[b]	aluminum foil and double bagged in zip-lock bags (whole specimen including shell); glass jar (homogenate)[a]
Inorganic arsenic[c]	aluminum foil and double bagged in zip-lock bags (whole specimen including shell);glass jar (homogenate)[a]
Organochlorine pesticide confirmation using GC/MS/MS[d]	aluminum foil and double bagged in zip-lock bags (whole specimen including shell);glass jar (homogenate)[a]

[a] The laboratory will identify the appropriate size jar for the homogenate in order to ensure 1 inch headspace.

[b] Tissue homogenate will be archived frozen at ARI, and sent to Analytical Perspectives when specific samples for PCB and dioxin/furan congener analyses have been identified based on the Aroclor data.

[c] Following tissue homogenization, a frozen subsample of clam tissue will be sent to Brooks Rand for analysis of inorganic arsenic.

[d] CAS will provide confirmatory analyses

ARI – Analytical Resources, Inc.

CAS – Columbia Analytical Services, Inc.

GC/MS/MS – gas chromatography/mass spectrometry/mass spectrometry

PAH – polycyclic aromatic hydrocarbon

PCB – polychlorinated biphenyl

SVOC – semivolatile organic compound

Table 3-3. Container requirements for sediment samples

PARAMETER	CONTAINER TYPE
PCBs (as Aroclors), organochlorine pesticides, SVOCs (including PAHs)	16-oz glass jar[a]
Total metals including mercury, butyltins, TOC, total solids	16-oz glass jar[a]
Grain size	16-oz HDPE jar[b]
PCB congeners, dioxins and furans	8-oz glass jar[a,c]
Organochlorine pesticide confirmation using GC/MS/MS[d]	8-oz glass jar
Inorganic arsenic	4-oz glass jar

[a] One sample must be collected in duplicate for laboratory QA/QC samples.

[b] One sample must be collected in triplicate for laboratory QA/QC samples.

[c] Sediment will be archived at ARI, and sent to Analytical Perspectives when specific samples for PCB and dioxin/furan congener analyses have been identified based on tissue samples selected for congener analysis.

[d] CAS will provide confirmatory analyses

ARI – Analytical Resources, Inc.

CAS – Columbia Analytical Services, Inc.
HDPE – high-density polyethylene
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
SVOC – semivolatile organic compound
TOC – total organic carbon
GC/MS/MS – gas chromatography/mass spectrometry/mass spectrometry

Sample labels will be waterproof and self-adhering. Each sample label will contain the project number, sample identification, preservation technique, analyses, date, and time of collection and initials of the person(s) preparing the sample. A completed sample label will be affixed to each sample container. The labels will be covered with clear tape immediately after they have been completed to protect them from being stained or soiled from water and sediment. At each laboratory, a unique sample identifier will be assigned to each sample.

3.3.2 Decontamination procedures

All sediment sampling and homogenizing equipment, including the mixing bowl and stainless steel implements, will be decontaminated according to PSEP guidelines (1997a) between stations or samples using the following procedures:

1. Rinse with site water and wash with a scrub brush until free of sediment.
2. Wash with phosphate-free detergent.
3. Rinse with site water.
4. Rinse with distilled water.

Acid or solvent washes will not be used in the field because of safety considerations and problems associated with rinsate disposal and sample integrity. Specifically:

- The use of acids or organic solvents may pose a safety hazard to the field crew.
- Disposal and spillage of acids and solvents during field activities pose an environmental concern.
- Residues of solvents and acids on sampling equipment may affect sample integrity for chemical testing.

Any sampling equipment that cannot be cleaned to the satisfaction of the FC will not be used for further sampling activity.

3.3.3 Field-generated waste disposal

Excess sediment, non-target invertebrates, generated equipment rinsates, and decontamination water will be returned to each sampling location after sampling has been completed at that location. All disposable sampling materials and personal protective equipment used in sample processing, such as disposable coveralls, gloves, and paper towels, will be placed in heavy-weight garbage bags or other appropriate

containers. Disposable supplies will be removed from the site by sampling personnel and placed in a normal refuse container for disposal as solid waste.

3.3.4 Sample custody procedures

Samples are considered to be in custody if they are: 1) in the custodian's possession or view, 2) retained in a secured place (under lock) with restricted access, or 3) placed in a container and secured with an official seal(s) such that the sample cannot be reached without breaking the seal(s). Custody procedures will be used for all samples throughout the collection, transport, and analytical process. Custody procedures will be initiated during sediment and tissue sample collection. A COC form will accompany samples to the analytical laboratory. Each person who has custody of the samples will sign the COC form and ensure that the samples are not left unattended unless properly secured. Minimum documentation of sample handling and custody will include:

- Project name and unique sample number
- Sample collection date and time
- Any special notations on sample characteristics or problems
- Initials of the individual collecting the sample
- Date sample was sent to the laboratory
- Shipping company name and waybill number

The FC will be responsible for all sample tracking and custody procedures for samples in the field. The FC will be responsible for final sample inventory and will maintain sample custody documentation. The FC will also complete COC forms prior to removing samples from the sampling area. At the end of each day, and prior to transfer, COC entries will be made for all samples. Information on the labels will be checked against sample log entries, and sample tracking forms and samples will be recounted. COC forms will accompany all samples. The COC forms will be signed at each point of transfer. Copies of all COC forms will be retained and included as appendices to the data reports. Tissue and sediment samples will be shipped or hand delivered to the analytical laboratories in sealed coolers with custody seals.

The laboratories will ensure that COC forms are properly signed upon receipt of the samples and will note questions or observations concerning sample integrity on the COC or other sample receipt forms. The laboratories will contact the FC or project QA/QC coordinator immediately if discrepancies are discovered between the COC forms and the sample shipment upon receipt.

The laboratory will ensure that a sample tracking record follows each sample through all stages of laboratory processing. The sample tracking record for chemistry samples must contain, at a minimum, the name/initials of individuals responsible for

performing the analyses, dates of sample extraction/preparation and analyses, and the types of analyses being performed.

3.3.5 Shipping requirements

Sample coolers containing clam tissue and sediment samples will be transported directly to ARI. Subsamples of the homogenized composite samples will be shipped in sturdy coolers with ice or frozen gel packs to Analytical Perspectives, Brooks Rand, and CAS. The temperature inside the cooler(s) containing chemistry samples will be checked by the laboratory upon receipt of the samples. The laboratory will specifically note any coolers that do not contain ice packs or that are not sufficiently cold (4° ± 2°C) upon receipt. Each sample will be assigned a unique laboratory number, and samples will be grouped in appropriate sample delivery groups (SDGs).

Samples will be assigned a specific storage area within the laboratory and will be kept there until analyzed. Tissues will be frozen upon receipt until analysis. The analytical laboratory will not dispose of the environmental samples for this project until notified in writing by the project QA/QC coordinator.

3.4 ANALYTICAL METHODS

This section discusses laboratory methods, sample handling requirements, and DQIs for the chemical analyses of the tissue and co-located sediment samples. All samples will be analyzed for PCB Aroclors, organochlorine pesticides, SVOCs, total metals including mercury, inorganic arsenic, butyltins, total solids, lipids (tissue samples only), and grain size (sediment samples only). A subset of samples will be analyzed for PCB congeners and dioxins/furans. If pesticides are detected in the initial analysis, a second subset of samples may be analyzed for confirmation by GC/MS/MS. If insufficient sample mass is available for all tests, analyses will be prioritized in consultation with EPA and ways to reduce tissue mass requirements will be investigated.

3.4.1 Laboratory methods and sample handling

Chemical analyses of the tissue and sediment samples will be conducted at four different laboratories, as identified in Table 3-4.

Table 3-4. Chemical analyses by analytical laboratory

ARI	ANALYTICAL PERSPECTIVES	BROOKS RAND	CAS
PCB Aroclors Organochlorine pesticides[a] SVOCs Total metals, including mercury Butyltins Lipids Total solids Grain size	PCB congeners [b] Dioxins and furans [b]	Inorganic arsenic	Organochlorine pesticide confirmation by GC/MS/MS

[a] GC/MS/MS pesticide analysis may be conducted on a subset of samples at CAS if sufficient sample mass is available.

[b] PCB congener and dioxins/furans analysis will be conducted on a subset of samples if sufficient sample mass is available.

ARI – Analytical Resources, Inc.

CAS – Columbia Analytical Services, Inc.

GC/MS/MS – gas chromatography/mass spectrometry/mass spectrometry

PCB – polychlorinated biphenyl

SVOC – semivolatile organic compound

Clams (whole body, with shell) will be collected and stored according to species in the field and then shipped to ARI for archiving via freezing. All tissue samples will be homogenized at ARI according to their laboratory standard operating procedures, following an agreement between Windward and EPA as to how clam tissues should be composited. A frozen subsample of homogenized samples will be sent to Brooks Rand for inorganic arsenic analysis. The remaining samples will be stored at ARI until a subset of samples are identified for the analysis of polychlorinated biphenyl (PCB) congeners and dioxin and furan analysis and sent to Analytical Perspectives. In addition, a subset of samples may be submitted to CAS for gas chromatography/mass spectrometry/mass spectrometry (GC/MS/MS) confirmation of the pesticide results.

If sufficient tissue is available clam tissue samples will be analyzed for inorganic arsenic, semivolatile organic compounds (SVOCs),[6] total metals,[7] total mercury, PCBs as Aroclors, organochlorine pesticides, lipids, percent solids, and butyltins. All 209 PCB congeners will be analyzed in a subset of the clam tissue samples using a tiered approach (Windward 2004). In this approach, all clam tissue samples will first be analyzed for total PCBs as an Aroclor sum, and a split sample will be archived. Based on the Aroclor results, selected clam samples will be analyzed for PCB congeners and dioxins and furans.

[6] SVOC analyses for clam samples will include polycyclic aromatic hydrocarbons.

[7] Antimony, arsenic, cadmium, chromium, cobalt, copper, lead, molybdenum, nickel, selenium, silver, thallium, vanadium, and zinc.

The co-located sediment samples collected at the clam and geoduck sampling locations will be analyzed for TOC, percent solids, grain size, SVOCs, total metals (including mercury), PCBs as Aroclors, butyltins, and organochlorine pesticides. A subset of clam and geoduck co-located sediment samples will also be analyzed for the full list of 209 PCB congeners.[8] The sediment samples to be analyzed for PCB congeners will be co-located with the tissue samples selected for PCB congener analysis. Analytical methods and sample handling requirements for tissue and sediment samples are presented in Tables 3-5 and 3-6, respectively.

Table 3-5. Laboratory analytical methods and sample handling requirements for tissue samples

Parameter	Method	Reference	Sample Holding Time[a]	Preservative
PCBs as Aroclors	GC/ECD	EPA 8082[b]	1 year to extract, 40 days to analyze	freeze/-20°C
PCB congeners	HRGC/HRMS	EPA 1668	1 year to extract, 1 year to analyze	freeze/-20°C
Dioxins and furans	HRGC/HRMS	EPA 1613B	1 year to extract, 1 year to analyze	freeze/-20°C
Organochlorine pesticides[c]	GC/ECD[d]	EPA 8081A	1 year to extract, 40 days to analyze	freeze/-20°C
PAHs	GC/MS	EPA 8270[e]	1 year to extract, 40 days to analyze	freeze/-20°C
SVOCs	GC/MS	EPA 8270D	1 year to extract, 40 days to analyze	freeze/-20°C
Arsenic (inorganic)	HG-AFS	EPA 1632	6 months	freeze/-20°C
Total mercury	CVAA	EPA 7471A	6 months	freeze/-20°C
Other total metals[f]	ICP-MS, ICP-AES, or GFAAS	EPA 6020, EPA 6010B, or EPA 7000	6 months	freeze/-20°C
Tributyltin, dibutyltin, monobutyltin (as ions)	GC/FPD	Krone et al. (1989)	1 year to extract, 40 days to analyze	freeze/-20°C
Lipids	DCM: acetone extraction gravimetric	NOAA (1993)	1 year	freeze/-20°C
Total solids	freeze-dried or oven-dried	PSEP (1986) or EPA 160.2	6 months	freeze/-20°C

a All samples will be archived frozen at the laboratory until the Windward PM or QA/QC officer authorizes their disposal.

b If more than one Aroclor is detected in a sample, the laboratory will choose unique peaks to quantify each Aroclor.

c Target pesticides include 4,4'-DDT, 4,4'-DDE, 4,4'-DDD, 2,4'-DDT, 2,4'-DDE, 2,4'-DDD, aldrin, alpha-BHC, beta-BHC, delta-BHC, gamma-BHC, oxychlordane, alpha- and gamma-chlordane, cis- and trans-nonachlor, dieldrin, endosulfan, endosulfan sulfate, endrin, heptachlor, heptachlor epoxide, hexachlorobenzene, methoxychlor, mirex, and toxaphene.

d All extracts will be archived frozen, and detected pesticides and Aroclors may have their identification confirmed with GC/MS/MS by EPA 1699 (modified) at CAS, as necessary, to meet project needs.

[8] Dioxin-like PCB congeners include congeners 77, 81, 105, 114, 118, 123, 126, 156, 157, 167, 169, and 189; and principal PCB congeners include congeners 66, 101, 110, 138, 153, and 180.

[e] Target PAHs include: anthracene, pyrene, dibenzofuran, benzo(g,h,i)perylene, indeno(1,2,3-cd)pyrene, perylene, benzo(b)fluoranthene, fluoranthene, benzo(k)fluoranthene, acenaphthylene, chrysene, benzo(a)pyrene, dibenz(a,h)anthracene, benzo(a)anthracene, acenaphthene, phenanthrene, fluorene, 1-methylnaphthalene, naphthalene, and 2-methylnaphthalene.

[f] Antimony, arsenic, cadmium, chromium, cobalt, copper, lead, molybdenum, nickel, selenium, silver, thallium, vanadium, and zinc.

BHR-AA – borohydride reduction-atomic absorption

CVAA – cold vapor atomic absorption spectrophotometry

DCM – dichloromethane

GC/ECD – gas chromatography/electron capture detection

GC/FPD – gas chromatography/flame photometric detection

GC/MS – gas chromatography/mass spectrometry

GFAAS – graphite furnace atomic absorption spectrophotometry

HRGC/HRMS – high-resolution gas chromatography/high-resolution mass spectrometry

HG-AFS – hydride generation-atomic fluorescence spectrometry

ICP-AES – inductively coupled plasma-atomic emission spectrometry

ICP-MS – inductively coupled plasma-mass spectrometry

NOAA – National Oceanic and Atmospheric Administration

PAH – polycyclic aromatic hydrocarbon

PSEP – Puget Sound Estuary Program

SIM – selective ion monitoring

SVOC – semivolatile organic compound

Table 3-6. Laboratory analytical methods and sample handling requirements for sediment samples

Parameter	Method	Reference	Sample Holding Time[a]	Preservative
PCBs as Aroclors	GC/ECD	EPA 8082A	14 days to extract, 40 days to analyze[b]	cool/4°C
PCB congeners[c]	HRGC/HRMS	EPA 1668	1 year to extract, 40 days to analyze	freeze/-20°C
Dioxins and furans	HRGC/HRMS	EPA 1613B	1 year to extract, 40 days to analyze	freeze/-20°C
Organochlorine pesticides[d]	GC/ECD	EPA 8081A	14 days to extract, 40 days to analyze[b]	cool/4°C
PAHs[e]	GC/MS	EPA 8270-SIM	14 days to extract, 40 days to analyze[b]	cool/4°C
SVOCs	GC/MS	EPA 8270D	cool/4°C	cool/4°C
Tributyltin, dibutyltin, monobutyltin (as ions)	GC/FPD	Krone et al. (1989)	14 days to extract, 40 days to analyze[b]	cool/4°C
Other total metals[f]	ICP-MS, ICP-AES, or GFAAS	EPA 6020, EPA 6010B, or EPA 7000	1 year	cool/4°C
Total mercury	CVAA	EPA 7471A	28 days[g]	cool/4°C
Grain size	sieve/pipette	PSEP (1986)	None	none
TOC	combustion	Plumb (1981)	28 days[g]	cool/4°C
Percent solids	oven-dried	PSEP (1986)	7 days[g]	cool/4°C

[a] All samples will be archived frozen at the laboratory until the Windward PM or QA/QC officer authorizes their disposal.

[b] Sediment can also be frozen to increase the holding time to 1 year to extraction. Aqueous rinsate blanks have a maximum holding time of 7 days to extract and 40 days to analyze and will be stored at 4°C.

[c] complete list of 209 congeners

[d] Target pesticides include 4,4'-DDT, 4,4'-DDE, 4,4'-DDD, 2,4'-DDT, 2,4'-DDE, 2,4'-DDD, aldrin, alpha-BHC, beta-BHC, delta-BHC, gamma-BHC, oxychlordane, alpha- and gamma-chlordane, cis- and trans-nonachlor, dieldrin, endosulfan, endosulfan sulfate, endrin, heptachlor, heptachlor epoxide, hexachlorobenzene, methoxychlor, mirex, and toxaphene.

[e] Target PAHs include anthracene, pyrene, dibenzofuran, benzo(g,h,i)perylene, indeno(1,2,3-cd)pyrene, perylene, benzo(b)fluoranthene, fluoranthene, benzo(k)fluoranthene, acenaphthylene, chrysene, benzo(a)pyrene, dibenz(a,h)anthracene, benzo(a)anthracene, acenaphthene, phenanthrene, fluorene, 1-methylnaphthalene, naphthalene, and 2-methylnaphthalene.

[f] Antimony, arsenic, cadmium, chromium, cobalt, copper, lead, molybdenum, nickel, selenium, silver, thallium, vanadium, and zinc.

[g] Sediment may be frozen, with a maximum holding time of 6 months.

CVAA – cold vapor atomic absorption spectrophotometry

EPA – US Environmental Protection Agency

GC/ECD – gas chromatography/electron capture detection

GC/FPD – gas chromatography/flame photometric detection

GC/MS – gas chromatography/mass spectrometry

GFAA – graphite furnace atomic absorption spectrophotometry

HRGC/HRMS – high-resolution gas chromatography/high-resolution mass spectrometry

ICP-AES – inductively coupled plasma-atomic emission spectrometry

ICP-MS – inductively coupled plasma-mass spectrometry

PAH – polycyclic aromatic hydrocarbon

PCB – polychlorinated biphenyl

PSEP – Puget Sound Estuary Program

SIM – selective ion monitoring

SVOC – semivolatile organic compound

TOC – total organic carbon

3.4.2 Data quality indicators

The parameters used to assess data quality are precision, accuracy, representativeness, comparability, completeness, and sensitivity. Table 3-7 list specific DQIs for laboratory analyses of all samples. Target MDLs and RLs are presented in Appendices C and D for tissue and sediment, respectively. These parameters are discussed in greater detail in the following sections.

Table 3-7. Data quality indicators for chemical analyses

Parameter	Precision (Laboratory Replicates)	Accuracy		Completeness
		Instrument Calibration (% Difference)	Spiked Samples (% Recovery)	
PCBs as Aroclors	±50%	±25	laboratory QC limits[a]	95%
Organochlorine pesticides	±50%	±25	laboratory QC limits[a]	95%
SVOCs	±50%	±25	laboratory QC limits[a]	95%
PAHs	±50%	±25	laboratory QC limits[a]	95%
PCB congeners	±50%	±15	laboratory QC limits[a]	95%

Parameter	Precision (Laboratory Replicates)	Accuracy		Completeness
		Instrument Calibration (% Difference)	Spiked Samples (% Recovery)	
Dioxins and furans	±50%	±25	laboratory QC limits[a]	95%
Total mercury	±30%	±20	75 – 125	95%
Other total metals	±30%	±10	75 – 125	95%
Inorganic arsenic	±25%	±15	75 – 125	95%
Butyltins	±50%	±15	laboratory QC limits[a]	95%
Lipids	±30%	na	na	95%
Grain size	±30%	na	na	95%
Total solids	±20%	na	na	95%
TOC	±30%	na	laboratory QC limits[a]	95%

[a] The laboratory's performance-based control limits that are in effect at the time of analysis will be used as accuracy limits for LCS and MS/MSD samples.

na – not applicable

PAH – polycyclic aromatic hydrocarbon

PCB – polychlorinated biphenyl

QC – quality control

SIM – selected ion monitoring

SVOC – semivolatile organic compound

TOC – total organic carbon

3.4.2.1 Precision

Precision is the measure of the reproducibility among individual measurements of the same property, usually under similar conditions, such as multiple measurements of the same sample. Precision is assessed by performing multiple analyses on a sample and is expressed as an RPD when duplicate analyses are performed and as %RSD when more than two analyses are performed on the same sample (e.g., triplicates). Precision is assessed by laboratory duplicate analyses (i.e., laboratory replicate samples, MS/MSD, LCS duplicates) for all parameters except when reference materials are not available or spiking of the matrix is inappropriate. In these cases, precision is assessed by laboratory triplicate analyses. Precision measurements can be affected by the nearness of a chemical concentration to the MDL, where the percent error (expressed as either %RSD or RPD) increases. The DQI for precision varies depending on the analyte (Table 3-8). The equations used to express precision are as follows:

$$\text{RPD} = \frac{(\text{measured conc} - \text{measured duplicate conc})}{(\text{measured conc} + \text{measured duplicate conc}) \div 2} \times 100$$ **Equation 1**

$$\%\text{RSD} = (\text{SD}/\text{D}_{\text{ave}}) \times 100$$ **Equation 2**

where:

$$SD = \sqrt{\left(\frac{\left(\sum Dn - D_{ave}\right)^2}{(n-1)}\right)}$$

SD	=	standard deviation
D	=	sample concentration
D_{ave}	=	average sample concentration
n	=	number of samples

3.4.2.2 Accuracy

Accuracy is an expression of the degree to which a measured or computed value represents the true value. Accuracy may be expressed as a percentage recovery for MS and LCS analyses. The DQI for accuracy varies, depending on the analyte (Table 3-8). The equation used to express accuracy for spiked samples is as follows:

$$\text{Percent recovery} = \frac{\text{spike sample result} - \text{unspiked sample result}}{\text{amount of spike added}} \times 100$$ **Equation 3**

3.4.2.3 Representativeness

Representativeness expresses the degree to which data accurately and precisely represent an environmental condition. The sampling approach was designed to address the specific objectives described in Section 2.2. Assuming those objectives are met, the samples collected should be considered adequately representative of the environmental conditions they are intended to characterize.

3.4.2.4 Comparability

Comparability expresses the confidence with which one dataset can be evaluated in relation to another dataset. Sample collection and chemical and physical testing will adhere to the most recent PSEP QA/QC procedures (PSEP 1997b) and EPA and PSEP analysis protocols.

3.4.2.5 Completeness

Completeness is a measure of the amount of data that is determined to be valid in proportion to the amount of data collected. Completeness will be calculated as follows:

$$\text{Completeness} = \frac{\text{number of valid measurements}}{\text{total number of data points planned}} \times 100$$ **Equation 4**

The DQI for completeness for all components of this project is 95%. Data that have been qualified as estimated because the QC criteria were not met will be considered valid for the purpose of assessing completeness. Data that have been qualified as rejected will not be considered valid for the purpose of assessing completeness.

3.4.2.6 Sensitivity

Analytical sensitivity is the minimum concentration of an analyte above which a data user can be reasonably confident that the analyte was reliably detected and quantified.

Standard tissue mass requirements to meet the target MDLs and RLs for each particular analytical method are specified in Table 3-8. Because collecting the standard tissue mass may be difficult for some clam tissue samples, an analysis was conducted to determine if a lower tissue mass could be collected and still meet the risk-based ACGs described in Appendix C. Clam tissue mass[9] cannot be reduced below the standard requirements because of the low MDLs and RLs needed to meet ACGs; 200 g of clam tissue mass will be required per sample to meet the target DQIs. Table 3-8 summarizes the tissue mass and sediment volume needed for each sample type. If insufficient tissue is collected to achieve the target mass, then alternate strategies will be identified with approval from EPA including reduced sample mass with higher RLs for analytes that are likely to be detected based on clam tissue data from similar sites (Lockheed west and LDW).

Table 3-8. Tissue mass and sediment volume required per analytical method

Parameter	Method	Tissue Mass (g)	Sediment Volume (oz)
PCB congeners	EPA 1668	25	4
Dioxin/furans	EPA 1613	25	4
SVOCs (including PAHs, and phthalates)	EPA 8270D	30	8
PCB Aroclors	EPA 8082	30	4
Organochlorine pesticides[a]	EPA 8081A	25	4
Organochlorine pesticides[a]	EPA 1699 (modified)	25	4
Inorganic arsenic	EPA 1632	5	4
Mercury	EPA 7471A	2	2
Other metals[b]	EPA 6010B 6020, or 7000	3	2
Tributyltin	Krone et al. (1989)	20	4
Lipids	NOAA (1993)	5	na
total solids	PSEP (1997)	5	2
TOC	Plumb, 1991	na	2
grain size	PSEP, 1997	na	16
Total Mass		**200**	**68**

[a] A subset of samples will be submitted for GC/MS/MS analysis of pesticides, 25 grams would be needed..

[b] Antimony, arsenic, cadmium, chromium, cobalt, copper, lead, molybdenum, nickel, selenium, silver, vanadium, zinc.

EPA – US Environmental Protection Agency

na – not applicable

NOAA – National Oceanic and Atmospheric Administration

[9] The required clam tissue mass does not include the weight of the shell.

PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
PSEP – Puget Sound Estuary Program
SIM – selective ion monitoring
SVOC – semivolatile organic compound
TOC – total organic carbon

The purpose of collecting sediment samples at clam sampling locations is to evaluate risks associated with direct sediment contact resulting from clamming. Appendix D contains an evaluation of the sediment MDLs and RLs relative to risk-based ACGs (for both direct and indirect contact) for the co-located sediment samples to be collected at clam sampling locations.

3.5 QUALITY ASSURANCE/QUALITY CONTROL

The QA/QC criteria for the laboratory analyses are described in the following subsections.

3.5.1 Chemical analyses quality control criteria

Before analyzing the samples, the laboratory must provide written protocols for the analytical methods to be used, calculate MDLs for each analyte in each matrix type, and establish an initial calibration curve for all analytes. The laboratory must demonstrate their continued proficiency through participation in inter-laboratory comparison studies and through repeated analyses of SRMs, calibration checks, method blanks, and spiked samples.

3.5.1.1 Determination of MDLs

The MDL is defined as the lowest concentration of an analyte or compound that a method can detect in either a sample or a blank with 99% confidence. The laboratories determine MDLs using standard procedures outlined in 40CFR136, in which seven or more replicate samples are fortified at 1 to 5 times (but not to exceed 10 times) the expected MDL concentration. The MDL is then determined by calculating the standard deviation of the replicates and multiplying by the Student's t-factor (e.g., 3.14 for seven replicates).

3.5.1.2 Sample delivery group

Project- and/or method-specific QC measures such as MS/MSD or laboratory replicate samples will be analyzed per SDG, preparatory batch, or analytical batch, as specified in Table 3-9. An SDG is defined as no more than 20 samples or a group of samples received at the laboratory within a 2-week period. Although an SDG may span 2 weeks, all holding times specific to each analytical method will be met for each sample in the SDG.

Table 3-9. Laboratory quality control sample analysis summary

Analysis Type	Initial Calibration	Second Source Initial Calibration Verification	Continuing Calibration Verification	Laboratory Control Sample	Laboratory Replicate Sample	Matrix Spike	Matrix Spike Duplicate	Method Blank	Standard Reference Material[a]	Surrogate Spike
PCB Aroclors	prior to analysis	after initial calibration	every 10 to 20 analyses or 12 hrs	1 per prep batch	na	1 per batch or SDG	1 per batch or SDG	1 per prep batch	each batch or SDG	each sample
PCB congeners and dioxins/furans	prior to analysis	after initial calibration	prior to 12-hr analytical batch	1 per prep batch	na	na	na	1 per prep batch	na	each sample
Organochlorine pesticides[b]	prior to analysis	after initial calibration	every 10 to 20 analyses or 12 hrs	1 per prep batch	na	1 per batch or SDG	1 per batch or SDG	1 per prep batch	each batch or SDG	each sample
Mercury	prior to analysis	after initial calibration	every 10 samples	1 per prep batch	1 per batch or SDG	1 per batch or SDG	na	1 per prep batch	each batch or SDG	na
Other metals, including inorganic arsenic	prior to analysis	after initial calibration	every 10 samples	1 per prep batch	1 per batch or SDG	1 per batch or SDG	na	1 per prep batch	each batch or SDG	na
SVOCs, including PAHs	prior to analysis	after initial calibration	every 10 to 20 analyses or 12 hrs	1 per prep batch	na	1 per batch or SDG	1 per batch or SDG	1 per prep batch	each batch or SDG	each sample
Butyltins	prior to analysis	after initial calibration	every 10 samples	1 per prep batch	na	1 per batch or SDG	1 per batch or SDG	1 per prep batch	each batch or SDG	each sample
Grain size	na	na	na	na	2 per batch or SDG	na	na	na	na	na
TOC	daily	after initial calibration	every 10 samples	1 per prep batch	1 per batch or SDG	1 per batch or SDG	na	1 per prep batch	na	na
Percent solids	na	na	na	na	1 per batch or SDG	na	na	1 per prep batch	na	na
Lipids	na	na	na	na	1 per batch or SDG	na	na	na	na	na

Note: A batch is a group of samples of the same matrix analyzed or prepared at the same time, not to exceed 20 samples.

[a] An LCS may be used to assess accuracy when SRM is unavailable (i.e., for tissue matrices).

[b] Aroclor standards will be run as interference check samples for this analysis.

na – not applicable
PCB – polychlorinated biphenyl
PAH – polycyclic aromatic hydrocarbon
SDG – sample delivery group
SIM – selected ion monitoring
SVOC – semivolatile organic compound
TOC – total organic carbon

3.5.1.3 Laboratory quality control criteria

The laboratory analyst's will review the results of QC analyses (described below) of each analytical batch immediately after the samples have been analyzed. The QC sample results will be evaluated to determine whether control limits have been exceeded. If control limits are exceeded, then appropriate corrective action must be initiated before a subsequent group of samples is processed. For example, recalibration followed by reprocessing of the affected samples. The project QA/QC coordinator must be contacted immediately by the laboratory PM if satisfactory corrective action to achieve the DQIs outlined in this QAPP is not possible. All laboratory corrective action reports relevant to the analysis of project samples must be included in the data deliverable packages.

All primary chemical standards and standard solutions used in this project will be traceable to the National Institute of Standards and Technology, Environmental Resource Associates, National Research Council of Canada, or other documented, reliable commercial sources. The accuracy of the standards should be verified through comparison with an independent standard. Laboratory QC standards are verified a multitude of ways. Second-source calibration verification (i.e., same chemicals manufactured by two different vendors) are analyzed to verify initial calibrations. New working standard mixes (e.g., calibrations, spikes) should be verified against the results of the original solution before being put into use and be within 10% of the true value. Newly purchased standards should be verified against current data. Any impurities found in the standard must be documented. The following subsections summarize the procedures that will be used to assess data quality throughout sample analysis.

Field Duplicate Samples

Field duplicate samples will be collected to evaluate variability attributable to sample homogenization and subsequent sample handling and are useful in assessing potential sample heterogeneity and matrix effects. Field duplicate samples are collected from the same homogenized material as the original sample and are submitted to the laboratory and analyzed as a discrete, separate sample. This type of field QA/QC sample is also referred to as a field split sample (PSEP 1997). A minimum of one field duplicate will be analyzed for each sediment SDG or for every 20 samples, whichever is more frequent.

Laboratory Replicate Samples

Laboratory replicate samples provide information on the precision of the analysis and are useful in assessing potential sample heterogeneity and matrix effects. Laboratory replicates are subsamples of the original sample that are prepared and analyzed as a separate sample, assuming sufficient sample matrix is available. A minimum of one laboratory replicate sample will be analyzed for each SDG or for every 20 samples, whichever is more frequent, for inorganic and conventional parameters.

Matrix Spikes and Matrix Spike Duplicates

The analysis of MS samples provides information on the extraction efficiency of the method on the sample matrix. Through the performance of MSD analyses, information on the precision of the method is also provided for organic analyses. For organic analyses, a minimum of one MS/MSD pair will be analyzed for each SDG, when sufficient sample volume is available. For inorganic analyses (i.e., metals), a minimum of one MS sample will be analyzed for each SDG, when sufficient sample volume is available. MS/MSD samples are not performed for PCB congeners and dioxin/furan analyses.

Method Blanks

Method blanks are analyzed to assess possible laboratory contamination at all stages of sample preparation and analysis. A minimum of one method blank will be analyzed for each extraction/digestion batch or for every 20 samples, whichever is more frequent.

Standard Reference Material

SRMs are samples of similar matrix and of known analyte concentration that are processed through the entire analytical procedure and used as an indicator of method accuracy. A minimum of one SRM will be analyzed for each SDG or for every 20 samples, whichever is more frequent.

Surrogate Spikes

All samples analyzed for organic compounds will be spiked with appropriate surrogate compounds as defined in the analytical methods.

Laboratory Control Samples

LCSs are prepared from a clean matrix similar to the project samples and are spiked with known amounts of the target compounds. The recoveries of the compounds are used as a measure of the accuracy of the test methods.

Interference Check Samples

In order to identify specific organochlorine pesticides that may coelute with PCB congeners, single point mid-concentration PCB standards (Aroclors 1248, 1254, and 1260) should be run regularly with single-component pesticides in the initial calibration. Additional Aroclors should be analyzed if they are detected in project samples. The resulting data will be reviewed by data validators in order to assess potential interference issues that could have affected the reported pesticide results.

Internal Standard Spikes

Internal standard spikes may be used for calibrating and quantifying organic compounds and metals by means of inductively coupled plasma-mass spectrometry (ICP-MS). If internal standards are used, all calibration, QC, and project samples will be spiked with the same concentration of the selected internal standard(s). Internal

standard recoveries and retention times must be within method and/or laboratory criteria.

Method of Standard Additions

If matrix interferences are found to be present during metals analysis, it may be necessary to compensate for the interferences by performing a method of standard additions (MSA). The MSA technique involves adding known amounts of standard to one or more aliquots of the sample digest. If MSA is performed, a different MSA curve must be generated for each sample. An MSA curve generated for a single sample must not be applied to other samples unless it can be clearly demonstrated that all samples exhibit the same matrix effect.

3.6 INSTRUMENT/EQUIPMENT TESTING, INSPECTION, AND MAINTENANCE

Prior to each field event, measures will be taken to test, inspect, and maintain all field equipment. All equipment, including the DGPS unit and digital camera, will be tested for use before leaving for the field event.

The FC will be responsible for overseeing the testing, inspection, and maintenance of all field equipment. The laboratory PM will be responsible for ensuring that laboratory equipment testing, inspection, and maintenance requirements are met.

3.7 INSTRUMENT/EQUIPMENT CALIBRATION AND FREQUENCY

Multipoint initial calibrations will be performed on each instrument prior to sample analysis, after each major interruption to the analytical instrument, and when more than one continuing calibration verification sample does not meet the specified criteria. The number of points used in the initial calibration is defined in each analytical method. Continuing calibration verifications will be performed daily for organic analyses, once every 10 samples for the inorganic analyses and with every sample batch for conventional parameters to ensure proper instrument performance.

Gel permeation chromatography calibration verifications will be performed at least once every 7 days, and corresponding raw data will be submitted by the laboratory with the data package. In addition, florisil performance checks will be performed for every florisil lot, and the resulting raw data will be submitted with the data package, when applicable.

The calibration of analytical equipment used for chemical analysis includes instrument blanks or continuing calibration blanks, which provide information on the stability of the instrument's baseline. Continuing calibration blanks will be analyzed immediately after the continuing calibration verification at a frequency of one blank for every 10 samples analyzed for metals analyses and one blank for every 12 hours for organic analyses. If the continuing calibration blank does not meet the specified criteria, the analysis must be discontinued. The analysis may be resumed after corrective actions have been taken to meet the method specifications. All project samples analyzed by an

instrument found to be out of compliance must be reanalyzed. None of the field equipment requires calibration.

3.8 INSPECTION/ACCEPTANCE OF SUPPLIES

The field team leaders for each sampling event will have a checklist of supplies required for each day in the field (see Section 3.2.5). The FC will gather and check these supplies daily for satisfactory conditions before each field event. Batteries used in the DGPS unit and digital camera will be checked daily and recharged as necessary. Supplies for field sampling will be inspected upon delivery and accepted if the condition of the supplies is satisfactory. For example, jars will be inspected to ensure that they are of the correct size and quantity and have not been damaged in shipment.

3.9 NON-DIRECT MEASUREMENTS

Tide stage data will be obtained from the Harbor Tides website (http://www.saltwatertides.com/dynamic.dir/washingtonsites.html) (Kay please enter into EndNote), which provides daily tide tables for a station at the Lockheed Shipyard on Harbor Island, Seattle, Washington.

3.10 DATA MANAGEMENT

All field data will be recorded on field forms (see Appendix B), which will be checked for missing information by the FC at the end of each field day and amended as necessary. After sampling has been completed, all data from field forms will be entered into a Microsoft Excel® spreadsheet for import into the project database. A secondary QC check will be done to ensure that 100% of the data were properly transferred from the field forms to the spreadsheet. This spreadsheet will be kept on the Windward network server, which is backed up daily. Field forms will be archived in the Windward library. All photographs will be transferred to the secure network or a CD at the end of the sampling effort.

Field sampling and analytical information will be submitted to the EPA's Analytical Services Tracking System (ANSETS) no later than the 15th of the month after sampling activities have occurred and the sampling compositing and analysis scheme have been approved. The project QA/QC coordinator will be responsible for the submitting the required information to ANSETS.

Analytical laboratories are expected to submit data in an electronic format as described in Section 2.6.2. The laboratory PM will contact the project QA/QC coordinator prior to data delivery to discuss specific format requirements.

A library of routines will be used to translate typical electronic output from laboratory analytical systems and to generate data analysis reports. The use of automated routines ensures that all data are consistently converted into the desired data structures and that operator time is kept to a minimum. In addition, routines and

methods for quality checks will be used to ensure such translations are correctly applied.

Written documentation will be used to clarify how field and analytical laboratory duplicates and QA/QC samples were recorded in the data tables and to provide explanations of other issues that may arise. The data management task will include keeping accurate records of field and laboratory QA/QC samples so that project team members who use the data will have appropriate documentation. Data management files will be stored on a secure computer.

4 Assessment and Oversight

4.1 Compliance Assessments and Response Actions

EPA or other management agencies may observe field activities during each sampling event, as needed. If situations arise in which there is an inability to follow QAPP methods precisely, the Windward PM will determine the appropriate actions or consult EPA if the issue is significant.

4.1.1 Compliance assessments

Laboratory and field performance assessments consist of EPA-conducted onsite reviews of QA systems and equipment for sampling, calibration, and measurement. EPA personnel may conduct a laboratory audit prior to sample analysis. Any pertinent laboratory audit reports will be made available to the project QA/QC coordinator upon request. Analytical and taxonomy laboratories are required to have written procedures that address internal QA/QC; these procedures will be submitted for review by the project QA/QC coordinator upon request to ensure compliance with the QAPP. All laboratories and QA/QC coordinators are required to ensure that all personnel engaged in sampling and analysis tasks have appropriate training.

4.1.2 Response actions for field sampling

The FC, or a designee, will be responsible for correcting equipment malfunctions throughout field sampling and for resolving situations in the field that may result in nonconformance or noncompliance with the QAPP. All corrective measures will be immediately documented in the field logbook, and protocol modification forms will be completed.

4.1.3 Corrective action for laboratory analyses

Analytical laboratories are required to comply with their current written standard operating procedures, laboratory QA plan, and analytical methods. All laboratory personnel will be responsible for reporting problems that may compromise the quality of the data. Laboratory personnel will identify and correct any anomalies before continuing with sample analysis. The laboratory PMs will be responsible for ensuring

that appropriate corrective actions are initiated, as required, for conformance with this QAPP.

The project QA/QC coordinator will be notified immediately if any QC parameter exceeds the project DQIs outlined in this QAPP (Table 3-7) and cannot be resolved through standard corrective action procedures. A description of the anomaly, the steps taken to identify and correct the anomaly, and the treatment of the relevant sample batch (i.e., recalculation, reanalysis, and re-extraction) will be submitted with the data package using the case narrative or corrective action form.

4.2 REPORTS TO MANAGEMENT

Progress reports will be prepared by the FC for submittal to the EWG following each sampling event. The project QA/QC coordinator will also prepare progress reports after the sampling is completed and samples have been submitted for analysis, when information is received from the laboratory, and when analyses are complete. The status of the samples and analyses will be indicated with emphasis on any deviations from the QAPP. A data report will be written after validated data are available for each sampling event, as described in Section 2.6.4.

5 Data Validation and Usability

5.1 DATA VALIDATION

The laboratory analyst is responsible for ensuring that the analytical data are correct and complete, that appropriate procedures have been followed, and that QC results are within the acceptable limits. The data validation process begins at the laboratory with the review and evaluation of data by supervisory personnel or QA specialists. The project QA/QC coordinator is responsible for ensuring that all analyses performed by the laboratories are correct, properly documented, and complete, and that they satisfy the project DQOs specified in this QAPP.

Data are not considered final until validated. Data validation will be conducted following EPA guidance (1995; EPA 1996, 1999, 2004, 2005). Independent third-party data review and summary validation of the analytical chemistry data will be conducted by EcoChem. A minimum of 20% of sample results or a single SDG will undergo full data validation. Full data validation parameters include:

- Quality control analysis frequencies
- Analysis holding times
- Laboratory blank contamination
- Instrument calibration
- Surrogate recoveries
- LCS recoveries

- MS recoveries
- MS/MSD RPDs
- Compound identifications
- Compound quantitations
- Instrument performance checks (i.e., tune ion abundances)
- Internal standard areas and retention time shifts

If no discrepancies are found between reported results and raw data in the set that undergoes full data validation, validation can proceed as a summary-level data validation on the rest of the data using all the QC forms submitted in the laboratory data package. QA review of the sediment and tissue chemistry data will be performed in accordance with the QA requirements of the project; the technical specifications of the analytical methods indicated in Tables 3-5, 3-6, and 3-7; and EPA guidance for organic and inorganic data review (EPA 1995, 2004, 1999, 2005, 1996). The EPA PM may have EPA peer review the third-party validation or perform data assessment/validation on a percentage of the data.

All discrepancies and requests for additional, corrected data will be discussed with the laboratories prior to issuing the formal data validation report. The project QA/QC coordinator should be informed of all contacts with the laboratories during data validation. Review procedures used and findings made during data validation will be documented on worksheets. The data validator will prepare a data validation report that will summarize QC results, qualifiers, and possible data limitations. Only validated data with appropriate qualifiers will be released for use in the EW SRI/FS. Rejected data will not be used for any purpose.

5.2 Reconciliation with Data Quality Objectives

Data quality assessment will be conducted by the project QA/QC coordinator. The results of the third-party independent review and validation will be reviewed, and cases where the projects DQOs were not met will be identified. The usability of the data will be determined in terms of the magnitude of the DQO exceedance.

6 References

Anchor, Windward. 2008. East Waterway Operable Unit: Existing information summary report. Anchor Environmental, L.L.C., and Windward Environmental LLC, Seattle, WA.

Anchor, Windward, Battelle, KPFF, Coast and Harbor Engineering. 2008. East Waterway Operable Unit supplemental remedial investigation/feasibility study: final conceptual site model and data gaps analysis report. Prepared for Port of Seattle. Anchor Environmental, L.L.C., Seattle, WA; Windward

Environmental LLC, Seattle, WA; Battelle Memorial Institute, Seattle, WA; KPFF Consulting Engineers, Seattle, WA; and Coast and Harbor Engineering, Edmonds, WA.

EPA. 1995. EPA Region 10 SOP For the validation of Method 1668 toxic, dioxin-like, PCB data. Revision 1.0. Environmental Services Division, US Environmental Protection Agency, Region 10, Seattle, WA.

EPA. 1996. EPA Region 10 SOP for the validation of polychlorinated dibenzodioxin (PCDD) and polychlorinated dibenzofuran (PCDF) data. Revision 2.0. Environmental Services Division, US Environmental Protection Agency, Region 10, Seattle, WA.

EPA. 1999. USEPA contract laboratory program national functional guidelines for organic data review. EPA-540/R-99/008. Office of Emergency and Remedial Response, US Environmental Protection Agency, Washington, DC.

EPA. 2002. Guidance for quality assurance project plans. QA/G-5. EPA/240/R-02/009. Office of Environmental Information, US Environmental Protection Agency, Washington, DC.

EPA. 2004. USEPA contract laboratory program national functional guidelines for inorganic data review. EPA 540-R-04-004. Office of Emergency and Remedial Response, US Environmental Protection Agency, Washington, DC.

EPA. 2005. National functional guidelines for chlorinated dibenzo-p-dioxins (CDDs) and chlorinated dibenzofurans (CDFs) data review. OSWER 9240.1-51. EPA 540-R-05-001. Office of Superfund Remediation and Technology Innovation, US Environmental Protection Agency, Washington, DC.

Krone CA, Brown DW, Burrows DG, Chan SL, Varanasi U. 1989. Butyltins in sediment from marinas and waterways in Puget Sound Washington State, USA. Mar Pollut Bull 20:528-531.

NOAA. 1993. Tissue lipid determination method. In: Sampling and analytical methods of the National Status and Trends Program national benthic surveillance and mussel watch projects, 1984-1992. Vol 2: Comprehensive descriptions of complementary measurements. NOAA technical memorandum NOS ORCA 71. National Status and Trends Program, National Oceanic and Atmospheric Administration, Silver Spring, MD.

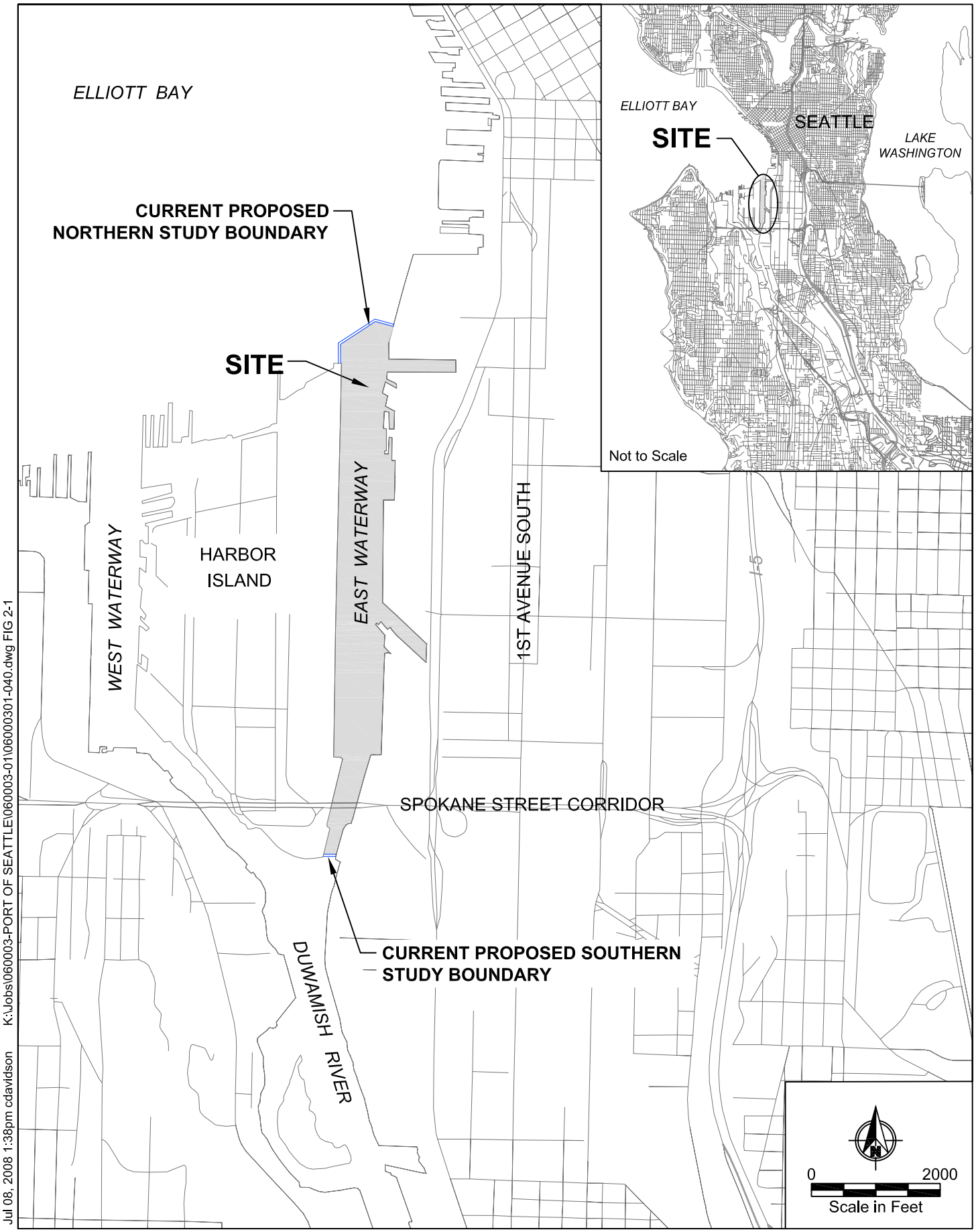
Plumb R, Jr. 1981. Procedures for handling and chemical analysis of sediment and water samples. Waterways Experiment Station, US Army Corps of Engineers, Vicksburg, MS.

PSEP. 1986. Recommended protocols for measuring conventional sediment variables in Puget Sound. Prepared for the Puget Sound Estuary Program. US Environmental Protection Agency, Region 10, Seattle, WA.

PSEP. 1997. Recommended guidelines for sampling marine sediment, water column, and tissue in Puget Sound. Final report. Prepared for the US Environmental Protection Agency, Seattle, WA. Puget Sound Water Quality Action Team, Olympia, WA.

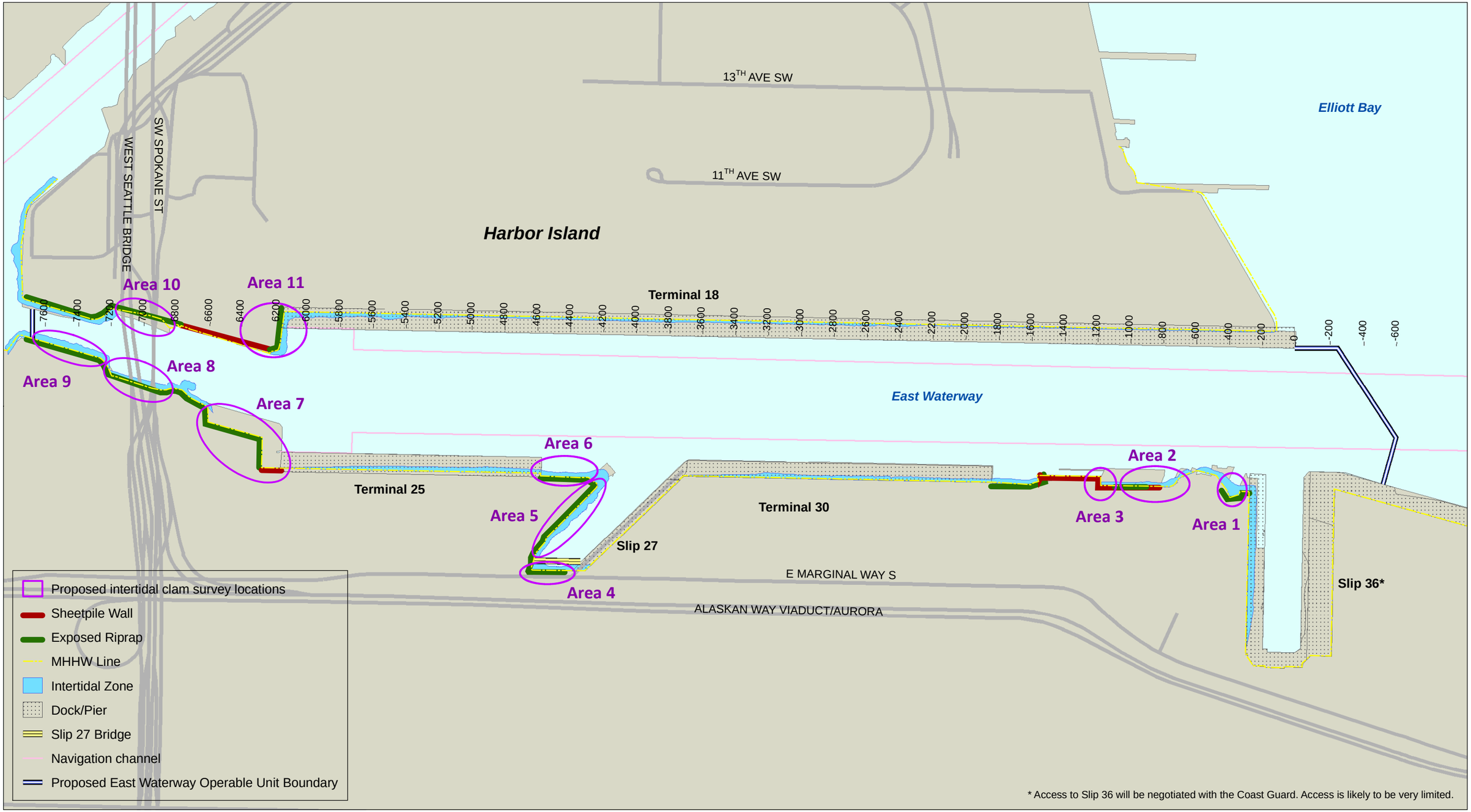
Windward. 2004. Lower Duwamish Waterway remedial investigation. Task 8: Phase 2 RI work plan. Prepared for Lower Duwamish Waterway Group. Windward Environmental LLC, Seattle, WA.

7 Maps



Jul 08, 2008 1:38pm cdavidson K:\Jobs\060003-PORT OF SEATTLE\060003-01\06000301-040.dwg FIG 2-1

Map 2-1
Vicinity Map
East Waterway Operable Unit



Wind Ward environmental LLC

N

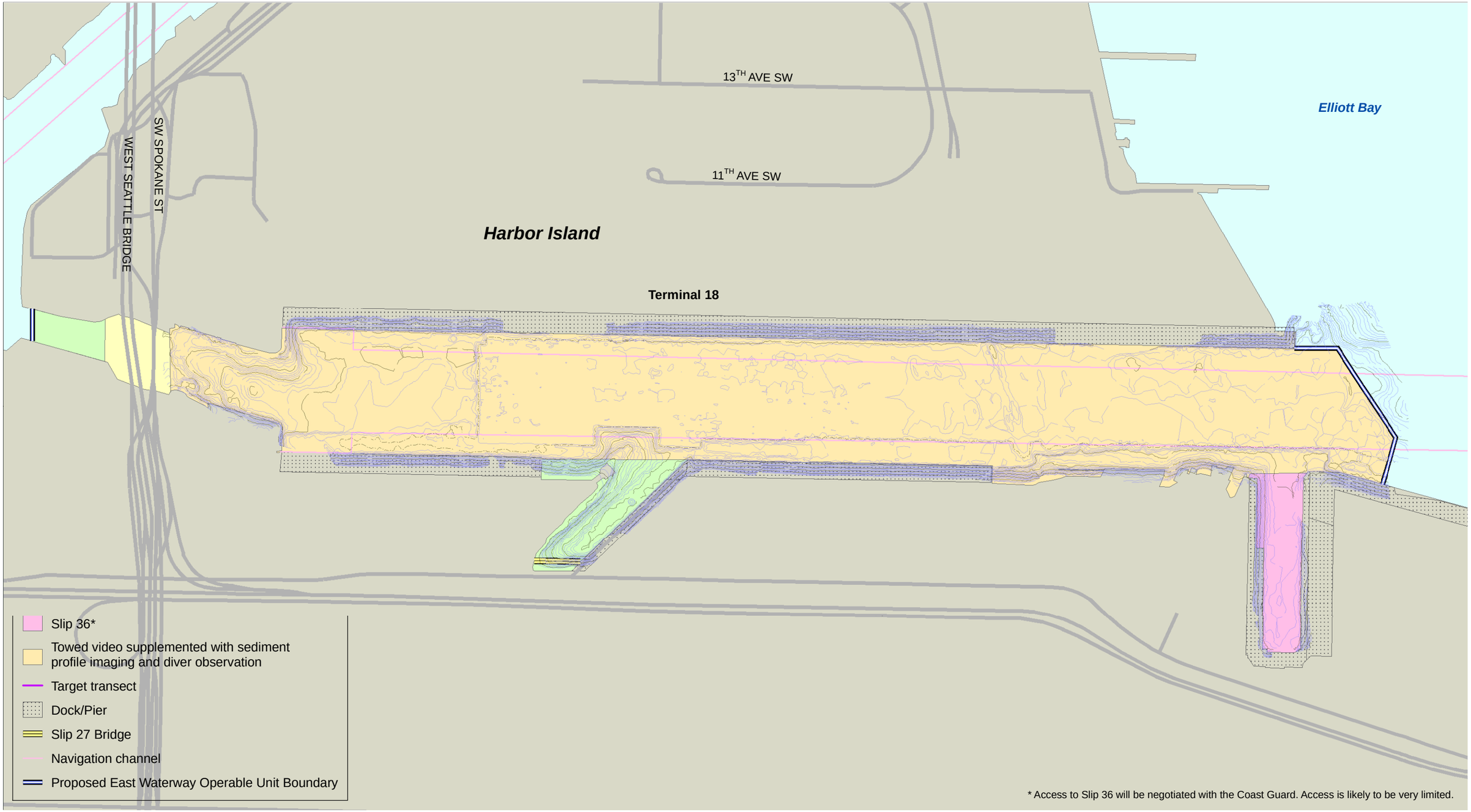
0 1,000 2,000 Feet

0 250 500 Meters

Map 2-2. Proposed intertidal clam survey locations

DRAFT

Prepared by CEI, 06/19/09; CEH, 07/23/09; MAP #3320; W:\Projects\00-08-08 East Waterway\EW R1-FS\Data\GIS\QA\PPC\Clam Survey Memo



Wind Ward environmental LLC

N

0 1,000 2,000 Feet

0 250 500 Meters

Map 3-1. Proposed visual observation - subtidal clam habitat map

DRAFT

Prepared by CEJ, 06/19/08; CEH, 07/03/08; MAP # W:\Projects\00-08-08 East Waterway\EW RI-FS\Data\GIS\QAPP\Clam Survey Memo

APPENDIX A

Health and Safety Plan

EAST WATERWAY OPERABLE UNIT
SUPPLEMENTAL REMEDIAL INVESTIGATION/ FEASIBILITY STUDY
HEALTH AND SAFETY PLAN CLAM STUDIES

For submittal to:

The US Environmental Protection Agency
Region 10
Seattle, WA

July 2008

Prepared by: Windward environmental LLC

200 West Mercer Street, Suite 401 • Seattle, Washington • 98119

Health and Safety Plan

By their signature, the undersigned certify that this health and safety plan is approved and that it will be used to govern health and safety aspects of fieldwork described in the quality assurance project plan to which it is attached.

Susan McGroddy Project Manager	July 31, 2008 Date
Tad Deshler Corporate Health and Safety Manager	July 31, 2008 Date
Helle Andersen Field Coordinator/Health and Safety Officer	July 31, 2008 Date

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Acronyms

CFR	Code of Federal Regulations
CPR	cardiopulmonary resuscitation
EW	East Waterway
FC	field coordinator
HAZWOPER	Hazardous Waste Operations and Emergency Response
HSM	health and safety manager
HSO	health and safety officer
HSP	health and safety plan
OSHA	Occupational Safety and Health Administration
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PEC	project emergency coordinator
PFD	personal flotation device
PPE	personal protective equipment
PM	project manager
QAPP	quality assurance project plan
ROV	remotely operated video
TCDD	tetrachlorodibenzo-*p*-dioxin
USCG	US Coast Guard

1 Introduction

This site-specific health and safety plan (HSP) describes safe working practices for conducting field activities at potentially hazardous sites and for handling potentially hazardous materials or waste products. This HSP covers elements as specified in 29CFR1910§120. The goal of the HSP is to establish procedures for safe working practices for all field personnel.

This HSP addresses all activities associated with collection and handling of invertebrates (e.g., clams) in the East Waterway (EW). During site work, this HSP will be implemented by the field coordinator (FC), who is also the designated site health and safety officer (HSO), in cooperation with the corporate health and safety manager (HSM) and the project manager (PM).

All personnel involved in fieldwork on this project are required to comply with this HSP. The content of this HSP reflects the types of activities that are anticipated to be performed, knowledge of the physical characteristics of the site, and consideration of preliminary chemical data from previous investigations at the site. The HSP may be revised based on new information and/or changed conditions during site activities. Revisions will be documented in the project records.

2 Site Description and Project Scope

2.1 Site Description

The sampling area is in the EW (see Map 2-2 in the quality assurance project plan [QAPP] to which this HSP is attached). The area is affected by tidal fluctuations. The QAPP to which this HSP is attached provides complete details of the sampling program.

2.2 Scope and Duration of Work

This section summarizes the types of work that will be performed during field activities. Specific tasks to be performed are as follows:

- Survey of subtidal habitat characteristics using a remotely operated video (ROV) camera
- Collection of clams on intertidal beaches by digging with hand tools
- Collection of geoducks by scuba diving
- Sample handling, processing, and shipping

The ROV survey will be performed July 15 and 16, 2008; intertidal clam sampling will commence as early as July 29, 2008, and will be completed by August 2, 2008, as

described in the QAPP. Following a review of the ROV survey data, scuba diving for geoducks will be coordinated with rockfish sampling in August 2008.

3 Health and Safety Personnel

Key health and safety personnel and their responsibilities are described below. These individuals are responsible for the implementation of this HSP.

Project Manager: The PM has overall responsibility for the successful outcome of the project. The PM will ensure that adequate resources and budget are provided for the health and safety staff to carry out their responsibilities during fieldwork. The PM, in consultation with the HSM, makes final decisions concerning the implementation of the HSP.

Field Coordinator/Health and Safety Officer: Because of the limited scope and duration of fieldwork, the FC and HSO will be the same individual. The FC/HSO will direct field sampling activities, coordinate the technical components of the field program with health and safety components, and ensure that work is performed according to the QAPP. The FC/HSO will implement this HSP at the work location and will be responsible for all health and safety activities and the delegation of duties to a health and safety technician in the field, if appropriate. The FC/HSO also has stop-work authority, to be used if there is an imminent safety hazard or potentially dangerous situation. The FC/HSO or his designee shall be present during sampling and operations.

Corporate Health and Safety Manager: The HSM has overall responsibility for the preparation, approval, and revision of this HSP. The HSM will not necessarily be present during fieldwork but will be readily available, if required, for consultation regarding health and safety issues during fieldwork.

Field Crew and Dive Team: All field crew and dive team members must be familiar and comply with the information in this HSP. They also have the responsibility to report any potentially unsafe or hazardous conditions to the FC/HSO immediately. The dive team members must also adhere to practices in Research Support Services' dive plan (Attachment 1).

4 Hazard Evaluation and Control Measures

This section discusses potential physical and chemical hazards that may be associated with the proposed project activities and presents control measures for addressing these hazards. The activity hazard analysis (Section 4.4) lists the potential hazards associated with each site activity and the recommended site control. Confined space entry will not be necessary for this project. Therefore, hazards associated with this activity are not discussed in this HSP.

4.1 PHYSICAL HAZARDS

For this project, it is anticipated that physical hazards present a greater risk of injury than do chemical hazards.

4.1.1 Slips, trips, and falls

As with all fieldwork sites, caution should be exercised to prevent slips on slick surfaces. In particular, sampling from a boat or other floating platform requires careful attention to minimize the risk of falling down or falling overboard. The same care should be used in rainy conditions or on the shoreline where there are slick rocks. Slips can be minimized through the use of boots with good treads, made of material that does not become overly slippery when wet.

Trips are always a hazard on the uneven deck of a boat, in cluttered work areas, or in the intertidal zone where uneven substrate is common. Personnel will keep work areas as free as possible from obstacles that could interfere with walking.

Falls can also be a hazard. Personnel can avoid falls by working as far from exposed edges as possible, erecting railings, and using fall protection when working on elevated platforms. For this project, no work that would present a fall hazard is anticipated.

4.1.2 Sampling equipment

No sampling equipment other than a shovel and trowel will be used in the clam survey. Before sampling activities begin, all personnel will attend a training session to discuss the equipment that will be onboard the sampling vessel.

4.1.3 Falling overboard

Some of the sampling activities will be done from a boat. As with any work from a floating platform, there is a chance of falling overboard. Personal flotation devices (PFDs) will be worn by all personnel while working from the boat.

4.1.4 Manual lifting

Equipment and samples must be lifted and carried. Back strain can result if lifting is done improperly. During any manual handling tasks, personnel should lift with the load supported by their legs, not their backs. For heavy loads, an adequate number of people, or if possible, a mechanical lifting/handling device, will be used.

4.1.5 Heat stress, hypothermia, or frostbite

Sampling operations and conditions that might result in heat stress, hypothermia, or frostbite are not anticipated. Sampling will occur during a time of year when extreme weather conditions are not expected.

4.1.6 Weather

In general, field team members will be equipped for the normal range of weather conditions. The FC/HSO will be aware of current weather conditions and of the potential for those conditions to pose a hazard to the field crew. Some conditions that might force work stoppage are electrical storms, high winds, or high waves resulting from winds.

4.1.7 Sharp objects

Sampling operations might result in the exposure of field personnel to sharp objects on top of or buried within the sediment. If these objects are encountered, field personnel should not touch them. Also, field personnel should not dig in the sediment by hand.

4.1.8 Scuba diving

Scuba diving presents an array of risks not common to a normal worksite. Therefore, tasks that involve diving will be performed by a professional diver who has been properly trained and certified and is aware of the myriad inherent risks involved with scuba diving in hazardous environments. With proper training, the risk of these potential hazards can be minimized. Commercial divers provided by Research Support Services will adhere to their dive plan (Attachment 1).

The diver will dive line-tended, with wireless communication to the surface. A safety diver will tend the line and wear a headset to talk with the diver in the water. The safety diver will also be suited up and ready to don gear if necessary. In the unlikely event that the in-water diver would require assistance, the diver could be retrieved using the tending line or assisted by the safety diver. Emergency oxygen and first aid will be on the boat, as well as a dive plan that will list local hospitals and dive-related emergency contact information (Attachment 1).

Equipment failure is always a concern. Divers should be familiar with their specific type of equipment and check the tank, regulator, buoyancy control device, gauges, and any other equipment to make sure everything is in proper working order prior to use. The compressed air supply is filled by a local dive store so an air check is not necessary. The diver is also equipped with a pony bottle, which is a small emergency (bailout) air tank.

Divers must be careful to avoid pilings and other obstacles that might snag gear or entrap the diver. Having a clear sense of the layout of the area before getting into the water and taking extra caution during times of low visibility will minimize the risk from these hazards.

Hypothermia sets in much more quickly in water than in air. Wearing proper insulation and knowing the symptoms can help prevent this hazard. Warm clothes should be available on board the support boat.

Nitrogen narcosis is a risk associated with spending too much time at depth. This project will not require diving below approximately 50 ft, so the risk of narcosis is minimal. However, it is still necessary to consult dive tables to create a dive profile for each dive. Strict adherence to the diver safety manual should prevent nitrogen narcosis.

If boat traffic is a possibility, a dive flag must be deployed in the vicinity of the divers. Divers should surface as close as possible to the flag and/or support boat. Diving will not be done in the channel, where shipping activity takes place. The dive tender will continuously monitor Channels 13, 14, and 16 for boat traffic near the dive area, advise other vessels of diving operations, and, if possible, warn off boat traffic that may pose a hazard to divers.

4.2 VESSEL HAZARDS

Because of the high volumes of vessel and barge traffic on the EW, precautions and safe boating practices will be implemented to ensure that the field boat does not interrupt vessel traffic. Additional potential vessel emergency hazards and responses are listed in Table 1.

Table 1. Potential vessel emergency hazards and responses

POTENTIAL EMERGENCY OR HAZARD	RESPONSE
Fire or explosion	If manageable, personnel should attempt to put out a small fire with a fire extinguisher. Otherwise, personnel should call the USCG or 911 and evacuate the area (by rescue boat or swimming) and meet at a designated area. The FC/HSO will take roll call to make sure everyone evacuated safely. Emergency meeting places will be determined in the field during the daily safety briefing.
Medical emergency or injury	At least one person with current first aid and CPR training will be aboard the vessel at all times. This person will attempt to assess the nature and severity of the injury, immediately call 911, and perform CPR if necessary. Personnel should stop work and wait for medical personnel to arrive. Once the emergency has passed, the FC/HSO should fill out a site accident report.
Person overboard	All personnel aboard the sampling vessel will wear PFDs at all times. One person should keep an eye on the individual who fell overboard and shout the distance (boat lengths) and direction (o'clock) of the individual from the vessel. Personnel should stop work and use the vessel to retrieve the individual in the water.
Sinking vessel	Personnel should call the USCG immediately. If possible, personnel should wait for a rescue boat to arrive to evacuate vessel personnel. See fire or explosion (above) for emergency evacuation procedures. The FC/HSO will take a roll call to make sure everyone is present.
Lack of visibility	If navigation visibility or personal safety is compromised because of smoke, fog, or other unanticipated hazards, personnel should stop work immediately. The vessel operator and FC/HSO will assess the hazard and, if necessary, send out periodic horn blasts to mark vessel location to other vessels potentially in the area, move to a secure location (i.e., berth), and wait for the visibility to clear.
Loss of power	Personnel should stop work and call the USCG for assistance. Personnel should use oars to move vessel towards the shoreline. Other vessel personnel should watch for potential collision hazards and notify the vessel operator if hazards exist. Personnel should secure the vessel to a berth, dock, or mooring as soon as possible.

Potential Emergency or Hazard	Response
Collision	Personnel should stop work and call the USCG for assistance. The FC/HSO and vessel operator will assess damage and potential hazards. If necessary, the vessel will be evacuated and secured until repairs can be made.

CPR – cardiopulmonary resuscitation
FC – field coordinator
HSO – health and safety officer
PFD – personal flotation device
USCG – US Coast Guard

4.3 Chemical Hazards

Previous investigations have shown that some chemical substances are present at higher-than-background concentrations in the sampling area. For the purpose of discussing potential exposure to substances in sediments, the chemicals of concern are metals, tributyltin, dioxins and furans, polycyclic aromatic hydrocarbons (PAHs), and polychlorinated biphenyls (PCBs).

4.3.1 Exposure routes

Potential routes of chemical exposure include inhalation, dermal contact, and ingestion. Exposure will be minimized by using safe work practices and by wearing the appropriate personal protective equipment (PPE). Further discussion of PPE requirements is presented in Section 7.

Inhalation — Inhalation is not expected to be an important route of exposure for this project.

Dermal exposure — Dermal exposure to hazardous substances associated with sediments, surface water, or equipment decontamination will be controlled through the use of PPE and adherence to detailed sampling and decontamination procedures.

Ingestion — Ingestion is not considered a major route of exposure for this project. Accidental ingestion of surface water is possible. However, careful handling of equipment and containers aboard the boat should prevent the occurrence of water splashing or spilling during sample collection and handling activities.

4.3.2 Chemical hazards

Metals and tributyltin — Exposure to metals may occur via ingestion or skin contact. As mentioned above, neither is likely as an exposure route. Metal fumes or metal-contaminated dust will not be encountered during field and sample handling activities. Large amounts of sediment would need to be ingested for any detrimental effects to occur. Momentary skin contact allows little, if any, opportunity for the passage of any of the metals into the body. Field procedures require the immediate washing of sediments from exposed skin.

Polycyclic aromatic hydrocarbons — Exposure to PAHs may occur via ingestion or skin contact. The most important human health exposure pathway for this group of chemicals, inhalation, is not expected to occur at this site. Animal studies have shown that PAHs can cause harmful effects on skin, body fluids, and ability to fight disease after both short- and long-term exposure, but these effects have not been documented in people. Some PAHs may reasonably be expected to be carcinogens. Large amounts of sediment would need to be ingested for any detrimental effects to occur. Momentary skin contact allows little, if any, opportunity for the passage of any of the compounds into the body. Field procedures require the immediate washing of sediments from exposed skin.

Polychlorinated biphenyls — Prolonged skin contact with PCBs may cause acne-like symptoms known as chloracne. Irritation to eyes, nose, and throat may also occur. Acute and chronic exposure can damage the liver and cause symptoms of edema, jaundice, anorexia, nausea, abdominal pains, and fatigue. PCBs are a suspected human carcinogen. Skin absorption may substantially contribute to the uptake of PCBs. Large amounts of sediment would need to be ingested for any detrimental effects to occur. Momentary skin contact allows little, if any, opportunity for the passage of any of these compounds into the body. Field procedures require the immediate washing of sediments from exposed skin.

Dioxins/furans — Prolonged skin contact with dioxins/furans may cause acne-like symptoms known as chloracne. Other effects to the skin, such as red skin rashes, have been reported to occur in people following exposure to high concentrations of 2,3,7,8- tetrachlorodibenzo-*p*-dioxin (TCDD). Acute and chronic exposure can damage the liver, result in an increase in the risk of diabetes and abnormal glucose tolerance, and may increase the risk for reproductive and developmental effects. 2,3,7,8-TCDD is a possible human carcinogen, and a mixture of dioxins/furans with six chlorine atoms (four of the six chlorine atoms at the 2, 3, 7, and 8 positions) is a probable human carcinogen. Skin absorption may substantially contribute to the uptake of dioxins/furans. Large amounts of sediment would need to be ingested for any detrimental effects to occur. Momentary skin contact allows little, if any, opportunity for the passage of any of the compounds into the body. Field procedures require the immediate washing of sediments from exposed skin.

4.4 ACTIVITY HAZARD ANALYSIS

The activity hazard analysis summarizes the field activities to be performed during the project, outlines the hazards associated with each activity, and presents controls that can reduce or eliminate the risk of the hazard occurring. Table 2 presents the activity hazard analysis for the following activities:

- Sampling from a boat
- Scuba diving
- Clam-digging at intertidal beaches

Table 2. Activity hazard analysis

ACTIVITY	HAZARD	CONTROL
Sampling from a boat	falling overboard	Use care in boarding and departing from vessel. Wear a PFD.
	skin contact with contaminated sediments or liquids	Wear modified Level D PPE.
	back strain	Use appropriate lifting techniques when transporting equipment and supplies to or from the boat or seek help.
Scuba diving	loss of communication	Terminate the dive.
	equipment failure	Conduct a pre-dive check; have dive tender and/or safety diver present during dive.
	scrapes and bruises; entrapment by pilings and other obstacles	Be familiar with the area before entering the water. Exercise caution when visibility is low.
	hypothermia	Wear appropriate insulation. Be aware of the symptoms and have warm clothes available.
	nitrogen narcosis	Consult dive tables prior to each dive.
	boat traffic	Deploy the dive flag in the vicinity of the divers. Ascend carefully and as close as possible to the support boat. Have dive tender continuously monitor Channels 13, 14, and 16 for boat traffic near dive area. Ensure that dive tender advises other vessels of diving operations and warns off boat traffic that may pose a hazard to the divers.
Clam digging in intertidal beaches	skin contact with contaminated sediments or liquids	Wear modified Level D PPE.
	slips, trips, and falls	Wear boots with good treads and use caution when walking on slippery surfaces and riprap.
	back strain	Use appropriate lifting techniques when digging in sediment with shovel.

PFD – personal flotation device

PPE – personal protective equipment

5 Work Zones and Shipboard Access Control

During sampling and sample handling activities, work zones will be established to identify where sample collection and processing are actively occurring. The intent of the zone is to limit the migration of sample material out of the zone and to restrict access to active work areas by defining work zone boundaries.

5.1 WORK ZONE

The work zones on shore and on the boat will encompass the areas where sample collection and handling activities are being performed. On the beach and on the boat, the FC/HSO will delineate the work zone as a particular area. Only persons with appropriate training, PPE, and authorization from the FC/HSO will be allowed to enter the work zone while work is in progress.

5.2 DECONTAMINATION STATION

A decontamination station will be set up, and personnel will clean soiled boots or PPE prior to leaving the work zone. The station will have the buckets, brushes, soapy water, rinse water, or wipes necessary to clean boots, PPE, or other equipment leaving the work zones. Plastic bags will be provided for expendable and disposable materials. If the location does not allow for the establishment of a decontamination station, the FC/HSO will provide alternatives to prevent the spread of contamination.

Decontamination of the boat will also be completed at the end of each work day. Cockpit and crew areas will be rinsed down with site water to minimize the accumulation of sediment.

5.3 ACCESS CONTROL

Boat security and access control will be the responsibility of the FC/HSO and boat captain. Boat access will be granted only to essential project personnel and authorized visitors. Any security or access control problems will be reported to the PM or appropriate authorities.

6 Safe Work Practices

Following common sense rules will minimize the risk of exposure or accident at the work site. The general safety rules listed below will be followed onsite:

- Do not climb over or under obstacles of questionable stability.
- Do not eat, drink, smoke, or perform other hand-to-mouth transfers in the work zone.
- Work only in well-lighted spaces.
- Never enter a confined space without the proper training, permits, and equipment.
- Make eye contact with equipment operators when moving within the range of their equipment.
- Be aware of the movements of shipboard equipment when not in the operator's range of vision.
- Get immediate first aid for all cuts, scratches, abrasions, or other minor injuries.
- Use the established sampling and decontamination procedures.
- Always use the buddy system.
- Be alert to your own and other workers' physical condition.

- Report all accidents, no matter how minor, to the FC/HSO.
- Do not do anything dangerous or unwise even if ordered by a supervisor.

7 Personal Protective Equipment and Safety Equipment

Appropriate PPE will be worn as protection against potential hazards. In addition, a PFD will be required for all personnel when working aboard the boat. Prior to donning PPE, personnel will inspect their PPE for any defects that might render the equipment ineffective.

Fieldwork will be conducted in Level D or modified Level D PPE, as discussed in Sections 7.1 and 7.2. Situations that would require PPE beyond modified Level D are not anticipated. Should the FC/HSO determine that PPE beyond modified Level D is necessary, the HSM will be notified and alternative PPE selected.

7.1 Level D Personal Protective Equipment

Individuals performing general activities in which skin contact with contaminated materials is unlikely will wear Level D PPE. Level D PPE includes the following:

- Cotton overalls or lab coats
- Chemical-resistant steel-toed boots
- Chemical-resistant gloves
- Safety glasses

7.2 Modified Level D Personal Protective Equipment

Individuals performing activities in which skin contact with contaminated materials is possible but inhalation risks are not expected will be required to wear an impermeable outer suit. The type of outerwear will be chosen according to the types of chemical contaminants that might be encountered. Modified Level D PPE includes the following:

- Impermeable outer garb, such as rain gear or waders
- Chemical-resistant steel-toed boots
- Chemical-resistant outer gloves

7.3 Safety Equipment

In addition to the above-identified PPE, basic emergency and first aid equipment will also be provided. Equipment for the field team will include:

- A copy of this HSP
- First aid kit adequate for the number of personnel in the field crew

- Emergency eyewash

The FC/HSO will ensure that the safety equipment is available. Equipment will be checked daily to ensure its readiness for use.

8 Monitoring Procedures for Site Activities

A monitoring program that addresses the potential site hazards will be implemented. For this project, air, dust, and noise monitoring will not be necessary. No volatile organic compounds have been identified among the expected contaminants, the sampled media will be wet and will not pose a dust hazard, and none of the equipment emits high-amplitude (i.e., > 85 dBA) noise. For this project, the monitoring program will consist of all individuals monitoring themselves and their co-workers for signs of potential physical stress or illness.

All personnel will be instructed to look for and inform each other of any deleterious changes in their physical or mental conditions during the performance of all field activities. Examples of such changes are as follows:

- Headaches
- Dizziness
- Nausea
- Symptoms of heat stress
- Blurred vision
- Cramps
- Irritation of eyes, skin, or respiratory system
- Changes in complexion or skin color
- Changes in apparent motor coordination
- Increased frequency of minor mistakes
- Excessive salivation or changes in papillary response
- Changes in speech ability or speech pattern
- Shivering
- Blue lips or fingernails

If any of these conditions develop, work will be halted immediately and the affected person(s) evaluated. If further assistance is needed, personnel at the local hospital will be notified, and an ambulance will be summoned if the condition is thought to be serious. If the condition is the direct result of sample collection or handling activities, procedures will be modified to address the problem.

9 Decontamination

Decontamination is necessary to prevent the migration of contaminants from the work zone(s) into the surrounding environment and to minimize the risk of exposure of personnel to contaminated materials that might adhere to PPE. The following subsections discuss personnel and equipment decontamination. The following supplies will be available to perform decontamination activities:

- Wash buckets
- Rinse buckets
- Long-handled scrub brushes
- Clean water sprayers
- Paper towels
- Plastic garbage bags
- Alconox® or similar decontamination solution

9.1 Minimization of Contamination

The first step in addressing contamination is to prevent or minimize exposure to existing contaminated materials and the spread of those materials. During field activities, the FC/HSO will enforce the following measures:

Personnel

- Do not walk through areas of obvious or known contamination.
- Do not handle, touch, or smell contaminated materials directly.
- Make sure PPE has no cuts or tears prior to use.
- Fasten all closures on outer clothing, covering with tape if necessary.
- Protect and cover any skin injuries.
- Stay upwind of airborne dusts and vapors.
- Do not eat, drink, chew tobacco, or smoke in the work zones.

Sampling equipment and boat

- Place clean equipment on a plastic sheet or aluminum foil to avoid direct contact with contaminated media.
- Keep contaminated equipment and tools separate from clean equipment and tools.
- Clean boots before entering the boat.

9.2 PERSONNEL DECONTAMINATION

The FC/HSO will ensure that all site personnel are familiar with personnel decontamination procedures. Personnel will perform decontamination procedures, as appropriate, before eating lunch, taking a break, or leaving the work location. Decontamination procedures for field personnel include:

1. Rinse off the outer suit if it is heavily soiled.
2. Wash and rinse outer gloves and boots with water.
3. Remove and inspect outer gloves and discard them if damaged.
4. Wash hands if taking a break.
5. Don necessary PPE before returning to work.
6. Dispose of soiled, disposable PPE before leaving for the day.

In addition to the decontamination procedures listed above, divers will:

1. Thoroughly rinse dive suit and gear after each dive.
2. Inspect gear for mud or stains and re-rinse or scrub with Alconox®, if necessary.
3. Discard any damaged or heavily soiled gear after the project, if necessary.
4. Launder dry suit underwear after the project.

9.3 SAMPLING EQUIPMENT DECONTAMINATION

Before use at each sampling location, shovels and trowels will be rinsed in site water to dislodge and remove any sediment and ensure that they are cleared of all debris before use. Stainless steel spoons and bowls will be decontaminated before each sample is collected.

9.4 VESSEL DECONTAMINATION

Some sampling will be conducted from a boat. Care will be taken to minimize the amount of sediment spilled on the vessel. The vessel deck will be hosed off regularly to remove sediment from the cockpit and crew areas to minimize slipping hazards and the transport of sediment on boots through work zones.

10 Disposal of Contaminated Materials

Contaminated materials that may be generated during field activities include PPE, decontamination fluids, and excess sample material. These contaminated materials will be disposed of as an integral part of the project.

10.1 PERSONAL PROTECTIVE EQUIPMENT

Gross surface contamination will be removed from PPE. All disposable sampling materials and PPE, such as disposable coveralls, gloves, and paper towels used in the sample processing, will be placed in heavyweight garbage bags. Filled garbage bags will be placed in a normal refuse container for disposal as solid waste.

10.2 EXCESS SAMPLE MATERIALS

At each sampling location, all excess specimens and sediment will be returned to the collection site.

11 Training Requirements

Individuals who perform work at locations where potentially hazardous materials and conditions may be encountered must meet specific training requirements. It is not anticipated that hazardous concentrations of contaminants will be encountered in sampled material, so training will consist of site-specific instruction for all personnel and the oversight of inexperienced personnel by an experienced person for one working day. The following subsections describe the training requirements for this fieldwork.

11.1 PROJECT-SPECIFIC TRAINING

In addition to Hazardous Waste Operations and Emergency Response (HAZWOPER) training, as described in Section 2.5 of the QAPP, field personnel will undergo training specifically for this project. All personnel must read this HSP and be familiar with its contents before beginning work. Personnel will acknowledge reading the HSP by signing the Field Team Health and Safety Plan Review Form (Attachment 2). The completed form will be kept in the project files.

The boat captain and FC/HSO or a designee will provide project-specific training prior to the first day of fieldwork and whenever new workers arrive. Field personnel will not be allowed to begin work until project-specific training has been completed and documented by the FC/HSO. Training will address the HSP and all health and safety issues and procedures pertinent to field operations. Training will include, but not be limited to, the following topics:

- Activities with the potential for chemical exposure
- Activities that pose physical hazards, and actions to control the hazard
- Ship access control and procedure
- Use and limitations of PPE
- Decontamination procedures
- Emergency procedures

- Use and hazards of sampling equipment
- Location of emergency equipment
- Vessel safety practices
- Emergency evacuation and emergency procedures

11.2 Daily Safety Briefings

The FC/HSO or a designee and the boat captain will present safety briefings before the start of each day's activities. These safety briefings will outline the activities expected for the day, update work practices and hazards, address any specific concerns associated with the work location, and review emergency procedures and routes. The FC/HSO or designee will document safety briefings in the logbook.

11.3 First Aid and CPR

At least one member of the field team must have first-aid and cardiopulmonary resuscitation (CPR) training. The diver and dive tender will also be trained in first-aid and CPR as required by the Research Support Services' diver safety manual. Documentation of which individuals possess first-aid and CPR training will be kept in the project health and safety files.

12 Medical Surveillance

A medical surveillance program conforming to the provisions of 29CFR1910§120(f) will not be necessary for field team members because the field team members do not meet any of the four criteria outlined in the regulations for the implementation of a medical surveillance program:

- Employees who are or may be exposed to hazardous substances or health hazards at or above permissible exposure levels for 30 days or more per year (1910.120(f)(2)(I)
- Employees who must wear a respirator for 30 days or more per year (1910.120(f)(2)(ii))
- Employees who are injured or become ill due to possible overexposures involving hazardous substances or health hazards from an emergency response or hazardous waste operation (1910.120(f)(2)(iii))
- Employees who are members of HAZMAT teams (1910.120(f)(2)(iv))

As described in Section 8, employees will monitor themselves and each other for any deleterious changes in their physical or mental condition during the performance of all field activities.

13 Reporting and Record Keeping

Each member of the field crew will sign the HSP review form (see Attachment 2). If necessary, accident/incident report forms and Occupational Safety and Health Administration (OSHA) Form 200s will be completed by the FC/HSO.

The FC/HSO or a designee will maintain a health and safety field logbook that records health-and-safety-related details of the project. Alternatively, entries may be made in the field logbook, in which case a separate health and safety field logbook will not be required. The logbook must be bound and the pages must be numbered consecutively. Entries will be made with indelible blue ink. At a minimum, each day's entries must include the following information:

- Project name or location
- Names of all personnel
- Weather conditions
- Type of fieldwork being performed

The individual maintaining the entries will initial and date the bottom of each completed page. Blank space at the bottom of an incompletely filled page will be lined out. Each day's entries will begin on the first blank page after the previous workday's entries.

14 Emergency Response Plan

As a result of the hazards and the conditions under which operations will be conducted, the potential exists for an emergency situation to occur. Emergencies may include personal injury, exposure to hazardous substances, fire, explosion, or release of toxic or non-toxic substances (i.e., spills). OSHA regulations require that an emergency response plan be available to guide actions in emergency situations.

Onshore organizations will be relied upon to provide response in emergency situations. The local fire department and ambulance service can provide timely response. Field personnel will be responsible for identifying emergency situations, providing first aid, if applicable, notifying the appropriate personnel or agency, and evacuating any hazardous area. Shipboard personnel will attempt to control only very minor hazards that could present an emergency situation, such as a small fire, and will otherwise rely on outside emergency response resources.

The following subsections identify the individual(s) who should be notified in case of emergency, provide a list of emergency telephone numbers, offer guidance for particular types of emergencies, and provide directions for getting from any sampling location to a hospital.

14.1 PRE-EMERGENCY PREPARATION

Before the start of field activities, the FC/HSO will ensure that preparation has been made in anticipation of emergencies. This preparation includes the following:

- Meeting with equipment handlers concerning emergency procedures to be followed in the event of an injury
- Conducting a training session informing all field personnel of emergency procedures, locations of emergency equipment and their use, and proper evacuation procedures
- Conducting a training session (led by senior staff responsible for operating field equipment) to apprise field personnel of operating procedures and specific risks associated with field equipment
- Ensuring that field personnel are aware of the existence of the emergency response plan in the HSP and ensuring that a copy of the HSP accompanies the field team

14.2 PROJECT EMERGENCY COORDINATOR

The FC/HSO will serve as the project emergency coordinator (PEC) in the event of an emergency. She will designate a replacement for times when she is not available or is not serving as the PEC. The designation will be noted in the logbook. The PEC will be notified immediately when an emergency is recognized. The PEC will be responsible for evaluating the emergency situation, notifying the appropriate emergency response units, coordinating access with those units, and directing onboard interim actions before the arrival of emergency response units. The PEC will notify the HSM and the PM as soon as possible after initiating an emergency response action. The PM will have responsibility for notifying the client.

14.3 EMERGENCY RESPONSE CONTACTS

All personnel must know whom to notify in the event of an emergency situation, even though the FC/HSO has primary responsibility for notification. Table 3 lists the names and phone numbers for emergency response services and individuals.

Table 3. Emergency response contacts

CONTACT	TELEPHONE NUMBER
Emergency Numbers	
Ambulance	911
Police	911
Fire	911
Harborview Medical Center	(206) 323-3074
US Coast Guard Office Emergency General information	 (206) 286-5400 (206) 442-5295 UHF Channel 16
National Response Center	(800) 424-8802
US Environmental Protection Agency	(908) 321-6660
Washington State Department of Ecology – Northwest Region Spill Response (24-hour emergency line)	(206) 649-7000
Project Management Emergency Contacts	
Susan McGroddy, Project Manager	(206) 812-5421
Tad Deshler, Corporate Health and Safety Manager	(206) 812-5406
Helle Andersen, Field Coordinator/ Health and Safety Officer	(206) 353-9346 (site cellular telephone)

14.4 RECOGNITION OF EMERGENCY SITUATIONS

Emergency situations will generally be recognizable through observation. An injury or illness will be considered an emergency if it requires treatment by a medical professional and cannot be treated with simple first-aid techniques.

14.5 DECONTAMINATION

In the case of evacuation, decontamination procedures will be performed only if doing so does not further jeopardize the welfare of site workers. If an injured individual is also heavily contaminated and must be transported by emergency vehicle, the emergency response team will be informed of the type of contamination. To the extent possible, contaminated PPE will be removed but only if doing so does not exacerbate the injury. Plastic sheeting will be used to reduce the potential for spreading contamination to the inside of the emergency vehicle.

14.6 FIRE

Field personnel will attempt to control only small fires. If an explosion appears likely, personnel will follow evacuation procedures specified during the training session. If a fire cannot be controlled with the onboard fire extinguisher that is part of the required safety equipment, personnel will either withdraw from the vicinity of the fire or evacuate the site as specified during the training session.

14.7 PERSONAL INJURY

In the event of serious personal injury, including unconsciousness, possibility of broken bones, severe bleeding or blood loss, burns, shock, or trauma, the first responder will immediately do the following:

- Administer first aid, if qualified.
- If not qualified, seek out an individual who is qualified to administer first aid, if time and conditions permit.
- Notify the PEC of the incident, the name of the individual, the location, and the nature of the injury.

The PEC will immediately do the following:

- Notify the boat captain and FC/HSO, and the appropriate emergency response organization.
- Assist the injured individual.
- Follow the emergency procedures for retrieving or disposing of equipment and leave the site and proceed to the predetermined land-based emergency pick-up.
- Designate someone to accompany the injured individual to the hospital.
- If a life-threatening emergency occurs (i.e., injury in which death is imminent without immediate treatment), the FC/HSO or boat captain will call 911 and arrange to meet the emergency responder at the nearest accessible location or dock. For injuries or emergencies that are not life-threatening (e.g., broken bones, minor lacerations), the PEC will follow the procedures outlined above and proceed to the Harbor Island Marina or to an alternative location if that would be more expedient.
- Notify the HSM and the PM.

If the PEC determines that emergency response is not necessary, he or she may direct someone to decontaminate and transport the individual by vehicle to the nearest hospital. Directions describing the route to the hospital are provided in Section 14.10.

If a worker leaves the site to seek medical attention, another worker should accompany them to the hospital. When in doubt about the severity of an injury or exposure, always seek medical attention as a conservative approach and notify the PEC.

The PEC will be responsible for completing all accident/incident field reports, OSHA Form 200s, and other required follow-up forms.

14.8 Overt Personal Exposure or Injury

If an overt exposure to toxic materials occurs, the first responder to the victim will initiate actions to address the situation. The following actions should be taken, depending on the type of exposure.

14.8.1 Skin contact

- Wash/rinse the affected area thoroughly with copious amounts of soap and water.
- If eye contact has occurred, rinse eyes for at least 15 minutes using the eyewash that is part of the onboard emergency equipment.
- After initial response actions have been taken, seek appropriate medical attention.

14.8.2 Inhalation

- Move victim to fresh air.
- Seek appropriate medical attention.

14.8.3 Ingestion

- Seek appropriate medical attention.

14.8.4 Puncture wound or laceration

- Seek appropriate medical attention.

14.9 Spills and Spill Containment

No bulk chemicals or other materials subject to spillage are expected to be used during this project. Accordingly, no spill containment procedure is required for this project.

14.10 Emergency Route to the Hospital

The name, address, and telephone number of the hospital that will be used to provide medical care is as follows:

Harborview Medical Center
325 Ninth Avenue
Seattle, WA
(206) 323-3074

Directions from the vicinity of EW to Harborview Medical Center are as follows:

- Dock the vessel at the First Avenue S boat launch.
- Drive east on S River Street.
- Turn left on Occidental Avenue S.

- Turn left on E Marginal Way S.
- Turn right on S Michigan Street.
- Look for the entrance ramps to I-5 northbound.
- Head north on I-5.
- Take the James Street exit.
- Head east on James Street to Ninth Avenue.
- Turn right on Ninth Avenue.
- Emergency entrance will be two blocks south on the right.

15 References

PSEP. 1997. Recommended guidelines for sampling marine sediment, water column, and tissue in Puget Sound. Final Report. Prepared for the U.S. Environmental Protection Agency, Seattle, Washington, and the Puget Sound Water Quality Action Team, Olympia, WA.

Attachment 1. Dive Plan

RSS RESEARCH SUPPORT SERVICES, INC. 206-550-5202
8010 NE Lovgren Road, Bainbridge Island, WA 98110 eparker@rssincorporated.com

DIVE SAFETY AND WORK PLAN
East Waterway Rockfish Collection and Clam Survey
for
Windward Environmental

EMERGENCY RESPONSE INFORMATION

NOTE: Call local 911 first in case of any medical emergency prior to traveling to the emergency medical facility. Call DAN with questions regarding treatment of diving emergencies.

Telephone emergency: 911 and DAN 1-919-684-8111

Coast Guard emergency: 1-206-217-6000 (*CG from any cell phone)

Dive Emergency Gear: First aid kit, emergency oxygen kit, VHF radio, and cellular phones

Field Cellular Phone: 206-550-5202 Eric Parker

Nearest Dive Emergency Medical Facilities:

Harborview Medical Center, 325 9th Ave., Seattle (206) 731-3074 emergency room

Virginia Mason Hospital, Hyperbaric Medicine Dept., 1202 Terry Ave., Seattle

(206) 583-6543 hyperbaric; (206) 583-6433 emergency room and after hours hyperbaric

U.S. Naval Torpedo Station, Keyport (360) 396-2111 or (360) 396-8111

Nearest Non-dive Emergency Medical Facilities:

Virginia Mason Hospital, Hyperbaric Medicine Dept., 925 Seneca Street, Seattle
(206) 583-6433 emergency room

DIVE PLAN

Project: Rockfish Collection and Clam Surveys

Work window: Start 0900, end 1700

Project Managers: Eric Parker, RSS; Susan McGroddy, Windward Environmental

Dates of operation: August 2008, dates to be decided

Location of Dive: East Waterway, Seattle

Staging Location: Harbor Island Marina

Primary Divers: Eric Parker
Jeff Christiansen

Tender: Judd Dunlap

Purpose of Work: Collect fish for tissue sampling, conduct transect surveys for clam presence.

Number of Dives Anticipated: 15

Maximum depth Anticipated: 50 ft.

Depth for Majority of Work: 40 ft. and shallower

Breathing Gas: Air

Pre-Dive Procedures:

- The U.S. Coast Guard in Seattle will be provided with an emailed copy of this Dive Plan prior to the dive operations (email sectorseattlewwm@.uscg.mil).
- The Coast Guard VTS will be notified on VHF channel 14 or by phone at (206) 217-6152 on the day of work prior to commencing diving operations and again when work is finished for the day.
- A pre-dive briefing will be conducted to familiarize divers and surface personnel of site-specific hazards and to ensure readiness to work.

General Work Plan:

- Operations will be conducted from the *Carolyn Dow*, a 36' aluminum landing craft anchored adjacent to the dive location.
- Divers will be connected to eachother via a safety line.
- Divers and tender will communicate via single side band wireless equipment.

Safety Procedures:

- Diving operations will be conducted in accordance with federal and state health and safety regulations and according to procedures outlined in the RSS Dive Safety Manual. The Windward Site Specific Health and Safety Plan will apply to non-diving components of this operation and will be reviewed by all participants.
- The operation will be checked in with Seattle VTS as a non-participant and will monitor VHF channels 14 and 13. No special vessel consideration (such as a no wake zone) is requested.
- A red-and-white diver flag and blue-and-white alpha flag will be flown conspicuously when divers are in the water.
- Contamination precautions will include a drysuit with attached latex hood and gloves and positive pressure full-face mask.
- Emergency oxygen will be available on site in case of a pressure-related injury. In addition to administration of oxygen to an injured diver, basic first aid and activation of EMS will apply.

Area of operations:

Attachment 2. Field Team Health and Safety Plan Review

I have read a copy of the health and safety plan, which covers field activities that will be conducted to investigate potentially contaminated areas in the EW. I understand the health and safety requirements of the project, which are detailed in this health and safety plan.

Signature	Date
Signature	Date
Signature	Date
Signature	Date
Signature	Date
Signature	Date
Signature	Date
Signature	Date
Signature	Date
Signature	Date
Signature	Date

APPENDIX B

Field Collection Forms

Project Name:		Project no.	
Date:		Station:	
Start/Stop time:			X:
Sampling Method:			Y:
Weather:		Sample ID:	
Crew:			

Clam species	#	Shell length (cm)		Clam species	#	Shell length (cm)

Comments:

Project: East Waterway intertidal clam collection **Date:** 2008 **Time:**

Location (beach): **Weather:**

Field personnel:

Sampling unit (station or transect):

Sampling unit location description:

Habitat Type: ☐ Estuarine ☐ Marine

☐ Intertidal ☐ Subtidal

Approximate depth/elevation:
(Estimate range if transect)

Substrate type

☐ Hard pan ☐ Mixed coarse *(Cobble, gravel, sand)* ☐ Mixed fine *(Sand and mud)*

☐ Boulder ☐ Gravel ☐ Mud

☐ Cobble ☐ Sand ☐ Organic *(Wood chips, detritus)*

☐ Artificial

Describe any unique substrate characteristic or condition:

Bottom slope *(Estimate)* **Salinity**

Energy--Estuarine Habitats

☐ Open *Moderate wind/wave*

☐ Partially enclosed *Restricted flow (e.g., spit, bar)*

☐ Lagoon *Enclosed*

☐ Tidal channel/slough

Common species:
(Estimate % cover for vegetation)

Notes:

PROTOCOL MODIFICATION FORM

Project Name and Number: _____

Material to be Sampled: _____

Measurement Parameter: _____

_____

_____

Standard Procedure for Field Collection & Laboratory Analysis (cite reference):

_____

_____

_____

_____

_____

Reason for Change in Field Procedure or Analysis Variation: _____

_____

_____

_____

_____

_____

Variation from Field or Analytical Procedure: _____

_____

_____

_____

_____

_____

Special Equipment, Materials or Personnel Required: _____

_____

_____

_____

_____

_____

Initiator's Name: _____ Date: _____

Project Manager: _____ Date: _____

QA Manager: _____ Date: _____

APPENDIX C

Risk-Based Analytical Concentration Goals

Appendix C. Clam Tissue Analytical Concentration Goals

C.1 INTRODUCTION

This appendix addresses the following question:

> Are standard analytical methods proposed for the chemical analyses of clam tissue sufficiently sensitive to meet the needs of the East Waterway (EW) ecological and human health risk assessments?

To answer this question, standard reporting limits (RLs) and method detection limits (MDLs) were compared to analytical concentration goals (ACGs). ACGs for clams are defined for ecological receptors as the concentration of a chemical in tissue of its prey associated with no effects, and defined for human health as the concentration of a chemical in food that has been identified as having an acceptable risk level (e.g., excess cancer risk no higher than 10^{-6} or HQ less than 0.1 for non-cancer risk). ACGs have not been developed by the US Environmental Protection Agency (EPA) Region 10 for the receptors of interest. Therefore, these concentrations were determined by reviewing the toxicological literature for wildlife, and by reviewing human health guidance documents. Although information from the toxicological literature is used in this document, the objective of this memo is not to establish the toxicity reference values (TRVs) to be used for the EW risk assessments. The TRVs to be used in those assessments will be determined in consultation with EPA.

To determine ACGs for this quality assurance project plan (QAPP), risk-based concentrations (RBCs) were identified or derived for each receptor species that consumes clams (i.e., pigeon guillemot, river otter, and humans).[1] The ACG for clam tissue is equal to the lowest RBC for any receptor ingesting clams.

The remainder of this appendix is organized as follows:

- Section C.2.0 – RBC derivation methods for each receptor
- Section C.3.0 – Comparison of ACGs to RLs and MDLs
- Section C.4.0 – Tables
- Section C.5.0 – References

Tables C-1 through C-7 summarize RBCs for all receptors for each chemical, list studies selected for each receptor for the calculation of RBCs, compare ACGs to RLs and MDLs, and summarize tissue mass requirements to meet target RLs and MDLs. These tables are located in Section C.4.0.

[1] Crabs also consume clams, but risk will be evaluated using a critical tissue residue approach rather than a dietary approach.

C.2 RISK-BASED CONCENTRATIONS

For this QAPP, RBCs are tissue concentrations associated with an acceptable risk level as derived from the ecological toxicity literature or slope factors ana RfDs established by EPA for human health assessment. The RBCs were derived using the same process as was used in QAPP prepared for fish and crab sampling for the LDW RI. . In this appendix, RBCs are derived for humans and ecological receptors that consume clams (i.e., English sole, juvenile Chinook salmon, pigeon guillemot, and river otter).

The following sections describe how RBCs were derived for each receptor. The RBCs for each of the receptors are summarized in Table C-1; this table includes RBCs for chemicals of interest (COIs) presented in Table C-2. This list presents COIs identified for the Lower Duwamish Waterway (LDW) ERA ana HHRA (Windward 2007a, 2007b), which will provide a basis for the analyte list for the EW because sufficient tissue data do not currently exist to provide a site-specific list. The chemicals of potential concern (COPC) list for the EW will be developed once sufficient data are available to conduct a screening evaluation. Available toxicity data for the chemicals in Table C-2 were used to derive RBCs using methods described in the remainder of this section. For some chemicals in Table C-2, no relevant toxicity data were available for certain receptors and thus RBCs were not derived.

C.2.1 Dietary RBC Derivation for the Protection of Birds and Mammals

RBCs for the protection of piscivorous birds and mammals are expressed as chemical concentrations in the tissues of their prey. RBCs derived for the protection of pigeon guillemot and river otter will be considered in the determination of ACGs for the clam tissue samples.

Toxicity data identified for bird and mammal species were NOAELs, which are the highest dietary doses at which no adverse effects were observed, and LOAELs, which are the lowest dietary doses at which adverse effects were observed. Effects endpoints included growth, reproduction, and survival.

The NOAELs and LOAELs derived from the literature are expressed as dietary doses in mg/kg body weight (bw)/day. These dietary doses were converted to RBCs in prey tissue in mg/kg ww using the receptor's food ingestion rate and body weight. Table C-1 summarizes wildlife RBCs, including both NOAELs and LOAELs, if available. The NOAEL-based RBC is the most relevant concentration; LOAEL-based RBCs are presented in case the NOAEL-based RBC is less than the target MDL. Tables C-3 and C-4 present summary information for the studies selected to derive RBCs in bird and mammal prey items, respectively, including the endpoint, test species, exposure pathway, and reference for each NOAEL and LOAEL shown. The following sections describe the literature search process and the conversion of dietary doses to dietary RBCs.

Literature Search

Studies relating tissue concentrations in crabs to adverse effects were identified from a search of BIOSIS, EPA's ECOTOX database, the National Library of Medicine's TOXNET database, the US Fish and Wildlife Service's Contaminant Review series, the Oak Ridge National Laboratory's database, and EPA's IRIS database. Original sources of toxicity data were obtained and reviewed to verify effects data summarized in the databases as well as the suitability of the studies. The databases were searched for studies that evaluated effects on survival, growth, and reproduction. The following guidelines were considered in the selection of TRVs for wildlife.

- Studies using field-collected data were not used to obtain NOAELs and LOAELs, but were considered if no other toxicity data were available for a COI. Studies conducted using IP injection, intramuscular injection, forced ingestion, or oral gavage as exposure routes were not considered for selecting NOAELs and LOAELs unless no other toxicity data are available for a COI.
- Studies using drinking water as the exposure medium were not used to select NOAELs and LOAELs because bioavailability from water may be different from that of food. If no other toxicity data were available, then drinking water studies were considered.
- Studies with egg production endpoints for chicken or quail, such as Edens and Garlich (1983) and Edens et al. (1976) are considered highly uncertain and were only considered if data from other more appropriate studies were not available. These data are considered uncertain because chickens and quail have been bred to have high egg-laying rates. Even with a significant reduction in their baseline egg production, these egg production rates may be much higher than those of any wild avian species. These differences in reproductive physiology result in high uncertainty in extrapolating a reproductive effect threshold from egg production rates for chickens or quails.
- Toxicity studies conducted with chemical forms not likely found in the EW, such as the fungicide methylmercury dicyandiamide, were not used to select NOAELs and LOAELs. Toxicity of these chemical forms is not comparable to the toxicity of forms of chemicals present in the EW.

RBCs were derived from the study with the lowest LOAEL, and the study with the highest NOAEL that was lower than the LOAEL for the same endpoint. If no NOAEL with the same endpoint as the selected LOAEL was available, the NOAEL was selected as the highest NOAEL below the selected LOAEL based on another endpoint (survival, growth, or reproduction).

For chemicals without NOAELs lower than the selected LOAEL, the NOAEL was determined using the following uncertainty factors following EPA Region 10 guidance (EPA 1997):

- Acute or subchronic LOAEL/10
- Chronic or critical lifestage LOAEL/5
- LC50 (or similar)/50

For some chemicals, no relevant toxicity data were available and RBCs could not be calculated.

RBC Derivation

The NOAELs and LOAELs derived from toxicity studies were expressed as daily dietary doses normalized for body weight. To convert these doses to a tissue concentration in ingested food, the following equation was used:

$$C_F = (\text{Dose} \times \text{BW})/\text{DFC}$$

where:

C_F = concentration in food (mg/kg ww)
Dose = NOAEL or LOAEL (mg/kg bw/day)
BW = body weight (kg)
DFC = daily food consumption rate (kg ww/day)

If the NOAEL or LOAEL was based on a reproductive endpoint, the C_F was calculated using the female BW and DFC. If the NOAEL or LOAEL was based on growth or survival, C_F was calculated using the male and female average for BW and DFC. The BW and DFC values used in deriving RBCs are presented in Table C-6. The lowest calculated C_F for each receptor was chosen as the RBC, as summarized in Table C-1. RBCs are presented for both NOAELs and LOAELs, where available.

C.2.2 Dietary RBC Derivation for the Protection of Humans

RBCs for the protection of humans that might ingest clams are expressed as chemical concentrations in clam tissue. Human health guidance documents were reviewed for RBCs for human health. EPA Region 10 has not developed RBCs in food organisms for the protection of human health. EPA Region 9 has developed RBCs for the protection of human health for exposures to soil and water (EPA 1996), but not for consumption of fish tissue. The Model Toxics Control Act (MTCA, a Washington State statute), which contains human health risk-based cleanup levels for several media, considers uptake into tissue (i.e., fish) from surface water but does not directly provide a human health RBC for tissue. EPA Region 3 (EPA 2001) provides an approach for the development of RBCs for fish tissue, which, after modification for site-specific exposure factors, was used to derive RBCs for clam tissue in this appendix.

RBCs can be calculated for chemicals with either carcinogenic or non-carcinogenic endpoints; some chemicals have both types of endpoints. The RBC equations are shown below:

$$\text{RBC(carcinogenic)} = \frac{TR \times BW \times AT_c}{EF \times ED \times IR \times CF \times CSF}$$

$$\text{RBC(noncarcinogenic)} = \frac{THQ \times RfD \times BW \times AT_n}{EF \times ED \times IR \times CF}$$

where:

TR = target risk (1×10^{-6})
BW = body weight (79 kg)
AT_c = averaging time, carcinogenic (25,550 days)
EF = exposure frequency (365 days/yr)
ED = exposure duration (70 years)
IR = ingestion rate (98 g/day)
CF = conversion factor (0.001 kg/g)
CSF = cancer slope factor (kg-day/mg, chemical-specific)
THQ = target hazard quotient (0.1, EPA 1996)
RfD = reference dose (mg/kg-day, chemical-specific)
AT_n = averaging time, non-carcinogenic (25,550 days)

For calculation of RBCs(cargenogenic) for certain PCBs and dioxins, the CSF of the index comound ($CSF_{i.c.}$) is multiplied by the TEF (Van den Berg et al. 2006) as follows to calculate the RBC:

$$\text{RBC(carcinogenic)} = \frac{TR \times BW \times AT_c}{EF \times ED \times IR \times CF \times CSF_{i.c.} \times TEF}$$

The seafood ingestion rate is the 95th percentile rate for the combined consumption of pelagic fish, benthic fish, and shellfish as estimated in the Tulalip Tribes fish consumption survey (Toy et al. 1996). For calculation of RBCs for clam tissue presented in this document, the Region 3 RBC values were adjusted using the parameters provided in the equations above.

C.3 COMPARISON OF ACGS TO RLS AND MDLS

The ACGs for clam tissue were determined by selecting the lowest RBC for each chemical for each receptor that consumes clams, as presented in Table C-1. These ACGs are compared with target RLs and MDLs in Table C-6.

As shown in Table C-6, the target RLs for 54 of the 106 chemicals with ACGs were less than the ACGs, and thus the specified methods are sufficiently sensitive to provide

definitive data for the risk assessments for those chemicals. However, the RLs for 52 other chemicals were higher than the ACGs derived for human health or ecological RBCs, and the MDLs for 35 of these chemicals were higher than the ACGs. The target RLs and MDLs in Table C-6 are the lowest that can be reasonably obtained using standard EPA-approved analytical methods. The chemicals with RLs higher than ACGs are 22 SVOCs, 7 individual PCB Aroclors, total PCBs, dioxin and furan congeners, 14 organochlorine pesticides, total and inorganic arsenic, antimony, thallium, and mercury. The chemicals with MDLs higher than ACGs are 11 SVOCs, 6 individual PCB Aroclor, total PCBs, dioxin and furan congeners, 14 organochlorine pesticides, total and inorganic arsenic, and mercury. Therefore, application of the cited analytical methods could result in some uncertainty regarding whether these chemicals represent a significant risk if they were undetected using these standard methods.

Total PCBs, antimony, total and inorganic arsenic, mercury, thallium and the six PAHs with RLs higher than ACGs were detected in all of the clam samples collected during the LDW RI. In addition, dioxins ana furans were frequently detected in fish tissue collected in 2007 near Kellogg Island and along the Elliott Bay waterfront (Gries 2008). Therefore, it is expected that EW data for these chemicals will be sufficient for use in the risk assessments, because elevated RLs relative to ACGs are only problematic when chemicals are not detected.

Of the 54 chemicals with RLs higher than ACGs for human receptors, only two chemicals exceeded ACGs for ecological receptors (i.e., mercury and aldrin). If these chemicals are undetected using the cited analytical methods, there could be some uncertainty regarding whether these chemicals represent a significant risk, primarily in the human health risk assessment. For the undetected chemicals with RLs above the ACGs, the ramifications for the HHRA and ERA will be discussed in the uncertainty assessments.

The laboratories will make all reasonable efforts to achieve the target MDLs and RLs for all chemicals. Additional efforts may include modified extraction techniques (e.g., extracting a higher sample volume or adjusting the final extract volume), sample cleanup procedures (e.g., gel-permeation column chromatography), using a lower concentration for the lowest standard in the initial calibration, or adjusting the amount of extract injected into the instrument. If no PCB Aroclors are detected in a sample, a low-level extraction technique may be performed. Lower target MDLs and RLs may be available for pesticides using a GC/MS/MS technique developed by Columbia Analytical Services, Inc., although the target MDLs and RLs are not yet known.

C.4 TABLES

Table C-1. Receptor-specific dietary RBCs for clams

Analyte	RBC (mg/kg ww)				
		Pigeon Guillemot		River Otter	
	Human Health	NOAEL-Based	LOAEL-Based	NOAEL-Based	LOAEL-Based
PAHs					
Acenaphthene	5.0	na	na	na	na
Acenaphthylene	na	na	na	na	na
Anthracene	25	na	na	na	na
Benzo(a)anthracene	0.0011	na	na	na	na
Benzo(a)pyrene	0.00011	1.4	7.0	12	60
Benzo(b)fluoranthene	0.0011	na	na	na	na
Benzo(k)fluoranthene	0.011	na	na	na	na
Benzo(g,h,i)perylene	na	na	na	na	na
Chrysene	0.11	na	na	na	na
Dibenzo(a,h)anthracene	0.00011	na	na	na	na
Dibenzofuran	0.084	na	na	na	na
Fluoranthene	3.4	na	na	na	na
Fluorene	3.4	na	na	na	na
Indeno(1,2,3-cd)pyrene	0.0011	na	na	na	na
1-Methylnaphthalene	na	na	na	910	na
2-Methylnaphthalene	0.34	na	na	330	690
Naphthalene	1.7	na	na	810	na
Phenanthrene	na	na	na	na	na
Pyrene	2.5	na	na	na	na
Total PAHs	na	40	200	na	na
Other SVOCs					
1,2,4-Trichlorobenzene	0.84	na	na	na	na
1,2-Dichlorobenzene	7.6	na	na	na	na
1,3-Dichlorobenzene	0.25	na	na	na	na
1,4-Dichlorobenzene	0.034	na	na	na	na
2,4,5-Trichlorophenol	8.4	na	na	na	na
2,4,6-Trichlorophenol	0.073	na	na	na	na
2,4-Dichlorophenol	0.25	na	na	na	na
2,4-Dimethylphenol	1.7	na	na	na	na
2,4-Dinitrophenol	0.17	na	na	na	na
2,4-Dinitrotoluene	0.17	na	na	na	na
2,6-Dinitrotoluene	0.084	na	na	na	na
2-Chloronaphthalene	6.7	na	na	na	na
2-Chlorophenol	0.42	na	na	na	na
2-Methylphenol	4.2	na	na	na	na
3,3'-Dichlorobenzidine	0.0018	na	na	na	na
4-Chloroaniline	0.34	na	na	na	na
4-Methylphenol	0.42	na	na	na	na
4-Nitrophenol	na	na	na	na	na
Aniline	0.14	na	na	na	na

Analyte	RBC (mg/kg ww)				
		Pigeon Guillemot		River Otter	
	Human Health	NOAEL-Based	LOAEL-Based	NOAEL-Based	LOAEL-Based
Benzidine	0.0000035	na	na	na	na
Benzoic acid	340	na	na	490	4,500
Benzyl alcohol	42	na	na	na	na
Bis(2-chloroethyl)ether	0.00073	na	na	na	na
Bis(2-ethylhexyl)phthalate	0.058	330	1,600	260	540
Bis-chloroisopropyl ether	0.00073	na	na	na	na
Butyl benzyl phthalate	17	na	na	1,500	4,500
Carbazole	0.040	na	na	na	na
Di-ethyl phthalate	67	na	na	11,000	22,000
Dimethyl phthalate	na	na	na	na	na
Di-n-butyl phthalate	8.4	na	na	96	480
Hexachlorobutadiene	0.010	na	na	na	na
Hexachloroethane	0.058	na	na	na	na
Isophorone	0.85	na	na	na	na
Nitrobenzene	0.042	na	na	na	na
N-Nitrosodimethylamine	0.000016	na	na	na	na
N-Nitrosodi-n-propylamine	0.00012	na	na	na	na
N-Nitrosodiphenylamine	0.16	na	na	na	na
Pentachlorophenol	0.0067	na	na	na	na
Phenol	25	na	na	360	720
PCBs					
Aroclor 1016	0.012	na	na	na	na
Aroclor 1221	0.00040	na	na	na	na
Aroclor 1232	0.00040	na	na	na	na
Aroclor 1242	0.00040	na	na	na	na
Aroclor 1248	0.00040	na	na	na	na
Aroclor 1254	0.00040	na	na	na	na
Aroclor 1260	0.00040	na	na	na	na
Total PCBs	0.00040	2.4	7.0	0.27	0.53
PCB congeners (based on 2,3,7,8-TCDD)[a]	na	7.0×10^{-5}	7.0×10^{-4}	4.2×10^{-6}	3.2×10^{-5}
PCB-77 [a]	0.000054	na	na	na	na
PCB-81 [a]	0.000018	na	na	na	na
PCB-105 [a]	0.00018	na	na	na	na
PCB-114 [a]	0.00018	na	na	na	na
PCB-118 [a]	0.00018	na	na	na	na
PCB-123 [a]	0.00018	na	na	na	na
PCB-126 [a]	5.4×10^{-8}	na	na	na	na
PCB-156 [a]	0.00018	na	na	na	na
PCB-157 [a]	0.00018	na	na	na	na
PCB-167 [a]	0.00018	na	na	na	na
PCB-169 [a]	1.8×10^{-7}	na	na	na	na
PCB-189 [a]	0.00018	na	na	na	na
Dioxins/furans					
2,3,7,8-tetrachlorodibenzo-*p*-dioxin [a]	5.4×10^{-9}	7.0×10^{-5}	7.0×10^{-4}	4.2×10^{-6}	3.2×10^{-5}

Analyte	RBC (mg/kg ww)				
	Human Health	Pigeon Guillemot		River Otter	
		NOAEL-Based	LOAEL-Based	NOAEL-Based	LOAEL-Based
1,2,3,7,8-pentachlorodibenzo-*p*-dioxin [a]	5.4×10^{-9}	na	na	na	na
1,2,3,6,7,8-hexachlorodibenzo-*p*-dioxin [a]	5.4×10^{-8}	na	na	na	na
1,2,3,4,7,8-hexachlorodibenzo-*p*-dioxin [a]	5.4×10^{-8}	na	na	na	na
1,2,3,7,8,9-hexachlorodibenzo-*p*-dioxin [a]	5.4×10^{-8}	na	na	na	na
1,2,3,4,6,7,8-heptachlorodibenzo-*p*- dioxin [a]	5.4×10^{-7}	na	na	na	na
Octachlorodibenzo-*p*-dioxin [a]	1.8×10^{-5}	na	na	na	na
2,3,7,8-tetrachlorodibenzofuran [a]	5.4×10^{-8}	na	na	na	na
1,2,3,7,8-pentachlorodibenzofuran [a]	1.8×10^{-7}	na	na	na	na
2,3,4,7,8-pentachlorodibenzofuran [a]	1.8×10^{-8}	na	na	na	na
1,2,3,6,7,8-hexachlorodibenzofuran [a]	5.4×10^{-8}	na	na	na	na
1,2,3,7,8,9-hexachlorodibenzofuran [a]	5.4×10^{-8}	na	na	na	na
1,2,3,4,7,8-hexachlorodibenzofuran [a]	5.4×10^{-8}	na	na	na	na
2,3,4,6,7,8-hexachlorodibenzofuran [a]	5.4×10^{-8}	na	na	na	na
1,2,3,4,6,7,8-heptachlorodibenzofuran [a]	5.4×10^{-7}	na	na	na	na
1,2,3,4,7,8,9-heptachlorodibenzofuran [a]	5.4×10^{-7}	na	na	na	na
Octachlorodibenzofuran [a]	1.8×10^{-5}	na	na	na	na
Metals					
Antimony	0.034	na	na	9,000	na
Arsenic	0.00054	50	200	16	33
Cadmium	0.084	7.5	20	21	79
Chromium	0.25	5.0	25	8,900	na
Cobalt	na	12	120	0.61	6.1
Copper	3.4	100	140	110	160
Lead	na	29	100	66	540
Mercury	0.0084	0.090	0.45	0.010	0.051
Molybdenum	0.42	30	150	1.5	15
Nickel	1.7	380	530	50	120
Selenium	0.42	2.5	4.1	0.33	0.49
Silver	0.42	na	na	na	na
Thallium	0.0059	12	120	4.5	na
Vanadium	0.084	6.0	11	6.4	16
Zinc	25	410	620	960	1,900
Di-n-butyltin	na	na	na	23	45
Tri-n-butyltin	0.025	7.0	18	2.4	12
Organochlorine Pesticides					
4,4'-DDD	0.0034	na	na	na	na
4,4'-DDE	0.0024	na	na	na	na
4,4'-DDT	0.0024	na	na	na	na
Total DDT	na	0.32	1.6	7.2	7.8
Aldrin	0.000048	0.040	0.20	5.0	25
alpha-BHC	0.00013	na	na	na	na
beta-BHC	0.00045	na	na	35	190
Chlordane	0.0023	3.0	10	1.1	5.6

Analyte	RBC (mg/kg ww)				
		Pigeon Guillemot		River Otter	
	Human Health	NOAEL-Based	LOAEL-Based	NOAEL-Based	LOAEL-Based
Dieldrin	0.000050	0.40	0.60	0.23	1.1
Endosulfan	0.50	50	na	5.1	15
Endosulfan sulfate	na	na	na	na	na
Endrin	0.025	0.35	1.0	2.4	5.5
gamma-BHC (Lindane)	0.00062	8.0	18	390	na
Heptachlor	0.00018	2.5	25	6.0	11
Heptachlor epoxide	0.000089	na	na	na	na
Hexachlorobenzene	0.00050	5.5	6.0	0.16	0.78
Methoxychlor	0.42	170	1,700	100	340
Mirex	0.017	na	na	na	na
Toxaphene	0.00073	na	na	na	na

na – toxicity data not available or not applicable based on the selection criteria discussed in Section C.2. For PCB Aroclors and ecological receptors, RBCs for total PCBs will be used, although the studies used to derive the total PCB RBCs may have been based on individual Aroclors.

[a] Dioxin-like PCB and dioxin/furan congeners will be evaluated as toxic equivalents (TEQs) in the risk assessments, rather than as individual congeners. However, because TEQs are calculated, rather than measured by the laboratory, RBCs for individual congeners are presented to facilitate comparison with RLs for those congeners. In reality, risks will be assessed based on sums of these congeners (normalized per their relative toxicity to TCDD), and thus comparison to RLs on a congener-specific basis is somewhat uncertain.

Table C-2. COIs from LDW RI

METALS	PAHS
Antimony	Acenaphthene
Arsenic (inorganic As and total As)	Acenaphthylene
Cadmium	Anthracene
Chromium	Benzo(a)anthracene
Cobalt	Benzo(a)pyrene
Copper	Benzo(b)fluoranthene
Lead	Benzo(g,h,i)perylene
Mercury	Benzo(k)fluoranthene
Molybdenum	Chrysene
Nickel	Dibenzofuran
Selenium	Dibenzo(a,h)anthracene
Silver	Fluoranthene
Thallium	Fluorene
Vanadium	Indeno(1,2,3-cd)pyrene
Zinc	Naphthalene
BUTYLTINS	Phenanthrene
Dibutyltin as ion	Pyrene
Tributyltin as ion	**PCBS**
ORGANOCHLORINE PESTICIDES	Total PCBs (Aroclors and congeners)
4,4'-DDD	**DIOXINS AND FURANS**
4,4'-DDE	2,3,7,8 –TCDD
4,4'-DDT	1,2,3,7,8-PeCDD
Aldrin	1,2,3,4,7,8-HxCDD
alpha-BHC	1,2,3,6,7,8–HxCDD
gamma-BHC	1,2,3,7,8,9-HxCDD
Chlordane (alpha and gamma)	1,2,3,4,6,7,8-HpCDD
Dieldrin	OCDD
Endrin	2,3,7,8 –TCDF
Heptachlor	1,2,3,7,8-PeCDF
Methoxychlor	2,3,4,7,8-PeCDF
SVOCs	1,2,3,4,7,8-HxCDF
1,2-Dichlorobenzene	1,2,3,6,7,8–HxCDF
1,4-Dichlorobenzene	1,2,3,7,8,9-HxCDF
2-Methylnaphthalene	2,3,4,6,7,8-HpCDF
2-Methylphenol	1,2,3,4,6,7,8-HpCDF
Benzoic acid	1,2,3,6,7,8,9-HpCDF
Benzyl alcohol	OCDF
Bis(2-ethylhexyl)phthalate	
Di-n-butyl phthalate	
Hexachlorobenzene	
Pentachlorophenol	
Phenol	

Table C-3. Studies selected to derive RBCs in prey items of birds

Analyte	NOAEL (mg/kg bw/day)	LOAEL (mg/kg bw/day)	Endpoint[a]	Test Species	Reference
PAHs					
Benzo(a)pyrene	0.28[b]	1.4	reproduction	Pigeon	Hough et al (1993)
Total PAHs	8	40	growth	Mallard	Patton and Dieter (1980)
Other SVOCs					
Bis(2-ethylhexyl) phthalate	65.8[c]	329	reproduction	Chicken	Ishida et al.(1982)
PCBs and Dioxins					
PCBs	0.49	na	reproduction	screech owl	McLane and Hughes (1980)
	na	1.4	reproduction	ringed turtle dove	Peakall et al.(1972); Peakall and Peakall (1973)
2,3,7,8-TCDD	1.4×10^{-5}	1.4×10^{-4}	reproduction, survival	ring-necked pheasant	Nosek et al. (1992)
Metals and Butyltins					
Arsenic	10	40	reproduction	Mallard	Stanley et al.(1994)
Cadmium	1.5	na	growth	Chicken	Cain et al.(1983)
	na	4	growth	Japanese quail	Richardson et al.(1974)
Chromium	1	5	reproduction	black duck	Haseltine et al. (unpublished), as cited in (1996)
Cobalt	2.31[d]	23.1	growth	Chicken	Diaz et al. (1994)
Copper	ns	29	growth	Chicken	Smith (1969)
	21	ns	growth	Chicken	Poupoulis and Jensen (1976)
Lead	ns	20	reproduction	Japanese quail	Edens et al.(1976)
	5.82	na	reproduction	American kestrel	Pattee (1984)
Mercury	0.018[b]	0.091	growth	great egret	Spalding et al.(2000)
Molybdenum	6.0[b]	30	reproduction	Chicken	Lepore and Miller (1965)
Nickel	77	107	growth, survival	Mallard	Cain and Pafford (1981)
Selenium	0.5	0.82	reproduction	Mallard	Heinz et al.(1987)
Thallium	2.4[d]	24	survival	Pheasant	Hudson et al. (1984)
Vanadium	1.2	2.3	growth	Chicken	Ousterhout and Berg (1981)

Analyte	NOAEL (mg/kg bw/day)	LOAEL (mg/kg bw/day)	Endpoint[a]	Test Species	Reference
Zinc	82	124	growth	Chicken	Roberson and Schaible (1960)
Tributyltin	1.4	3.6	reproduction	Japanese quail	Coenen et al. (1992)
Organochlorine pesticides					
Aldrin	0.008[b]	0.04	survival	Quail	DeWitt (1956)
Total chlordane	na	2	survival	bobwhite quail	Hill et al. (1975); Heath et al. (1972)
	0.6	na	growth, survival	bobwhite quail	Ludke (1976)
Total DDTs	0.064[e]	0.32	reproduction	Mallard	Davison and Sell (1974)
Dieldrin	0.08	0.12	survival	Quail	DeWitt (1956)
Endosulfan	10	na	reproduction	gray partridge	Abiola (1992)
Endrin	0.07	0.2	survival	Quail	DeWitt (1956)
Hexachloro-benzene	na	1.2	reproduction	Japanese quail	Schwetz et al.(1974)
	1.1	na	reproduction	Japanese quail	Vos et al.(1971)
gamma-BHC (Lindane)	1.6	3.6	reproduction	Mallard	Chakravarty and Lahiri (1986); Chakravarty et al.(1986)
Heptachlor	0.5[d]	5.0	survival	bobwhite quail	Hill et al. (1975); Heath et al. (1972)
Methoxychlor	34.6	346	reproduction, survival	zebra finch	Gee et al. (2004); Millam et al. (2002)

[a] The NOAEL and/or LOAEL presented applies to all endpoints listed for a specific chemical

[b] NOAEL estimated from a chronic LOAEL using an uncertainty factor of 5

[c] There was a NOAEL of 1.45 mg/kg bw/day from a study that reported no effect on eggshell thinning, but this is an unbounded NOAEL at a substantially lower concentration than the study with observed effects. Therefore, the NOAEL was estimated from the reproductive LOAEL using an uncertainty factor of 5.

[d] NOAEL estimated from an acute or subchronic LOAEL using an uncertainty factor of 10.

[e] There was a NOAEL of 0.19 mg/kg bw/day from a study that reported no effect on eggshell thinning from exposure of barn owls to DDT (Mendenhall et al. 1983). However, there is evidence indicating that p,p'-DDE rather than DDT is the likely cause of eggshell thinning (Lundholm 1997). Therefore, the NOAEL was estimated from the DDE LOAEL for eggshell thinning using a factor of 5.

Table C-4. Studies selected to derive RBCs in prey items of mammals

Analyte	NOAEL (mg/kg bw/day)	LOAEL (mg/kg bw/day)	Endpoint[a]	Test Species	Reference
PAHs					
Benzo(a)pyrene	2.0[b]	10	reproduction	mouse	MacKenzie and Angevine (1981)
1-Methylnaphthalene	150	na	growth	mouse	Murata et al. (1993)
2-Methylnaphthalene	54	114	growth	mouse	Murata et al.(1997)
Naphthalene	133	na	growth, survival	mouse	Shopp et al. (1984)
Other SVOCs					
Butyl benzyl phthalate	250	750	growth, reproduction	rat	Tyl et al.(2004)
Bis(2-ethylhexyl)phthalate	44	91	reproduction	mouse	Tyl et al.(1988)
Diethyl phthalate	1,860	3,721	growth/reproduction	mouse	Lamb et al.(1987)
Di-n-butyl phthalate	16[b]	80	reproduction	rat	Wine et al.(1997)
Benzoic acid	80	na	growth, survival	rat	Ignat'ev (1965), as cited in IRIS (EPA 2006)
	na	750	growth	rat	Marquardt (1980)
Phenol	60	120	growth, reproduction	rat	Argus Research Laboratories (1997), as cited in IRIS (EPA 2006); Charles River Laboratories (1988) and NTP (1983), as cited in IRIS (EPA 2006)
PCBs and Dioxins					
PCBs	0.045[c]	0.089	reproduction	mink	Brunström et al.(2001)
2,3,7,8-TCDD	6.5×10^{-7}	4.9×10^{-6}	growth	guinea pig	DeCaprio et al. (1986)
Metals and Butlytins					
Antimony	1,489	na	growth	rat	Hext et al. (1999)
Arsenic	2.6	5.4	growth	rat	Byron et al.(1967)
Cadmium	3.5	13	growth	rat	Machemer and Lorke (1981)
Chromium	1,466	na	growth	rat	Ivankovic and Preussman (1975)
Cobalt	0.1	1.0	growth	rat	Chetty et al. (1979)
Copper	18	26	reproduction	mink	Aulerich et al. (1982)
Lead	11	90	reproduction	rat	Azar et al.(1973)
Mercury	0.0017[b]	0.0084	growth	rat	Verschuuren et al.(1976)
Molybdenum	0.258[d]	2.58	reproduction, survival	mouse	Schroeder and Mitchener (1971)

ANALYTE	NOAEL (mg/kg bw/day)	LOAEL (mg/kg bw/day)	ENDPOINT[a]	TEST SPECIES	REFERENCE
Nickel	8.4	20	reproduction, growth	rat	Ambrose et al.(1976)
Selenium	0.055	0.08	growth	rat	Halverson et al.(1966)
Thallium	0.74	na	growth	rat	Formigli et al. (1986)
Vanadium	1.05	na	growth	mouse	Schroeder and Balassa (1967)
	na	2.7	growth	rat	Adachi et al. (2000)
Zinc	160	320	reproduction	rat	Schlicker and Cox (1968)
Tributyltin	0.4	2	reproduction	rat	Omura et al.(2001)
Dibutyltin	na	7.6	reproduction, growth	rat	Ema et al. (2003)
	3.8	na	growth	rat	Harazono and Ema (2003)
Organochlorine Pesticides					
Aldrin	0.83	4.1	survival	rat	Fitzhugh et al.(1964)
Chlordane	0.18	0.92	growth	mouse	Khasawinah and Grutsch (1989)
Total DDT	na	1.3	reproduction	mouse	Ware and Good (1967)
	1.2	na	reproduction	rat	Duby et al.(1971)
Dieldrin	0.038[b]	0.19	reproduction	mouse	Treon and Cleveland (1955)
Endosulfan	0.84	2.5	survival/ growth	mouse	Hack et al. (1995)
Endrin	0.4	ns	survival, growth	rat	Treon et al.(1955)
	na	0.92	survival, reproduction	mouse	Good and Ware (1969)
Heptachlor	1	1.8	survival/ growth/ reproduction	mink	Crum et al.(1993)
Hexachlorobenzene	0.026[b]	0.13	reproduction	mink/ferret	Bleavins et al.(1984)
gamma-BHC	64	na	growth	rat	Srinivasan et al.(1991)
beta-BHC	5.7	31	survival/ growth	rat	Van Velsen et al.(1986)
Methoxychlor	17	na	growth, reproduction	rat	Masutomi et al.(2003)
	na	56	growth, reproduction	rat	You et al.(2002)

na – NOAEL or LOAEL not available or not applicable based on the selection criteria discussed in Section C.2

[a] The NOAEL and/or LOAEL presented applies to all endpoints listed for a specific chemical.

[b] NOAEL estimated from an chronic LOAEL using an uncertainty factor of 5.

[c] NOAEL estimated from a chronic LOAEL using an uncertainty factor of 2.

[d] NOAEL estimated from an acute or subchronic LOAEL using an uncertainty factor of 10.

Table C-5. Body weights and daily food consumption values used to derive RBCs for pigeon guillemot and river otter

Receptor	Body Weight (kg)	Reference	Daily Food Consumption (kg ww/day)	Method and Reference
Pigeon guillemot (female or male)[a]	0.474	Storer (1952)	0.095	Estimated as 20% of body weight (Koelink 1972)
River otter (female)	7.9	Melquist and Hornocker (1983; as cited in EPA 1993)	1.32	Function of metabolic rate and caloric content of prey (Nagy 1987; as cited in EPA 1993)
River otter (average male and female)	8.55		1.41	

[a] Data on the difference between females and males were not available.

Table C-6. Comparison of target detection limits and ACGs

Method and Analyte	Detection Limits[a] (mg/kg ww)		Clam Tissue ACG (mg/kg ww)[b]	Receptor with ACG lower than MDL
	MDL	RL		
EPA Method 8270D				
PAHs				
Acenaphthene	0.017	0.067	5.0	
Acenaphthylene	0.015	0.067	na	
Anthracene	0.014	0.067	25	
Benzo(a)anthracene	**0.016**	**0.067**	0.0011	humans
Benzo(a)pyrene	**0.017**	**0.067**	0.00011	humans
Benzo(b)fluoranthene	**0.027**	**0.067**	0.0011	humans
Benzo(k)fluoranthene	0.015	**0.067**	0.011	humans
Benzo(g,h,i)perylene	0.0010	0.067	na	
Chrysene	0.015	0.067	0.11	
Dibenzo(a,h)anthracene	**0.014**	**0.067**	0.00011	humans
Dibenzofuran	0.015	0.067	0.084	
Fluoranthene	0.006	0.067	3.4	
Fluorene	0.018	0.067	3.4	
Indeno(1,2,3-cd)pyrene	0.012	**0.067**	0.011	humans
1-Methylnaphthalene	0.016	0.067	na	
2-Methylnaphthalene	0.016	0.067	0.34	
Naphthalene	0.015	0.067	1.7	
Phenanthrene	0.015	0.067	na	
Pyrene	0.013	0.067	2.5	
Total PAHs[b]	0.027	0.067	4.0	
Other SVOCs				
1,2,4-Trichlorobenzene	0.016	0.067	0.84	
1,2-Dichlorobenzene	0.018	0.067	7.6	
1,3-Dichlorobenzene	0.016	0.067	0.25	
1,4-Dichlorobenzene	0.014	**0.067**	0.034	humans
2,4,5-Trichlorophenol	0.065	0.33	8.4	
2,4,6-Trichlorophenol	0.065	**0.33**	0.073	humans
2,4-Dichlorophenol	0.12	**0.33**	0.25	humans
2,4-Dimethylphenol	0.031	0.067	1.7	
2,4-Dinitrophenol	0.11	**0.67**	0.17	humans
2,4-Dinitrotoluene	0.10	**0.33**	0.17	humans
2,6-Dinitrotoluene	**0.11**	**0.33**	0.084	humans
2-Chloronaphthalene	0.014	0.067	6.7	
2-Chlorophenol	0.012	0.067	0.42	
2-Methylphenol	0.023	0.067	4.2	

Method and Analyte	Detection Limits[a] (mg/kg ww)		Clam Tissue ACG (mg/kg ww)[b]	Receptor with ACG lower than MDL
	MDL	RL		
3,3'-Dichlorobenzidine	**0.21**	**0.33**	0.0018	humans
4-Chloroaniline	0.20	0.33	0.34	
4-Methylphenol	0.033	0.067	0.42	
4-Nitrophenol	0.10	0.33	na	
Aniline	0.067	0.067	0.14	
Benzidine	**0.067**	**0.67**	3.5×10^{-6}	humans
Benzoic acid	0.17	0.67	340	
Benzyl alcohol	0.15	0.33	42	
bis(2-chloroethyl)ether	**0.015**	**0.067**	0.00073	humans
bis(2-ethylhexyl)phthalate	0.027	0.067	0.058	
bis-chloroisopropyl ether	0.015	**0.067**	0.00073	humans
Butyl benzyl phthalate	0.0077	0.067	17	
Carbazole	0.0077	**0.067**	0.040	humans
Di-ethyl phthalate	0.020	0.067	67	
Dimethyl phthalate	0.017	0.067	na	
Di-n-butyl phthalate	0.0071	0.067	8.4	
Hexachlorobutadiene	0.015	**0.067**	0.010	humans
Hexachloroethane	0.016	0.067	0.058	
Isophorone	0.018	0.067	0.85	
Nitrobenzene	0.014	**0.067**	0.042	humans
N-Nitrosodimethylamine	**0.086**	**0.33**	1.6×10^{-5}	humans
N-Nitrosodi-n-propylamine	**0.067**	**0.33**	0.00012	humans
N-Nitrosodiphenylamine	0.016	0.067	0.16	
Pentachlorophenol	**0.17**	**0.33**	0.0067	humans
Phenol	0.033	0.067	25	
EPA Method 8082				
Aroclor 1016	0.0029	**0.020**	0.012	humans
Aroclor 1221	**0.0029**	**0.020**	0.00040	humans
Aroclor 1232	**0.0029**	**0.020**	0.00040	humans
Aroclor 1242	**0.0039**	**0.020**	0.00040	humans
Aroclor 1248	**0.0039**	**0.020**	0.00040	humans
Aroclor 1254	**0.0039**	**0.020**	0.00040	humans
Aroclor 1260	**0.0039**	**0.020**	0.00040	humans
Total PCBs[d]	**0.0039**	**0.020**	0.00040	humans
EPA Method 1613B				
Dioxin and furan congeners[c]	**1.2×10^{-7}**	**5.0×10^{-7}**	5.4×10^{-9}	humans
EPA Method 1668A				
PCB congeners[c]	1.78×10^{-6}	1.00×10^{-6}	2.4×10^{-6}	

Method and Analyte	Detection Limits[a] (mg/kg ww)		Clam Tissue ACG (mg/kg ww)[b]	Receptor with ACG lower than MDL
	MDL	RL		
EPA Method 6020, 6010B, or 7000				
Antimony	0.013	**0.2**	0.034	humans
Arsenic	**0.17**	**0.5**	0.00054	humans
Cadmium	0.016	**0.2**	0.084	humans
Chromium	**0.14**	**0.5**	0.25	humans
Cobalt	0.008	0.2	1.2	
Copper	0.058	0.5	3.4	
Lead	0.078	1.0	2.9	
Molybdenum	0.008	0.2	0.42	
Nickel	0.11	0.5	1.7	
Selenium	0.67	2.0	0.25	
Silver	0.006	0.2	0.42	
Thallium	0.005	**0.2**	0.0059	humans
Vanadium	0.034	0.2	0.084	
Zinc	0.44	4.0	25	
EPA Method 1632				
Inorganic arsenic	**0.003**	**0.03**	0.00054	humans
EPA Method 7471A				
Mercury	0.005	**0.01**	0.0084	humans
TBT Method - Krone 1989				
Di-n-butyltin	0.0039	0.012	23	
Tri-n-butyltin	0.0034	0.0080	0.025	
EPA Method 8081A				
4,4'-DDD	**0.015**	**0.020**	0.0034	humans
4,4'-DDE	**0.012**	**0.020**	0.0024	humans
4,4'-DDT	**0.013**	**0.020**	0.0024	humans
Total DDT	0.015	0.020	0.032	
Aldrin	**0.0057**	**0.010**	4.8×10^{-5}	humans
alpha-BHC	**0.0048**	**0.010**	0.00013	humans
beta-BHC	**0.0039**	**0.010**	0.00045	humans
Total chlordane[b]	**0.060**	**0.010**	0.0023	humans
Dieldrin	**0.012**	**0.020**	5.0×10^{-5}	humans
Endosulfan	0.011	0.020	0.50	
Endosulfan sulfate	0.013	0.020	na	
Endrin	0.015	0.020	0.029	
gamma-BHC (Lindane)	**0.0050**	**0.010**	0.00062	humans
Heptachlor	**0.0056**	**0.010**	0.00018	humans
Heptachlor epoxide	**0.0051**	**0.010**	0.000089	humans

Method and Analyte	Detection Limits[a] (mg/kg ww)		Clam Tissue ACG (mg/kg ww)[b]	Receptor with ACG lower than MDL
	MDL	RL		
Hexachlorobenzene	0.0042	**0.010**	0.00050	humans
Methoxychlor	0.063	0.010	0.42	
Mirex	**0.020**	**0.020**	0.017	humans
Toxaphene	**1.0**	**1.0**	0.00073	humans

Note: Actual RLs and MDLs will vary based on the amount of sample volume used for each analysis, matrix interferences, and the analytical dilution.
MDLs and RLs in **bold** exceed the ACG.

[a] RLs and MDLs from Analytical Resources, Inc, Brooks Rand, and Analytical Perspectives

[b] RLs and MDLs for calculated totals are the highest of the RLs and MDLs for the individual components.

[c] Dioxin-like PCB congeners and dioxin and furan congeners will be evaluated as 2,3,7,8-TCDD toxic equivalents (TEQs) in the risk assessments, rather than as individual congeners. Thus, ACGs for PCB and dioxin and furan TEQs are presented. Because risks will be assessed based on sums of these congeners (normalized per their relative toxicity to TCDD), the comparison to MDLs on a congener-specific basis is somewhat uncertain. MDLs and RLs presented are for PCB 126 and 2,3,7,8-TCDD.

ACG – analytical concentration goal

MDL – method detection limit

RL – reporting limit

na – not available

C.5 REFERENCES

Abiola FA. 1992. Ecotoxicity of organochloride insecticides: effects of endosulfan on bird reproduction and evaluation of its induction effect in partridge (*Perdix perdix* L.). Revue Med Vet 143(5):443-450.

Adachi A, Asai K, Koyama Y, Matsumoto Y, Okano T. 2000. Subacute vanadium toxicity in rats. J Health Sci 46(6):503-508.

Ambrose AM, Larson PS, Borzelleca JF, Hennigar Jr GR. 1976. Long term toxicologic assessment of nickel in rats and dogs. J Food Sci Technol 13(4):181-187.

Aulerich RJ, Ringer RK, Bleavins MR, Napolitano A. 1982. Effects of supplemental dietary copper on growth, reproductive performance and kit survival of standard dark mink and the acute toxicity of copper to mink. J Anim Sci 55(2):337-343.

Azar A, Trochimowicz HJ, Maxfield ME. 1973. Review of lead studies in animals carried out at Haskell Laboratory-two-year feeding study and response to hemorrhage study. In: Barth D, ed, Environmental Health Aspects of Lead, International Symposium, Amsterdam. Commission of European Communities, pp 199-210.

Bleavins MR, Aulerich RJ, Ringer RK. 1984. Effects of chronic dietary hexachlorobenzene exposure on the reproductive performance and survivability of mink and European ferrets. Arch Environ Contam Toxicol 13:357-365.

Brunström B, Lund BE, Bergman A, Asplund L, Athanassiadis I, Athanasiadou M, Jensen S, Örberg J. 2001. Reproductive toxicity in mink (*Mustela vison*) chronically exposed to environmentally relevant polychlorinated biphenyl concentrations. Environ Toxicol Chem 20(10):2318-2327.

Byron WR, Bierbower GW, Brouwer JB, Hansen WH. 1967. Pathologic changes in rats and dogs from two-year feeding of sodium arsenite or sodium arsenate. Toxicol Appl Pharmacol 10:132-147.

Cain BW, Pafford EA. 1981. Effects of dietary nickel on survival and growth of mallard ducklings. Arch Environ Contam Toxicol 10:737-745.

Cain BW, Sileo L, Franson JC, Moore J. 1983. Effects of dietary cadmium on mallard ducklings. Environ Res 32:286-297.

Chakravarty S, Lahiri P. 1986. Effect of lindane on eggshell characteristics and calcium level in the domestic duck. Toxicology 42:245-258.

Chakravarty S, Mandal A, Lahiri P. 1986. Effect of lindane on clutch size and level of egg yolk protein in domestic duck. Toxicology 39:93-103.

Chetty KY, Rau S, Drummond L, Desaiah D. 1979. Cobalt induced changes in immune response and adenosine triphosphatase activities in rats. J Environ Sci Health B14(5):525-544.

Coenen TMM, Brouwer A, Enninga IC, Koeman JH. 1992. Subchronic toxicity and reproduction effects if tri-n-butyltin oxide in Japanese quail. Arch Environ Contam Toxicol 23:457-463.

Crum JA, Bursian SJ, Aulerich RJ, Polin D, Braselton WE. 1993. The reproductive effects of dietary heptachlor in mink (*Mustela vison*). Arch Environ Contam Toxicol 24:156-164.

Davison KL, Sell JL. 1974. DDT thins shells of eggs from mallard ducks maintained on *ad libitum* or controlled-feeding regimens. Arch Environ Contam Toxicol 2(3):222-232.

DeCaprio AP, McMartin DN, O'Keefe PW, Rej R, Silkworth JB, Kaminsky LS. 1986. Subchronic oral toxicity of 2,3,7,8-tetrachlorodibenzo-*p*-dioxin in the guinea pig: comparisons with a PCB-containing transformer fluid pyrolysate. Fund Appl Toxicol 6:454-463.

DeWitt JB. 1956. Chronic toxicity to quail and pheasants of some chlorinated insecticides. Agric Food Chem 4(10):863-866.

Diaz GJ, Julian RJ, Squires EJ. 1994. Lesions in broiler chickens following experimental intoxication with cobalt. Avian Dis 38(2):308-316.

Duby RT, Travis HF, Terrill CE. 1971. Uterotropic activity of DDT in rats and mink and its influence on reproduction in the rat. Toxicol Appl Pharmacol 18:348-355.

Edens FW, Garlich JD. 1983. Lead-induced egg production decrease in leghorn and Japanese quail hens. Poult Sci 62:1757-1763.

Edens FW, Benton E, Bursian SJ, Morgan GW. 1976. Effect of dietary lead on reproductive performance in Japanese quail, *Coturnix coturnix japonica*. Toxicol Appl Pharmacol 38:307-314.

Ema M, Harazono A, Hirose A, Kamata E. 2003. Protective effects of progesterone on implantation failure induced by dibutyltin dichloride in rats. Toxicol Let 143:233-238.

EPA. 1993. Wildlife exposure factors handbook. EPA/600/R-93/187a. Office of Research and Development, US Environmental Protection Agency, Washington, DC.

EPA. 1997. EPA Region 10 supplemental ecological risk assessment guidance for Superfund. EPA/910/R-97/005. Region 10 Office of Environmental Assessment Risk Evaluation Unit, US Environmental Protection Agency, Seattle, WA.

EPA. 2006. Integrated Risk Information System (IRIS) database [online]. US Environmental Protection Agency, Washington, DC. [Cited 1/2006.] Available from: http://www.epa.gov/iris/.

Fitzhugh OG, Nelson AA, Quaife ML. 1964. Chronic oral toxicity of aldrin and dieldrin in rats and dogs. Food Chem Toxicol 2:551-562.

Formigli L, Scelsi R, Poggi P, Gregotti C, Di Nucci A, Sabbioni E, Gottardi L, Manzo L. 1986. Thallium-induced testicular toxicity in the rat. Environ Res 40:531-539.

Gee JM, Craig-Veit CB, Millam JR. 2004. Posthatch methoxychlor exposure adversely affects reproduction of adult zebra finches, *Taeniopygia guttata*. Bull Environ Contam Toxicol 73:607-612.

Good EE, Ware GW. 1969. Effects of insecticides on reproduction in the laboratory mouse. IV. Endrin and dieldrin. Toxicol Appl Pharmacol 14:201-203.

Gries TH. 2008. Personal communication on May 15, 2008 (e-mail to Debra Williston, King County, regarding PSAMP 2007 dioxin and furan data). Washington Department of Ecology, Lacey, WA.

Hack R, Ebert E, Leist KH. 1995. Chronic toxicity and carcinogenicity studies with the insecticide endosulfan in rats and mice. Food Chem Toxicol 33(11):941-950.

Halverson AW, Palmer IS, Guss PL. 1966. Toxicity of selenium to post-weanling rats. Toxicol Appl Pharmacol 9:477-484.

Harazono A, Ema M. 2003. Suppression of decidual cell resonse induced by dibutyltin dichloride in pseudopregnant rats: as a cause of early embryonic loss. Reprod Toxicol 17:393-399.

Heath RG, Spann JW, Hill EF, Kreitzer JF. 1972. Comparative dietary toxicities of pesticides to birds. Wildlife no. 152. Patuxent Wildlife Research Center, Bureau of Sport Fisheries and Wildlife, Laurel, MD.

Heinz GH, Hoffman DJ, Krynitsky AJ, Weller DMG. 1987. Reproduction in mallards fed selenium. Environ Toxicol Chem 6:423-433.

Hext PM, Pinto PJ, Rimmel BA. 1999. Subchronic feeding study of antimony trioxide in rats. J Appl Toxicol 19:205-209.

Hill EF, Heath RG, Spann JW, Williams JD. 1975. Lethal dietary toxicities of environmental pollutants to birds. US Fish and Wildlife Service, Laurel, MD.

Hough JL, Baird MB, Sfeir GT, Pacini CS, Darrow D, Wheelock C. 1993. Benzo(a)pyrene enhances atherosclerosis in white carneau and show racer pigeons. Arterioscler Thromb 13:1721-1727.

Hudson RH, Tucker RK, Haegele MA. 1984. Handbook of toxicity of pesticides to wildlife. Resource publication 153. 2nd ed. US Fish and Wildlife Service, Washington, DC.

Ishida M, Suyama K, Adachi S, Hoshino T. 1982. Distribution of orally administered di-ethylhexyl phthalate in laying hens. Poult Sci 61:262-267.

Ivankovic S, Preussman R. 1975. Absence of toxic and carcinogenic effects after administration of high doses of chromic oxide pigment in subacute and long-term feeding experiments in rats. Food Cosmet Toxicol 13:347-351.

Khasawinah AM, Grutsch JF. 1989. Chlordane: 24-month tumorigenicity and chronic toxicity test in mice. Regul Toxicol Pharmacol 10:244-254.

Koelink AF. 1972. Bioenergetics of growth in the pigeon guillemot *Cepphus columba*. M.Sc. thesis. University of British Columbia, Vancouver, BC.

Lamb JC, Chapin RE, Teague J, Lawton AD, Reel JR. 1987. Reproductive effects of four phthalic acid esters in the mouse. Toxicol Appl Pharmacol 88:255-269.

Lepore PD, Miller RF. 1965. Embryonic viability as influenced by excess molybdenum in chicken breeder diets. Proc Soc Exper Biol Med 118:155-157.

Ludke JL. 1976. Organochlorine pesticide residues associated with mortality: additivity of chlordane and endrin. Bull Environ Contam Toxicol 16:253-260.

Machemer L, Lorke D. 1981. Embryotoxic effect of cadmium on rats upon oral administration. Toxicol Appl Pharmacol 58:438-443.

MacKenzie KM, Angevine DM. 1981. Infertility in mice exposed *in utero* to benzo(a)pyrene. Biol Reprod 24:183-191.

Masutomi N, Shibutani M, Takagi H, Uneyama C, Takahashi N, Hirose M. 2003. Impact of dietary exposure to methoxychlor, genestein, or diisononyl phthalate during the perinatal period on the development of the rat endocrine/reproductive systems in later life. Toxicology 192:149-170.

McLane MAR, Hughes DL. 1980. Reproductive success of screech owls fed Aroclor 1248. Arch Environ Contam Toxicol 9:661-665.

Melquist WE, Hornocker MG. 1983. Ecology of river otters in west central Idaho. In: Kirkpatrick RL, ed, Wildlife monographs. Vol 83. The Wildlife Society, Bethesda, MD, p 60.

Millam JR, Craig-Veit CB, Batchelder ME, Viant MR, Herbeck TM, Woods LW. 2002. An avian bioassay for environmental estrogens: the growth response of zebra finch (*Taeniopygia guttata*) chick oviduct to oral estrogens. Environ Toxicol Chem 21(12):2663-2668.

Murata Y, Denda A, Maruyama H, Konishi Y. 1993. Chronic toxicity and carcinogenicity studies of 1-methylnaphthalene in B6C3F$_1$ mice. Fund Appl Toxicol 21:44-51.

Murata Y, Denda A, Maruyama H, Nakae D, Tsutsumi M, Tsujiuchi T, Konishi Y. 1997. Chronic toxicity and carcinogenicity studies of 2-methylnaphthalene in B6C3F$_1$ mice. Fund Appl Toxicol 36:90-93.

Nagy KA. 1987. Field metabolic rate and food requirement scaling in mammals and birds. Ecol Monogr 57(2):111-128.

Nosek JA, Craven SR, Sullivan JR, Hurley SS, Peterson RE. 1992. Toxicity and reproductive effects of 2,3,7,8-tetrachlorodibenzo-*p*-dioxin in ring-necked pheasant hens. J Toxicol Environ Health 35:187-198.

Omura M, Ogata R, Kubo K, Shimasaki Y, Aou S, Oshima Y, Tanaka A, Hirata M, Makita Y, Inoue N. 2001. Two-generation reproductive toxicity study ot tributyltin chloride in male rats. Toxicol Sci 64:224-232.

Ousterhout LE, Berg LR. 1981. Effects of diet composition on vanadium toxicity in laying hens. Poult Sci 60:1152-1159.

Pattee OH. 1984. Eggshell thickness and reproduction in American kestrels exposed to chronic dietary lead. Arch Environ Contam Toxicol 13:29-34.

Patton JF, Dieter MP. 1980. Effects of petroleum hydrocarbons on hepatic function in the duck. Comp Biochem Physiol 65C:33-36.

Peakall DB, Peakall ML. 1973. Effect of a polychlorinated biphenyl on the reproduction of artificially and naturally incubated dove eggs. J Appl Ecol 10(3):863-868.

Peakall DB, Lincer JL, Bloom SE. 1972. Embryonic mortality and chromosomal alterations caused by Aroclor 1254 in ring doves. Environ Health Perspect 1:103-104.

Poupoulis C, Jensen LS. 1976. Effect of high dietary copper on gizzard integrity of the chick. Poult Sci 55:113-121.

Richardson ME, Fox MRS, Bry BE, Jr. 1974. Pathological changes produced in Japanese quail by ingestion of cadmium. J Nutr 104:323-338.

Roberson RH, Schaible PJ. 1960. The tolerance of growing chicks for high levels of different forms of zinc. Poult Sci 39:893-895.

Sample BE, Opresko DM, Suter GW. 1996. Toxicological benchmarks for wildlife. 1996 revision. ES/ERM-86/R3. Office of Environmental Management, US Department of Energy, Washington, DC.

Schlicker SA, Cox DH. 1968. Maternal dietary zinc, and development and zinc, iron, and copper content of the rat fetus. J Nutr 95:287-294.

Schroeder HA, Balassa JJ. 1967. Arsenic, germanium, tin and vanadium in mice: effects on growth, survival and tissue levels. J Nutr 92:245-252.

Schroeder HA, Mitchener M. 1971. Toxic effects of trace elements on the reproduction of mice and rats. Arch Environ Health 23:102-106.

Schwetz BA, Norris JM, Kociba RJ, Keeler PA, Cornier RF, Gehring PJ. 1974. Reproduction study in Japanese quail fed hexachlorobutadiene for 90 days. Toxicol Appl Pharmacol 30:255-265.

Shopp GM, White Jr KL, Holsapple MP, Barnes DW, Duke SD, Anderson AC, Condie Jr LW, Hayes JR, Borzelleca JF. 1984. Naphthalene toxicity in CD-1 mice: general toxicology and immunotoxicology. Fund Appl Toxicol 4:407-419.

Smith MS. 1969. Responses of chicks to dietary supplements of copper sulphate. Brit Poult Sci 10:97-108.

Spalding MG, Frederick PC, McGill HC, Bouton SN, McDowell LR. 2000. Methylmercury accumulation in tissues and its effects on growth and appetite in captive great egrets. J Wildl Dis 36(3):411-422.

Srinivasan K, Mahadevappa KL, Radhakrishnamurty R. 1991. Toxicity of beta-and gamma-hexachlorocyclohexane in rats of different ages. Bull Environ Contam Toxicol 47:623-627.

Stanley TR, Jr, Spann JW, Smith GJ, Rosscoe R. 1994. Main and interactive effects of arsenic and selenium on mallard reproduction and duckling growth and survival. Arch Environ Contam Toxicol 26:441-451.

Storer RW. 1952. A comparison of variation, behaviour and evolution in the seabird genera *Uria* and *Cepphus*. U Calif Publ Zool 52:121-222.

Treon JF, Cleveland FP. 1955. Toxicity of certain chlorinated hydrocarbon insecticides for laboratory animals, with special reference to aldrin and dieldrin. Agric Food Chem 3:402-408.

Treon JF, Cleveland FP, Cappel J. 1955. Toxicity of endrin for laboratory animals. Agric Food Chem 3:842-848.

Tyl RW, Price CJ, Marr MC, Kimmel CA. 1988. Developmental toxicity evaluation of dietary di(2-ethylhexyl) phthalate in Fischer 344 rats and CD-1 mice. Fund Appl Toxicol 10:395-412.

Tyl RW, Myers CB, Marr MC, Fail PA, Seely JC, Brine DR, Barter RA, Butala JH. 2004. Reproductive toxicity evaluationof dietary butyl benzyl phthalate (BBP) in rats. Reprod Toxicol 18:241-264.

Van den Berg M, Birnbaum LS, Denison M, De Vito M, Farland W, Feeley M, Fiedler H, Hakansson H, Hanberg A, Haws L, Rose M, Safe S, Schrenk D, Tohyama C, Tritscher A, Tuomisto J, Tysklind M, Walker N, Peterson RE. 2006. The 2005

World Health Organization reevaluation of human and mammalian toxic equivalency factors for dioxins and dioxin-like compounds. Tox Sci 93(2):223-241.

Van Velsen FL, Danse LHJC, van Leeuwen FXR, Dormans JAMA, van Logten MJ. 1986. The subchronic oral toxicity of the beta-isomer of hexachlorocyclohexane in rats. Fund Appl Toxicol 6:697-712.

Verschuuren HG, Kroes R, Den Tonkelaar EM, Berkvens JM, Helleman PW, Rauws AG, Schuller PL, Van Esch GJ. 1976. Toxicity of methylmercury chloride in rats. II. Reproduction study. Toxicology 6:97-106.

Vos JG, van der Maas HL, Musch A, Ram E. 1971. Toxicity of hexachlorobenzene in Japanese quail with special reference to porphyria, liver damage, reproduction, and tissue residues. Toxicol Appl Pharmacol 18:944-957.

Ware GW, Good EE. 1967. Effects of insecticides on reproduction in the laboratory mouse. II. Mirex, telodrin, and DDT. Toxicol Appl Pharmacol 10:54-61.

Windward. 2004. Lower Duwamish Waterway remedial investigation. Quality assurance project plan: Fish and crab tissue collection and chemical analyses. Prepared for Lower Duwamish Waterway Group. Windward Environmental LLC, Seattle, WA.

Windward. 2007a. Lower Duwamish Waterway remedial investigation. Baseline ecological risk assessment. Prepared for Lower Duwamish Waterway Group. Windward Environmental LLC, Seattle, WA.

Windward. 2007b. Lower Duwamish Waterway remedial investigation. Baseline human health risk assessment. Prepared for Lower Duwamish Waterway Group. Windward Environmental LLC, Seattle, WA.

Wine RN, Li LH, Barnes LH, Gulati DK, Chapin RE. 1997. Reproductive toxicity of di-n-butylphthalate in a continuous breeding protocol in Sprague-Dawley rats. Environ Health Perspect 105:101-107.

You L, Casanova M, Bartolucci EJ, Fryczynski MW, Dorman DC, Everitt JI, Gaido KW, Ross SM, Heck HD. 2002. Combined effects of dietary phytoestrogen and synthetic endocrine-active compound on reproductive development in Sprague-Dawley rats: genistein and methoxychlor. Toxicol Sci 66:91-104.

Appendix D. Risk-based Analytical Concentration Goals for Sediment

D.1 INTRODUCTION

This appendix addresses the following question:

> Are standard analytical methods proposed for the chemical analysis of sediment samples sufficiently sensitive to meet the needs of the East Waterway ecological and human health risk assessments?

To answer this question, standard laboratory reporting limits (RLs) and method detection limits (MDLs) were compared to analytical concentration goals (ACGs) for sediment. To determine ACGs for this quality assurance project plan (QAPP), sediment risk-based concentrations (RBCs) were identified or derived for the protection of benthic invertebrates and humans. RBCs in sediment are not relevant for other ecological receptors because sediment is generally a very small dietary component for the fish and other wildlife receptor species that will be evaluated in the ecological risk assessment (ERA). The risk-based ACGs for sediment are equal to the lowest RBC for each chemical. For example, if RBCs are identified or calculated for humans and benthic invertebrates for cadmium, the risk-based ACG for cadmium in sediment is set by the RBC for the receptor most sensitive to cadmium (the lowest of the two RBCs).

For the protection of benthic invertebrates, RBCs are defined as the concentration of a chemical in sediment corresponding to numerical criteria found in the Washington State Sediment Management Standards (SMS). The SMS include numerical criteria for 47 chemicals or groups of chemicals. The lowest numerical criterion for each chemical is called the Sediment Quality Standard (SQS). The Dredged Material Management Program (DMMP) also includes criteria for chemicals in sediment. The lowest guideline in that program is called the Screening Level (SL). RBCs are set equal to the SQS or to the SLs if no SQS is available for a given chemical.

Sediment RBCs are defined for the protection of wildlife receptors as the concentration of a chemical in sediment incidentally ingested by that receptor that is associated with no adverse effects on growth, reproduction, or survival.[1] For the protection of human health, RBCs are defined by two methods. In one method, which was applied to all chemicals, RBCs are defined as the concentration of a chemical in sediment incidentally ingested or directly contacted that has been identified as having an acceptable risk level (e.g., excess cancer risk of 10^{-6} or HQ less than 0.1 for non-cancer risk). In the other method, which was applied for chemicals likely to bioaccumulate in fish and shellfish

[1] The lowest concentration associated with adverse effects was used if data were not available for a concentration associated with no effects.

consumed by humans, sediment RBCs were based on a back-calculation[2] from clam tissue RBCs.

Sediment RBCs have not been developed by EPA Region 10 or Ecology for the protection of humans. Therefore human RBCs were calculated by reviewing human health guidance documents. Although information from the toxicological literature is used in this document, the objective of this memo is not to establish the toxicity reference values (TRVs) to be used for the ecological and human health risk assessments. The TRVs to be used in those assessments will be determined during in consultation with EPA.

The remainder of this appendix is organized as follows:

- Section C.2.0 – RBC derivation methods for benthic invertebrates and humans
- Section C.3.0 – Comparison of ACGs to RLs
- Tables C-1 through C-5 (located at the end of this appendix) summarize RBCs for all receptors for each chemical, provide background information for RBC selection, and compare ACGs and RLs.

D.2 RISK-BASED CONCENTRATIONS

For this QAPP, RBCs are sediment concentrations associated with an acceptable risk level as derived from state standards, the toxicity literature, or human health guidance documents. In this appendix, sediment RBCs are derived for the protection of the following receptors through several exposure pathways:

- Benthic invertebrates exposed to chemicals via direct contact with sediment
- Humans exposed to chemicals via direct contact or incidental ingestion of sediment
- Humans exposed to chemicals via seafood consumption

Sediment RBCs were calculated from clam tissue RBCs using a biota-sediment accumulation factor, as described in Windward (2004a). The clam tissue RBCs were calculated using the total seafood consumption rate rather than the consumption rate of clams. The following sections describe how RBCs were derived for each receptor. The specific chemicals for which RBCs were derived are discussed in the sections below for each receptor, and are summarized in Table D-1.

[2] Sediment RBCs were calculated from clam tissue RBCs using a biota-sediment accumulation factor, as described in Windward (2004a). The clam tissue RBCs were calculated using the total seafood consumption rate rather than the consumption rate of clams.

Table D-1. Receptor-specific RBCs for sediment

Analyte	Receptor-Specific RBC (mg/kg dw)		
	Human Health[a]		Benthic Invertebrates[b]
	Indirect Exposure	Direct Exposure	
Metals			
Antimony	na	**3.1**	150
Arsenic	**0.006**	0.39	57
Cadmium	**0.003**	7	5.1
Chromium	100	**23**	260
Cobalt	na	na	na
Copper	**1.3**	310	390
Lead	na[c]	**40**	450
Mercury	**0.016**	0.78	0.41
Molybdenum	na	**39**	na
Nickel	na[c]	160	**140**
Selenium	na[c]	**39**	na
Silver	na[c]	39	**6.1**
Thallium	na	**0.51**	na
Vanadium	na	**39**	na
Zinc	**16**	2,300	410
Organometals			
Tri-n-butyltin ion	**0.00028**	1.8	0.0085
PAHs			
2-Methylnaphthalene	1.7	31	**0.19**
Acenaphthylene	na	na	**0.33**
Acenaphthene	540	340	**0.080**
Anthracene	900	1,700	**1.1**
Benzo(a)anthracene	**0.0052**	0.15	0.55
Benzo(a)pyrene	**0.00076**	0.015	0.50
Benzo(b)fluoranthene	**0.0047**	0.15	na
Benzo(g,h,i)perylene	na	na	**0.16**
Benzo(k)fluoranthene	**0.047**	1.5	na
Total benzofluoranthenes	na	na	**1.2**
Chrysene	**0.48**	15	0.50
Dibenzo(a,h)anthracene	na[c]	**0.015**	0.06
Dibenzofuran	0.56	na	**0.075**
Fluoranthene	2.1	230	**0.80**
Fluorene	na[c]	230	**0.12**
Indeno(1,2,3-cd)pyrene	**0.0029**	0.15	0.17
Naphthalene	4.5	3.9	**0.50**
Phenanthrene	na	na	**0.50**
Pyrene	8.9	170	**5.0**
Total LPAHs	na	na	**1.9**
Total HPAHs	na	na	**4.8**
Phthalates			
Bis(2-ethylhexyl)phthalate	**0.12**	35	0.24
Butyl benzyl phthalate	30	na	**0.025**

Analyte	Receptor-Specific RBC (mg/kg dw)		
	Human Health[a]		Benthic Invertebrates[b]
	Indirect Exposure	Direct Exposure	
Di-ethyl phthalate	na	4,900	**0.31**
Dimethyl phthalate	1,400	na	**0.27**
Di-n-butyl phthalate	14	610	**1.1**
Di-n-octyl phthalate	3.0	na	**0.29**
Other SVOCs			
1,2,4-Trichlorobenzene	na[c]	180	**0.0041**
1,2-Dichlorobenzene	12	1,000	**0.012**
1,3-Dichlorobenzene	na[c]	na	**0.17**
1,4-Dichlorobenzene	0.073	2.6	**0.016**
2,4,5-Trichlorophenol	**37**	610	na
2,4,6-Trichlorophenol	na	**44**	na
2,4-Dichlorophenol	**1.1**	18	na
2,4-Dimethylphenol	na	120	**0.029**
2,4-Dinitrophenol	na	**12**	na
2,4-Dinitrotoluene	na	**12**	na
2,6-Dinitrotoluene	na	**6.1**	na
2-Chloronaphthalene	na	**6,300**	na
2-Chlorophenol	**1.8**	39	na
2-Methylphenol	na	na	**0.063**
3,3'-Dichlorobenzidine	na	**1.1**	na
4-Chloroaniline	na	**24**	na
4-Methylphenol	1.8	na	**0.67**
Aniline	na	**85**	na
Benzoic acid	na	24,000	**0.65**
Benzyl alcohol	na	3,100	**0.057**
Bis(2-chloroethyl)ether	na	**0.19**	na
Bis-chloroisopropyl ether	na	**0.19**	na
Carbazole	**0.23**	24	na
Hexachlorobenzene	na	0.30	**0.0019**
Hexachlorobutadiene	0.023	6.2	**0.020**
Hexachloroethane	**0.12**	35	1.4
Isophorone	na	**510**	na
Nitrobenzene	na	**3.1**	na
N-Nitrosodimethylamine	na	**0.0023**	na
N-Nitrosodi-n-propylamine	na	**0.069**	na
N-Nitrosodiphenylamine	na	99	**0.055**
Pentachlorophenol	na	3.0	**0.36**
Phenol	210	1,800	**0.42**
PCBs			
Aroclor 1016	**0.0061**	0.39	na
Aroclor 1221	**0.00021**	0.17	na
Aroclor 1232	**0.00021**	0.17	na
Aroclor 1242	**0.00021**	0.22	na
Aroclor 1248	**0.00021**	0.22	na
Aroclor 1254	**0.00021**	0.22	na

Analyte	Receptor-Specific RBC (mg/kg dw)		
	Human Health[a]		Benthic Invertebrates[b]
	Indirect Exposure	Direct Exposure	
Aroclor 1260	**0.00021**	0.22	na
Total PCBs	**0.00021**	na	0.06
PCB-77 [d]	**0.0035**	na	na
PCB-81 [d]	**0.0035**	na	na
PCB-105 [d]	**0.0035**	na	na
PCB-114 [d]	**0.00070**	na	na
PCB-118 [d]	**0.0035**	na	na
PCB-123 [d]	**0.0035**	na	na
PCB-126 [d]	**0.0000035**	na	na
PCB-156 [d]	**0.00070**	na	na
PCB-157 [d]	**0.00070**	na	na
PCB-167 [d]	**0.035**	na	na
PCB-169 [d]	**0.000035**	na	na
PCB-189 [d]	**0.0035**	na	na
Dioxins/furans			
2,3,7,8-TCDD	**3.5×10^{-7}**	4.5×10^{-6}	na
1,2,3,7,8-PeCDD[d]	**3.5×10^{-7}**	na	na
1,2,3,4,7,8-HxCDD[d]	**7.0×10^{-7}**	na	na
1,2,3,6,7,8-HxCDD[d]	**3.5×10^{-6}**	na	na
1,2,3,7,8,9-HxCDD[d]	**3.5×10^{-6}**	na	na
1,2,3,4,6,7,8-HpCDD[d]	**3.5×10^{-6}**	na	na
OCDD[d]	**3.5×10^{-6}**	0.013	na
2,3,7,8-TCDF[d]	**3.5×10^{-6}**	3.2×10^{-5}	na
1,2,3,7,8-PeCDF[d]	**3.5×10^{-6}**	1.1×10^{-4}	na
2,3,4,7,8-PeCDF[d]	**3.5×10^{-6}**	1.1×10^{-5}	na
1,2,3,4,7,8-HxCDF[d]	**3.5×10^{-6}**	na	na
1,2,3,6,7,8-HxCDF[d]	**7.0×10^{-6}**	na	na
1,2,3,7,8,9-HxCDF[d]	**3.5×10^{-5}**	na	na
2,3,4,6,7,8-HxCDF[d]	**3.5×10^{-5}**	na	na
1,2,3,4,6,7,8-HpCDF[d]	**3.5×10^{-5}**	na	na
1,2,3,4,7,8,9-HpCDF[d]	**0.0035**	na	na
OCDF[d]	**0.0035**	na	na
Pesticides			
2,4'-DDD	**0.0083**	2	na
2,4'-DDE	**0.0026**	1.4	na
2,4'-DDT	**0.00092**	1.7	na
4,4'-DDD	**0.0083**	2	na
4,4'-DDE	**0.0026**	1.4	na
4,4'-DDT	**0.00092**	1.7	na
Total DDTs	**0.00092**	na	0.0069
Aldrin	**0.000063**	0.029	0.01
alpha-BHC	na[c]	**0.077**	na
beta-BHC	**0.00063**	0.27	na
alpha-Chlordane	na	1.6	**0.010**
Chlordane[e]	**0.0017**	1.6	na

Analyte	Receptor-Specific RBC (mg/kg dw)		
	Human Health[a]		Benthic Invertebrates[b]
	Indirect Exposure	Direct Exposure	
Dieldrin	**0.000033**	0.030	0.01
alpha-Endosulfan	**0.50**	37	na
beta-Endosulfan	**0.50**	37	na
Endosulfan sulfate	**0.50**	37	na
Endrin	**0.027**	1.8	na
gamma-BHC (Lindane)	**0.00083**	0.52	0.01
Heptachlor	**0.00025**	0.11	0.01
Heptachlor epoxide	na[c]	**0.053**	na
Methoxychlor	**0.44**	31	na
Mirex	na[c]	**0.027**	na
Toxaphene	na[c]	**0.44**	na
VOCs			
Ethylbenzene	na	**5.7**	na
Tetrachloroethene	na	**0.57**	na
Total xylenes	na	**260**	na
Trichloroethene	na	**2.8**	na

NOTE: Values in **BOLD** were used as ACGs in Table D-5.

na – toxicity data not available or not applicable

[a] The RBC for a given chemical may be derived from either carcinogenic or non-carcinogenic endpoints. For chemicals with both endpoints, the lower RBC is shown.

[b] RBCs for benthic invertebrates are equivalent to the SQS/SL for chemicals with standards expressed on a dry weight basis. For chemicals with standards expressed on an organic-carbon normalized basis, an organic carbon content of 0.5% was assumed to convert the standards to dry weight.

[c] This chemical was identified as an important bioaccumulative chemical by EPA (2000), but no BSAF is available from the sources listed in Section D.2.2.2, so no RBC for indirect exposure was calculated.

[d] Dioxin-like PCB and dioxin/furan congeners will be evaluated as toxic equivalents (TEQs) in the risk assessments, rather than as individual congeners. However, because TEQs are calculated, rather than measured by the laboratory, RBCs for individual congeners are presented to facilitate comparison with RLs for those congeners. In reality, risks will be assessed based on sums of these congeners (normalized per their relative toxicity to TCDD), and thus comparison to RLs on a congener-specific basis is somewhat uncertain.

[e] RBCs for chlordane for human health are based on toxicity of mixtures of chlordane-related compounds (e.g., alpha- and gamma-chlordane, cis- and trans-nonachlor).

D.2.1 RBC derivation for the protection of benthic invertebrates

RBCs for the protection of benthic invertebrates are expressed as chemical concentrations in sediment, to which benthic invertebrates are directly exposed. The benthic invertebrate RBCs are derived from the SQS or from DMMP SLs when SQS are not available. There are 14 chemicals that have SLs but do not have an SQS value. The SQS and SL values are presented in Table D-2. The RBCs in Table D-1 for benthic invertebrates are equivalent to the SQS/SL for chemicals where the SQS is expressed on a dry weight basis. For chemicals with standards expressed on an organic-carbon (OC) normalized basis, a lower-than-average OC content of 0.5% was assumed to convert the SQS to its dry weight equivalent.

No sediment-based SQS or SL is available for TBT. The benthic invertebrate sediment RBC for TBT is calculated for the purposes of this appendix using a tissue effect value along with a modified bioaccumulation factor (BAF), as described below.

The tissue effect value was obtained from a review of effects data associated with TBT in benthic invertebrate tissues. The lowest LOEC (lowest-observed-effect concentration; the lowest concentration at which an adverse effect was observed) was 2.4 mg/kg dry weight (dw) associated with reduced growth of the polychaete *Armandia brevis* (Meador and Rice 2001). The highest NOEC (no-observed-effect concentration; the highest concentration at which no adverse effect was observed) found in a laboratory study was 0.85 mg/kg dw (reduced condition index in Pacific oysters, assuming a moisture content of 80% (Davies et al. 1988)). The LOEC and NOEC are 0.48 and 0.17 mg/kg ww, respectively. The NOEC of 0.17 mg/kg ww was used as the tissue effect concentration for calculating the RBC only for the purposes of this appendix (the NOECs and LOEC to be used in the EW remedial investigation will be developed as part of the Phase 2 ERA).

The modified bioaccumulation factor was derived as described in the using a wet weight tissue concentration and a sediment concentration expressed on an organic carbon-normalized basis, as follows:

$$\text{Modified BAF for TBT} = \frac{\text{Biota (mg/kg ww)}}{\text{Sediment (mg/kg OC)}}$$

Equation 1

The modified BAF used in this appendix is 0.10 (Windward, 2003). The sediment RBC was then calculated using Equation 2:

$$\text{Sediment (mg/kg dw)} = \frac{\text{Tissue effect concentration (mg/kg ww)}}{\text{Modified BAF for TBT}} \times 0.5\%\text{OC in sediment} \times 0.01$$

Equation 2

Using this approach, the sediment RBC for benthic invertebrates for TBT is 0.0085 mg/kg dw (Table D-1).

Table D-2. Chemical criteria used to derive sediment RBCs for benthic invertebrates

CHEMICAL	UNIT	SQS	SL
Metals			
Antimony	mg/kg dw	ns	150
Arsenic	mg/kg dw	57	sa
Cadmium	mg/kg dw	5.1	sa
Chromium	mg/kg dw	260	sa
Copper	mg/kg dw	390	sa
Lead	mg/kg dw	450	sa
Mercury	mg/kg dw	0.41	sa
Nickel	mg/kg dw	ns	140
Silver	mg/kg dw	6.1	sa
Zinc	mg/kg dw	410	sa

CHEMICAL	UNIT	SQS	SL
PAHs			
2-Methylnaphthalene	mg/kg OC	38	sa
Acenaphthene	mg/kg OC	16	sa
Acenaphthylene	mg/kg OC	66	sa
Anthracene	mg/kg OC	220	sa
Benzo(a)anthracene	mg/kg OC	110	sa
Benzo(a)pyrene	mg/kg OC	99	sa
Benzo(g,h,i)perylene	mg/kg OC	31	sa
Total benzofluoranthenes	mg/kg OC	230	sa
Chrysene	mg/kg OC	110	sa
Dibenzo(a,h)anthracene	mg/kg OC	12	sa
Dibenzofuran	mg/kg OC	15	sa
Fluoranthene	mg/kg OC	160	sa
Fluorene	mg/kg OC	23	sa
Indeno(1,2,3-cd)pyrene	mg/kg OC	34	sa
Naphthalene	mg/kg OC	99	sa
Phenanthrene	mg/kg OC	100	sa
Pyrene	mg/kg OC	1,000	sa
Total HPAHs	mg/kg OC	960	sa
Total LPAHs	mg/kg OC	370	sa
Phthalates			
bis(2-ethylhexyl)phthalate	mg/kg OC	47	sa
Butyl benzyl phthalate	mg/kg OC	4.9	sa
Diethyl phthalate	mg/kg OC	61	sa
Dimethyl phthalate	mg/kg OC	53	sa
Di-n-butyl phthalate	mg/kg OC	220	sa
Di-n-octyl phthalate	mg/kg OC	58	sa
Polychlorinated biphenyls			
Total PCB Aroclors	mg/kg OC	12	sa
Other SVOCs			
1,2,4-Trichlorobenzene	mg/kg OC	0.81	sa
1,2-Dichlorobenzene	mg/kg OC	2.3	sa
1,3-Dichlorobenzene	mg/kg OC	ns	170
1,4-Dichlorobenzene	mg/kg OC	3.1	sa
2,4-Dimethylphenol	µg/kg dw	29	sa
2-Methylphenol	µg/kg dw	63	sa
4-Methylphenol	µg/kg dw	670	sa
Benzoic acid	µg/kg dw	650	sa
Benzyl alcohol	µg/kg dw	57	sa
Hexachlorobenzene	mg/kg OC	0.38	sa
Hexachlorobutadiene	mg/kg OC	3.9	sa
Hexachloroethane	µg/kg dw	ns	1,400
N-Nitrosodiphenylamine	mg/kg OC	11	sa
Pentachlorophenol	µg/kg dw	360	sa
Phenol	µg/kg dw	420	sa
Pesticides			
Aldrin	µg/kg dw	ns	10

CHEMICAL	UNIT	SQS	SL
alpha-chlordane	µg/kg dw	ns	10
total DDT	µg/kg dw	ns	6.9
Dieldrin	µg/kg dw	ns	10
gamma-BHC	µg/kg dw	ns	10
Heptachlor	µg/kg dw	ns	10
VOCs			
Ethylbenzene	µg/kg dw	ns	10
Tetrachloroethene	µg/kg dw	ns	57
Trichloroethene	µg/kg dw	ns	160
Total xylenes	µg/kg dw	ns	40

OC – organic carbon
dw – dry weight
ns – SQS not available
sa – SQS available and used as the preferred criterion

D.2.2 RBC derivation for the protection of humans

RBCs for the protection of human health were derived for both direct and indirect (i.e., seafood consumption) exposure pathways and are presented in Table D-1. For non-bioaccumulative chemicals, RBCs were calculated for direct exposure pathways, as described in Section D.2.2.1. For bioaccumulative chemicals, RBCs were calculated for the seafood consumption pathway, as described in Section D.2.2.2. Bioaccumulative compounds were identified by EPA (2000).

D.2.2.1 Direct sediment exposure pathway

RBCs for the protection of humans that may directly contact or incidentally ingest sediment are expressed as chemical concentrations in sediment. Human health guidance documents were reviewed for RBCs for human health. Oak Ridge National Laboratory (ORNL) presents RBCs for the protection of human health from exposures to soil that have been agreed upon by EPA Regions 3, 6, and 9 (ORNL 2008). The Model Toxics Control Act (MTCA, a Washington State statute) also includes RBCs for soil, but they are generally higher than the ORNL RBCs because of different exposure parameters. Consequently, ORNL RBCs were used instead of MTCA RBCs because they are more health protective and because they represent the best available science agreed upon by three EPA regional offices. The soil RBCs represent very conservative ACGs for East Waterway (EW) sediments because they are based on residential soil exposure scenarios at a target HQ of 0.1.

ORNL (2008) contains soil RBCs for both industrial and residential scenarios. Residential RBCs were used in this appendix because they are more health protective than the industrial RBCs. ORNL RBCs for chemicals with noncarcinogenic effects were decreased by a factor of 10 to account for the target hazard quotients of 0.1 used in

screening by EPA Region 10.[3] ACGs can be calculated for chemicals with either carcinogenic or non-carcinogenic endpoints; some chemicals have both types of endpoints. For chemicals with both endpoints, the lower ACG is shown in Table D-5.

D.2.2.2 Indirect sediment exposure pathway

RBCs for the indirect sediment exposure pathway (i.e., seafood consumption) require that a relationship be developed between chemical concentrations in tissue and sediment. One commonly used method for evaluating such a relationship for nonpolar organic chemicals that may bioaccumulate is the biota sediment accumulation factor (BSAF).

BSAFs can be derived using Equation 4:

$$BSAF = \frac{C_{WB} \div F_L}{C_{sed} \div F_{oc}} \qquad \textbf{Equation 4}$$

where:

C_{WB}	=	chemical concentration in whole-body tissue (mg/kg ww)
C_{sed}	=	chemical concentration in sediment (mg/kg dw)
F_L	=	fraction lipid in tissue (kg lipid/kg ww)
F_{oc}	=	fraction organic carbon in sediment (kg OC/kg dw)

A key variable in the BSAF equation is the sediment concentration (C_{sed}). The BSAF equation is based on the assumption that C_{sed} represents the average chemical concentration in sediment to which the organism is exposed. For animals with very small home ranges, such as clams, this assumption may be reasonable if sediment data are collected concurrently with tissue data at the tissue collection locations. For animals with larger home ranges, such as fish, there is greater uncertainty in this assumption because many fish are highly mobile and are not likely to inhabit all areas of their home range with equal frequency. Consequently, fish BSAFs for a given chemical may easily range over at least an order of magnitude (USACE 2003).

Equation 4 can be rearranged to solve for C_{sed}, as follows:

$$C_{sed} = \frac{(C_{WB} \div F_L) \times F_{oc}}{BSAF} \qquad \textbf{Equation 5}$$

For this appendix, the C_{WB} based on 98 g/day was used in Equation 5. More details on calculation of chemical concentrations in tissue, including for chemicals with toxic equivalency factors can be found in Appendix C. The BSAFs used to calculate ACGs for sediment (i.e., C_{sed} in Equation 5) were from four sources:

[3] EPA Region 10 recommends a target hazard quotient of 0.1; therefore, the EPA Region 9 RBCs (which are based on a target hazard quotient of 1) have been adjusted by dividing by 10 for the ACG.

- US Army Corps of Engineers Environmental Residue-Effects Database (ERED) - http://www.wes.army.mil/el/ered/
- Tracey GA, Hansen DJ. 1996. Use of biota-sediment accumulation factors to assess similarity of nonionic organic chemical exposure to benthically-coupled organisms of differing trophic mode. Arch Environ Contam Toxicol 30:467-475.
- EPA. 1997. The incidence and severity of sediment contamination in surface waters of the United States. Volume 1: National Sediment Quality Survey. EPA 823-R-97-006. US Environmental Protection Agency, Office of Science and Technology, Washington, DC.
- Washington State Department of Health. 1995. Tier I report, development of sediment quality criteria for the protection of human health. Washington State Department of Health, Olympia, Washington.

The BSAFs cited in these four sources will not necessarily be used for any other purpose in the EW RI other than developing sediment ACGs in this appendix. BSAFs for bivalve mollusks are most appropriate for the ACG calculation, as described above. However, some fish BSAFs were used in this appendix when bivalve BSAFs were not available (i.e., some SVOCs and 2,3,7,8-TCDD).

D.3 COMPARISON OF ACGS TO RLS

ACGs were determined for sediment by selecting the lowest RBC for each chemical from Table D-1. These ACGs for sediment were compared with RLs, which represent the minimum analyte concentrations that can be reliably quantified, and with MDLs, which are lower than the RL and represent the minimum analyte concentration that can be detected with 99% confidence.

As shown in Table D-5, all ACGs are higher than the target RLs and MDLs, with the exception of five PAHs (benzo(a)pyrene, benzo(a)anthracene, benzo(b)fluoranthene, dibenzo(a,h)anthracene, and indeno(1,2,3-c,d)pyrene), six other semivolatile organic compounds (1,2,4-trichlorobenzene, 1,2-dichlorobenzene, 1,4-dichlorobenzene, hexachlorobenzene, n-nitrosodimethylamine, and n-nitrosodi-n-propylamine), six PCB Aroclors, total PCBs, one PCB congener, 4dioxin/furan congeners, three metals (arsenic, cadmium, mercury), tributyltin, and nine pesticides (2,4,'-DDT, 4,4,'-DDT, total DDTs, aldrin, beta-BHC, total chlordane, dieldrin, gamma-BHC, and heptachlor). When the ACGs for these analytes are compared with the target MDLs, ACGs for 13 of these chemicals are higher than the target MDL, indicating that the test methods should be sufficiently sensitive to detect these chemicals at concentrations above the ACGs. Twenty-two chemicals have ACGs lower than both their target RL and MDL (six Aroclors, total PCBs, four PAHs, three other SVOCs, tributyltin, arsenic, cadmium, four pesticides, and total DDTs).

Four PAHs listed above with target MDLs or RLs greater than the ACG, as well as cadmium, mercury, tributyltin, Aroclor 1260 and total PCBs were detected in over 80% of the historical surface sediment samples using standard test methods with comparable target RLs. Arsenic, dibenzo(a,h)anthracene, 1,4-dichlorobenzene, and Aroclor 1254 were detected in over 50% of the historical sediment samples (68%, 54%, 52%, and 68%, respectively). Based on these historical results, the PAHs, PCBs, and metals listed above are also likely to be detected in most or all the sediment samples described in this QAPP. Consequently, the fact that the ACGs are lower than both the MDL and RL should not compromise the quality of the data to be used in the risk assessments for these chemicals.

The MDLs and RLs for 1,2,4-trichlorobenzene, 1,2-dichlorobenzene, Aroclor 1242, Aroclor 1248, 2,4'-DDT, 4,4'-DDT, aldrin, dieldrin, total DDTs, and total chlordane are higher than the respective ACGs. These chemicals were detected in 2 to 28% of the historical sediment samples. For the undetected chemicals with RLs above the ACGs, the ramifications for the HHRA and ERA will be discussed in the uncertainty assessments.

The five other SVOCs listed above with target MDLs and RLs greater than the ACG will also be analyzed by EPA 8270D-SIM to achieve lower RLs; hexachlorobenzene will also be analyzed by EPA 8081A. N-nitrosodiphenylamine and N-nitrosodimethylamine are known to be difficult to quantify in sediment. Lower target MDLs and RLs may be available for pesticides using a GC/MS/MS technique developed by Columbia Analytical Services, Inc., although the target MDLs and RLs are not yet known.

The laboratories will make all reasonable efforts to achieve the target MDLs and RLs for all chemicals. Additional efforts may include modified extraction techniques (e.g., extracting a higher sample volume or adjusting the final extract volume), sample cleanup procedures (e.g., gel-permeation column chromatography), using a lower concentration for the lowest standard in the initial calibration, or adjusting the amount of extract injected into the instrument. If no PCB Aroclors are detected in a sample, a low-level extraction technique may be performed.

Table D-5. Comparison of sediment ACGs to target RLs and MDLs

CHEMICAL	MDL[a]	RL[a]	SEDIMENT ACG[b]
Metals (EPA 6020/7471A)			
Antimony	0.013	0.2	3.1
Arsenic	**0.17**	**0.5**	0.006
Cadmium	**0.016**	**0.2**	0.003
Chromium	0.136	0.5	23
Cobalt	0.008	0.2	na
Copper	0.043	0.5	1.3
Lead	0.078	1.0	40
Mercury	0.005	**0.05**	0.016

CHEMICAL	MDL[a]	RL[a]	SEDIMENT ACG[b]
Molybdenum	0.008	0.2	39
Nickel	0.111	0.5	140
Selenium	0.671	2	39
Silver	0.006	0.2	6.1
Thallium	0.005	0.2	0.51
Vanadium	0.034	0.2	39
Zinc	0.443	4.0	16
Organometals (Krone 1989)			
Tri-n-butyltin ion	**0.0012**	**0.0040**	0.00028
PAHs (EPA 8270D)			
2-Methylnaphthalene	0.0082	0.020	0.19
Acenaphthylene	0.0087	0.020	0.33
Acenaphthene	0.0082	0.020	0.08
Anthracene	0.0077	0.020	1.1
Benzo(a)anthracene	**0.0059**	**0.020**	0.0052
Benzo(a)pyrene	**0.0082**	**0.020**	0.00076
Benzo(b)fluoranthene	**0.0095**	**0.020**	0.0047
Benzo(g,h,i)perylene	0.0068	0.020	0.16
Benzo(k)fluoranthene	0.0093	0.020	0.047
Total benzofluoranthenes[c]	0.0095	0.020	1.2
Chrysene	0.0066	0.020	0.48
Dibenzo(a,h)anthracene	0.0086	**0.020**	0.015
Dibenzofuran	0.0076	0.020	0.075
Fluoranthene	0.0079	0.020	0.80
Fluorene	0.0090	0.020	0.12
Indeno(1,2,3-cd)pyrene	**0.0086**	**0.020**	0.0029
Naphthalene	0.0087	0.020	0.50
Phenanthrene	0.0084	0.020	0.50
Pyrene	0.0078	0.020	5.0
Total LPAHs[d]	0.0090	0.020	1.9
Total HPAHs[e]	0.0095	0.020	4.8
Phthalates (EPA 8270D)			
Bis(2-ethylhexyl)phthalate	0.011	0.020	0.12
Butyl benzyl phthalate	0.011	0.020	0.025
Di-ethyl phthalate	0.016	0.020	0.31
Dimethyl phthalate	0.0078	0.020	0.27
Di-n-butyl phthalate	0.012	0.020	1.1
Di-n-octyl phthalate	0.0083	0.020	0.29
Other SVOCs (EPA 8270D)			
1,2,4-Trichlorobenzene	**0.0091**	**0.020**	0.0041
1,2-Dichlorobenzene	0.0079	**0.020**	0.012
1,3-Dichlorobenzene	0.0075	0.020	0.17

CHEMICAL	MDL[a]	RL[a]	SEDIMENT ACG[b]
1,4-Dichlorobenzene	0.0074	**0.020**	0.016
2,4,5-Trichlorophenol	0.045	0.10	37
2,4,6-Trichlorophenol	0.046	0.10	44
2,4-Dichlorophenol	0.041	0.10	1.1
2,4-Dimethylphenol	0.015	0.020	0.029
2,4-Dinitrophenol	0.11	0.20	12
2,4-Dinitrotoluene	0.039	0.10	12
2,6-Dinitrotoluene	0.054	0.10	6.1
2-Chloronaphthalene	0.0080	0.020	6,300
2-Chlorophenol	0.0075	0.020	1.8
2-Methylphenol	0.014	0.020	0.063
3,3'-Dichlorobenzidine	0.049	0.10	1.1
4-Chloroaniline	0.035	0.10	24
4-Methylphenol	0.013	0.020	0.67
Aniline	0.067	0.067	85
Benzoic acid	0.12	0.20	0.65
Benzyl alcohol	0.015	0.020	0.057
Bis(2-chloroethyl)ether	0.0075	0.020	0.19
Bis-chloroisopropyl ether	0.0080	0.020	0.19
Carbazole	0.0066	0.020	0.23
Hexachlorobenzene	**0.0080**	**0.020**	0.0019
Hexachlorobutadiene	0.0081	0.020	0.020
Hexachloroethane	0.0072	0.020	0.12
Isophorone	0.0083	0.020	510
Nitrobenzene	0.0088	0.020	3.1
N-Nitrosodimethylamine	**0.035**	**0.10**	0.0023
N-Nitrosodi-n-propylamine	0.036	**0.10**	0.069
N-Nitrosodiphenylamine	0.0087	0.020	0.055
Pentachlorophenol	0.048	0.10	0.36
Phenol	0.014	0.020	0.42
Selected SVOCs by EPA 8270D-SIM			
1,2,4-Trichlorobenzene	0.0016	**0.0067**	0.0041
1,2-Dichlorobenzene	0.0013	0.0067	0.012
1,4-Dichlorobenzene	0.0022	0.0067	0.016
2,4-Dimethylphenol	0.0039	0.0067	0.029
2-Methylphenol	0.0034	0.0067	0.063
Benzyl alcohol	0.016	0.033	0.057
Butyl benzyl phthalate	0.0040	0.0067	0.025
Dibenzo(a,h)anthracene	0.00050	0.0063	0.015
Dimethyl phthalate	0.0017	0.0065	0.27
Hexachlorobenzene	**0.0020**	**0.0067**	0.0019
Hexachlorobutadiene	0.0029	0.0067	0.020

CHEMICAL	MDL[a]	RL[a]	SEDIMENT ACG[b]
N-Nitrosodiphenylamine	0.0031	0.0067	0.055
N-Nitrosodimethylamine	**0.024**	**0.033**	0.0023
N-Nitrosodi-n-propylamine	0.0027	0.033	0.069
Pentachlorophenol	0.013	0.033	0.36
PCBs			
Aroclor 1016	0.0013	0.0040	0.0061
Aroclor 1221	**0.0013**	**0.0040**	0.00021
Aroclor 1232	**0.0013**	**0.0040**	0.00021
Aroclor 1242	**0.0028**	**0.0040**	0.00021
Aroclor 1248	**0.0028**	**0.0040**	0.00021
Aroclor 1254	**0.0028**	**0.0040**	0.00021
Aroclor 1260	**0.0028**	**0.0040**	0.00021
Total PCBs[f]	**0.0028**	**0.0040**	0.00021
PCB Congeners (EPA 1668)[g]			
PCB-77	4.6E-05	1.0E-06	0.0035
PCB-81	3.0E-05	1.0E-06	0.0035
PCB-105	4.0E-05	1.0E-06	0.0035
PCB-114	3.6E-05	1.0E-06	0.0007
PCB-118	9.3E-05	1.0E-06	0.0035
PCB-123	4.7E-05	1.0E-06	0.0035
PCB-126	**4.2E-05**	1.0E-06	3.5E-06
PCB-156	4.4E-05	1.0E-06	0.0007
PCB-157	4.4E-05	1.0E-06	0.0007
PCB-167	3.7E-05	1.0E-06	0.035
PCB-169	3.0E-05	1.0E-06	3.5E-05
PCB-189	3.3E-05	1.0E-06	0.0035
Dioxins/furans (EPA 1613B)[g]			
2,3,7,8-TCDD	7.40E-08	**5.0E-07**	3.50E-07
1,2,3,7,8-PeCDD	2.10E-07	**2.5E-06**	3.50E-07
1,2,3,4,7,8-HxCDD	2.60E-07	**2.5E-06**	7.00E-07
1,2,3,6,7,8-HxCDD	2.90E-07	2.5E-06	3.50E-06
1,2,3,7,8,9-HxCDD	2.48E-07	2.5E-06	3.50E-06
1,2,3,4,6,7,8-HpCDD	2.80E-07	2.5E-06	3.50E-06
OCDD	3.88E-07	**5.0E-06**	3.50E-06
2,3,7,8-TCDF	7.80E-08	5.0E-07	3.50E-06
1,2,3,7,8-PeCDF	1.82E-07	2.5E-06	3.50E-06
2,3,4,7,8-PeCDF	2.38E-07	2.5E-06	3.50E-06
1,2,3,4,7,8-HxCDF	2.22E-07	2.5E-06	3.50E-06
1,2,3,6,7,8-HxCDF	2.06E-07	2.5E-06	7.00E-06
1,2,3,7,8,9-HxCDF	2.52E-07	2.5E-06	3.50E-05

CHEMICAL	MDL[a]	RL[a]	SEDIMENT ACG[b]
2,3,4,6,7,8-HxCDF	2.40E-07	2.5E-06	3.50E-05
1,2,3,4,6,7,8-HpCDF	3.28E-07	2.5E-06	3.50E-05
1,2,3,4,7,8,9-HpCDF	2.98E-07	2.5E-06	0.0035
OCDF	6.22E-07	5.0E-06	0.0035
Pesticides (EPA 8081A)			
2,4'-DDD	0.0012	0.0020	0.0083
2,4'-DDE	0.00093	0.0020	0.0026
2,4'-DDT	**0.0010**	**0.0020**	0.00092
4,4'-DDD	0.0013	0.0020	0.0083
4,4'-DDE	0.0012	0.0020	0.0026
4,4'-DDT	0.00088	**0.0020**	0.00092
Total DDTs[h]	**0.0013**	**0.0020**	0.00092
Aldrin	**0.00048**	**0.0010**	0.000063
alpha-BHC	0.00062	0.0010	0.077
beta-BHC	0.00039	**0.0010**	0.00063
alpha-Chlordane	0.00061	0.0010	0.010
Total chlordane[i]	0.0010	**0.0020**	0.0017
Dieldrin	**0.00084**	**0.0020**	0.000033
alpha-Endosulfan	0.00067	0.0010	0.50
beta-Endosulfan	0.0012	0.0020	0.50
Endosulfan sulfate	0.00088	0.0020	0.50
Endrin	0.0012	0.0020	0.027
gamma-BHC (Lindane)	0.00049	**0.0010**	0.00083
Heptachlor	**0.00040**	**0.0010**	0.00025
Heptachlor epoxide	0.00038	0.0010	0.053
Methoxychlor	0.0033	0.010	0.44
Mirex	0.0010	0.0020	0.027
Toxaphene	0.048	0.10	0.44
VOCs (EPA 8260B)			
Ethylbenzene	0.00041	0.0010	5.7
Tetrachloroethene	0.00042	0.0010	0.57
Total xylenes	0.00062	0.0010	260
Trichloroethene	0.00034	0.0010	2.8

RLs and MDLs in **BOLD** are greater than at least one of their respective ACGs.

na – not available

[a] Target RLs and MDLs are the most recent values provided by ARI and Analytical Perspectives. Actual RLs and MDLs will vary based on amount of sample analyzed, matrix interferences, analytical dilution, percent solids of the sample and/or updates to RLs and MDLs by the laboratory. The MDLs provided for PCB and dioxin congeners are the average MDLs of sample-specific detection limits, calculated from specific samples over 4-6 years

[b] ACG for sediment is the lowest of the RBCs for benthic invertebrates and humans.

[c] Total benzofluoranthenes is the sum of benzo(b)fluoranthene and benzo(k)fluoranthene. RL and MDL are the highest of the RLs and MDLs for benzo(b)fluoranthene or benzo(k)fluoranthene.

[d] Total LPAHs is the sum of naphthalene, 2-methyl naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, and anthracene. RL and MDL are the highest RL and MDL for the LPAHs.

[e] Total HPAHs is the sum of fluoranthene, pyrene, benz(a)anthracene, chrysene, benzo(k)fluoranthene, benzo(b)fluoranthene, benzo(a)pyrene, indeno(1,2,3-cd)pyrene, dibenz(a,h)anthracene, and benzo(g,h,i)perylene. RL and MDL are the highest RL and MDL for the HPAHs.

[f] Total PCBs is the sum of the Aroclors. RL and MDL are the highest RL and MDL for the individual Aroclors.

[g] Dioxin-like PCB and dioxin/furan congeners will be evaluated as toxic equivalents (TEQs) in the risk assessments, rather than as individual congeners. However, because TEQs are calculated, rather than measured by the laboratory, RBCs for individual congeners are presented to facilitate comparison with RLs for those congeners. In reality, risks will be assessed based on sums of these congeners (normalized per their relative toxicity to TCDD), and thus comparison to RLs on a congener-specific basis is somewhat uncertain.

[h] Total DDT is the sum of 4,4'-DDD, 4,4-DDE, 4,4'-DDT, 2,4'-DDD, 2,4-DDE, and 2,4'-DDT. RL and MDL are the highest RL and MDL for the DDT isomers.

[i] Total chlordane is the sum of oxychlordane, alpha- and gamma-chlordane, and cis- and trans-nonachlor. RL and MDL are the highest RL and MDL for the chlordane-related compounds.

D.4 REFERENCES

Abiola FA. 1992. Ecotoxicity of organochloride insecticides: effects of endosulfan on bird reproduction and evaluation of its induction effect in partridge (*Perdix perdix* L.). Revue Med Vet 143(5):443-450.

Cain BW, Pafford EA. 1981. Effects of dietary nickel on survival and growth of mallard ducklings. Arch Environ Contam Toxicol 10:737-745.

Chakravarty S, Lahiri P. 1986. Effect of lindane on eggshell characteristics and calcium level in the domestic duck. Toxicology 42:245-258.

Chakravarty S, Mandal A, Lahiri P. 1986. Effect of lindane on clutch size and level of egg yolk protein in domestic duck. Toxicology 39:93-103.

Chung KH, Sukgrand YO, Kang MH. 1988. The toxocity of chromium and its interaction with manganese and molybdenum in chicks. Kor J Anim Sci 27(6):391-395.

Davies IM, Drinkwater J, McKie JC. 1988. Effects of tributyltin compunds from antifoulants on Pacific oysters (*Crassostrea gigas*) in Scottish sea lochs. Aquaculture 74:319-330.

DeWitt JB. 1956. Chronic toxicity to quail and pheasants of some chlorinated insecticides. Agric Food Chem 4(10):863-866.

DiGiulio RT, Scanlon P. 1984. Sublethal effects of cadmium ingestion on mallard ducks. Arch Environ Contam Toxicol 13:765-771.

Edens FW, Benton E, Bursian SJ, Morgan GW. 1976. Effect of dietary lead on reproductive performance in Japanese quail, *Coturnix coturnix japonica*. Toxicol Appl Pharmacol 38:307-314.

Eisler R. 2002. Contaminant hazard reviews, 1985-1999. US Fish and Wildlife Service Biological Reports. Patuxent Wildlife Research Center, US Fish and Wildlife Service, Laurel, MD. http://www.pwrc.usgs.gov/.

EPA. 1993. Wildlife exposure factors handbook. EPA/600/R-93/187a [online]. Office of Research and Development, US Environmental Protection Agency, Washington, DC. Available from: <http://cfpub.epa.gov/ncea/cfm/wefh.cfm?ActType=default>.

EPA. 2000. Bioaccumulation testing and interpretation for the purpose of sediment quality assessment: status and needs. US EPA Bioaccumulation Analysis Workgroup. EPA-823-R-00-001.

EPA. 2002. EPA Region 9 preliminary remediation goals (PRGs). Revised October 1, 2002. US Environmental Protection Agency, Region 9, San Francisco, CA.

EPA. 2007. Human health medium-specific screening levels. US Environmental Protection Agency Region 6, Dallas, TX.

Fergin TJ, Schafer EC. 1977. Toxicity of dieldrin to bobwhite quail in relation to sex and reproductive status. Arch Environ Contam Toxicol 6:213-219.

Fleming WJ, McLane MAR, Cromartie E. 1982. Endrin decreases screech owl productivity. J Wildl Manage 46(2):462-468.

Heath RG, Spann JW, Kreitzer JF. 1969. Marked DDE impairment of mallard reproduction in controlled studies. Nature 224:47-48.

Heinz GH, Hoffman DJ, Gold LG. 1989. Impaired reproduction of mallards fed an organic form of selenium. J Wildl Manage 53(2):418-428.

Hill EF, Heath RG, Spann JW, Williams JD. 1975. Lethal dietary toxicities of environmental pollutants to birds. US Fish and Wildlife Service, Laurel, MD.

Ishida M, Suyama K, Adachi S, Hoshino T. 1982. Distribution of orally administered di-ethylhexyl phthalate in laying hens. Poult Sci 61:262-267.

Kolaja GJ. 1977. The effects of DDT, DDE and their sulfonated derivatives on eggshell formation in the mallard duck. Bull Environ Contam Toxicol 17:697-701.

Lepore PD, Miller RF. 1965. Embryonic viability as influenced by excess molybdenum in chicken breeder diets. Proc Soc Exp Biol Med 118: 155-157.

Lincer JL. 1975. DDE-induced eggshell-thinning in the American kestrel: a comparison of the field situation and laboratory results. J Appl Ecol 12(3):781-793.

Ludke JL. 1976. Organochlorine pesticide residues associated with mortality: additivity of chlordane and endrin. Bull Environ Contam Toxicol 16:253-260.

Maxson SJ, Oring LW. 1980. Breeding season time and energy budgets of the polyandrous spotted sandpiper. Behaviour 74:200-263.

McLane MAR, Hughes DL. 1980. Reproductive success of screech owls fed Aroclor 1248. Arch Environ Contam Toxicol 9:661-665.

Meador JP, Rice CA. 2001. Impaired growth in the polychaete *Armandia brevis* exposed to tributyltin in sediment. Mar Environ Res 51:113-129.

Mehring AL, Brumbaugh JH, Sutherland AJ, Titus HW. 1960. The tolerance of growing chickens for dietary copper. Poult Sci 39:713-719.

Mendenhall VM, Klaas EE, McLane MAR. 1983. Breeding success of barn owls (*Tyto alba*) fed low levels of DDE and dieldrin. Arch Environ Contam Toxicol 12:235-240.

Naber EC, Ware GW. 1965. Effect of kepone and mirex on reproductive performance in the laying hen. Poult Sci 44:875-880.

Nagy KA. 1987. Field metabolic rate and food requirement scaling in mammals and birds. Ecol Monogr 57(2):111-128.

Nagy KA, Girard IA, Brown TK. 1999. Energetics of free-ranging mammals, reptiles, and birds. Annu Rev Nutr. 247-277.

ORNL. 2008. Preliminary remediation goals, EPA Regions 3, 6, and 9, from Screening Levels for Chemical Contaminants database [online]. Oak Ridge National Laboratory, US Department of Energy, Oak Ridge Reservation, TN. [Cited 7/29/08.] Available from: http://epa-prgs.ornl.gov/chemicals/index.shtml#top.

Patton JF, Dieter MP. 1980. Effects of petroleum hydrocarbons on hepatic function in the duck. Comp Biochem Physiol 65C:33-36.

Peakall DB. 1974. Effects of di-N-butylphthalate and di-2-ethylhexylphthalate on the eggs of ring doves. Bull Environ Contam Toxicol 12:698-702.

Peakall DB, Lincer JL, Bloom SE. 1972. Embryonic mortality and chromosomal alterations caused by Aroclor 1254 in ring doves. Environ Health Perspect 1:103-104.

Prescott CA, Wilkie BN, Hunter B, Julian RJ. 1982. Influence of purified grade of pentachlorophenol on the immune response of chickens. Am J Vet Res 43(3):481-487.

Roberson RH, Schaible PJ. 1960. The tolerance of growing chicks for high levels of different forms of zinc. Poult Sci 39:893-896.

Romoser GL, Dudley WA, Machlin LJ, Loveless L. 1961. Toxicity of vanadium and chromium for the growing chick. Poult Sci 40:1171-1173.

Sample BE, Opresko DM, Suter GW. 1996. Toxicological benchmarks for wildlife. 1996 revision. ES/ERM-86/R3. Office of Environmental Management, US Department of Energy, Washington, DC.

Schlatterer BT, Coenen MM, Ebert E, Grau R, Hilbig V, Munk R. 1993. Effects of bis(tri–n-butyltin)oxide in Japanese quail exposed during egg laying period: an interlaboratory comparison study. Arch Environ Contam Toxicol 24: 440-448.

Schwetz BA, Norris JM, Sparschu GL, Rowe VK, Gehring PJ, Emerson JL, Gerbig CG. 1973. Toxicology of chlorinated dibenzo-p-dioxins. Environ Health Perspect 5:87-99.

Schwetz BA, Norris JM, Kociba RJ, Keeler PA, Cornier RF, Gehring PJ. 1974. Reproduction study in Japanese quail fed hexachlorobutadiene for 90 days. Toxicol Appl Pharmacol 30:255-265.

Spalding MG, Frederick PC, McGill HC, Bouton SN, McDowell LR. 2000. Methylmercury accumulation in tissues and its effects on growth and appetite in captive great egrets. J Wildl Dis 36(3):411-422.

USACE. 2003. Environmental Residue-Effects Database. US Army Corps of Engineers, Waterways Experiment Station, Vicksburg, MS. On-line database - http://el.erdc.usace.army.mil/ered/. Last database update November 2003.

USFWS. 1964. Pesticide-wildlife studies, 1963: a review of Fish and Wildlife Service investigations during the calendar year. Circular 199. Fish and Wildlife Service, US Department of the Interior, Washington, DC.

White DH, Finley MT. 1978. Effects of dietary cadmium in mallard ducks. In: Hemphill DD, ed, Trace substances in environmental health - XII. University of Missouri, Columbia, MO, pp 220-223.

Windward. 2003a. Analyte approach for tissue samples. Memorandum submitted to EPA and Ecology, April 1 2003. Prepared for Lower Duwamish Waterway Group. Windward Environmental LLC, Seattle, WA.

Windward. 2003b. Lower Duwamish Waterway remedial investigation. Phase 1 remedial investigation report. Appendix A: Ecological risk assessment. Prepared for Lower Duwamish Waterway Group. Windward Environmental LLC, Seattle, WA.

Windward. 2004. Lower Duwamish Waterway remedial investigation. Quality assurance project plan: Benthic invertebrate sampling of the Lower Duwamish Waterway. Prepared for Lower Duwamish Waterway Group. Windward Environmental LLC, Seattle, WA.

Appendix E. Data Management

AVERAGING LABORATORY REPLICATE SAMPLES

Chemical concentrations obtained from the analysis of laboratory replicate samples (two or more analyses of the same sample) will be averaged for a closer representation of the "true" concentration as compared to the result of a single analysis. Averaging rules are dependent on whether the individual results are detected concentrations or reporting limits (RLs) for undetected chemicals. If all concentrations are detected for a single chemical, the values are simply averaged arithmetically for the sample and its associate laboratory replicate sample(s). If all concentrations are undetected for a given parameter, the minimum RL is selected. If the concentrations are a mixture of detected concentrations and RLs, any two or more detected concentrations are averaged arithmetically and RLs ignored. If there is a single detected concentration and one or more RLs, the detected concentration is reported. The latter two rules are applied regardless of whether the RLs are higher or lower than the detected concentration.

LOCATION AVERAGING

Results of chemical concentrations of discrete samples collected at a single sampling location that are submitted to the laboratory as individual samples and analyzed separately will be averaged for the purposes of mapping a single concentration per location. The averaging rules used for location averaging are the same as for laboratory replicate samples described above. This type of averaging is performed when multiple sediment samples are collected from the same location at the same time. For example: a sample and its field duplicate sample, often referred to as a split sample (PSEP 1997).

SIGNIFICANT FIGURES AND CALCULATIONS

Analytical laboratories report results with various numbers of significant figures depending on the laboratory's standard operating procedures, the instrument, the chemical, and the reported chemical concentration relative to the RL. The reported (or assessed) precision of each result is explicitly stored in the project database by recording the number of significant figures. Tracking of significant figures is used when calculating analyte sums and performing other data summaries. When a calculation involves addition, such as totaling PCBs, the calculation can only be as precise as the least precise number that went into the calculation. For example:

> 210 + 19 = 229 would be reported as 230 because although 19 is reported to 2 significant digits, the trailing zero in the number 210 is not significant.

When a calculation involves multiplication or division, the final result is rounded at the end of the calculation to reflect the value used in the calculation with the fewest significant figures. For example:

59.9 × 1.2 = 71.88 would be reported as 72 because there are two significant figures in the number 1.2.

When rounding, if the number following the last significant figure is less than 5, the digit is left unchanged. If the number following the last significant figure is equal to or greater than 5, the digit is increased by 1.

Many of the Washington State Sediment Management Standards (SMS) chemical criteria are in units normalized to the TOC content in the sediment sample (i.e., milligrams per kilogram organic carbon [mg/kg OC]). Only samples with TOC concentrations greater than or equal to 0.5% or less than or equal to 4.0% are considered appropriate for OC normalization. Samples with TOC concentrations less than 0.5% or greater than 4.0% are compared to dry weight chemical criteria. Chemical concentrations originally in units of micrograms per kilogram (µg/kg) dry weight were converted to mg/kg OC using the following equation:

$$\frac{(C_{\mu g/kg\ dry\ weight}) \times (0.001\ mg/\mu g)}{TOC}$$

Where:

C	=	the chemical concentration
TOC	=	the percent total organic carbon on a dry weight basis, expressed as a decimal (e.g., 1% = 0.01)

BEST RESULT SELECTION FOR MULTIPLE RESULTS

In some instances, the laboratory generates more than one result for a chemical for a given sample. Multiple results can occur for several reasons, including: 1) the original result did not meet the laboratory's internal quality control (QC) guidelines, and a reanalysis was performed; 2) the original result did not meet other project data quality objectives, such as a sufficiently low RL, and a reanalysis was performed; or 3) two different analytical methods were used for that chemical. In each case, a single best result is selected for use. The procedures for selecting the best result differ depending on whether a single or multiple analytical methods are used for that chemical.

For the same analytical method, if the results are:

- Detected and not qualified, then the result from the lowest dilution is selected, unless multiple results from the same dilution are available, in which case, the result with the highest concentration is selected.
- A combination of estimated and unqualified detected results, then the unqualified result is selected. This situation most commonly occurs when the original result is outside of calibration range, thus requiring a dilution.
- All estimated, then the "best result" is selected using best professional judgment in consideration of the rationale for qualification. For example, a result qualified based on laboratory replicate results outside of QC objectives

for precision would be preferred to a qualified result that is outside the calibration range.

- A combination of detected and undetected results, then the detected result is selected. If there is more than one detected result, the applicable rules for multiple results (as discussed above) are followed.
- All undetected results, then the lowest RL is selected.

If the multiple results are from different analytical methods, then the result from the preferred method specified in the quality assurance project plan (QAPP) or based on the consensus of the professional opinions of project chemists was selected.

The following rules are applied to multiple results from different analytical methods:

- For detected concentrations analyzed by the SVOC full-scan and selective ion monitoring (SIM) methods (i.e., PAHs), the highest detected concentration is selected. If the result by one method is detected and the result by the other method is not detected, then the detected result is selected for reporting, regardless of the method. If results are reported as non-detected by both methods, the undetected result with the lowest RL is selected. The SIM method is more analytically sensitive than the full-scan SVOC method, and the undetected results are generally reported at a lower RL by the SIM method than by the full-scan method. Therefore, the SIM method is selected for non-detected results unless an analytical dilution or analytical interferences elevated the SIM RL above the SVOC full-scan RL.
- Hexachlorobenzene and hexachlorocyclopentadiene are analyzed by EPA Methods 8081A, 8270, and/or 8270-SIM. The result from the method with the greatest sensitivity (i.e., lowest RL) is selected if all results are undetected. EPA Method 8081A results are generally selected, when available, because the standard laboratory RLs from this analysis are significantly lower than those from EPA Methods 8270 and 8270-SIM. When chemicals are detected, the detected result with the highest concentration is selected unless the detected concentration is qualified as estimated or tentatively identified, in which case the rule designating treatment of qualified and unqualified data would apply.

CALCULATED TOTALS

Total PCBs, total dichloro-diphenyl-trichloroethane (DDTs), total PAHs, and total chlordane are calculated by summing the detected values for the individual components available for each sample. For individual samples in which none of the individual components is detected, the total value is given a value equal to the highest RL of an individual component, and assigned the same qualifier (U or UJ), indicating an undetected result. Concentrations for the analyte sums are calculated as follows:

- **Total PCBs** are calculated, in accordance with the methods of the SMS, using only detected values for seven Aroclor mixtures.[1] For individual samples in which none of the seven Aroclor mixtures is detected, total PCBs are given a value equal to the highest RL of the seven Aroclors and assigned a U-qualifier indicating the lack of detected concentrations.
- **Total low-molecular-weight PAHs (LPAHs), high-molecular-weight PAHs (HPAHs), PAHs, and benzofluoranthenes** are also calculated in accordance with the methods of the SMS. Total LPAHs are the sum of detected concentrations for naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, and anthracene. Total HPAHs are the sum of detected concentrations for fluoranthene, pyrene, benzo(a)anthracene, chrysene, total benzofluoranthenes, benzo(a)pyrene, indeno(1,2,3,-c,d)pyrene, dibenzo(a,h)anthracene, and benzo(g,h,i)perylene. Total benzofluoranthenes are the sum of the b (i.e., benzo(b)fluoranthene), j, and k isomers. Because the j isomer is rarely quantified, this sum is typically calculated with only the b and k isomers. For samples in which all individual compounds within any of the three groups described above are undetected, the single highest RL for that sample represents the sum.
- **Total DDTs** are calculated using only detected values for the DDT isomers: 2,4′-DDD; 4,4′-DDD; 2,4′-DDE; 4,4′-DDE; 2,4′-DDT; and 4,4′-DDT. For individual samples in which none of the isomers are detected, total DDTs are given a value equal to the highest RL of the six isomers and assigned a U-qualifier, indicating the lack of detected concentrations.
- **Total chlordane** is calculated using only detected values for the following compounds: alpha-chlordane, gamma-chlordane, oxychlordane, cis-nonachlor, and trans-nonachlor. For individual samples in which none of these compounds is detected, total chlordane is given a value equal to the highest RL of the five compounds listed above and assigned a U-qualifier, indicating the lack of detected concentrations.

CALCULATION OF PCB CONGENER TEQS

PCB congener toxic equivalents (TEQs) are calculated using the World Health Organization (WHO) consensus toxic equivalency factor (TEF) values for fish, birds (Van den Berg et al. 1998), and mammals (Van den Berg et al. 2006) as presented in Table E-1. The TEQ is calculated as the sum of each congener concentration multiplied by the corresponding TEF value. When the congener concentration is reported as non-detected, then the TEF is multiplied by half the RL.

[1] Aroclors 1016, 1221, 1232, 1242, 1248, 1254, and 1260.

Table E-1. PCB Congener TEF Values

PCB Congener Number	TEF Value for Fish (unitless)	TEF Value for Birds (unitless)	TEF Value for Mammals (unitless)
77	0.0001	0.05	0.0001
81	0.0005	0.1	0.0003
105	<0.000005	0.0001	0.00003
114	<0.000005	0.0001	0.00003
118	<0.000005	0.00001	0.00003
123	<0.000005	0.00001	0.00003
126	0.005	0.1	0.1
156	<0.000005	0.0001	0.00003
157	<0.000005	0.0001	0.00003
167	<0.000005	0.00001	0.00003
169	0.00005	0.001	0.03
189	<0.000005	0.00001	0.00003

PCB – polychlorinated biphenyl
TEF – toxic equivalency factor

Calculation of Dioxin/Furan Congener TEQs

Dioxin/furan congener TEQs are calculated using the WHO consensus TEF values (Van den Berg et al. 2006) for mammals as presented in Table E-2. The TEQ is calculated as the sum of each congener concentration multiplied by the corresponding TEF value. When the congener concentration is reported as undetected, then the TEF is multiplied by half the RL.

Table E-2. Dioxin/Furan Congener TEF Values for Mammals

Dioxin/Furan Congener	TEF Value (unitless)
1,2,3,4,6,7,8-Heptachlorodibenzofuran	0.01
1,2,3,4,6,7,8-Heptachlorodibenzo-*p*-dioxin	0.01
1,2,3,4,7,8,9-Heptachlorodibenzofuran	0.01
1,2,3,4,7,8-Hexachlorodibenzofuran	0.1
1,2,3,4,7,8-Hexachlorodibenzo-*p*-dioxin	0.1
1,2,3,6,7,8-Hexachlorodibenzofuran	0.1
1,2,3,6,7,8-Hexachlorodibenzo-*p*-dioxin	0.1
1,2,3,7,8,9-Hexachlorodibenzofuran	0.1
1,2,3,7,8,9-Hexachlorodibenzo-*p*-dioxin	0.1
1,2,3,7,8-Pentachlorodibenzofuran	0.03
1,2,3,7,8-Pentachlorodibenzo-*p*-dioxin	1
2,3,4,6,7,8-Hexachlorodibenzofuran	0.1
2,3,4,7,8-Pentachlorodibenzofuran	0.3
2,3,7,8-Tetrachlorodibenzofuran	0.1
2,3,7,8-Tetrachlorodibenzo-p-dioxin	1

DIOXIN/FURAN CONGENER	TEF VALUE (unitless)
Octachlorodibenzofuran	0.0003
Octachlorodibenzo-p-dioxin	0.0003

TEF – toxic equivalency factor

CALCULATION OF CARCINOGENIC POLYCYCLIC AROMATIC HYDROCARBONS

Carcinogenic polycyclic aromatic hydrocarbons (cPAH) values are calculated using TEF values (California EPA 1994; Ecology 2001) based on the individual PAH component's relative toxicity to benzo(a)pyrene. TEF values are presented in Table E-3. The cPAH is calculated as the sum of each individual PAH concentration multiplied by the corresponding TEF value. When the individual PAH component concentration is reported as non-detected, then the TEF is multiplied by half the RL.

Table E-3. cPAH TEF Values

cPAH	TEF VALUE (unitless)
Benzo(a)pyrene	1
Benzo(a)anthracene	0.1
Benzo(b)fluoranthene	0.1
Benzo(k)fluoranthene	0.1
Bibenz(a,h)anthracene	0.4
Indeno(1,2,3-cd)pyrene	0.1
Chrysene	0.01

cPAH – carcinogenic polycyclic aromatic hydrocarbon
TEF – toxic equivalency factor

REFERENCES

California EPA. 1994. Health effects of benzo(a)pyrene. Office of Environmental Health Hazard Assessment, California Environmental Protection Agency, Berkeley, CA.

Ecology. 2001. Model Toxics Control Act Cleanup Regulation, Chapter 173-340 WAC. Publication No. 94-06. Toxics Cleanup Program, Washington State Department of Ecology, Olympia, WA.

PSEP. 1997. Recommended guidelines for sampling marine sediment, water column, and tissue in Puget Sound. Final report. Prepared for the US Environmental Protection Agency, Seattle, WA. Puget Sound Water Quality Action Team, Olympia, WA.

Van den Berg M, Birnbaum L, Bosveld ATC, Brunström B, Cook P, Feeley M, Giesy JP, Hanberg A, Hasegawa R, Kennedy S, Kubiak T, Larsen JC, van Leeuwen FXR, Djien Liem AK, Nolt C, Peterson RE, Poellinger L, Safe S, Schrenk D, Tillitt D,

Tysklind M, Younes M, Waern F, Zacharewski T. 1998. Toxic equivalency factors (TEFs) for PCBs, PCDDs, PCDFs for humans and wildlife. Environ Health Perspec 106(12):775-792.

Van den Berg M, Birnbaum LS, Denison M, De Vito M, Farland W, Feeley M, Fiedler H, Hakansson H, Hanberg A, Haws L, Rose M, Safe S, Schrenk D, Tohyama C, Tritscher A, Tuomisto J, Tysklind M, Walker N, Peterson RE. 2006. The 2005 World Health Organization reevaluation of human and mammalian toxic equivalency factors for dioxins and dioxin-like compounds. Tox Sci 93(2):223-241.